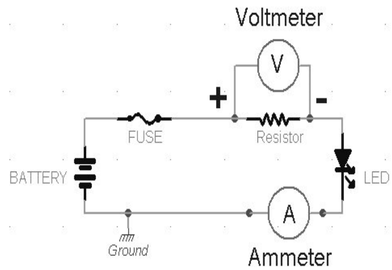
CFEST

Commercial Food Equipment Service Technician

Basic Training Program for Food Equipment Service Technicians in Electricity, Gas, Steam, Refrigeration, Hydraulics, and Pneumatics

Student Name: ______________________________

Commercial Food Equipment Service Technician



Fundamentals of Electricity

Introduction to Electricity in Cooking Equipment

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Unit 1: Intro to Electricity

Fundamentals of Electricity

Introduction

This book is designed to teach the basic principles and fundamentals of electricity as it related to repairing commercial cooking equipment and other appliances. This book presents simple, beginner level material on the subject on electricity and gradually increases in difficulty throughout. Considerable emphasis is laid on the fundamentals, physical concepts, principles and functions of various electrical components and the role they play in cooking equipment. Students are taught how to maintain and repair electrical appliances and electrical machines. They will also learn how to connect electrical circuits, and repair minor or major faults in the circuits both theoretically and practically. By learning this subjects students are able to gain the skills needed to become an entry-level commercial food equipment service technician.

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Notes:

Unit 1:
Intro to Electricity

Fundamentals of Electricity

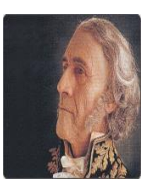
Introduction

Almost everyone is aware of the benefits of electricity. Electricity, defined as the flow of electrons in a conductor, is used every day by millions of people to power up electrical devices and appliances in their homes such as: lights, fans, refrigerators, air conditioners, toasters, computers, and hair dryers. Electricity is also used in our vehicles to start the engine, operated headlights, and power our radio among other things.

Electricity has been around since the ancient times and was known to the early Egyptians and Greeks. In the 18th century, the basic principles of electricity began to be researched. Many scientists were instrumental in developing the electrical theory we know today.

Benjamin Franklin's investigations into electricity caused him to be the first to propose that "vitreous" and "resinous" electricity were not different types of "electrical fluid", but the same electrical fluid under different pressures. He also was the first to label them as positive and negative. He also was the first to discover the principle of conservation of charge.

Luigi Galvani (1737 – 1798) was an Italian physician and physicist who investigated the nature and effects of what he conceived to be electricity in animal tissue. He is recognized as the pioneer of the bio electromagnetics. This was one of the first forays into the study of bioelectricity, a field that still studies the electrical patterns and signals of the nervous system.



Alessandro Volta (1745 – 1827) was an Italian physicist whose invention of the electric battery provided the first source of continuous current. He discovered and isolated methane gas in 1776. Three years later he was appointed to the chair of physics at the University of Pavia. The **volt**, a unit of the electromotive force that drives current, was named in his honor in 1881.

Michael Faraday (1791 – 1867) was an English physicist and chemist who discovered electromagnetic **induction**, diamagnetism, and electrolysis. He was the first to produce an electric current from a magnetic field, invented the first electric motor, demonstrated the relation between electricity and chemical bonding, discovered the effect of magnetism on light, and discovered and named diamagnetism, the peculiar behavior of certain substances in strong magnetic fields. The **farad**, unit of electrical capacitance is named in his honor.

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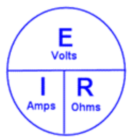
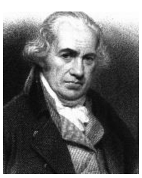
Fundamentals of Electricity

Introduction

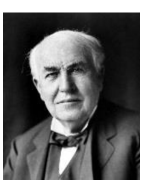


Georg Simon Ohm (1789 – 1854) was a German physicist who was best known for his controversial "Ohm's Law", which implies that the current flow through a conductor is directly proportional to the potential difference (voltage) and inversely proportional to the resistance. The physical unit of electrical resistance, the **Ohm**, also was named after him.

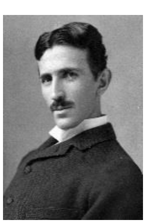


James Watts (1736 – 1819) was a Scottish instrument maker and inventor whose steam engine contributed substantially to the Industrial Revolution. He was elected fellow of the Royal Society of London in 1785. Because of his contributions to science and industry, the **watt**, the unit of power in the International System of Units (SI) equal to one joule of work performed per second (or 1/746 horsepower), was named after him.

Andre'-Marie Ampère (1775 – 1836) was a French physicist who founded and named the science of electrodynamics, now known as electromagnetism. His name endures in everyday life in the ampere, or **amp**, the unit for measuring electric current.



Thomas Alva Edison (1847-1931) was an American inventor who invented a revolutionary generator of unprecedented efficiency, the first commercial electric light and power system, an experimental electric railroad, and key elements of motion-picture apparatus, as well as a host of other inventions. He was also partially deaf. He also heavily promoted the concept of a direct current electrical grid but lost out to Tesla's alternating current.



Nikola Tesla (1856 – 1943) was a Serbian-American inventor and engineer who discovered and patented the rotating magnetic field, the basis of most alternating-current machinery. He also developed the three-phase system of electric power transmission. He immigrated to the United States in 1884 and sold the patent rights to his system of alternating-current dynamos, transformers, and motors to George Westinghouse. In 1891 he invented the Tesla coil, an induction coil widely used in radio technology.

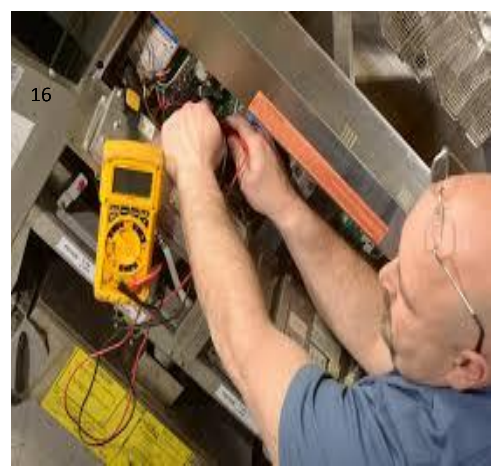
Heinrich Rudolf Hertz (1857 – 1894) was a German physicist. He showed that Scottish physicist James Clerk Maxwell's theory of electromagnetism was correct and that light and heat are electromagnetic radiations. He produced electromagnetic waves in the laboratory and measured their length and velocity. He showed that the nature of their vibration and their susceptibility to reflection and refraction were the same as those of light and heat waves. Hertz (abbreviated Hz) is the unit of frequency and equals the number of cycles per second and was named after Heinrich Hertz in the 1920s.

Unit 1:
Intro to Electricity

Fundamentals of Electricity

Introduction

As a Commercial Food Equipment Service Technician, you will need to understand many aspects of electricity. You need to know what electricity is, where it comes from, what it does, how it behaves, how to measure it, and how to work around it safely. We are going to learn the basics of electricity. When you understand how electricity works, how to read and interpret electrical wiring diagrams, and how to use a meter to check various electrical readings, you are well on your way to being able to troubleshoot and repair a large number of electrical devices and appliances. Electricity is not difficult to learn if you start out with the basics. Once you learn the basic concepts of electrical circuits and what different electrical components in those circuits do, you will be able to build on that knowledge and develop the troubleshooting skills needed to repair equipment. Electricity is a vast topic and there are many career paths you can take that require this knowledge. As with anything, it will take dedication and practice. Here we will break electricity down into bite size pieces that are easy to understand and build on. We will start out with where electricity comes from and then systematically follow electricity on its journey through the various components and circuits that it will encounter and explain along the way, what it is doing, why it is doing it and what happens when a problem arises. So, let's start where it all begins and explain what exactly electricity is.



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Lockout Tagout

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Unit 1:
Intro to Electricity

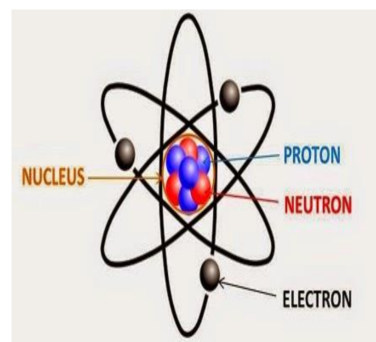
Fundamentals of Electricity

What is Electricity?

In this modern world, electricity is an energy source that plays a vital role in our lives. It is used in our homes, vehicles, businesses, and just about everywhere else. Most appliances need electricity to operate and do the work we require of them. To repair cooking equipment, students must know about this energy source and how it is applied. Electricity is one type of energy. All matter whether solid, liquid or, gaseous consists of minute particles known as Atoms. According to modem research electric current means flow of electrons. Electrons are a parts of the atom. So we need to know about the **atom**.

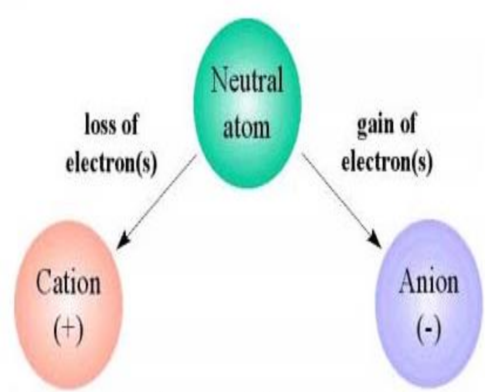
Atoms

Everything is made up of atoms. Atoms have a central core known as nucleus. It contains two type of particles. One is known as proton and carries positive charge (+) and the other is neutron, which is electrically neutral, which means it has not charge. Around the nucleus in elliptical orbit the electrons are revolving. Electrons carry a negative (-) charge. The number of electron are number of protons in a atom are equal. So the atom is electrically neutral. The number of protons in the nucleus of the atom gives the atomic number. The total numbers of neutrons and proton are known as atomic weight. The negligible weight of the electron is not taken in consideration to calculate atomic weight. Most electrons in atoms are bound together but if any electrons are on the outer shell of the orbit and are not tightly bound they can be removed easily by a magnetic force.



Ions

When the number of protons and electrons are not equal in an atom, it is called an ion instead of an atom. If an atom has more electrons than protons, it is called a negative ion. If an atom has less electrons than protons, it is called a positive ion.

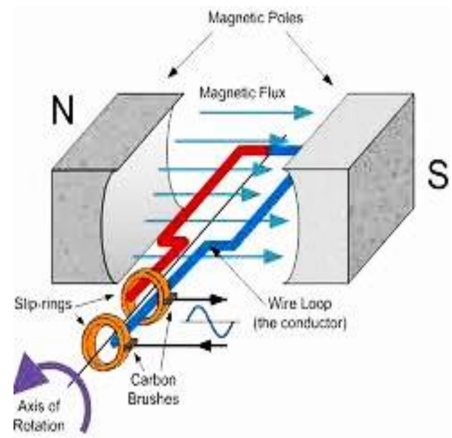


A neutral atom becomes an ion either by losing an electron (cation) or by gaining an electron (anion).

How Electricity is Produced

How is electricity produced?

Electricity is produced by the extraction of electrons from an atom. Electrons are extracted from an atom due to magnetism. Generators are used to accomplish this. In a generator the energized electricity is produced by the magnetic poles and armature winding. Basically, spinning a copper wire loop through a magnetic field will cause the electrons in the wire to move from one atom to another atom. This movement of electrons in a conductor (wire) is what we call electricity.



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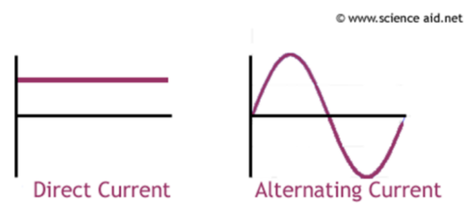
Current Types

Electricity is the flow of electrons around a circuit. There must be a complete circuit for this flow to happen. Electrons flowing through a circuit is called current. The two types of electrical current used are direct current (DC) and alternating current (AC).

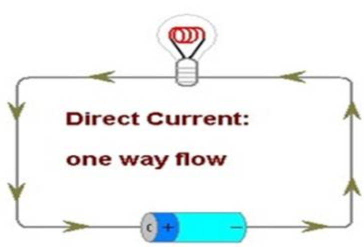


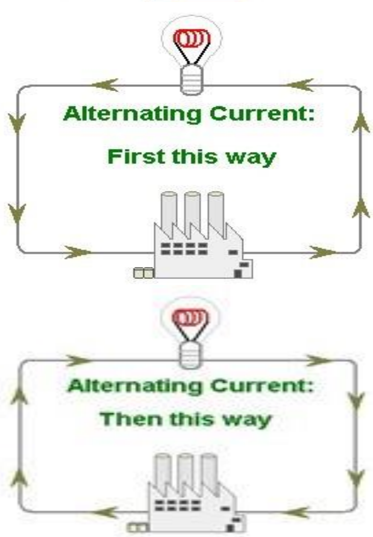
Direct Current

An example of a direct current power source is a battery. A battery creates voltage through a chemical reaction that takes place inside the battery. Batteries are used to power things like flashlights, vehicles, portable radios, and other portable devices. Current in a DC circuit only flows in one direction.

Alternating Current

Alternating current is the type of current used to supply power to electrical outlets found in homes and businesses. AC current powers the appliances we plug into those outlets such as coffee makers, televisions, computers, refrigerators, etc. Current in an AC circuit flows in two directions. AC current leaves the power source in one direction and then reverses and flows in the opposite direction. It alternates its direction sixty times per second. This is why it is called alternating current.





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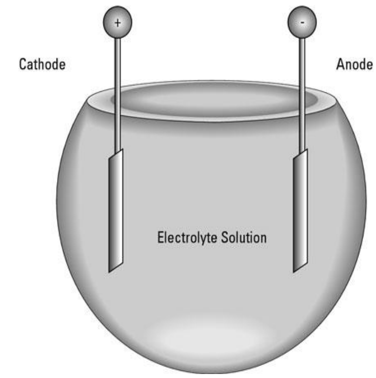
Batteries

What is a Battery?

A battery is a device that converts chemical energy into electrical energy in the form of voltage, which in turn can cause current to flow.



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How a Battery Works

A battery works by immersing two plates made of different metals into a special chemical solution called an electrolyte. The metals react with the electrolyte to produce a flow of charges that accumulate on the negative plate, called the anode. The positive plate, called the cathode, is sucked dry of charges. As a result, a voltage is formed between the two plates. These plates are connected to external terminals to which you can connect a circuit to cause current to flow. Batteries produce direct current (DC). DC Current flows in one direction only and flows from negative to positive.

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Battery Variations

Batteries come in many different shapes and sizes, but for electronics projects, you need concern yourself only with a few standard types of batteries, all of which are available at any grocery, drug, or department store. Cylindrical batteries come in four standard sizes: AAA, AA, C, and D. Regardless of the size, these batteries provide 1.5 V each; the only difference between the smaller and larger sizes is that the larger batteries can provide more current.

The cathode, or positive terminal, in a cylindrical battery is the end with the metal bump. The flat metal end is the anode, or negative terminal.

The rectangular battery is a 9 V battery. That little rectangular box actually contains six small cells, each about half the size of a AAA cell. The 1.5 volts produced by each of these small cells combine to create a total of 9 volts.

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Here are a few other things you should know about batteries:

•Besides AAA, AA, C, D, and 9 V batteries, many other battery sizes are available. Most of those batteries are designed for special applications, such as digital cameras, hearing aids, laptop computers, and so on.

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•All batteries contain chemicals that are toxic to you and to the environment. Treat them with care, and dispose of them properly according to your local laws. Don't just throw them in the trash.

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•You can (and should) use your multimeter to measure the voltage produced by your batteries. Set the multimeter to an appropriate DC voltage range (such as 20 V). Then, touch the red test lead to the positive terminal of the battery and the black test lead to the negative terminal.

http://www.dummies.com/programming/electronics/components/how-batteries-work-in-electronic-circuits/

Unit 1:
Intro to Electricity

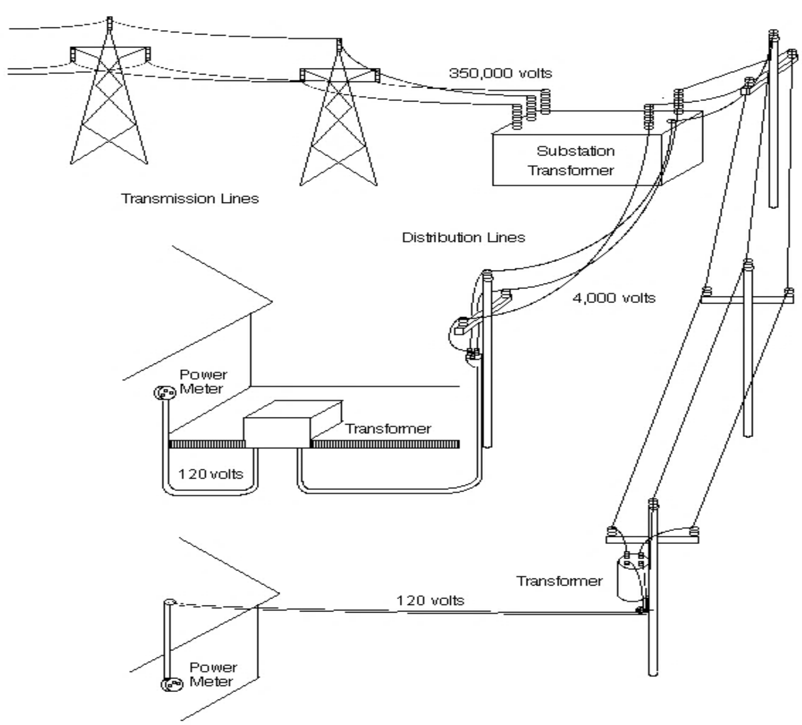
Fundamentals of Electricity

Power Distribution

Home Electric Wiring
This section covers the principles of electric wiring in homes. There are two 120 volt circuits coming from the power company's distribution system that go to a breaker panel and then out to many individual circuits in your home.

Power Company Distribution System
All power companies use an alternating current transmission scheme with long-range transmission voltages, sometimes in excess of 100,000 volts. The voltage phase changes 60 times per second and facilitates the use of transformers to step the voltage down at substations for local distribution and one more drop before it enters your home as two 120 volt circuits.

Local Distribution
Power is brought down from the high voltage transmission towers to substation transformers. Substation transformers lower the voltage for local distribution via power poles. The power pole line can come all the way to your home or be converted to an underground distribution system for the final leg to your house. Another transformer steps the voltage down to the two 120 volt circuits, plus a neutral wire, to your house.



Unit 1:

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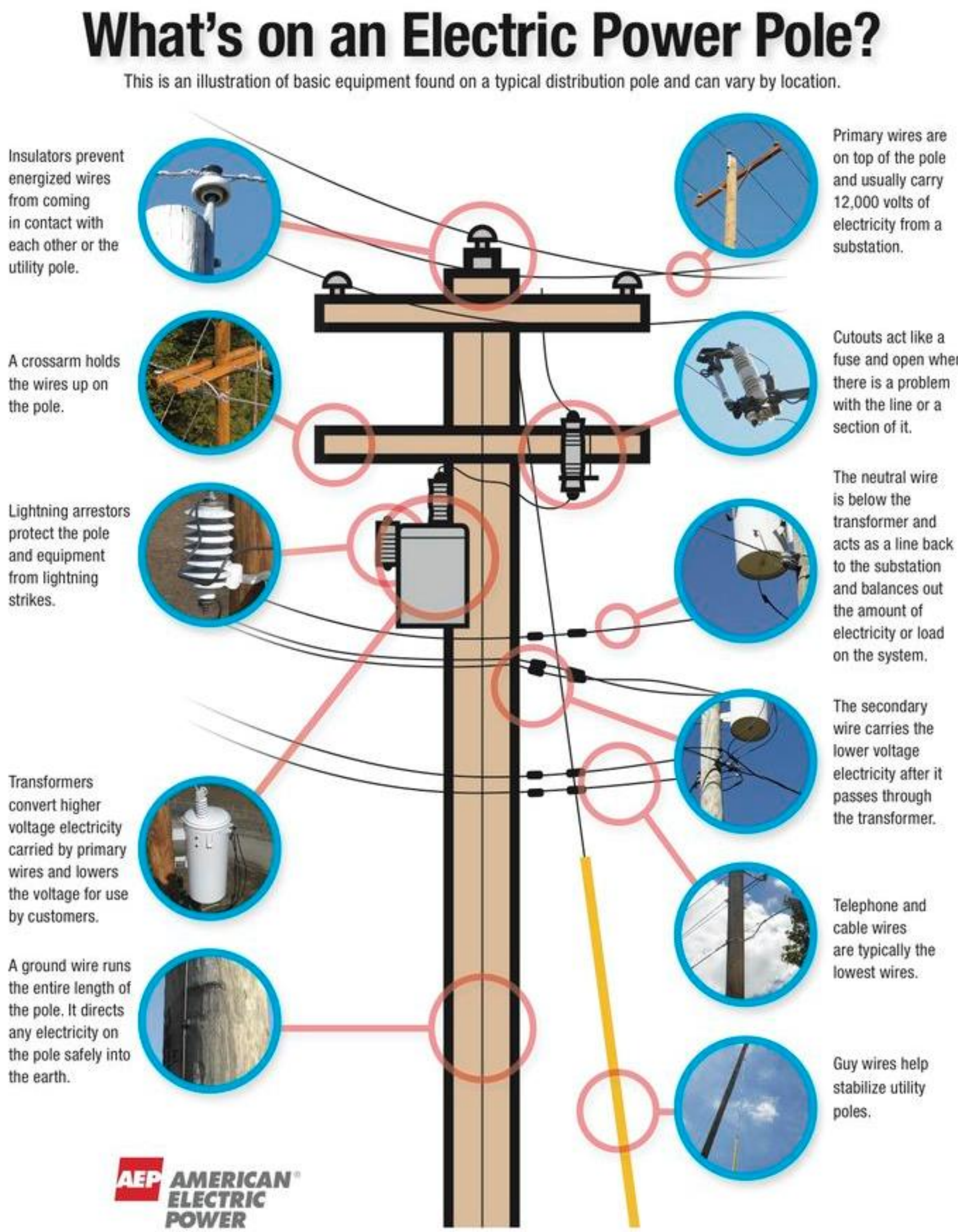
Power Distribution



Electrical Service Types

Electrical Service Types and Voltages
This page describes various types of utility electrical services and supply voltages. The nominal system supply voltages listed below can vary by ±10% or more.

Classification of Electrical Services
Alternating current electric power distribution systems can be classified by the following properties:
•**Frequency:** 50 Hz or 60 Hz
•**Number of phases:** single or three phase
•**Number of wires:** 2, 3, or 4 (not counting the safety ground)
•**Neutral present:**

- **Wye** connected systems have a neutral
- **Delta** connected systems typically do not have a neutral

•**Voltage classes:** (ANSI C84.1-2016)

- **Low Voltage:** 1000 volts or less
- **Medium Voltage:** greater than 1000 volts and less than 100 kV
- **High Voltage:** greater than 100 kV and equal to or less than 230 kV
- **Extra-High Voltage**: greater than 230 kV but less than 1000 kV
- **Ultra-High Voltage**: equal to or greater than 1000 kV

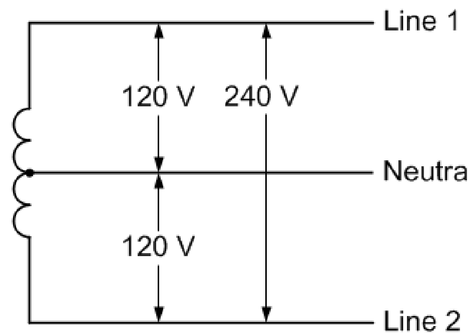
Wye Line-to-Neutral Voltage	Wye or Delta Line-to-Line Voltage
120	208
120	240
230	400
240	415
277	480
347	600

- Line-to-line voltages are typically 1.732 times the phase-to-neutral voltages: square root{3}=1.732
- In symmetrical three-phase electrical system, the phase-to-neutral voltages should be equal if the load is balanced.

Electrical Service Types

Common Electrical Services & Loads

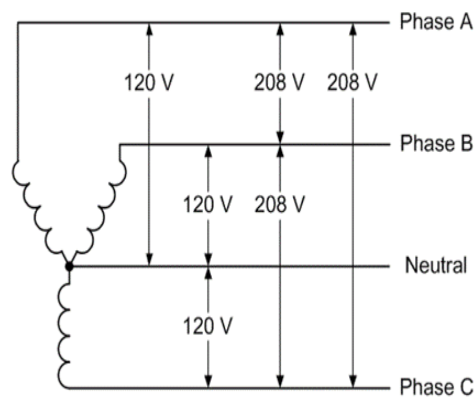
In the following drawings, the coil symbols represent the secondary winding of a utility service transformer or other step down transformer. Electrical code regulations in most jurisdictions require that the neutral conductor be bonded (connected) to the earth safety ground at the electrical service entrance.



Single Phase Three Wire

Single Phase Three Wire

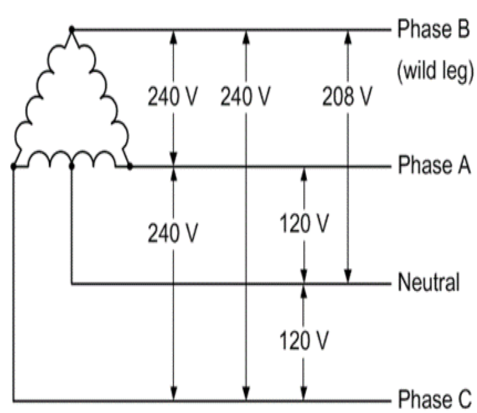
Also known as an Edison system, split-phase or center-tapped neutral. This is the most common residential service in North America. Line 1 to neutral and Line 2 to neutral are used to power 120 volt lighting and plug loads. Line 1 to Line 2 is used to power 240 volt single phase loads such as a water heater, electric range, or air conditioner.



Three Phase Four Wire Wye

Three Phase Four Wire Wye

The most common commercial building electric service in North America is 120/208 volt wye, which is used to power 120 volt plug loads, lighting, and smaller HVAC systems. In larger facilities the voltage is 277/480 volt and used to power single phase 277 volt lighting and larger HVAC loads. In western Canada 347/600V is common.



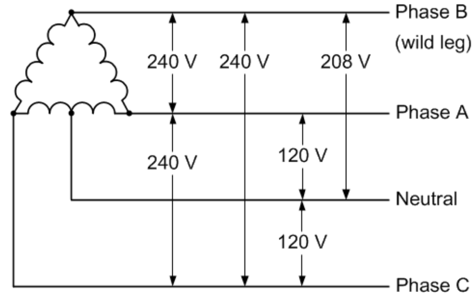
Three Phase Three Wire Delta

Three Phase Three Wire Delta

Used primarily in industrial facilities to provide power for three-phase motor loads, and in utility power distribution applications. Nominal service voltages of 240, 400, 480, 600, and higher are typical.

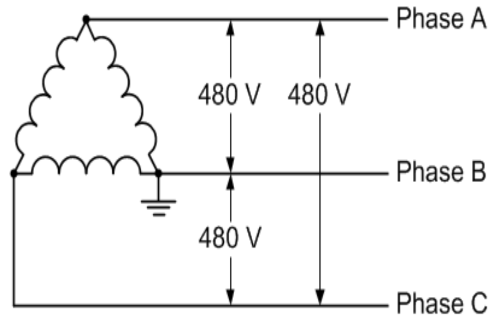
Electrical Service Types

Three Phase Four Wire Delta
Also known as a high-leg or wild-leg delta system. Used in older manufacturing facilities with mostly three-phase motor loads and some 120 volt single-phase lighting and plug loads. Similar to the Three Phase Three Wire Delta discussed above but with a center-tap on one of the transformer winding to create neutral for 120 volt single-phase loads. Motors are connected to phase A, B, and C, while single-phase loads are connected to either phase A or C and to neutral. Phase B, the high or wild leg, is not used as the voltage to neutral is 208 volt.



Three Phase Four Wire Delta

Three Phase Two Wire Corner Grounded Delta
Used to reduce wiring costs by using a service cable with only two insulated conductors rather then the three insulated conductors used in a convention three phase service entrance.



Three Phase Two Wire Corner Grounded Delta

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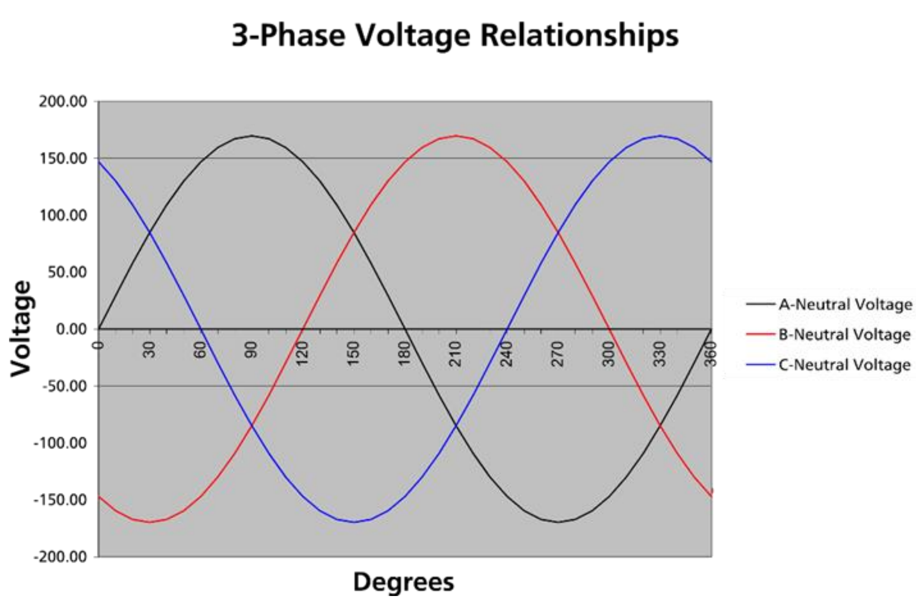
Three-Phase Power

There are two types of system available in electric circuit, single phase and three phase system. In single phase circuit, there will be only one phase, i.e. the current will flow through only one wire and there will be one return path called neutral line to complete the circuit. So in single phase minimum amount of power can be transported. Here the generating station and load station will also be single phase. This is an old system using from previous time. In 1882, new invention has been done on polyphase system, that more than one phase can be used for generating, transmitting and for load system. Three phase circuit is the polyphase system where three phases are send together from the generator to the load. Each phase are having a phase difference of 120°, i.e. 120° angle electrically. So from the total of 360°, three phases are equally divided into 120° each. The power in three phase system is continuous as all the three phases are involved in generating the total power. The sinusoidal waves for 3 phase system is shown below:



The three phases can be used as single phase each. So if the load is single phase, then one phase can be taken from the three phase circuit and the neutral can be used as ground to complete the circuit.

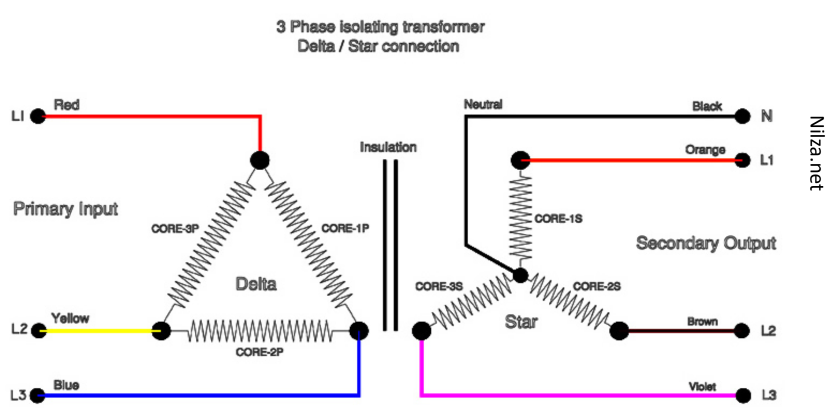
https://www.electrical4u.com/three-phase-circuit-star-and-delta-system/

Single Phase vs. Three-Phase Power

Why Three Phase is preferred Over Single Phase?
There are various reasons for this question because there are numbers of advantages over single phase circuit. The three phase system can be used as three single phase line so it can act as three single phase system. The three phase generation and single phase generation is same in the generator except the arrangement of coil in the generator to get 120° phase difference. The conductor needed in three phase circuit is 75% that of conductor needed in single phase circuit. And also the instantaneous power in single phase system falls down to zero as in single phase we can see from the sinusoidal curve but in three phase system the net power from all the phases gives a continuous power to the load.

Till now we can say that there are three voltage source connected together to form a three phase circuit and actually it is inside the generator. The generator is having three voltage sources which are acting together in 120° phase difference. If we can arrange three single phase circuit with 120° phase difference, then it will become a three phase circuit. So 120° phase difference is must otherwise the circuit will not work, the three phase load will not be able to get active and it may also cause damage to the system. The size or metal quantity of three phase devices is not having much difference. Now if we consider the transformer, it will be almost same size for both single phase and three phase because transformer will make only the linkage of flux. So the three phase system will have higher efficiency compared to single phase because for the same or little difference in mass of transformer, three phase line will be out whereas in single phase it will be only one. And losses will be minimum in three phase circuit. So overall in conclusion the three phase system will have better and higher efficiency compared to the single phase system.

In three phase circuit, connections can be given in two types:
1. Star connection
2. Delta connection



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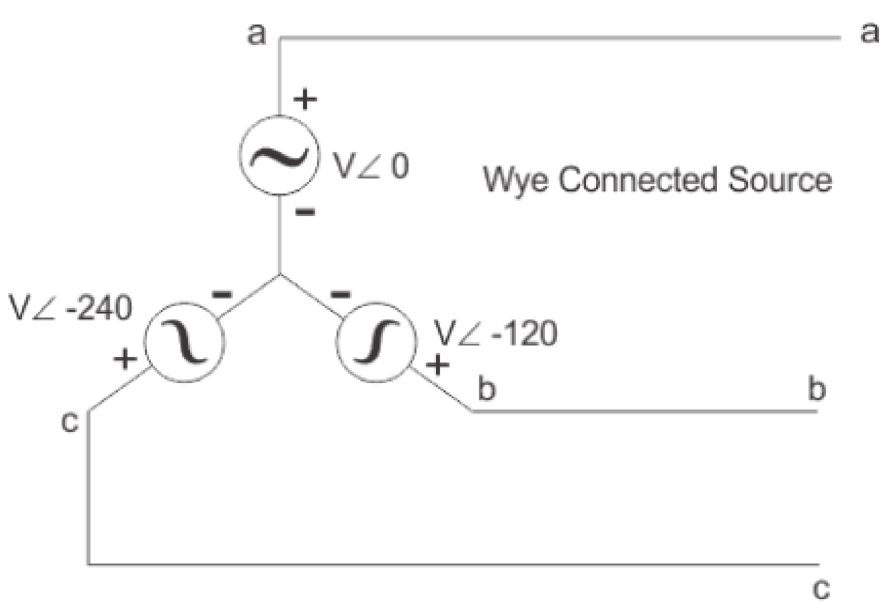
Star (Wye) Connection

Star Connection

In star connection, there is four wire, three wires are phase wire and fourth is neutral which is taken from the star point. Star connection is preferred for long distance power transmission because it is having the neutral point. In this we need to come to the concept of balanced and unbalanced current in power system.

When equal current will flow through all the three phases, then it is called as balanced current. And when the current will not be equal in any of the phase, then it is unbalanced current. In this case, during balanced condition there will be no current flowing through the neutral line and hence there is no use of the neutral terminal. But when there will be unbalanced current flowing in the three phase circuit, neutral is having a vital role. It will take the unbalanced current through to the ground and protect the transformer. Unbalanced current affects transformer and it may also cause damage to the transformer and for this star connection is preferred for long distance transmission. The star connection is shown below- star connected source. In star connection, the line voltage is √3 times of phase voltage. Line voltage is the voltage between two phases in three phase circuit and phase voltage is the voltage between one phase to the neutral line. And the current is same for both line and phase. It is shown as expression below:

$$E_{Line} = \sqrt{3}E_{phase} \ and \ I_{Line} = I_{Phase}$$



https://www.electrical4u.com/three-phase-circuit-star-and-delta-system/

Delta Connection

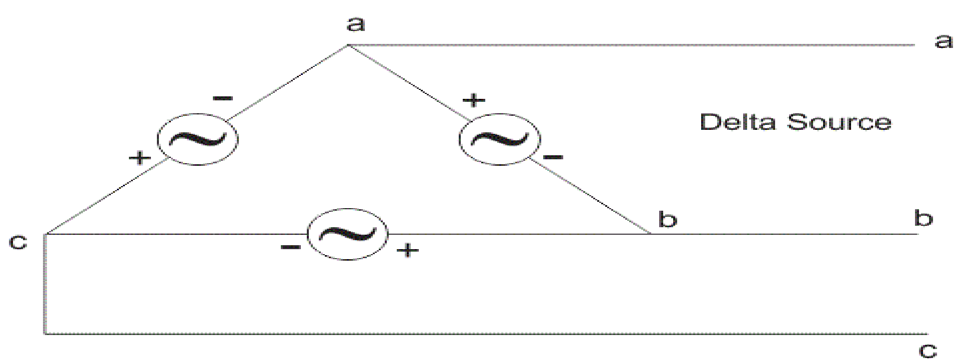
Delta Connection

In delta connection, there is three wires alone and no neutral terminal is taken. Normally delta connection is preferred for short distance due to the problem of unbalanced current in the circuit. The figure is shown below for delta connection. In the load station, ground can be used as neutral path if required. delta connected source. In delta connection, the line voltage is same with that of phase voltage. And the line current is √3 times of phase current. It is shown as expression below:

$$E_{Line} = E_{phase} \text{ and } I_{Line} = \sqrt{3} I_{Phase}$$

In three phase circuit, star and delta connection can be arranged in four different ways-

1. Star-Star connection
2. Star-Delta connection
3. Delta-Star connection
4. Delta-Delta connection



But the power is independent of the circuit arrangement of the three phase system. The net power in the circuit will be same in both star and delta connection. The power in three phase circuit can be calculated from the equation below:

$$P_{Total} = 3 \times E_{phase} \times I_{phase} \times PF$$

Since, there are three phases, the multiple of 3 is made in the normal power equation and the PF is power factor. Power factor is a very important factor in three phase system and some times due to certain error, it is corrected by using capacitors.

https://www.electrical4u.com/three-phase-circuit-star-and-delta-system/

Unit 1:
Intro to Electricity

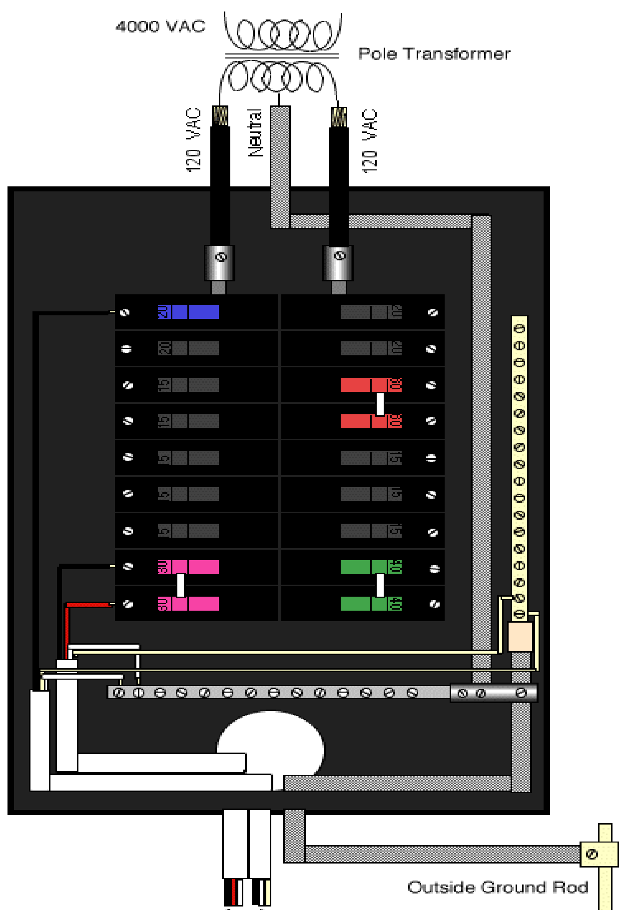
Breaker Panels

Power Meter

The power meter is much like the water meter in line with the water coming into your house. The power meter is in line with the power feed from your nearest transformer. The power meter is read by the local power company and displays the amount of power you use each month. The power is measured in kilowatt hours. The watt is the unit of electrical energy. One kilowatt-hour is equivalent to the use of 1000 watts of electricity (ten 100 watt light bulbs) for one hour. A kilowatt-hour typically costs from 7 – 10 cents.

Breaker Panels

The two primary 120 volt power feeds from the power meter are routed into the breaker panel for distribution into your home as power circuits.

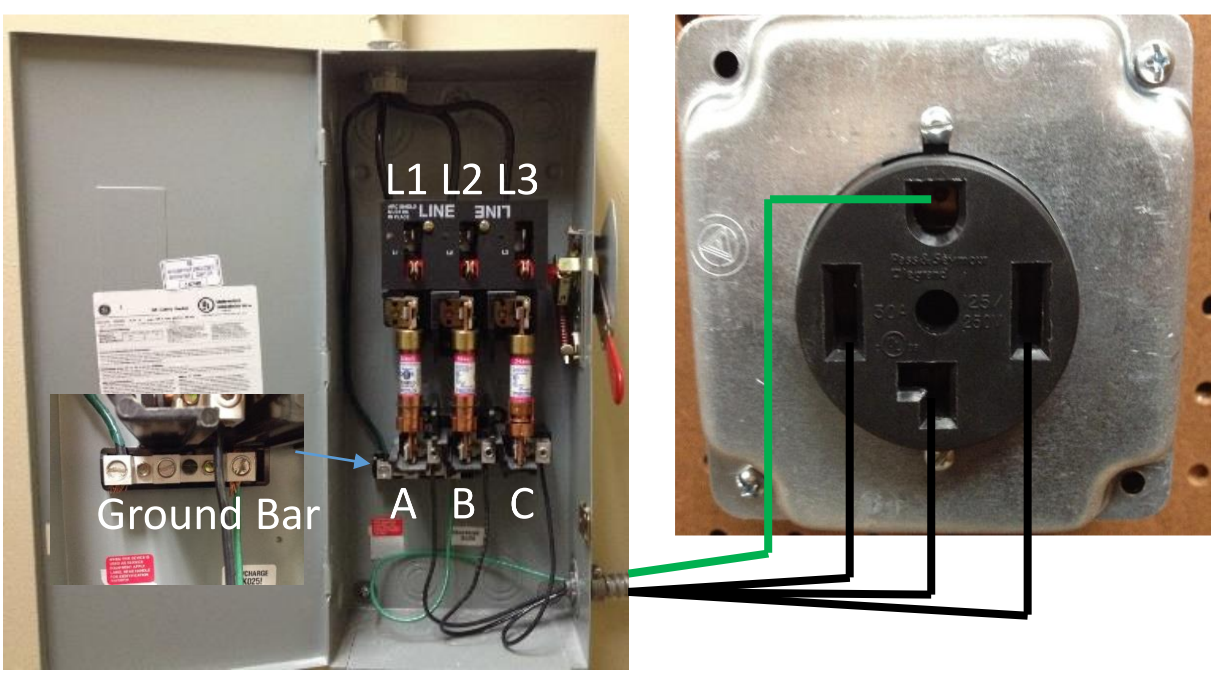


Notes:

The two power feeds are connected to two power buses located behind the circuit breakers. Note the lower left hand breakers in the diagram above (pink 30-amp ganged breakers). The top breaker, with the black wire leading to it, is connected to one 120 volt bus and the bottom breaker, with the red wire leading to it, is connected to the other 120 volt bus. The third white wire is connected to the neutral bus which in turn was connected to the center tap on the power company's transformer and to a ground rod outside.

Sub-Panels: Three Phase

The three-phase sub-panel shown below gets its power from a 3-pole, 80amp breaker in the main panel. Running power to this sub-panel allows the user to protect the circuit with fuses and shut off power to the appliance using this power whenever necessary. Three-phase power supplies 3 hot lines to the load. In this case there are 3 hot lines of 120 VAC each and the top (green) line is Ground. The lines are labeled line 1 (L1 – Phase A), line 2 (L2 – Phase B), line 3 (L3 – Phase C).



Hands On Exercise: Check voltage at a three phase breaker panel

In this procedure, you will use a DMM to check voltage at a three-phase breaker panel. Set DMM to the highest AC voltage setting. With panel disconnect lever turned on, check and record the voltage found at across the specified points.

CAUTION: HIGH VOLTAGE

- ❑ What is the voltage from L1 to ground? ___________
- ❑ What is the voltage from L2 to ground? ___________
- ❑ What is the voltage from L3 to ground? ___________
- ❑ What is the voltage from L1 to L2? ___________
- ❑ What is the voltage from L2 to L3? ___________
- ❑ What is the voltage from L1 to L3? ___________

Test Point

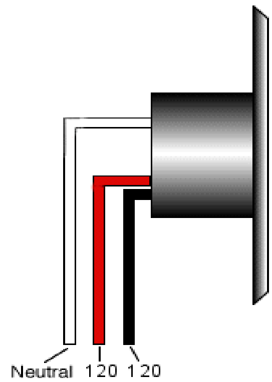
Ground

Power On

Wiring

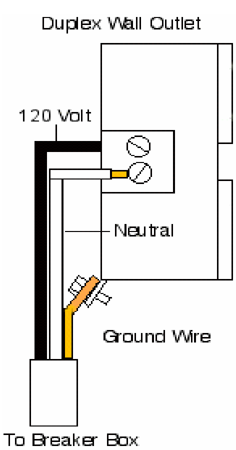
House Wiring

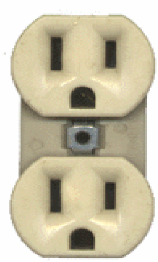
If we follow the dryer circuit out from the breaker box to the utility room, the wires are connected to the dryer wall plug as follows:



Note that there is no ground wire connected to the receptacle

Now let's take a look at the wall outlet circuit that starts with the black wire leading down from the top left 20-amp breaker in the breaker box image above. This is a single 120 volt circuit that will service 2 or 3 wall outlets. The white wire is connected to the common neutral bus. But for this circuit we have a copper ground wire that is connected to the common neutral bus and to the ground bus leading out to a ground rod. If we follow this wall outlet circuit out to a duplex wall outlet, it will be wired up as follows:





Take a close look at the picture of the duplex outlet above. Note that the vertical slot to the left is longer than the one to the right. This is an attempt to polarize the outlet so that things like a lamp will not have the hot wire on the sleeve section of the light bulb which would make it a greater shock hazard. IF the outlet is wired properly, the white wire is connected to the longer neutral slot to the left and the hot black wire is connected to the short slot to the right. One of the lamp cord plug blades is wider than the other and insures that the neutral and hot wires go to the right places.

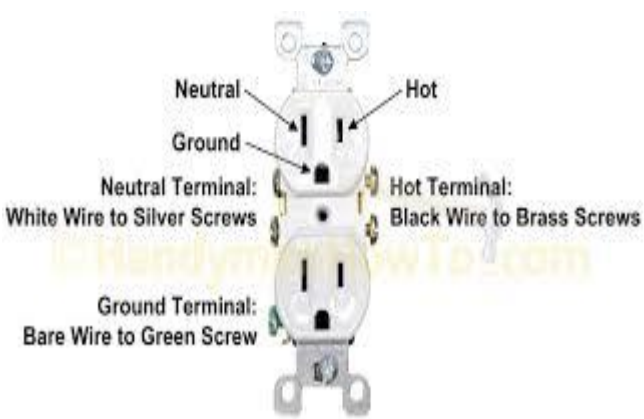
How about a plug with a ground lug on it? The first thing to notice is that the ground lug polarizes the plug because there is only one way to plug it in. Therefore there is no need to have a wide and a narrow blade. However, it's still possible to wire the outlet wrong. This is where the safety ground comes into play. If the outer case of an appliance is always connected to the safety ground it doesn't make much difference what happens to the other two wires. If the neutral wire shorts to the case nothing happens. If the hot wire shorts to the case, a short circuit is presented to the breaker and it should open. The safety ground prevents YOU from being the path for a circuit from a hot wire shorted to the case to ground.

Fundamentals of Electricity

US AC Power Circuit Wiring Color Codes

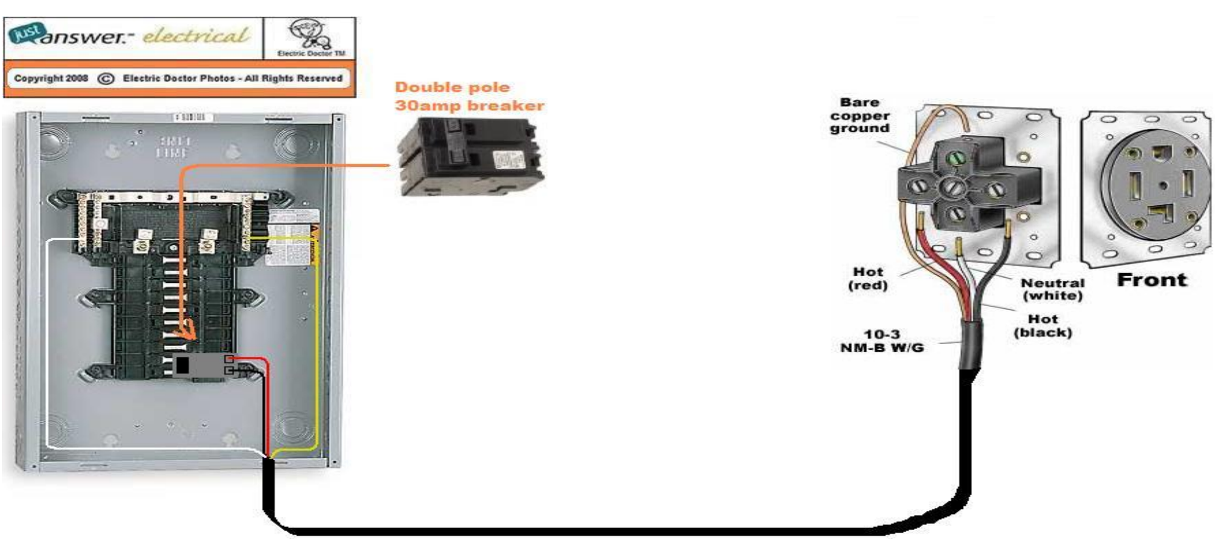
Function	label	Color, common	Color, alternative
Protective ground	PG	bare, green, or green-yellow	green
Neutral	N	white	grey
Line, single phase	L	black or red (2nd hot)	
Line, 3-phase	L1	black	brown
Line, 3-phase	L2	red	orange
Line, 3-phase	L3	blue	yellow

120 Volt AC outlet



3-Phase Power Connection

240 Volt, Single Phase AC outlet

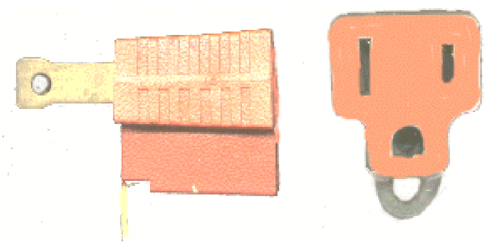


Grounding

Grounding Wire versus Grounded Conductor

Scroll back to the circuit breaker drawing and note that the bare copper safety wires and the white insulated wires come together on busses that are both connected to an external ground rod. The safety ground is sometimes called the "grounding conductor". The white neutral wire carries current for each circuit and is therefore called the "grounded conductor".

Older homes are wired with duplex outlets that lack the safety ground lugs. So what do you do if you have an appliance like a refrigerator that has a plug with a safety ground lug on it and you need to plug it into one of these old outlets? Sure, you use one of those nifty adapter things like the one shown below:



So, you slapped the adapter on the end of the refrigerator plug, plugged it in and it worked fine. But let's take a look at what you just did. The safety ground lug that you just defeated was connected to the outer metal shell of the refrigerator. A refrigerator has two types of heaters just under the skin - mullen heaters to keep the door seals from freezing onto the metal and shell heaters to keep the metal shell from sweating in humid surroundings. If the insulation on these heaters breaks down in the presense of water and you put your hand on the refrigerator, you will have a tingling sensation in your hand as electrical current flows through your body. Standing barefoot in water will increase the tingling to a stout jolt.

Do not remove the ground prong on any appliance. It is there for safety and sometimes required for proper operation of the appliance. In commercial businesses it is often against electrical code to remove the ground plug.

Notes:____

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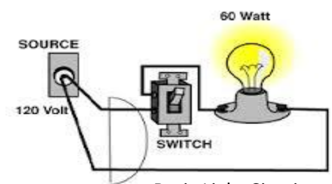
Unit 1:
Intro to
Electricity

Fundamentals of Electricity

Basic Circuit Components

Most electrical circuits have four basic components, a power supply, conductors, a switch, and a load. The switch can theoretically be eliminated but that would cause the load to operate continuously as long as the power supply is on.



Basic Light Circuit

Eng.buffalo.edu

Power Supply

The most common power supply is an electrical outlet. Electrical outlets in homes provide a constant 120 volts of alternating current (AC). This voltage is provided by the power company. Another type of power supply is a battery. Batteries use a chemical reaction to produce voltage. Batteries provide a constant source of voltage until they loose their charge.


120 Volt AC Wall Outlet

Nizla.net

Conductors

The conductor in a circuit connects all the component in the circuit together. They are typically made out of copper, but can also be other conductive materials such as aluminum, silver, and gold (extremely good conductors but not used much due to cost). Nickel wiring is used in cooking equipment where the wiring is subject to high temperatures. The "hot" conductor supplies voltage to the circuit and the "neutral" conductor provides a return path back to the source voltage to complete the circuit.


Solid and Stranded Copper Conductors

Dir.indiamat.com

Control Device (Switches)

Control devices are components that open and close circuits to control when the power is applied to a load to make it operate. Example: visualize turning on the light switch in your bedroom. When you turn off the switch, you are actually opening (or disconnecting) the circuit that sends power to the light bulb and the bulb goes out. When you turn the light switch on, you are closing (or connecting) the circuit that sends power to the light bulb and the bulb comes on.

Household Light Switch

Wtlightingmn.com

Loads

Loads are components that consume electrical power such as light bulbs, motors, heating elements, etc. In other words, loads do work of some kind. Some produce light (bulbs), some produce motion (motors), some produce heat (heating element).


Single Bulb Light Fixture with bulb

Remodelista.com

Unit 1:
Intro to Electricity

Fundamentals of Electricity

Conductors

What is a conductor?
A conductor is the wire which carries (Conducts) current from the supply point to the load is called conductors.

Loads
The component or device that is operated by using the current is called load. Some common loads are light bulbs, motors, solenoids, and heating elements.

Conducting Materials
Generally all types of metal can be used for conducting electricity. Some metals are better suited for conductivity than others. These are called "Good Conductors".

Properties of a Good Conductor
A good conductor:

- Allows current to flow easily through it
- Has low resistance
- Can handle high stress
- Is fairly flexible
- Doesn't corrode easily
- Isn't affected by heat
- Is cost effective

Photo credit: wisc-online.com

Common Conductors
Copper is the most common conductor due to its good conductivity, high availability and reasonable cost. Silver, Brass. Aluminum, Tungsten, and Nichrome are also considered good conductors. Nichrome is commonly used in heating elements.

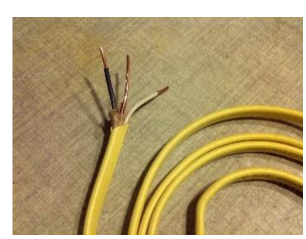


Photo credit: wisc-online.com

Wiring Tips

When splicing wires in an oven, remember that you're dealing with high temperatures. Normal connectors and wire insulation will melt under these conditions. Your parts dealer has high-temp connections, porcelain wire nuts and fiberglass-insulated wire for this purpose.

Loads

An electrical load is an electrical component or portion of a circuit that consumes electric power. This is opposed to a power source, such as a battery or generator, which produces power. In electric power circuits examples of loads are appliances and lights. The term may also refer to the power consumed by a circuit.

Loads affects the performance of circuits with respect to output voltages or currents, such as in sensors, voltage sources, and amplifiers. Mains power outlets provide an easy example: they supply power at constant voltage, with electrical appliances connected to the power circuit collectively making up the load. When a high-power appliance switches on, it dramatically reduces the load impedance.

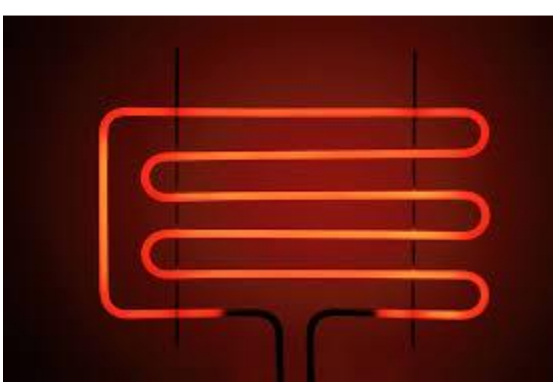
If the load impedance is not very much higher than the power supply impedance, the voltages will drop. In a domestic environment, switching on a heating appliance may cause incandescent lights to dim noticeably. Below are some examples of different types of loads.

Directindustry.com

Electric Motor

Warisonlighting .com

Light Bulb



Balickheatingelements.com

Heating Element

bulidlectroniccircuits .com

Resistor

Unit 2:
Measurement

Fundamentals of Electricity

Voltage

Voltage is named after Alexandro Volta. In electricity, voltage is called Electromotive Force (E). Voltage is the force causing the electrons to flow. Think of it as electrical pressure. This force is constant and is generated by the power company. The voltage supplied to standard wall outlets in 120 volts AC. Some equipment requires 208, 240, or 480 volts A.C.

Analog AC Voltmeter

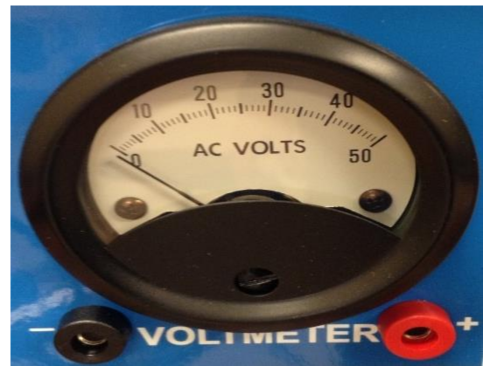
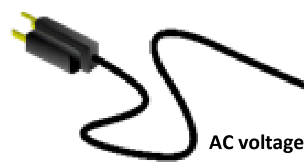


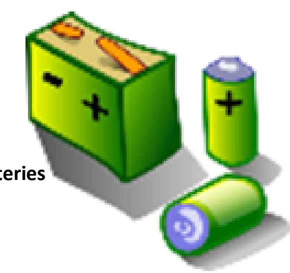
Photo credit: Kelly Wells

Electrical Pressure

Think of voltage as electrical pressure. Just like there is a certain amount of constant water pressure as you kitchen sink, there is a constant amount of "electrical" pressure (voltage) at your wall outlets. The standard household outlet has 120 volts waiting to flow when the circuit is completed by plugging in an appliance to that outlet. Batteries provide a constant voltage as well.



AC voltage power cord



Batteries

Photo credit: wisc-online.com

Potential Difference

Voltage is also called **"potential difference".** It is the push behind the electrons created by differences in atomic charges. In order for anything to flow (air, water, electrons), there must be a difference in pressure between the supply and the destination. The **"hot"** side of an electrical outlet has a potential of 120 volts and the neutral or ground has a potential voltage of zero volts. Because of this difference, electrons will flow from the hot to the neutral or ground. This difference can be measured with a device called **a voltmeter.**

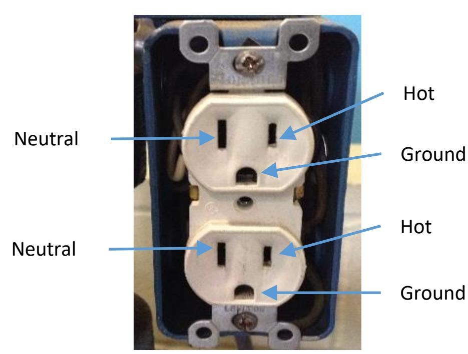


Photo credit: Kelly Wells

ELECTRIC COOKTOPS AND OVENS

Most electric cooking equipment uses two different electrical circuits. The heating elements usually run on 240 volts, and accessories such as lights, timers and rotisserie motors run on 120 volts. There are a few notable exceptions. Some smaller cooktops run on 120 volts. Also, in some fixed-temperature switch applications, 120 volts is applied to a 240-volt surface unit (burner) to achieve a "low" heat setting.

Grounding Wires

Always replace the green (ground) leads when you remove an electrical component. They're there for a reason. And NEVER EVER remove the third (ground) prong in the main power plug! They are especially important in spark ignition systems; the spark electrode will not spark without grounding.

Checking for Power

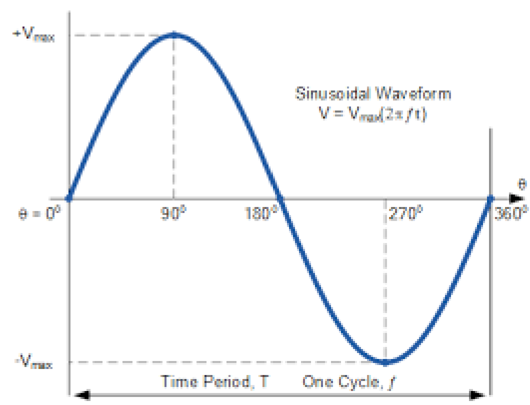
When testing for a 120-volt power supply from a wall outlet, you can plug in a small appliance such as a small fan or blow dryer (which you should have on your vehicle for thawing out froze up evaporators). If you're not getting full power out of the outlet, you'll know it right away. If you're testing for 240-volt power you need to use the DMM.

Electrical Safety

In electric cooking equipment, you're usually dealing with 240 volt circuits. DO NOT TAKE THIS LIGHTLY. Being hit with 120 volts is not fun. Anyone who works with electrical equipment has at one time or another. It's unpleasant, but unless exposure is more than a second or so, the only harm it usually does is to tick you off pretty good. However, 240 VOLTS CAN KNOCK YOU OFF YOUR FEET. IT CAN DO YOUR BODY SOME SERIOUS DAMAGE, VERY QUICKLY.

Frequency

Frequency
Hz" stands for the unit of Hertz, the measure of how rapidly alternating current alternates, a measure otherwise known as frequency. So, the column of figures labeled "60 Hz AC" refers to current that alternates at a frequency of 60 cycles (1 cycle = period of time where electrons flow one direction, then the other direction) per second.



Frequency Measurement Overview
Circuits and equipment may be designed to operate at a fixed or variable frequency. They may perform abnormally if operated at a different frequency than specified.

Example: An ac motor designed to operate at 60 Hz operates slower if the frequency is less than 60 Hz, or faster if frequency exceeds 60 Hz. For ac motors, any change in frequency causes a proportional change in motor speed. A five percent reduction in frequency yields a five percent reduction in motor speed.

Some digital multimeters include optional modes related to frequency measurement:
•Frequency Counter mode: It measures the frequency of ac signals. It can be used to measure frequency when troubleshooting electrical and electronic equipment.
•MIN MAX Recording mode: Permits frequency measurements to be recorded over a specific time period. It provides the same function with voltage, current and resistance.
•Autorange mode: Automatically selects the frequency measurement range. If the frequency of the measured voltage is outside of the frequency measurement range, a DMM cannot display an accurate measurement. Refer to the user's manual for specific frequency measurement ranges

In some circuits, there may be enough distortion on the line to prevent an accurate frequency measurement. Example: ac variable frequency drives (VFDs) can produce frequency distortions.

Reference: Digital Multimeter Principles by Glen A. Mazur, American Technical Publishers.

How to Measure Frequency

How to Measure Frequency
If your digital multimeter offers a frequency setting (Hz is the symbol) on the dial:

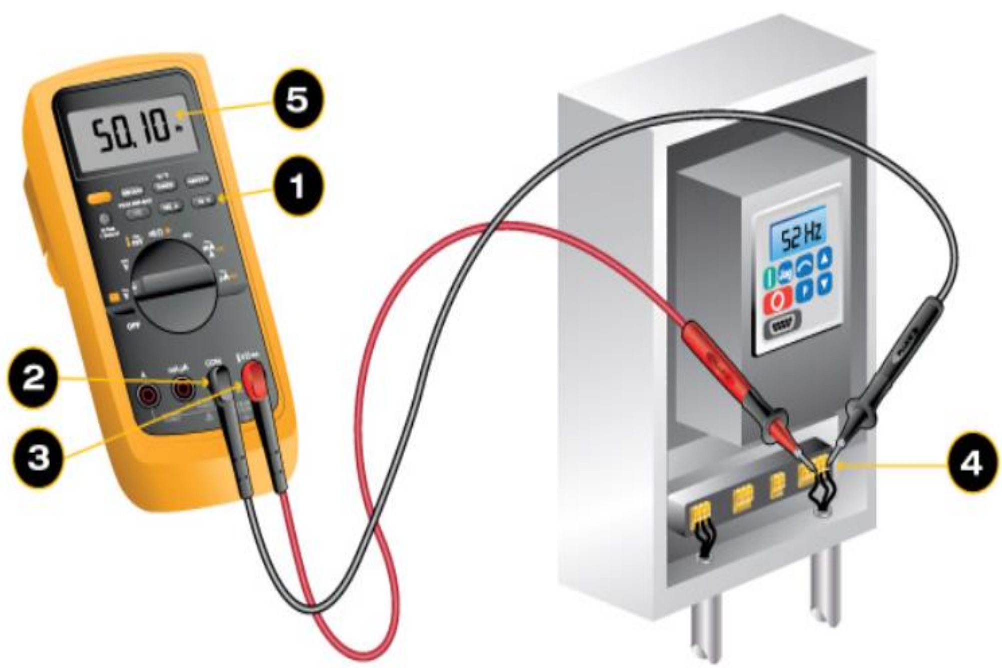
1. Turn the dial to Hz. It usually shares a spot on the dial with at least one other function. Some meters enter the frequency through a secondary function accessed by pushing a button and setting the rotary switch to ac or dc.

2. First insert the black test lead into the COM jack.

3. Then insert the red lead into the V Ω jack. When finished, remove the leads in reverse order: red first, then black.

4. Connect the black test lead first, the red test lead second. When finished, remove the leads in reverse order: red first, then black.

5. Read the measurement in the display. The abbreviation Hz should appear to the right of the reading.



Unit 2:
Measurement

Fundamentals of Electricity

Kirchhoff's Laws

What is Kirchhoff's Voltage Law?
Kirchhoff's voltage law states that the total voltage in a series circuit is equal to the sum of the individual voltage drops in the circuit.

Once the voltage drop across each load is found, add them all together and you will get a sum of the source voltage.

Kirchhoff's Voltage Law for a Series Circuit

$$V_T = V_{R1} + V_{R2} + V_{R3} \ldots$$

Where:

V_T = Total Voltage (volts)
V_{R1} = Voltage Drop across R1 (volts)
V_{R2} = Voltage Drop across R2 (volts)
V_{R3} = Voltage Drop across R3 (volts)

Kirchhoff's Voltage Law (KVL)
"The algebraic sum of all voltages in a loop must equal zero."

Kirchhoff's Current Law (KCL)
"The algebraic sum of all currents entering and exiting a node must equal zero."

Kirchhoff's Current Law Formula

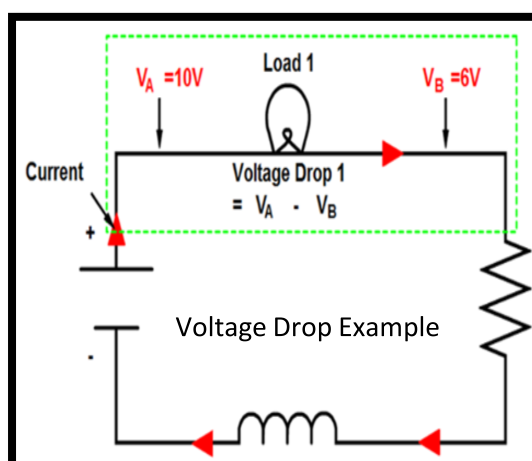
$$I_T = I_{R1} + I_{R2} + I_{R3} \ldots$$

Where:

I_T = Total Current (amps)
$I_{R1} I_{R2} I_{R3} \ldots$ = Current of Each Branch (amps)

How to Find Voltage Drop
The example below shows how to find the voltage drop across a load.

1. Turn on the power to the unit so the machine is operating and has current flowing through it.
2. Set your meter to voltage.
3. Measure the voltage from the input of the load to ground. This voltage is your first value (V_A).
4. Measure the voltage from the output of the load to ground. This voltage is your second value (V_B) and should be lower than the first.
5. Subtract the second value from the first value to get the voltage drop for that load. $V_A - V_B = V_T$



Unit 2:
Measurement

Fundamentals of Electricity

Current

We have just learned that voltage is the force that makes free electrons flow through a conductor. Current is the flow of electrons. We measure this flow in units of amperage or amps. Amperage is named in honor of Andre Ampere.

Kelly Wells

Clamp-on Ammeter

Amperage

Current is measured in amps with an ammeter. When 6.24×10^{18} (6.24 billion billion) electrons flow past a point (e.g. ammeter) per second it is measured as 1 amp. Increasing voltage also causes increased amperage.

Electrical Safety

A common phrase heard in reference to electrical safety goes something like this: “It’s not voltage that kills, its current!” While there is an element of truth to this, there’s more to understand about shock hazard than this simple adage. If voltage presented no danger, no one would ever print and display signs saying: DANGER—HIGH VOLTAGE! The principle that “current kills” is essentially correct. It is electric current that burns tissue, freezes muscles, and fibrillates hearts. However, electric current doesn’t just occur on its own: there must be voltage available to motivate electrons to flow through a victim. A person’s body also presents resistance to current, which must be taken into account.

Creative Commons

GFCI Outlet – 120 Volts AC

Ground Fault Circuit Interrupters

GFCI plugs and outlets detect any current flowing to ground instead of neutral and opens the circuit immediately to prevent current flow and possible electrocution.

Kelly Wells

GFCI Plug on Portable Air Conditioner Unit

Unit 2:
Measurement

Fundamentals of Electricity

Resistance

Resistance
Electrical resistance may be defined as the basic property of any substance due to which it opposes the flow of current through it.

While a voltage is applied across any substance, current starts flowing through it. But if we observe carefully, the current flows through the all substances are not equal even when the same voltage is applied across each of the substances. This is because current carrying capacity of all substances is not equal. The current depends upon the number of electrons' crossing the cross-section per unit time. Again this number of electrons crossing the cross-section is dependable on the free electrons available in the substances. If free electrons are plenty in a substance, the amount of current is more for same applied voltage across the substances.

The current through a substance not only depends upon the number of free electrons in it, but also depends upon the length of path an electron has to travel to reach from lower potential end to higher potential end of the substance. In addition to that, every electron has to collide randomly with other atoms and electrons in numbers of times during its traveling. So, every substance has a property to resist current through it and this property is known as electric resistance. If one volt across a conductor produces one ampere of current through it, then the resistance of the conductor is said to be one ohm (Ω).

Laws of Resistance
The resistance of any substance depends on the following factors,
1. The resistance of a substance depends on its length.
2. The resistance of a substance depends on its cross sectional area.
3. The resistance of a substance depends on the nature of material of the substance.
4. The resistance of a substance depends on the temperature of the substance.

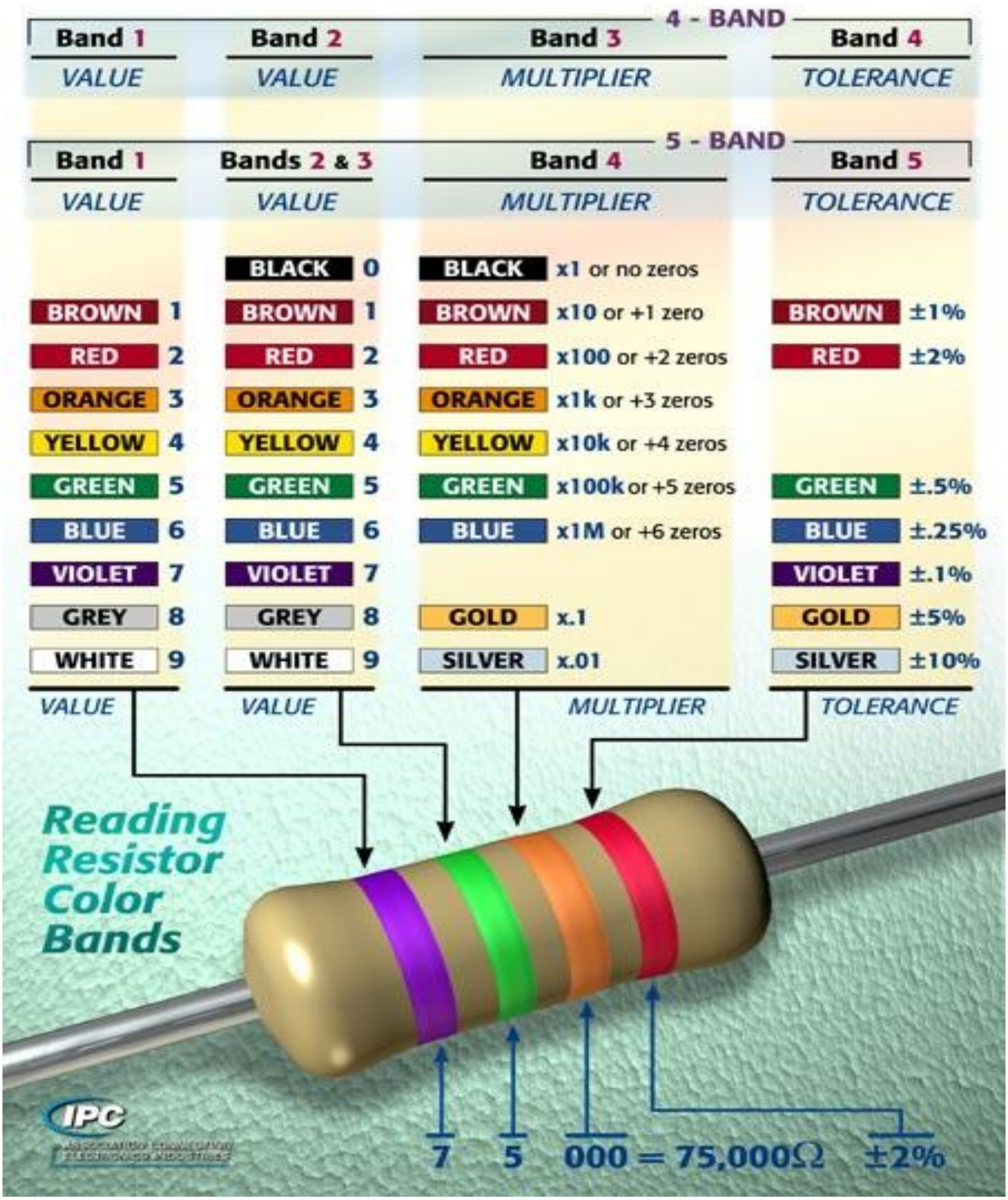
Resistance Variation with Temperature
There are some materials mainly metals, such as silver, copper, aluminum, which have plenty of free electrons. Hence this type of materials can conduct current easily that means they are least resistive. But the resistivity of these materials is highly dependable upon their temperature. Generally metals offer more electrical resistance if temperature is increased. On the other hand the resistance offered by a non - metallic substance (carbon resistor) normally decreases with increase of temperature.

https://www.electrical4u.com/electrical-dc-series-and-parallel-circuit/

Unit 2:
Measurement

Fundamentals of Electricity

Resistor Values



Unit 2:
Measurement

Fundamentals of Electricity

Power

Power
In addition to voltage and current, there is another measure of free electron activity in a circuit: power. First, we need to understand just what power is before we analyze it in any circuits.

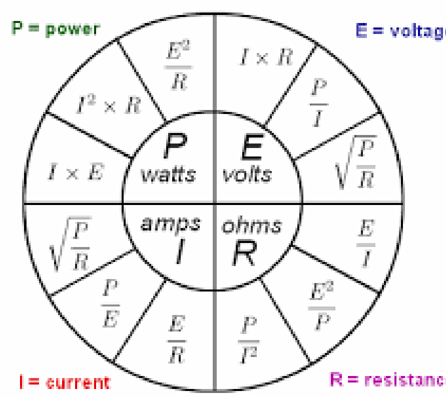
Power is a measure of how much work can be performed in a given amount of time. Work is generally defined in terms of the lifting of a weight against the pull of gravity. The heavier the weight and/or the higher it is lifted, the more work has been done. Power is a measure of how rapidly a standard amount of work is done.

In electric circuits, power is a function of both voltage and current. The formula for power is P = I x E (power equals amperage multiplied by voltage.

When using this formula, the unit of measurement for power is the watt, abbreviated with the letter "W."

It must be understood that neither voltage nor current by themselves constitute power.

Rather, power is the combination of both voltage and current in a circuit. Remember that voltage is the specific work (or potential energy) per unit charge, while current is the rate at which electric charges move through a conductor. Voltage (specific work) is analogous to the work done in lifting a weight against the pull of gravity. Current (rate) is analogous to the speed at which that weight is lifted. Together as a product (multiplication), voltage (work) and current (rate) constitute power.



Notes:________________

Ohm’s Law

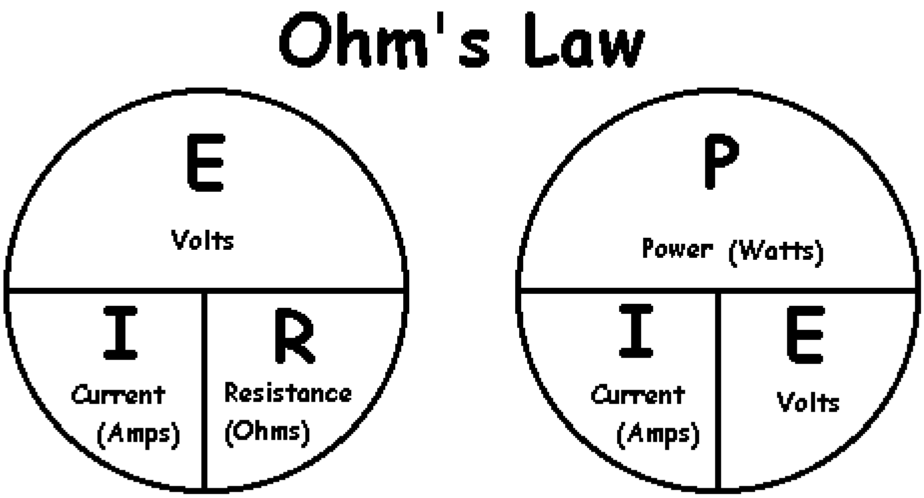
How voltage, current, and resistance relate
An electric circuit is formed when a conductive path is created to allow free electrons to continuously move. This continuous movement of free electrons through the conductors of a circuit is called a current, and it is often referred to in terms of ”flow,” just like the flow of a liquid through a hollow pipe. The force motivating electrons to ”flow” in a circuit is called voltage. Voltage is a specific measure of potential energy that is always relative between two points. When we speak of a certain amount of voltage being present in a circuit, we are referring to the measurement of how much potential energy exists to move electrons from one particular point in that circuit to another particular point. Without reference to two particular points, the term ”voltage” has no meaning.

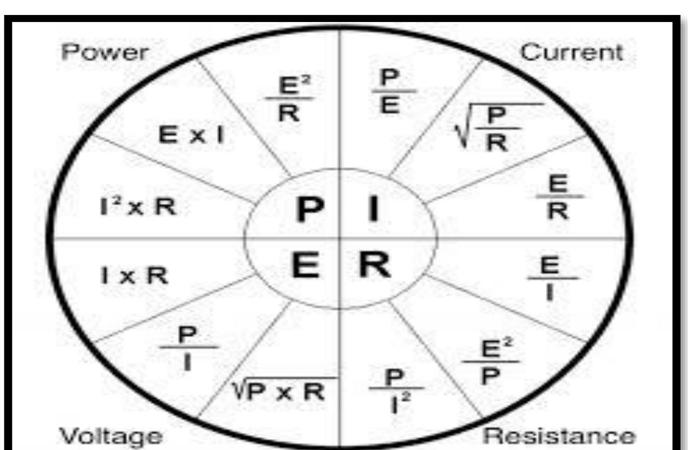
Electron Movement
Free electrons tend to move through conductors with some degree of friction, or opposition to motion. This opposition to motion is more properly called *resistance*. The amount of current in a circuit depends on the amount of voltage available to motivate the electrons, and also the amount of resistance in the circuit to oppose electron flow. Just like voltage, resistance is a quantity relative between two points. For this reason, the quantities of voltage and resistance are often stated as being ”between” or ”across” two points in a circuit.
To be able to make meaningful statements about these quantities in circuits, we need to be able to describe their quantities in the same way that we might quantify mass, temperature, volume, length, or any other kind of physical quantity. For mass we might use the units of
”kilogram” or ”gram.” For temperature we might use degrees Fahrenheit or degrees Celsius. Here are the standard units of measurement for electrical current, voltage, and resistance:

Quantity	Symbol	Unit of Measurement	Unit Abbreviation
Current	I	Ampere ("Amp")	A
Voltage	E *or* V	Volt	V
Resistance	R	Ohm	Ω

Ohm's Law

These units and symbols for electrical quantities will become very important to know as we begin to explore the relationships between them in circuits. The first, and perhaps most important, relationship between current, voltage, and resistance is called Ohm's Law, discovered by Georg Simon Ohm and published in his 1827 paper, The Galvanic Circuit Investigated Mathematically. Ohm's principal discovery was that the amount of electric current through a metal conductor in a circuit is directly proportional to the voltage impressed across it, for any given temperature. Ohm expressed his discovery in the form of a simple equation, describing how voltage, current, and resistance interrelate:

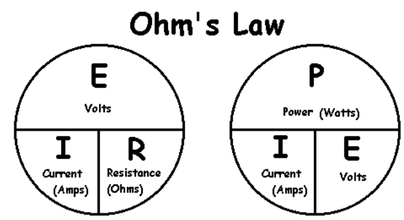




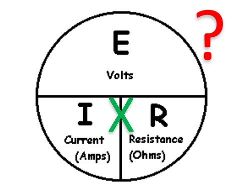
Unit 2:
Measurement

Fundamentals of Electricity

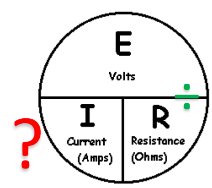
Ohm's Law



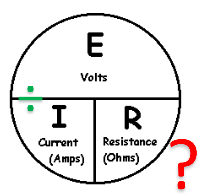
How does Ohm's Law work?
If you know two values, you can find the third with Ohm's Law. The two values on the bottom are always multiplied together. The value on top is always divided by the known value on the bottom.



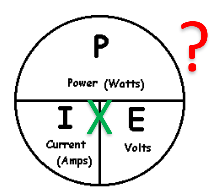
Voltage (Electromotive Force)
To find voltage (E) required for the circuit, you must multiply the amperage (I) and resistance (R) together.



Amperage (Intensity of Current)
To find amperage (I), voltage (E) would be divided by resistance (R).



Ohm's (Resistance to current Flow)
To find resistance (R), voltage (E) must be divided by amperage (I).



Watts (Power)
To find power (P), multiply amperage (I) by voltage (E).

Notes:____

Unit 2:
Measurement

Fundamentals of Electricity

Ohm's Law

Need Power, Know Voltage and Current

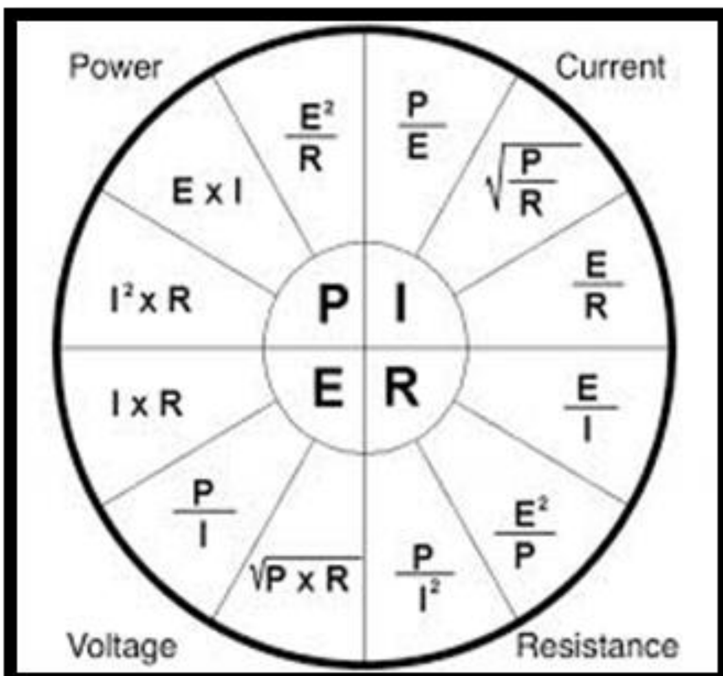
Need Power, Know Voltage and Resistance

Need Current, Know Power and Voltage

Need Current, Know Power and Resistance

Need Power, Know Current and Resistance

Need Current, Know Voltage and Resistance



Need Voltage, Know Current and Resistance

Need Resistance, know Voltage and Current

Need Voltage, Know Power and Current

Need Voltage, Know Power and Resistance

Need Resistance, Know Power and Current

Need Resistance, Know Voltage and Power

Unit 2:
Measurement

Metric Prefixes

Sometimes when dealing with electrical measurements the values can be very large or very small. To make things easier, prefixes are used. Some common used prefixes in electricity include:

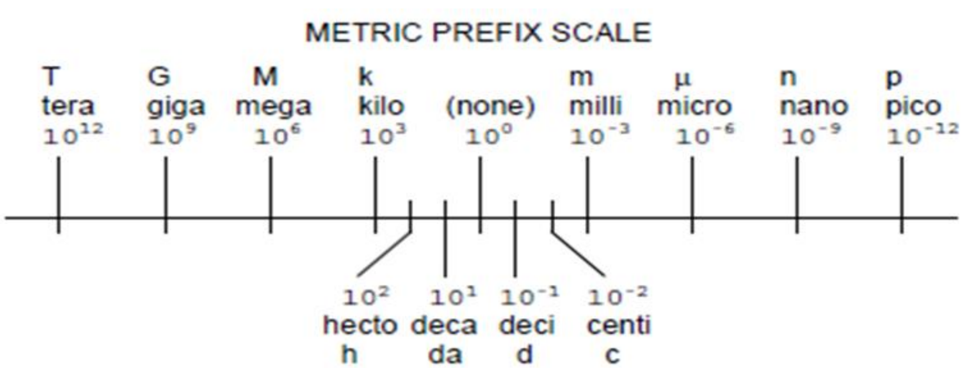
Right Side of Zero
Mega (M) = 1,000,000 (One Million)
1,000,000Ω = 1MΩ
Application: Checking wiring insulation

Kilo (k) = 1,000 (One Thousand)
1,000 Watts = 1kW
Application: Power rating

Left Side of Zero
Milli (m) = 1/1000th (One one-thousandth)
0.001 volt = 1mV
Application: Thermocouple voltage range

Micro (µ) = 1/1,000,000th (One millionth)
0.000001 amp = 1µA
Application: Flame rectification

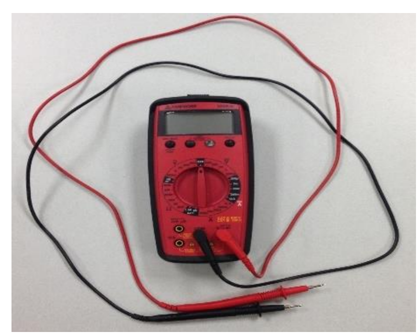
- Yotta = 10^{24} Symbol: Y
- Zetta = 10^{21} Symbol: Z
- Exa = 10^{18} Symbol: E
- Peta = 10^{15} Symbol: P
- Tera = 10^{12} Symbol: T
- Giga = 10^{9} Symbol: G
- Mega = 10^{6} Symbol: M
- Kilo = 10^{3} Symbol: k
- Hecto = 10^{2} Symbol: h
- Deca = 10^{1} Symbol: da
- Deci = 10^{-1} Symbol: d
- Centi = 10^{-2} Symbol: c
- Milli = 10^{-3} Symbol: m
- Micro = 10^{-6} Symbol: μ
- Nano = 10^{-9} Symbol: n
- Pico = 10^{-12} Symbol: p
- Femto = 10^{-15} Symbol: f
- Atto = 10^{-18} Symbol: a
- Zepto = 10^{-21} Symbol: z
- Yocto = 10^{-24} Symbol: y



Multimeters

Kelly Wells

Digital Multimeter (DMM)



Kelly Wells

Digital Multimeter with Leads

Kelly Wells

Digital Multi-meter / Ammeter

Multimeters are instruments used for taking a variety of electrical measurements types. Most multimeters will measure AC voltage, DC voltage, AC and DC amperage (up to 10 amps), resistance (Ohms), and continuity. Some are also clamp-on ammeters and some will even take temperature measurements using a thermocouple.

Measuring Circuit Voltage

Plug the probes into the meter. Red goes to the positive (+) and black to the negative (-).

Turn the selector dial or switch to the type of measurement you want. To measure alternating current, such as a wall outlet for home appliances use ACV or V~. To measure direct current, a battery for example - use DCV or V-.

Choose the range setting. The dial may have options from 10 to 1000 on the ACV side, and 5 to 1000 on the DCV side. The meter should be set at the top end of the voltage you are reading. For example the setting should be higher than 120 for a 120V wall outlet. If the measurement scale is set too low, the meter's internal fuse may burn out.

Hold the probes by the insulated handles and touch the red probe to the positive side of a DC circuit or either side of an AC circuit. Touch the other side with the black probe.

Read the digital display or analog dial for voltage measurement.

A digital multimeter is often referred to as a DMM.

Unit 2:
Measurement

Fundamentals of Electricity

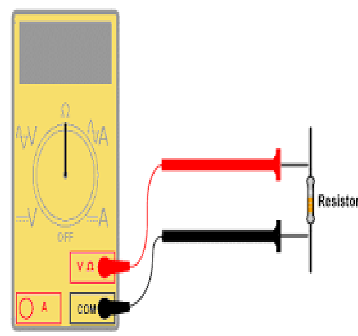
Multimeters - Resistance

Multimeters can also be used to measure resistance. Resistance is measured in Ohms. The symbol for Ohms is the Greek Omega symbol Ω. This setting will measure the resistance of components or the continuity of conductors, component windings, and component contacts.

Measuring Circuit Resistance
Select a setting within the Ω (ohms) section on the meter dial. Setting options are usually between 200 – 20M (million). Using higher range settings will increase the meters sensitivity to resistances.

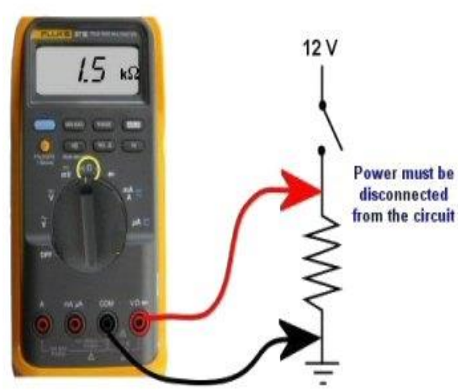
Disconnect the power and isolate the component.

Touch the positive (red) and negative (black) probes together, the reading you receive is a closed circuit (power can flow with 0 resistance). Now place the leads across the component. You should receive a resistance reading. If it reads “I” or O.L, there is no resistance and the circuit is open.



Technologyuk.net

Measuring Resistance Across a Resistor



Pinterest.com

Measuring Resistance

Notes:____________________________
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Unit 2:
Measurement

Multimeters - Continuity

How to test for continuity

1. Turn the dial to Continuity Test mode (continuity). It will likely share a spot on the dial with one or more functions, usually resistance (Ω). With the test probes separated, the multimeters display may show OL and Ω.
2. If required, press the continuity button.
3. First insert the black test lead into the COM jack.
4. Then insert the red lead into the V Ω jack. When finished, remove the leads in reverse order: red first, then black.
5. With the circuit **de-energized**, connect the test leads across the component being tested. The position of the test leads is arbitrary. Note that the component may need to be isolated from other components in the circuit.
6. The digital multimeter (DMM) beeps if a complete path (continuity) is detected. If the circuit is open (the switch is in the OFF position), the DMM will not beep.
7. When finished, turn the multimeter OFF to preserve battery life.

Digital Multimeter (DMM)

Kelly Wells

Continuity testing overview

•Continuity is the presence of a complete path for current flow. A circuit is complete when its switch is closed.
•A digital multimeters Continuity Test mode can be used to test switches, fuses, electrical connections, conductors and other components. A good fuse, for example, should have continuity.
•A DMM emits an audible response (a beep) when it detects a complete path.
•The beep, an audible indicator, permits technicians to focus on testing procedures without looking at the multimeter display.
•When testing for continuity, a multimeter beeps based on the resistance of the component being tested. That resistance is determined by the range setting of the multimeter. Examples:
◦If the range is set to 400.0 Ω, a multimeter typically beeps if the component has a resistance of 40 Ω or less.
◦If the range is set 4.000 kΩ, a multimeter typically beeps if the component has a resistance of 200 Ω or less.

•The lowest range setting should be used when testing circuit components that should have low-resistance value such as electrical connections or switch contacts.

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Testing Continuity of a Fuse

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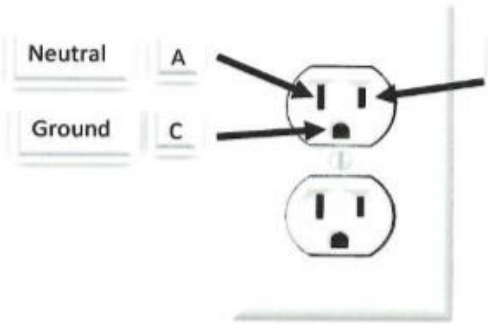
Testing Continuity of a Wire

Fundamentals of Electricity

Hands-On Exercise: Check Voltage at a 120VAC outlet



How to Check Voltage on a 120 Volt Wall Outlet

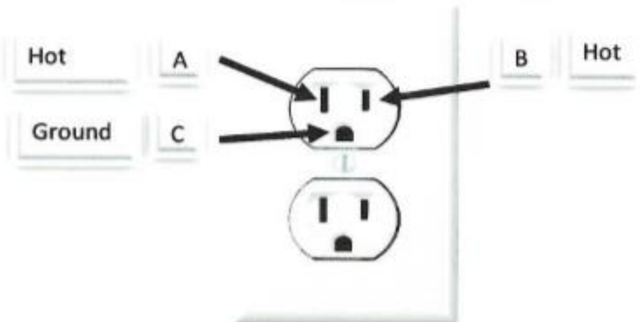
1. Set digital multimeter to **AC** Voltage in the highest range.
2. Put the red lead in **B** and the black lead in **A**. You should read around 120.
3. Put the red lead in **B** and the black lead in **C**. You should read around 120.
4. Put the red lead in **A** and the black lead in **C**. You should read around .5 volts or less.

Note: The bottom half of the outlet is the same as the top half of the outlet as the ports are internally connected.

Unit 2:
Measurement

Fundamentals of Electricity

Hands-On Exercise: Check Voltage at a 208 VAC Outlet



How to Check Voltage on a 208 Volt Wall Outlet

1. Set digital multimeter to **AC** Voltage in the highest range.
2. Put the red lead in **B** and the black lead in **A**. You should read around 208.
3. Put the red lead in **B** and the black lead in **C**. You should read around 120.
4. Put the red lead in **A** and the black lead in **C**. You should read around 120.

Note: The bottom half of the outlet is the same as the top half of the outlet as the ports are internally connected.

Clamp Meter Vs. DMM

Comparing clamp meters to digital multimeters

A digital multimeter is essentially a voltage-measuring tool with some current abilities. A clamp meter is basically a current-measuring tool with some voltage abilities. They are distinctly different instruments, each with its own advantages.

A digital multimeter (DMM) allows you to do electronic work because it offers high resolution, measuring in milliunits—millivolts, milliamps and milliohms. It also allows you to do electrical measurements, though current is usually limited to less than 20 amps. A digital multimeter, however, can measure higher currents if a plug-in clamp accessory is attached.

A clamp meter usually measures to the nearest tenth or hundredth of a unit, rather than in the milliunits available with a DMM. This is sufficient for electrical tasks.

Measuring situations

In years past, electricians used test probes rather than a clamp to measure current. A clamp allows you to measure current without breaking the circuit and get a current reading.

In addition, a new generation of clamp meters utilizes flexible current probes, which Fluke calls iFlex®. These Rogowski coil probes can squeeze between tightly packed wires or around large conductors. They can be handy in a number of situations:

- Measuring an analog conveyor speed signal and the respective motor current simultaneously, so you can calibrate the system for the required process flow.
- Monitoring solenoid output while monitoring input from the PLC, so you can test the solenoid.
- Simultaneously measuring electronic voltages and electrical currents at a motor drive, to troubleshoot line speed fluctuations.
- Monitoring feeder voltage and current simultaneously, to troubleshoot nuisance trips.

Simultaneous voltage and current measurements are part of troubleshooting. Yet you cannot do simultaneous measurements with one meter unless you step up several price ranges into equipment used for power quality work.

Effective troubleshooting often requires two meters, one to measure electrical current and one to measure voltage. For electricians, a clamp meter is the most versatile diagnostic tool available. Persons doing industrial troubleshooting, meanwhile, benefit from a separate clamp and DMM.

A cost-effective approach for many technicians is to buy one quality instrument designed primarily for voltage (a DMM) and another tool primarily used for current (a clamp meter).

The right combination of test equipment depends on the equipment you work on and the measurements you make. With a clamp meter, for example, you might need a low-pass filter to eliminate electronic interference that could distort readings.

Here are some general guidelines for deciding which tool might be right for you:

- **Basic DMM:** If your job requires only basic voltage and continuity measurements.
- **High-end DMM:** If your job involves power quality work. You'll need the high resolution and advanced features not found on clamp meters.
- **Basic clamp meter:** If you just need basic current measurements such as ensuring all three phases on your feeders are pulling the same current.
- **Logging clamp meter**: If you have intermittent breaker trips that you need to resolve.
- **DMM or clamp meter with a detachable display** (which can be separated 30 feet from the body of the clamp): If you want to take remote readings with greater safely and without needing a coworker to assist you.

Advanced clamp meter: If you need to accurately measure motor inrush current. Also, if you need a clamp meter with advanced signal processing to measure the output of a variable frequency drive.

www.fluke.com

How to Use an Ammeter

The ammeter show is a digital clamp-on ammeter/multimeter. It will also check voltage, resistance, temperature and other things.

Kelly Wells

Clamp-on Ammeter

Since an ammeter is used to measure current through a wire you must clamp it around only one wire at a time. If you need to check amperage at the power supply, a cord or device must be used to separate the hot and neutral wires so they can be clamped around individually. Here we will check the amperage draw of a desk fan.

The photo shows the ammeter set to read amperage and clamped around the black (hot) wire. This gives a reading of +0.241 amps. The fan is pulling 0.241 amps on its medium setting.

This photo shows the ammeter clamped around the white (neutral) wire. It gives a reading of - 0.247 amps. In AC voltage the voltage alternates between hot and neutral. This is why there is an amp reading on the neutral side.

This photo shows the ammeter clamped around the black (hot) and white (neutral) wires at the same time. This gives a reading of 0.001 amps. This is because the positive current running through the black wire (+0.24 amps) and the negative current running through the white wire (-0.24 amps) cancel each other out to give a reading of zero.

In-Rush Current

How and why to measure inrush current

When an electrical device is first powered on, inrush current is the surge or momentary burst of current that flows into it.

Think of a car sitting on flat pavement, parked in neutral, engine off. To get it moving without using the engine, a human would need to give it a substantial push, probably a vigorous leg drive. Once moving, though, the car's wheels roll more cooperatively with less physical oomph required.

That initial, emphatic leg drive is the equivalent of inrush current. The subsequent, easy-rolling motion equals the steady-state current flow that occurs in a motor once its gears and rotors have been jolted out of inertia and into motion.

Why does this measurement matter? Newer, high-efficiency motors draw more running current than their predecessors. Knowing the value of inrush current can help a technician locate a startup problem, whether it's in the motor or in the starting circuit. Inrush measurements are usually recorded in a preventative maintenance log for future reference.

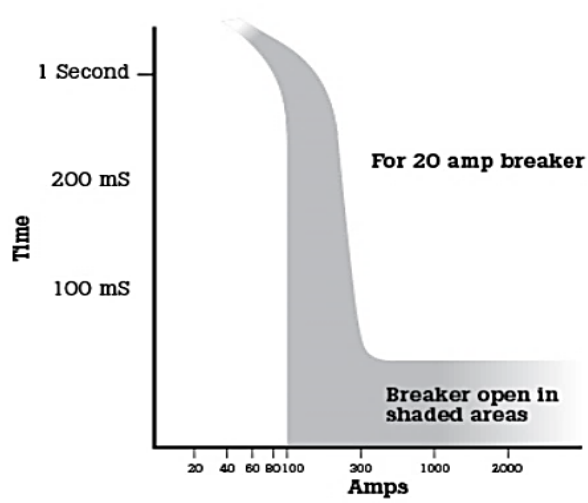
To provide repeatable motor inrush measurements, advanced clamp meters (such as the Fluke 370 series or the Fluke 381) use a "triggered" mode that synchronizes measurements with the starting current.

Technicians "arm" a meter by pressing its inrush button. The meter is then triggered by the inrush current. Once triggered, this inrush function takes approximately 400 samples over a 100-millisecond period and calculates the actual starting current.

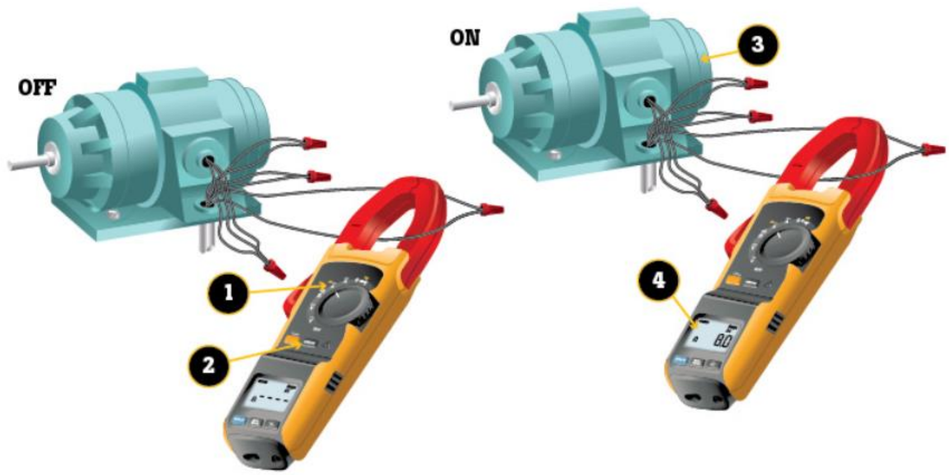
Inrush current may cause a meter's display to show a value that is higher than the rating of the circuit breaker, yet the breaker does not trip. Why so?

Inrush current can be 4 to 10 times greater than the normal running current, depending on the type of motor. So if a motor's running current is eight amperes and its circuit breaker is rated for 20 amperes, how is it possible that a clamp meter could display a measurement of 40 amps?

The reason the breaker or overload unit do not trip is because both devices work on a time-vs.-current curve. This curve (see chart) indicates how much current passes through the breaker, and for what length of time, without opening the circuit.



How To Measure In-Rush Current with a Clamp Meter



To measure the inrush current, technicians can use either a hard-jawed clamp meter or a flexible current probe. Only meters that offer an inrush button can measure inrush current. Here are steps for measuring it, in this case when using the Fluke 381 (see illustration above):

1. With the device to be tested turned off, turn the meter's dial to Hz~ A, ⎓ A, or, if a flexible current probe is being used, to iFlex Hz A.
2. Center the jaw or flexible probe around the device's live wire.
3. Push the inrush button, INRUSH on the face of the meter.
4. Switch on the device. The inrush current (spike) is displayed in the meter's display.

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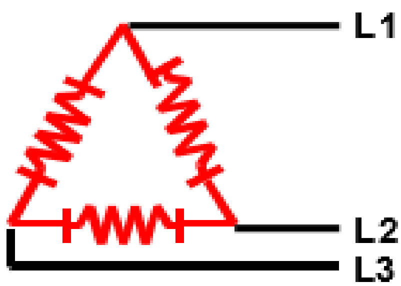
How to Find Amperage on Three-Phase Loads



Three Phase Amperage

To Determine Three Phase Amperage, Solve for Single Phase First

$$\frac{\text{Wattage}}{\text{Voltage}} = \text{Single Phase Amps}$$

Then divide the single phase amperage by 1.73 to determine three phase Amps.

ie. . $$\frac{17000W}{240V} = \frac{70.833 \text{ Amps}}{1.73}$$

$= 40.944$ Amps per phase

Clamp Meter Safety Tips

Safety tips

In its clamp meter product manuals, Fluke offers the following safety guidelines to help users avoid electrical shock or personal injury:

- Use the meter only as specified in this manual. Otherwise the protection provided by the meter can be compromised.
- Examine the case before you use the meter. Look for cracks or missing plastic.
- Carefully look at the insulation around the connectors.
- Never measure current while the test probes are inserted into the input jacks.
- Make sure the battery door is closed and latched before operating the meter.
- Remove the test probes from the meter before the battery door is opened.
- Examine the test probes for damaged insulation or exposed metal. Check test probe continuity. Replace damaged test probes before using the meter.
- Do not use the meter if it operates incorrectly. Protection can be compromised. When in doubt, have the meter serviced.
- Do not use the meter around explosive gas, vapor or in damp or wet environments.
- Use only the specified battery type, properly installed in the meter case, to power the meter.
- When measuring current with the meter's Jaw, keep fingers behind the tactile barrier.
- To avoid false readings that can lead to electrical shock and injury, replace the batteries as soon as the low-battery indicator  appears.
- When servicing the meter, use only specified replacement parts.
- Have the meter serviced only by qualified service personnel.
- Be careful around voltages > 30 V ac rms, 42 V ac peak, or 60 V dc. Such voltages pose a shock hazard.
- Do not apply more than the rated voltage, as marked on the meter, between the terminals or between any terminal and earth ground.
- When using the probes, keep fingers behind the finger guards on the probes.
- Connect the common test probe before connecting the live test probe. When disconnecting test probes, disconnect the live test probe first.
- Do not work alone so assistance can be rendered in an emergency.
- Use extreme caution when working around bare conductors or bus bars. Contact with the conductor could result in electric shock.
- Adhere to local and national safety codes. Individual protective equipment must be used to prevent shock and arc blast injury where hazardous live conductors are exposed.
- Disconnect circuit power and discharge all high-voltage capacitors before you measure resistance, continuity, or capacitance.
- Know your meter. For example, for the Fluke 374 and 375, do not measure ac/dc current in circuits carrying more than 1000 V or 600 A with the meter jaw.
- For the Fluke 376, do not measure ac/dc current in circuits carrying more than 1000 V or 1000 A with the meter's jaw.
- Never operate the meter with the back cover removed or the case open.
- Check your manual for specific restrictions. For some models, do not measure ac current in circuits carrying more than 1000 V or 2500 A with a flexible current probe.
- Do not apply a flexible current probe around or remove from HAZARDOUS LIVE conductors.
- Do not use the flexible current sensor if the inner contrasting insulation color is showing.
- When using a flexible current probe, take special care while fitting and removing the probe. De-energize the installation under test or wear suitable protective clothing.

Unit 3:
Components

Circuit Breakers

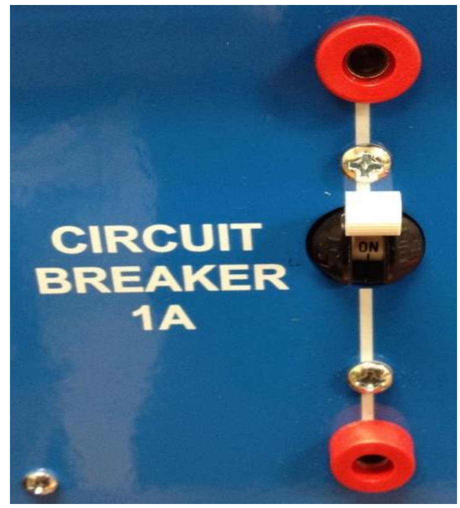
What are Circuit Breakers?
Circuit Breakers are reusable overcurrent protection devices. After tripping to break the circuit, the breaker can be reset to protect the circuit again.

There are two accepted definitions for circuit breakers:

- The National Electrical Manufacturers Association (NEMA) defines a circuit breaker as a device designed to open and close a circuit, by non-automatic means, and to open the circuit automatically on a predetermined overcurrent without injury to itself when properly applied within its rating.

- The American National Standards Institute (ANSI) states that a circuit breaker is a mechanical switching device capable of making, carrying and breaking currents under normal circuit conditions. Also, it is capable of making and carrying a current for a specified time, and breaking currents under specified abnormal circuit conditions such as those of a short circuit.

Notes:



1 amp Circuit Breaker in the on position

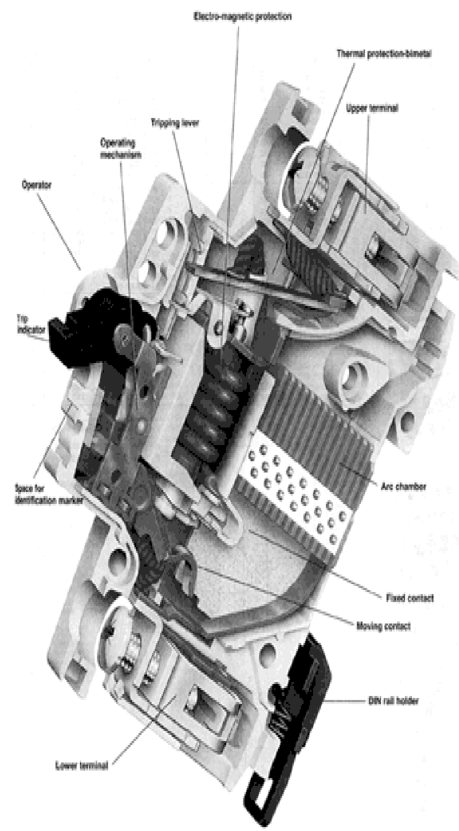
Circuit Breakers in a Breaker Panel

Unit 3:
Components

Fundamentals of Electricity

Circuit Breaker Frame

All circuit breakers have the following common design and functional characteristics:

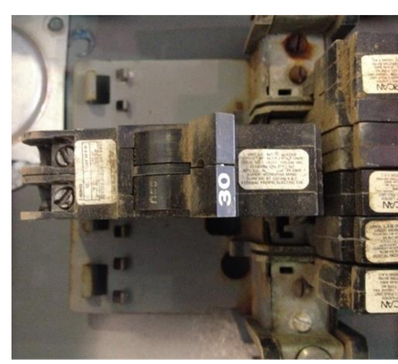


Circuit Breaker Frame

The circuit breakers frame provides a method by which all the required components can be mounted and kept in place, ensuring the proper operation of the circuit breaker. The circuit breaker frame provides the rigidity and strength required to successfully deal with the interruption process and achieve the desired Interrupting Ratings. The frame's mechanical strength must be sufficient to withstand the forces created by the square of the current (I2), which could be quite large and potentially destructive. The frame provides for insulation and isolation of the current path, offering personnel protection near the equipment during operation. The frame also plays a critical role in the circuit breakers ability to comply with standards. There are two types of frames:

- Metal Frame - Metal Frame circuit breakers are assembled from precise metal pieces that are bolted and welded together to form the frame. Older low voltage power circuit breakers and current medium voltage power circuit breakers are of the metal frame design. Historically, all power circuit breakers, both above and below 600 volts, have been referred to as metal frame circuit breakers. The metal frame design is still being used for higher voltages.

- Molded Insulating Material - Molded insulated material frames are made from a strong insulating material, such as glass-polyester or thermoset composite resins. Sizes vary according to the Ampere Rating size of the circuit breaker. Molded insulated material frames are primarily associated with low voltage molded case circuit breakers and insulated case circuit breakers. Because of advances in materials and technology, we are now seeing molded insulated case power circuit breakers at 600 volts and higher.

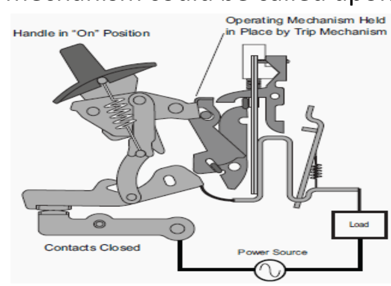


Circuit Breaker Contacts

Contacts and Operating Mechanism

Contacts in a circuit breaker provide a method for connecting the circuit with the system. They also provide a method for isolating a part of a circuit from the rest of the system. A contact set contains a fixed and movable contact. As a circuit breaker opens or closes, the fixed contact maintains its position while the movable contact moves to close (make) or open (break) the circuit. When all is said and done, contacts perform a simple function; they open and close. Circuit breakers require some type of operating mechanism to open and close the contacts. This operating mechanism can be mechanical or a combination of mechanical and power. Depending upon the type of circuit breaker being considered, the operating mechanism could be called upon to:

1. Open and close the contacts manually
2. Open and close the contacts on demand
3. Open the contacts automatically



Springs

Springs play a big role in the precise functioning of circuit breaker mechanisms. Springs are stretched or compressed to provide the energy necessary to assist with the proper opening or closing of the contacts. There are two types of spring-assisted mechanisms:

- Over Toggle Mechanism - A manual handle on the circuit breaker is operated to set the mechanism in motion. The handle is moved, whether opening or closing the circuit breaker, until a point is reached where the handle goes over-toggle (past the point of no return), and the spring-assisted mechanism automatically opens or closes the circuit breaker. This toggle mechanism is called the Quick-Make, Quick-Break type, which means that the speed with which the contacts open or close is independent of how fast the handle is moved. A motor operator can be used to operate the handle automatically in lieu of manual operation. The design is such that the circuit breaker would trip open when required, even if the manual handle was held in the ON (closed) position.

- Two Step Stored Energy Mechanism - The two-step stored energy mechanism is used when a lot of energy is required to close the circuit breaker and when it needs to close rapidly. The two-step stored energy process is designed to charge the closing spring and release energy to close the breaker. It uses separate opening and closing springs. This is important because it permits the closing spring to be changed independently of the opening process. This allows for an open-close-open duty cycle. The motor can be operated remotely, allowing maximum safety for the operator. The major advantages of the two-step stored energy mechanism are rapid reclosing and safety. Rapid reclosing is achieved by storing charged energy in a separate closing spring. Safety is achieved by providing remote charging of the spring.

Unit 3:
Components

Circuit Breaker Contacts

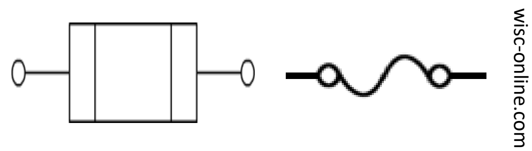
Trip Unit
For a circuit breaker to be effective, it needs to have some intelligence to enable it to perform automatically or respond to a command. Without this capability, a circuit breaker would just be a fancy switch. A trip unit is the circuit breakers intelligence. Its function is to trip the operating mechanism (open the circuit) in the event of these overcurrent conditions:
1. Thermal Overload
2. Short Circuit
3. Ground Fault
There are two types of Trip Units:

• Electromechanical - This type of trip unit is generally used in low voltage circuit breakers. It is integrally mounted into the circuit breaker and is temperature sensitive. Thermal magnetic trip units act to protect the conductor (wire), safeguarding equipment under high ambient conditions and permitting higher safe loading under low ambient conditions. This trip unit utilizes bimetals and electromagnets to provide overload and short circuit protection, which is referred to as thermal magnetic. The thermal trip portion is used for overload protection. Its action is achieved using a bimetal heated by the load current. On a sustained overload, the bimetal will deflect, causing the operating mechanism to trip. The magnetic trip portion is used for short circuit (instantaneous) protection. Its action is achieved with an electromagnet whose winding is in series with the load current. When a short circuit occurs, the current passing through the conductor causes the electromagnet's magnetic field to rapidly increase, attracting the armature and causing the circuit breaker to trip.

• Electronic - In general, electronic trip units are composed of three components, which are internal to the trip unit. These components include the current transformer, circuit board and flux transfer shunt trip. The current transformer is used in each current phase to monitor and reduce the current to the proper input level. The circuit board is the brains of the system. It interprets input current and makes a decision based on predetermined parameters. A decision to trip sends an output to the flux-transfer shunt trip. The flux-transfer shunt trip is the component that trips the circuit breaker.

Fuses

What is a fuse?
Fuses are circuit protection devices installed (in series) in circuits to protect the circuit from excess current. Current flows through a circuit and is controlled by resistance in the circuit. If for some reason this resistance is reduced (i.e., a direct short) then current flow increases. If current flow increases too much, the circuit is at risk. Conductors (wire) in the circuit are rated to handle only a certain amount a current. If the current flowing through a conductor exceeds the conductors rating, the conductor can heat up. If it heats up too much, the insulation on the conductor may melt which will expose the live wires. If the wires come in contact with the neutral wires, this can create a spark and start a fire. Fuses should never be bypassed and should always be replaced with the proper size replacement fuse.

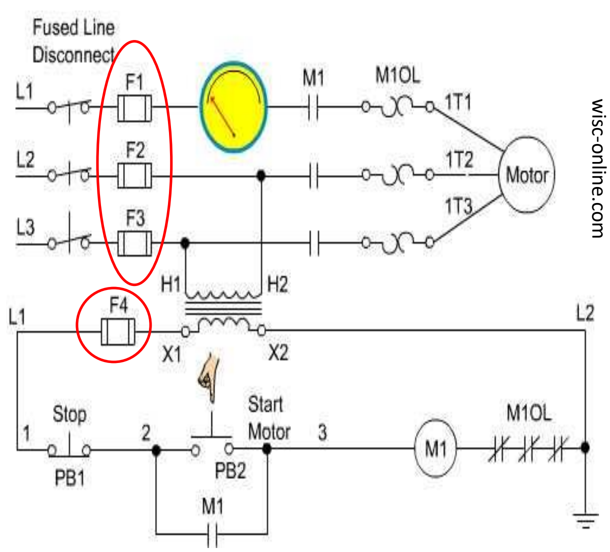


Fuse Schematic Symbols

Fuses on a Conveyor Oven

Blown Fuses
Fuses installed in circuits will open the circuit if excess current starts to flow in the circuit due to a fault. If a fuse opens (blows) it must be replaced in order for the circuit to work again. A blown fuse indicates a fault in the circuit and the technician should resolve this fault before returning the machine to operation.

Blown Fuse



Fuses on a Three-Phase Motor System

Unit 3:
Components

Fundamentals of Electricity

Switches

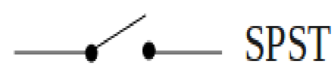
Switches
Most electric circuits contain an on/off switch. In addition to the on/off switch, many circuits contain switches that control how the circuit works or activate different features of the circuit. One way to classify switches is by the connections they make. Two important factors that determine what types of connections a switch makes are poles and throws.

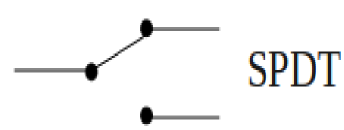
© Kelly Wells

Switch Poles
A switch pole refers to the number of separate circuits that the switch controls. A single-pole switch controls just one circuit. A double-pole switch controls two separate circuits. A double-pole switch is like two separate single-pole switches that are mechanically operated by the same lever, knob, or button.

Switch Throws
The number of throws indicates how many different output connections each switch pole can connect its input to. The two most common types are single-throw and double-throw.

Single-Throw Switch (SPST)
A single-throw switch is a simple on/off switch that connects or disconnects two terminals. When the switch is closed, the two terminals are connected and current flows between them. When the switch is opened, the terminals are not connected, so current does not flow.





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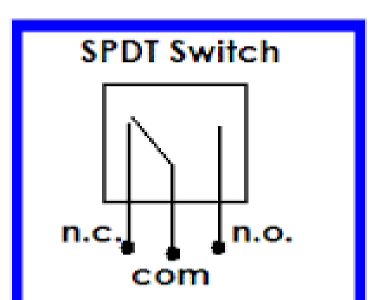
Double-Throw Switch (SPDT)
A double-throw switch connects an input terminal to one of two output terminals. Thus, a double-pole switch has three terminals. One of the terminals is called the common terminal. The other two terminals are often referred A and B or as normally open (NC) and normally closed (NO). A normal position indicates the position of the switch when it is not being actuated.

How Poles and Throws Work
When the switch is in one position, the common terminal is connected to the NC terminal, so current flows from the common terminal to the NC terminal but no current flows to the NO terminal. When the switch is moved to its other position, the terminal connections are reversed: current flows from the common terminal to the NO terminal, but no current flows though the NC terminal.



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http://www.dummies.com/programming/electronics/components/switches-in-electronic-circuits-poles-and-throws/

Unit 3:
Components

Fundamentals of Electricity
Switch Types

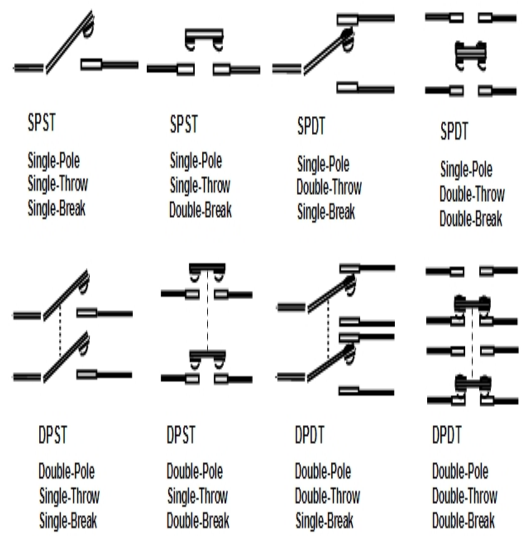
Switch Types
Switches vary in both the number of poles and the number of throws. Most switches have one or two poles and one or two throws. This leads to four common combinations:

- SPST (single pole, single throw): A basic on/off switch that turns a single circuit on or off. An SPST switch has two terminals: one for the input and one for the output.

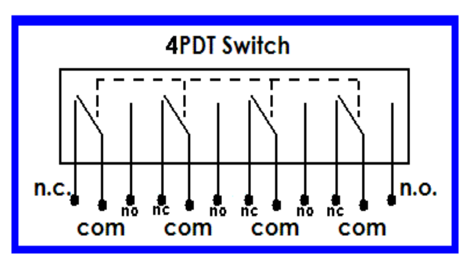
- SPDT (single pole, double throw): An SPDT switch routes one input circuit to one of two output circuits. This type of switch is sometimes called an A/B switch because it lets you choose between two circuits, called A and B. An SPDT switch has three terminals: one for the input and two for the A and B outputs.

- DPST (double pole, single throw): A DPST switch turns two circuits on or off. A DPST switch has four terminals: two inputs and two outputs.

- DPDT (double pole, double throw): A DPDT switch routes two separate circuits, connecting each of two inputs to one of two outputs. A DPDT switch has six terminals: two for the inputs, two for the A outputs, and two for the B outputs.



Switches With More Than Two Poles or Throws
Switches with more than two poles or more than two throws are not commonplace, but they do exist. Rotary switches lend themselves especially well to having many throws. For example, the rotary switch in a multimeter typically has 16 or more throws, one for each range of measurement the meter can make. These types of switches are common in the cooking equipment industry.



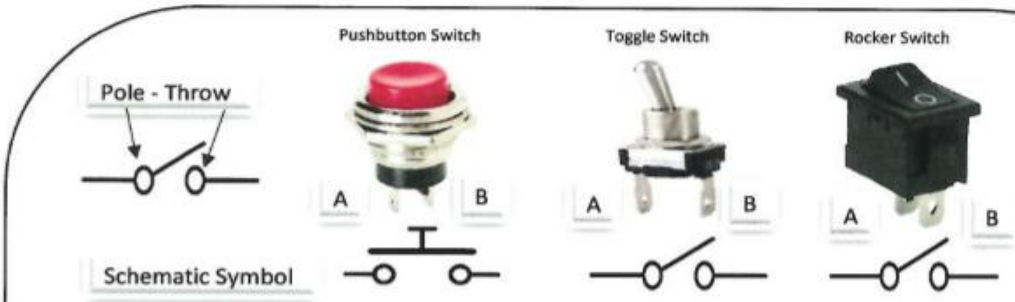
Common Variation
A common variation of a double throw switch is to have a middle position that does not connect to either output. Often called center open, this type of switch has three positions, but only two throws. For example, an SPDT center open switch can switch one input between either of two outputs, but in its center position, neither output is connected.

http://www.dummies.com/programming/electronics/components/switches-in-electronic-circuits-poles-and-throws/

Unit 3:
Components

Fundamentals of Electricity

Hands On Exercise: Test a switch for continuity and resistance

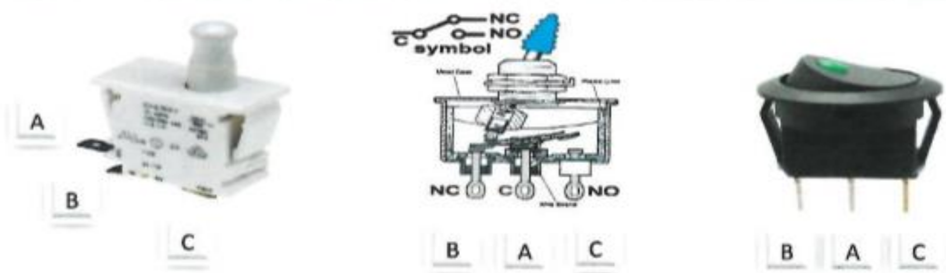


Switch Legend

Com = Common (Power In)
NC = Normally Closed (Connected to common when switch is not activated)
NO = Normally Open (Connects to common when switch is activated)

How to Test Continuity on a Single Pole Single Throw Switch

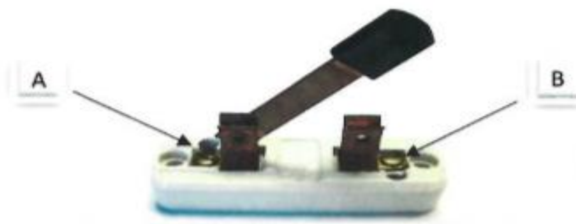
1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (e.g. - 200Ω).
3. Put one lead on terminal **A** (Com) and the other lead on terminal **B** (NO).
4. When the switch is open (off) you should read "**I**" or "**O.L**".
5. When the switch is closed (on) you should read "**000**" or higher indicating a small amount of resistance.

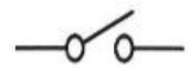


How to Test Continuity on a Single Pole Double Throw Switch

1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).
3. Set switch operator in the off position.
4. Put one lead on terminal A (Com) and the other lead on terminal B (NC). You should read "000". The circuit is closed.
5. Put one lead on terminal A (Com) and the other lead on terminal C (NO). You should read "I" or "O.L". The circuit is open.
6. Put one lead on terminal B and the other lead on terminal C. You should read "I" or "O.L".
7. Put one lead on terminal E and the other lead on terminal F. You should read "I" or "O.L".

Hands On Exercise: Test a knife switch for continuity and resistance

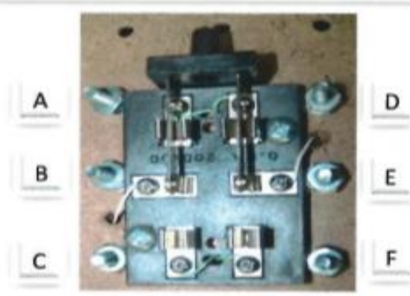


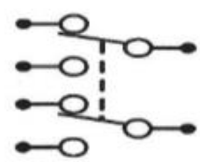


Schematic Symbol

How to Test a Single Pole Single Throw Knife Switch

1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).
3. Put one lead on terminal **A** and the other lead on terminal **B**.
4. When the switch is open (off) you should read "I" or "**O.L**".
5. When the switch is closed (on) you should read "**000**" or higher indicating a small amount of resistance.





Schematic Symbol

How to Test a Double Pole Double Throw Knife Switch

1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).
3. Set switch operator in the position shown in the photo above.
4. Put one lead on terminal **A** and the other lead on terminal **B**. You should read "000".
5. Put one lead on terminal **D** and the other lead on terminal **E**. You should read "000".
6. Put one lead on terminal **B** and the other lead on terminal **C**. You should read "I" or "O.L".
7. Put one lead on terminal **E** and the other lead on terminal **F**. You should read "I" or "O.L".

Transformers

Definition of Transformer

A transformer is a static machine used for transforming power from one circuit to another without changing frequency. This is a very basic definition of transformer. Since there is no rotating or moving part so transformer is a static device. Transformers operate only on AC supply. Transformers work on the principle of mutual induction.

Types of Transformers

Transformers can be categorized in different ways, depending upon their purpose, use, construction etc. The types of transformer are as follows: Step Up Transformer and Step Down Transformer. Step up transformers have a higher voltage on the secondary side than they do on the primary side. Step down transformers have a lower voltage on the secondary side than they do on the primary side.

Transformer in a conveyor oven

Primary Voltage

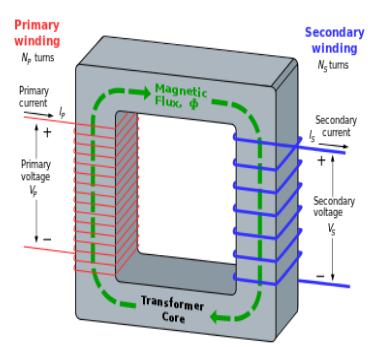
Line voltage from the AC power source connects to the primary (line) side of the transformer.

Secondary Voltage

Secondary voltage is the voltage induced by the primary voltage. The load that is using the induced voltage is connected to the secondary side. Some transformers have a circuit breaker on the secondary side.

Applications

A common application in food equipment is a step down transformer that reduced the line voltage supplied to the machine (typically 208 or 240 volts AC) to 24 volts AC to supply power for the electronics circuit. Typically electronic control boards use a supply voltage of 24 volts AC.



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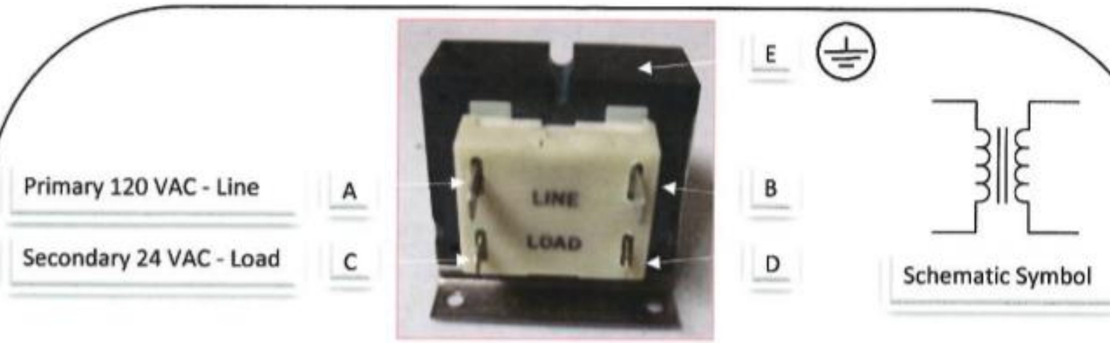
Hands On Exercise: Test a transformer for voltage and continuity



How to Check Voltage on a 120 Volt to 24 Volt Transformer.

1. Make sure power (120VAC) is connected to the line terminals.
2. Set meter to the AC voltage at the 200 volt setting.
3. Put one lead on terminal **A** and the other lead on terminal **B** and you should get a reading of 120 Volts. If not, check the power supply to the transformer.
4. Put one lead on terminal **C** and the other lead on terminal **D** and you should get a reading of 24 Volts AC. If not, the secondary winding is open. Replace the transformer.

How to Check Continuity on a Transformer.

1. Make sure **no power** is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).

Primary Winding Check

3. Put one lead on terminal **A** and the other lead on terminal **B**. You should read "000".

Secondary Winding Check

4. Put one lead on terminal **C** and the other lead on terminal **D**. You should read "000".

Check for Primary and Secondary Windings Shorted Together

5. Put one lead on terminal **A** and the other lead on terminal **C**. You should read "I" or "O.L".
6. Put one lead on terminal **B** and the other lead on terminal **D**. You should read "I" or "O.L".

Check for Primary Windings Shorted to Core

7. Put one lead on terminal **A** and the other lead on terminal **E**. You should read "I" or "O.L".

Check for Secondary Windings Shorted to Core

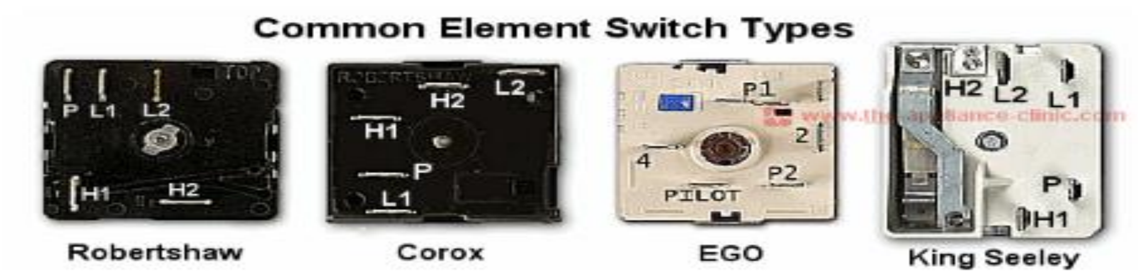
8. Put one lead on terminal **C** and the other lead on terminal **E**. You should read "I" or "O.L".

Unit 3:
Components

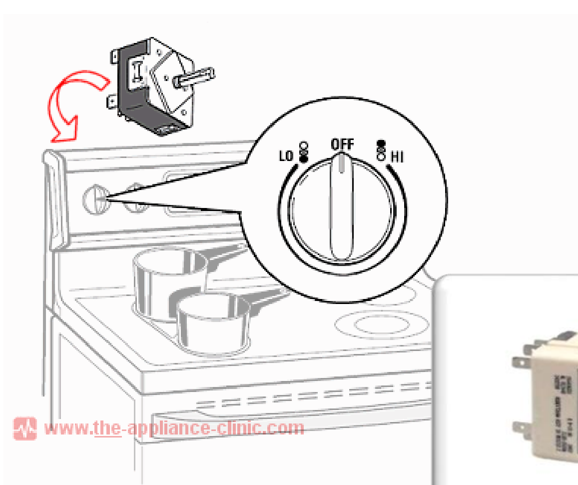
Fundamentals of Electricity

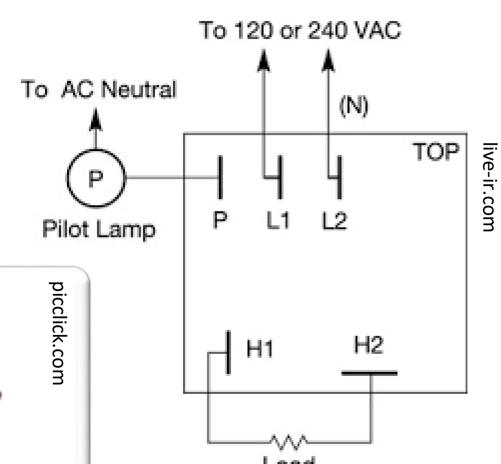
Infinite Switch

Electric Range Surface Element Switch
There have been several manufacturers that have produced different styles of element switches over the years. The most popular element control switch in use to this point has the "Infinite Heat Switch" manufactured my Robertshaw.



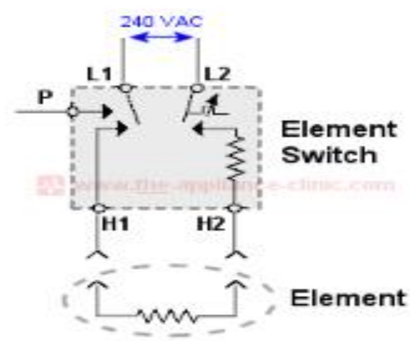
If your range's surface element is not heating at all and a check of the element and wiring didn't turn up any problems, there may be a problem in the control switch. For the element to totally not heat, no power can be getting to it. If a good element was getting power it HAS TO heat. There are no two ways about it!
The switch for the element will need to be accessed to have tests performed on it. Disconnect power from the appliance by either turning the house breakers off or unplugging the range from the wall. The rear panel of the range may need to be removed to access the switch wiring and terminals. On some newer range models or models with upfront controls, access to the switch terminals and wiring may be able to be done from the front.





Infinite Switch

Switching
Uncontrollable element
When turned "ON", the switch contact connecting terminals L1 and H1 closes and the contact between L2 and H2 closes. When the switch cycles power to the element to control its heat, the switch opens the contact between L2 and H2 stopping power flow to the element. The contacts between terminals L1 and H1 remain closed the whole time the switch is in an "ON" position.



If the element stays on "HI" regardless of the knob setting, the L2 to H2 contact is likely shorted closed. If the element stays on "HI" even when in the "OFF" position, both the L1 to H1 contact and L2 to H2 contact are shorted.

Surface Element Not Heating At All
The first test that can be done is checking the switch contacts for continuity. This must be done with power disconnected from the whole appliance and wiring removed from the element switch terminals.

With the wiring disconnected from the switch and the switch in the "HI" position, there should read continuity between terminals L1 and H1. There should also be continuity between terminals L2 and H2. If either of those tests show no continuity (ie. infinite resistance), the switch is likely defective and needs to be replaced.

The wiring diagram is for a Robertshaw infinite heat surface element control switch. If your switch terminal numbering differs, consult the range's wiring diagram or the images above to try to ascertain the correct terminals to test between.

If the above tests check out and there is no problem in the wiring from the switch to the element and the elements tests as good and you are still not getting any heat from the element, someone will have to verify that 240 volts is getting to the L1 and L2 terminals of the switch. There may be a problem with the range's wiring leading up to the switch. If 240 volts is present at terminals L1 and L2, someone can confirm power out of the switch by checking for 240 volts between switch terminals H1 and H2 with the switch set on "HI".

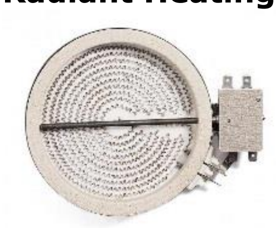
Unit 3:
Components

Heating Elements

Heating Elements

In most cooktops, the heating element is simply a big resistor wire, with enough resistance to generate a high heat. Usually these are nichrome wire, surrounded in ceramic insulation, with a steel sheath around the ceramic. On higher settings, the element glows red when operating. Heating occurs mainly by conduction; that is, the direct contact of the heating element to the cookware. Since the surface unit coil is flat, flat-bottomed cookware provides the best contact with these units and thus the most efficient operation.

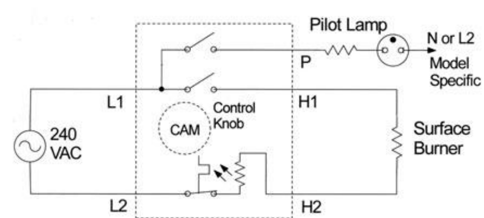
Radiant Heating Elements



A fairly recent development is the radiant heat cooktop. These have a radiant element (something like a very intense sunlamp) underneath a glass surface. These units do not heat the pot or pan by direct contact (conduction) like coil surface units. They heat by radiation, much like a sunlamp heats your skin.

Infinite Switch

To maintain a set temperature, the element is cycled on and off, usually by a switch called an infinite switch, and so named because it theoretically provides an infinite number of heat cycles. There are also fixed-temperature switches that vary the voltage going to the heating elements to maintain fixed, pre-set temperatures. These are push-button or rotary switches with fixed settings such as warm, low, medium and high.

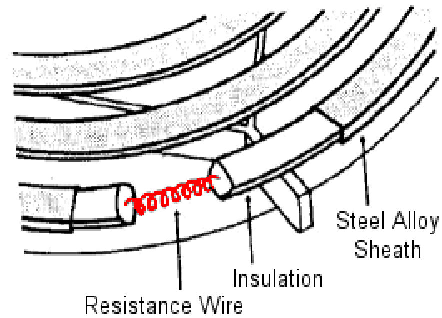


Range Control (Infinite) Switch

Heating Elements

Testing an Electric Range Surface Element

An electric range's element is basically just a resistance wire suspended inside of a hard metal alloy bent into various shapes, separated from it by insulation. When power is applied to it, the resistance wire generates heat which is conducted to the element's outer sheath where it can be absorbed by the cooking utensil or the air inside the oven cavity.



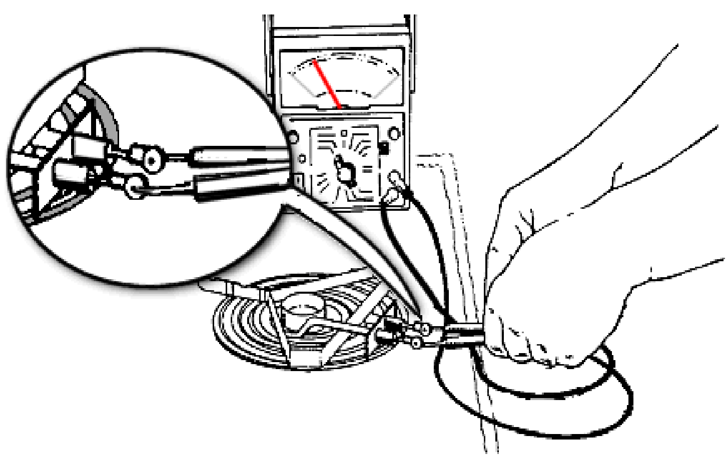
Cross-Section of a Conventional Coil Element

When this type of element fails, the internal resistance wire breaks causing an open circuit. Since the circuit is now open, no electrical current can flow through the element to generate heat.

The insulation between the resistance wire and the outer coating can also deteriorate. When this occurs the inner resistance wire can come into contact with the outer sheath causing a short to ground. The force of such a short can blow a hole right through the outer coating, melting it and sometimes damaging cookware being used at the time.

Element Testing

To test an element for continuity the appliance should first be disconnected from power. After the appliance has been made safe to work on, the element needs to be isolated from the rest of the electrical circuit by removing at least one of the connecting wires. Once that is done, an ohm meter or continuity tester's leads can be held against each terminal of the element.

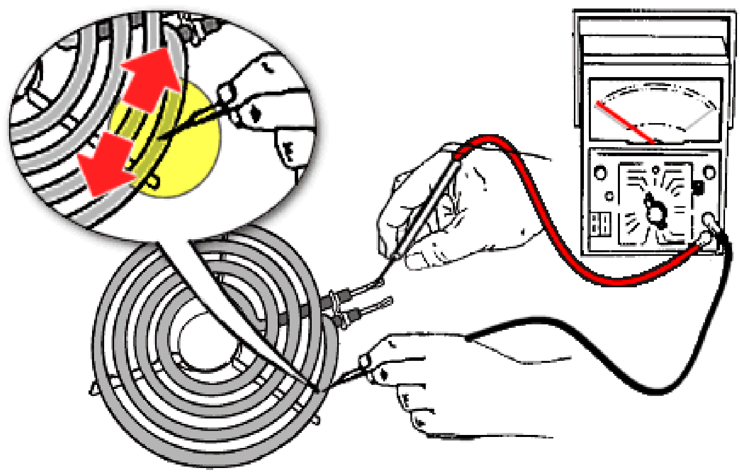


The exact resistance of an element is often not important as it will not usually change over its life span except to become totally open (show infinite resistance) when defective or becomes shorted to ground (see below). In case you're curious, a large cooktop surface burner is usually in the area of 27 ohms, a small 45 ohms. A bake or broil oven element's resistance may be in the area of 20 to 40 ohms depending on its wattage.

Heating Elements

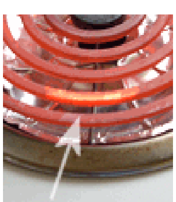
Short to Ground

An element can also become partially shorted to ground. While this may not be enough to create a dead short and cause the element to fail outright, it can create a shock hazard. To test an element for a short to ground, an ohmmeter should be set on its highest ohm scale (1K or 10K) and tested from one of the element's terminals to the element's metal sheath. It may be necessary to rub the outer element surface with the meter probe to make a good contact. If anything other than infinite resistance is shown, replace the element.



BTW. When performing the above test with the meter set on such a high ohm scale, be sure not to be touching *both* meter probe's metal tips with your fingers. If that were to happen the meter may display the resistance of your skin instead of just that of the element. You can touch *one* of the meter leads while testing without causing an erroneous reading.

Hot Spot



If while heating an electric range element has one spot which is glowing brighter than the mostly uniform color of the rest of the element, it is likely a sign of an impending failure. In such a case the element should be replaced to avoid possible critical failure as described above. This type of failure would likely show a short to ground if tested, which could also be a shock hazard.

Notes:____

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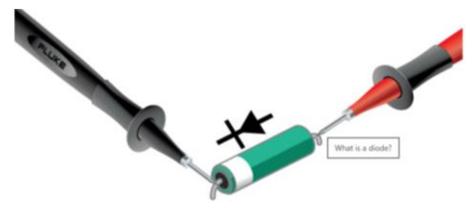
Diodes

What is a diode?

A diode is a semiconductor device that essentially acts as a one-way switch for current. It allows current to flow easily in one direction, but severely restricts current from flowing in the opposite direction.

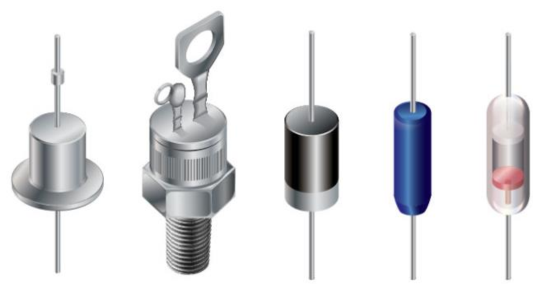


Rectifiers

Diodes are also known as rectifiers because they change alternating current (ac) into pulsating direct current (dc). Diodes are rated according to their type, voltage, and current capacity.

Polarity

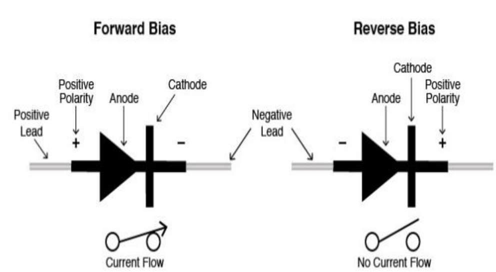
Diodes have polarity, determined by an anode (positive lead) and cathode (negative lead). Most diodes allow current to flow only when positive voltage is applied to the anode. A variety of diode configurations are displayed in this graphic.



Diodes are available in various configurations. From left: metal case, stud mount, plastic case with band, plastic case with chamfer, glass case.

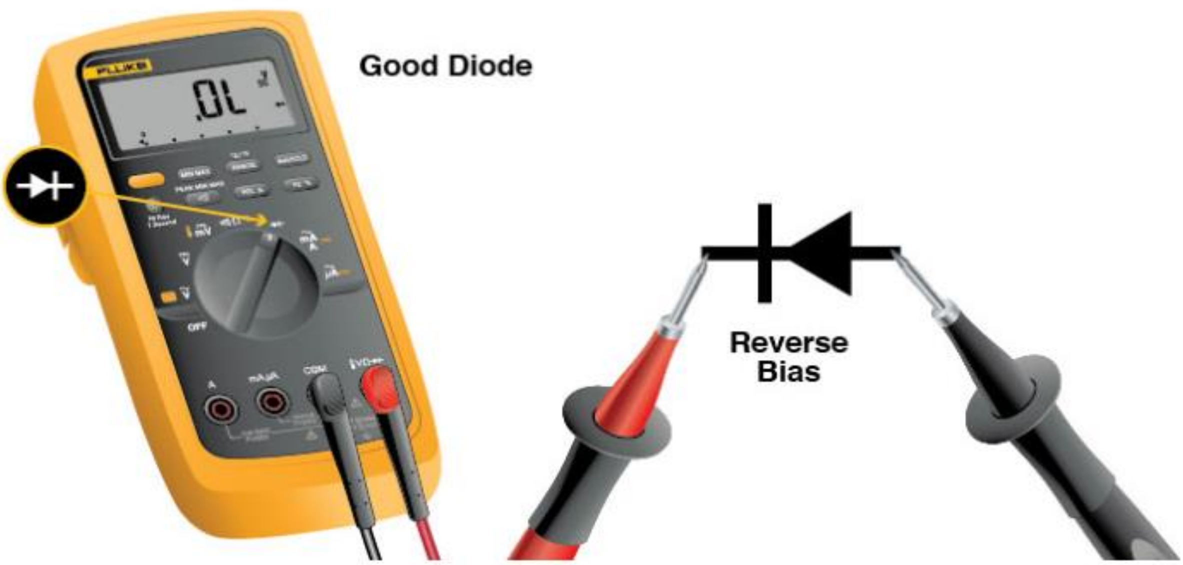
Current Flow Direction

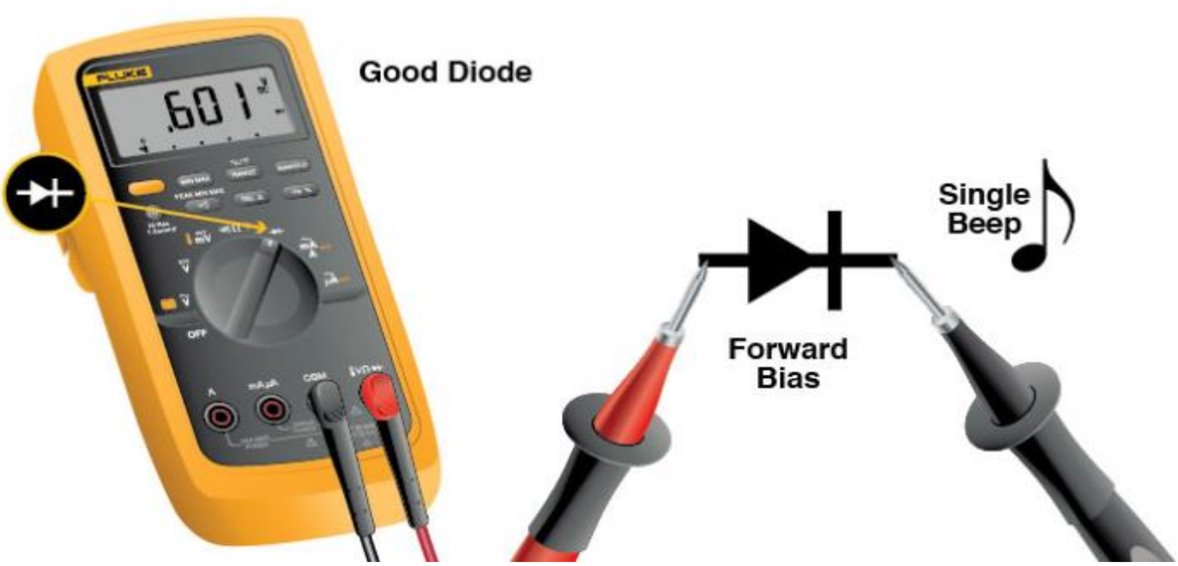
When a diode allows current flow, it is forward-biased. When a diode is reverse-biased, it acts as an insulator and does not permit current to flow. Strange but true: The diode symbol's arrow points against the direction of electron flow. Reason: Engineers conceived the symbol, and their schematics show current flowing from the positive (+) side of the voltage source to the negative (-). It's the same convention used for semiconductor symbols that include arrows—the arrow points in the permitted direction of "conventional" flow, and against the permitted direction of electron flow.



Testing Diodes

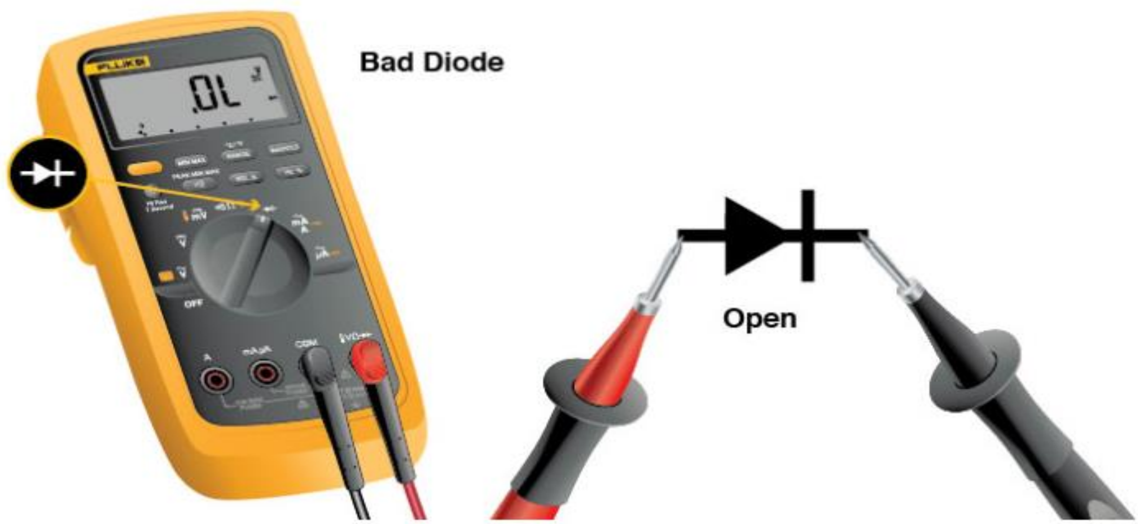
Testing Diodes
A digital multimeters Diode Test mode produces a small voltage between the test leads sufficient to forward-bias a diode junction. Normal voltage drop is 0.5 V to 0.8 V. The forward-biased resistance of a good diode should range from 1000 ohms to 10 ohms. When reverse-biased, a DMM's display will read OL (which indicates very high resistance).

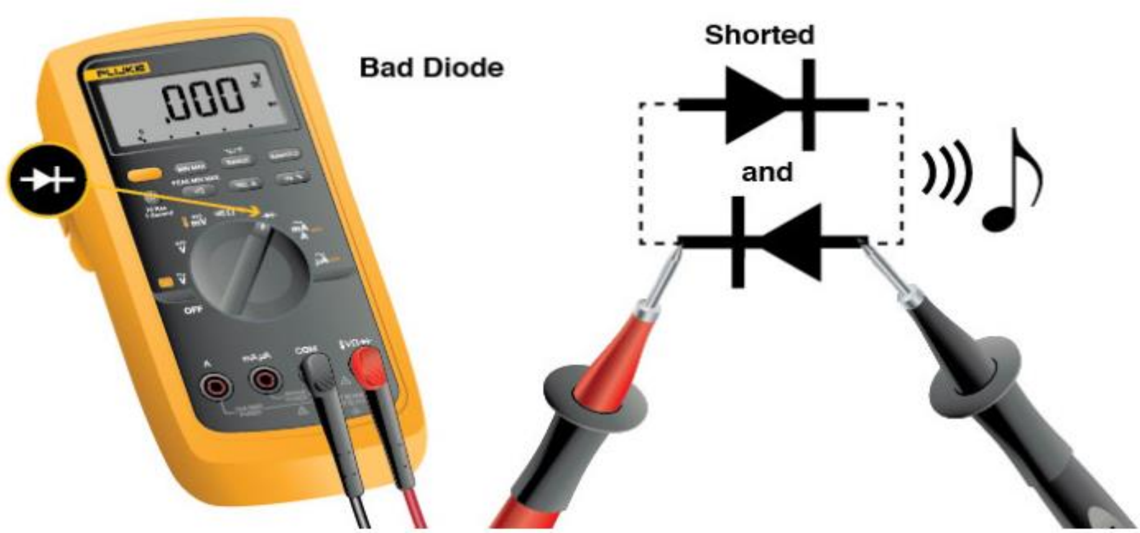




Testing Diodes

Diode Current Ratings
Diodes are assigned current ratings. If the rating is exceeded and the diode fails, it may short and either a) allow current to flow in both directions or b) halt current from flowing in either direction.





Reference: Digital Multimeter Principles by Glen A. Mazur, American Technical Publishers.

Unit 3:
Components

Fundamentals of Electricity

Relays

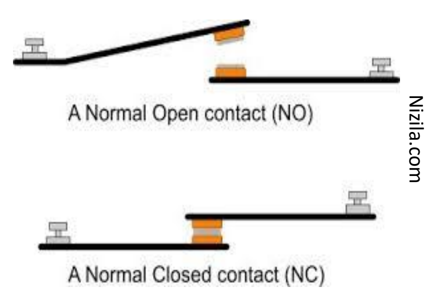
What is a Relay?
A relay is a switching device. It causes switch contacts to open or close through electromagnetism. This electromagnetism is produced by a coil in the relay. When power is applied to the coil, a magnet is created which pulls the switch contacts down. When power is disconnected from the coil, the magnetism goes away and the switch contacts go back to their original position because a spring is pulling them back.

The Coil
The voltage applied to the coil must be the amount and type specified on the relay. It may be AC or DC and the voltages range from 12 volts to 240 volts. The coil typically gets its power from a remote device such as a temperature switch other device.

NC NO Com Coil

Line Power out — Line Power in — Power from remote device to operate coil.

Switch Contacts
Relays can have two or more sets of switch contacts. Each set of switch contacts have a common terminal, normally closed terminal, and a normally open terminal. The switch contacts typically operate a circuit that uses a higher voltage than the coil. A switch opens and closes live voltage to the circuit. Live voltage is connected to the “Common” terminal. This voltage is also at the normally closed switch contact because there is a wire that connects each common terminal to the normally closed terminal. When the coil is energized and magnetism is created, the contacts pull towards the normally open contacts and power is now at the normally open contacts. Whatever is connected to the normally open contacts now receives the voltage that is connected to the common terminal. When power is removed from the coil a spring pulls the contact lever back to the normally closed contacts and power is back at the normally closed terminal. Not all sets of switch contacts have to be used.



Unit 3:
Components

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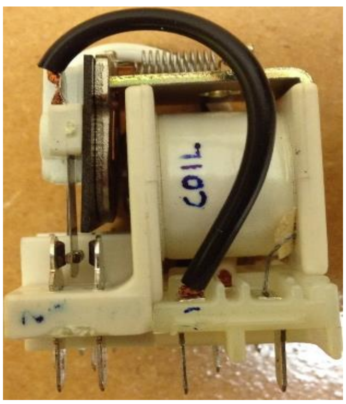
Relay Operation

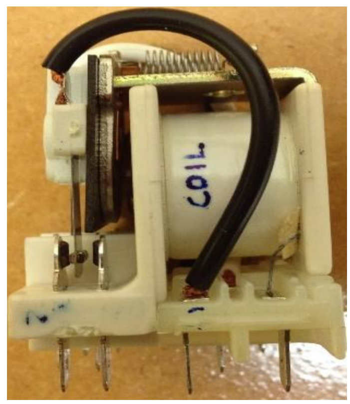
Relay condition when there is no power sent to the coil.



NC NO Com Coil

Line Power out — Line Power in — No Power Applied to coil.

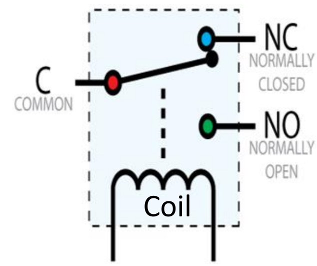
Relay condition when there is power sent to the coil.



NC NO Com Coil

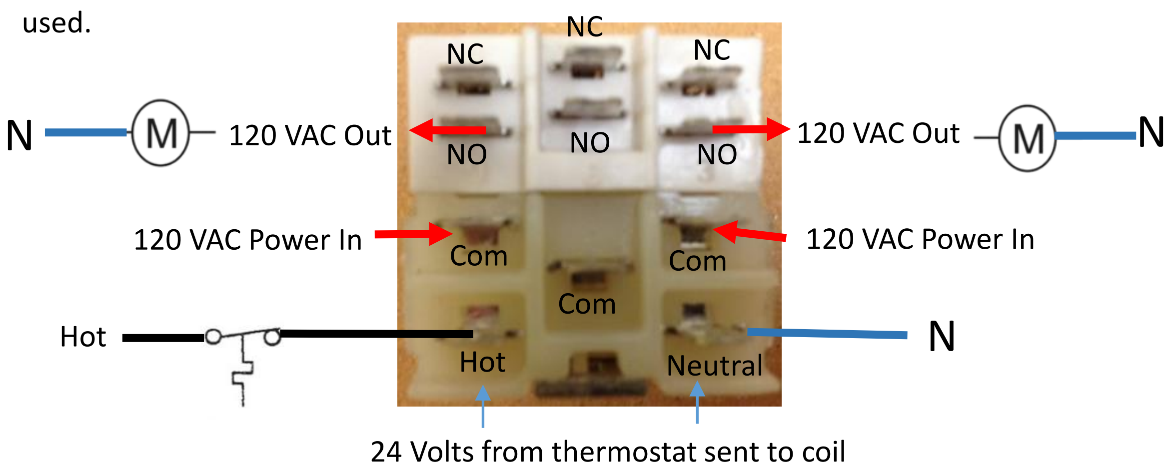
Line Power out — Line Power in — Power from remote device to operate coil.

Relay Schematic Symbol



The coil and the switch contacts on a relay are electrically isolated from one another. The dotted line represents a magnetic pull.

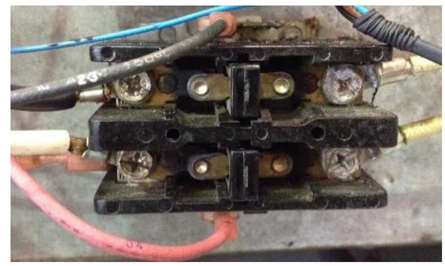
Example of Application: A thermostat sends 24 VAC to the coil contacts which causes 120 VAC to be sent to two exhaust fan motors simultaneously. Middle switch contacts are not used.



Contactors

Contactors

Contactors are a common type of ac relay whose current (amperage) rating is much higher than that of other types of relays.
This makes contactors ideal to control many types of high-power loads such as heavy-duty motors, lighting and heating equipment, and capacitor banks.



Contactor on Conveyor Oven

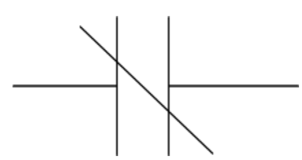
Contactor Function

A contactor can stand on its own as a power control device, or as part of a starter. Contactors are used in applications ranging from a light switch to the most complex, automated industrial equipment. Contactors are used by electrical equipment that is frequently turned off and on (opening and closing the circuit), such as lights, heaters and motors. The function of the contactor is always the same; to make and break all power supply lines running to a Load or, as defined by NEMA, to repeatedly establish and interrupt an electrical power circuit.

Magnetic Contactors

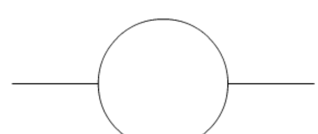
A magnetic contactor is operated electromechanically without manual intervention. This means that the contactor can be operated remotely, without the need for putting a person in a potentially dangerous location. Magnetic contactors use a small control current to open and close the circuit. The materials used to construct contacts or contactors are generally dependent on the kind of environment in which they will be used. Common contact materials are fine silver, coin silver, silver cadmium oxide, and the noble metals. In addition to these materials, special contact finishes may be required for certain applications. For example, if a relay is to be used in a mildly corrosive atmosphere, contactors should have a chromate-conversion coating.

Contactor Schematic Symbols



Normally Closed Contactor Contacts

Normally Open Contactor Contacts



Contactor Coil

Contactors

Definite Purpose Contactors

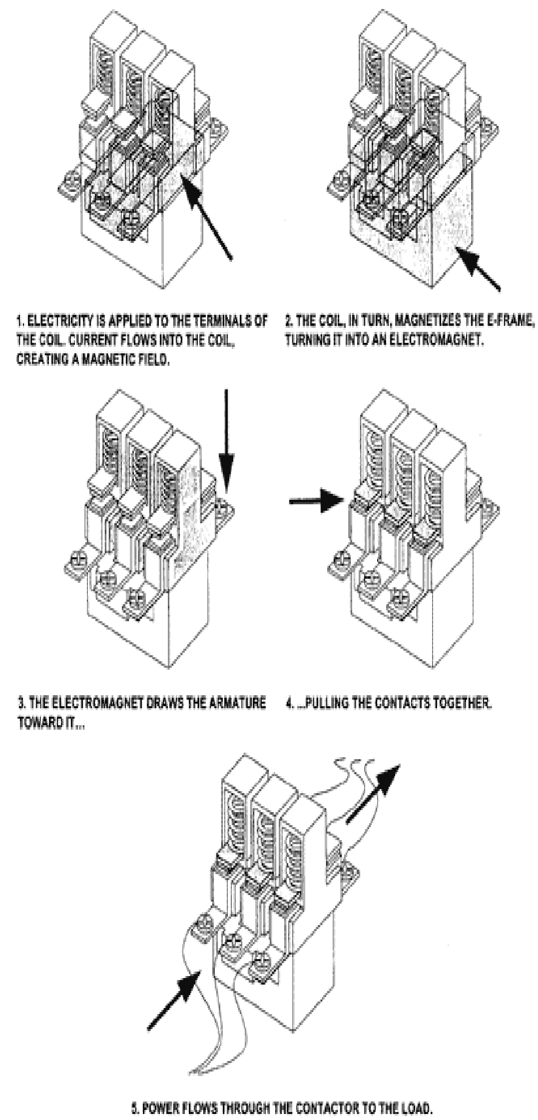
Definite Purpose Contactors are electrically operated switching devices specifically designed for the heating, ventilation, air conditioning and refrigeration (HVAC) industry. They are controlled by automatic thermostat control or manual pushbutton interfaces.

How Contactors Operate

The following components can be found in a contactor:

1. Movable contacts
2. Stationary contacts
3. Armature
4. Spring
5. Coil
6. E-Frame

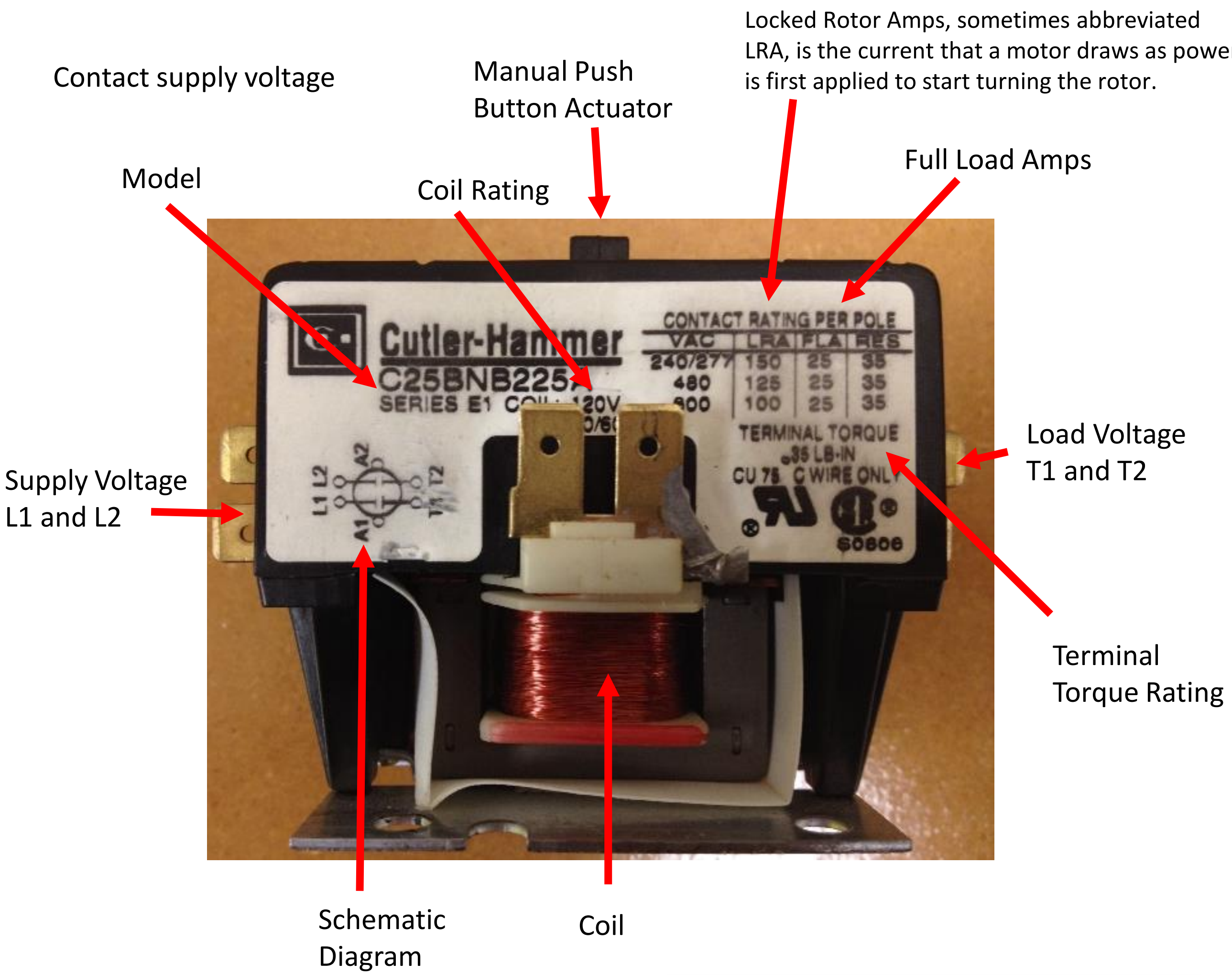
The E-Frame, when energized by the coil, becomes an electromagnet. The armature, a companion to the E-frame, is connected to a set of contacts. The armature is moveable but is held by a spring. When the coil is energized, the moveable contacts are pulled toward the stationary contacts because the armature is pulled toward the E-frame. Once the two sets of contacts meet, power can flow through the contactor to the load. When the coil is de-energized, the magnetic field is broken and the spring forces the two sets of contacts apart. Contactors are used when no overload protection is necessary, and at lower levels of electrical current. They are also operated electromechanically and use a small control current to open and close the circuit.

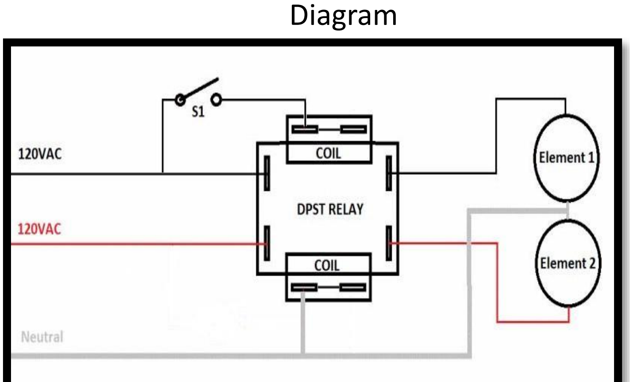


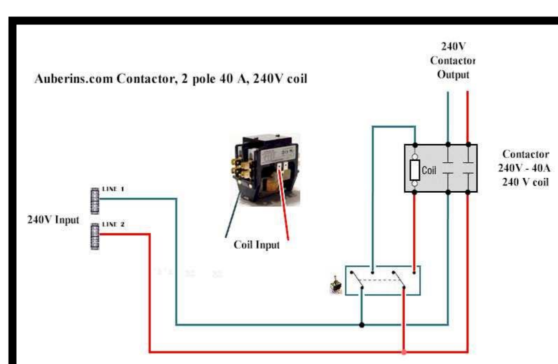
HOW A MAGNETIC CONTACTOR OPERATES

Contactors

Contactor Data Plate Explanation







Unit 3:
Components

Fundamentals of Electricity

Definite Purpose Contactors

Definite Purpose Contactors

Contactors are similar to relays but have higher current ratings and the coils are designed such a way that they can be replaced. They are primarily remotely controlled and electrically operated switches. They consist of one or more contact pairs that serve to open or close external circuits.

Type of Contactors: There are three major style of Contactors used in motor control applications.

NEMA style
IEC style
Definite Purpose

Definite Purpose (DP) Contactors are generally used in the Air conditioning, Electrical Heating, Ventilation, Refrigeration, welding, Pool and Spa, Electrical motor controllers and lighting applications. They can also be used in special applications requiring making and breaking of high current loads. They are UL recognized and CSA certified.

DP Contactors have FLA, LRA and Resistive ratings. They also have HP and Lighting rating. These are used in single phase and three phase applications up to 600VAC max.

FLA (Full load Amperes): This is motor (compressor) current when it is running at full load. This is generally inductive load with power factor @ 0.8.

LRA (Locked Rotor Amperes): This is a locked rotor (starting) current of the motor (compressor). This is generally inductive load with power factor @ 0.5.

Resistive Amperes: The current when the load is resistor. This is generally used for Electrical heating application. The power factor is @ 1.0.

DP Contactors are available in single pole, single pole with shunt, two pole, three pole and four pole configuration. The single pole, two pole and four pole have up to 40FLA /50A resistive rating. The three pole have up to 120FLA/150A resistive rating.

Method of Operation:

Contactors have two separate circuits. Main circuit and control circuit. The opening and closing of the main circuit is accomplished by an electromagnetic control circuit (Coil). The magnetic field is created in the core by the current in the coil. This attracts the armature. The movement of the armature closes and opens the main circuit. The main terminals can have either Screws or Lugs and can be with or without the ¼" quick connects.

Screw: Combo screw – requires having either ring or fork terminal on the wire to connect to contactor.

SEMS washer Screw – can connect solid wire under the SEMS washer.

Lugs: Can connect solid or stranded wire from the line and load circuit without any ring or fork terminal.

Quick connects: Unless the load is small (less than 15A), Quick connects are generally used to connect secondary circuits to main power coming to the contactor.

The control circuit supplies the power to the coil. The voltage for the main load circuit and control load circuit is often different. The DP contactors are mainly available with 24VAC, 120VAC, 208/240VAC, 277VAC, 480VAC and 575V AC coils. The coil terminals have dual ¼" QC. The coil terminals can have one ¼" QC and one screw (only 3P and 4P models). DC voltage coils are available for special applications. The DC coils have economizer coil design (called three lead DC as these have dual winding coils). Some of the DP 3 pole and 4 pole Contactors are available with 12VDC, 24VDC, 48VDC and 115VDC. Replacement coils are available for some of the 3 pole Contactors.

There are Auxiliary switches available for the 3 pole and 4 pole DP Contactors which can be snapped to the side of the Contactor. The switches are available in SPNO, SPNC, SPDT and 1NO1NC configuration. The Aux. switches can be used for control signals and lights with in the range of the rating of the switches.

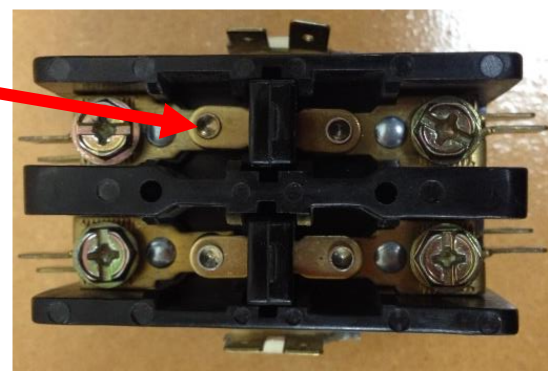
When selecting a Contactor for replacement, following conditions must be taken in to consideration.

1) The replacement Contactor must have equal or higher current rating
2) The contacts must be of original configuration like SPNO, DPNO, 3PNO etc.
3) The coil must be of same voltage and with in same VA range. (The VA of the coil can be higher if the transformer supplying the power to the coil can handle higher VA).
4) The terminal connections are compatible to original configuration.
5) Physical size of replacement must fit into space available.

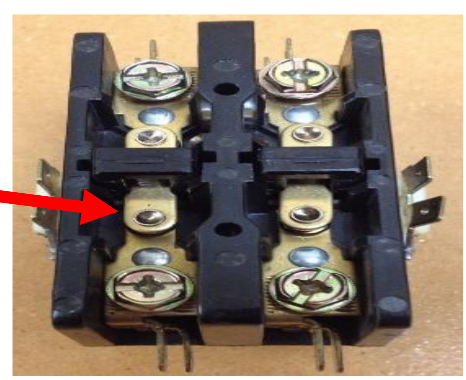
Contactor Failures

The most common contactor failure is a open contactor coil.

The switch contacts of the contactor will sometimes build up carbon on them over time. Carbon on the contacts introduces resistance into the circuit and opposes current flow.

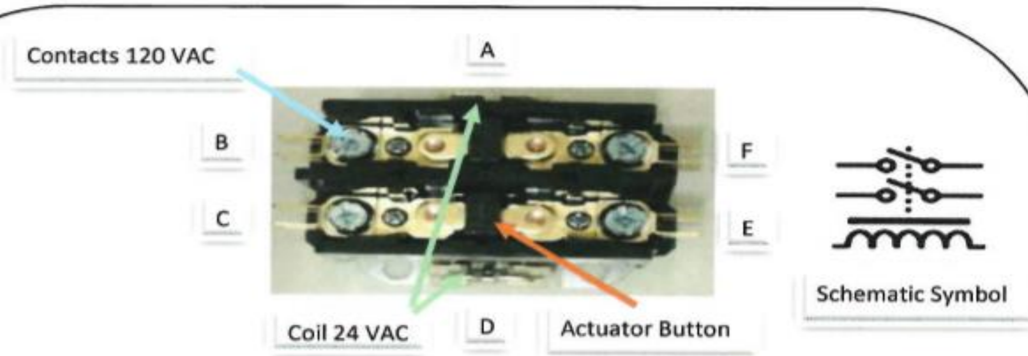


Sometimes debris or insects can get between the contacts and prevent current flow.



Fundamentals of Electricity

Hands On Exercise: Test a contactor for continuity and resistance



How to Check Voltage on a 240 Volt to Contactor with a 24 Volt Coil Installed on a Machine

1. Set meter to **AC** Voltage in the proper range.
2. Trace wires to see where the line voltage is coming in. It will be connected to the line terminals either **B & C** or **F & E**.
3. Example: If line voltage is at **B & C**, put one lead on terminal **B** and the other lead on terminal **C** and you should get a reading of 240 Volts. If not, check the voltage source.
4. When you manually activate the contactor by pushing the center button to make contact across one side to the other, you should get 240 volts at **F & E** as well.
5. To check for voltage across the coil, put one lead on terminal **A** and the other lead on terminal **D**. You should read 24 Volts when the controller (e.g. – Thermostat) sends power to the contactor.

How to Check Continuity on a Contactor

1. Make sure **no power** is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).

Coil Check

3. Put one lead on terminal **A** and the other lead on terminal **D**. You should read "**000**" or higher. If it reads "O.L", try a different range setting. If it still reads "O.L", the coil is open and the contactor is bad.

Switch Contacts Check

4. Put one lead on terminal **B** and the other lead on terminal **F**. You should read "**O.L**". When the actuator button is pushed you should read "000". A higher reading could indicate carbon buildup on the contact points.
5. Repeat Step 4 for contacts **C & E**

Check for Coil Winding Shorted to Ground ⏚

6. Put one lead on terminal **A** or **D** and the other lead on ground. You should read "I" or "**O.L**".

Unit 3:
Components

Fundamentals of Electricity

Solenoids

What is a Solenoid?
A solenoid is an electrical device that produces linear mechanical motion. A solenoid consists of a coil, an armature (plunger) and a spring.

Solenoid Valve

How a Solenoid Works
When power is supplied to a solenoid coil, an electromagnet is created. The magnetism causes an armature that is in the center of the coil to pull in. When power is disconnected from the coil, the magnetism goes away and a spring inside the coil pushes the armature or plunger out.

Solenoid Applications
Solenoids are used in all sorts of applications such as water valves, refrigerant valves, gas valves, etc.

Testing Solenoids

Solenoids are similar to relays; while a relay closes a switch, solenoids perform some mechanical function, like locking an oven door. They should be tested the same way. The coil should show SOME resistance, but continuity should be good. If a solenoid shows no continuity, there's a burnt or broken wire somewhere in the coil.

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Unit 3:
Components

Capacitors

Capacitors are used frequently in the food equipment industry. They are used on electronic printed circuit boards (PCBs) and are used to help motors get started and keep running.

Motor Capacitors

In some cases, single-phase induction motors use capacitors to create a much larger phase displacement to help start the motor. Capacitors cause capacitive reactance in a circuit, which is the opposition to the flow of current that causes voltage to lag behind current in a cycle. In a motor with both start and run windings, capacitors are added in series with the start winding.

When power is applied to the motor, electricity flows through the start and run windings. In the run winding, current lags behind voltage due to inductive reactance. In the start winding with a capacitor wired in series, voltage lags behind current due to capacitive reactance. This causes phase splitting, but with a larger displacement between the phases than can be caused by just the start and run windings alone.

A larger phase displacement leads to a higher starting torque, which means motors that use capacitors can start under heavier loads.

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Motor Capacitor Types

Motor Capacitor Types
There are two types of capacitors used with motors: start capacitors and run capacitors.

Start Capacitors
A capacitor used only during motor start-up to provide initial starting torque is called a start capacitor. A start capacitor is never used in a stator's run winding circuit. Start capacitors are usually dry electrolytic capacitors.

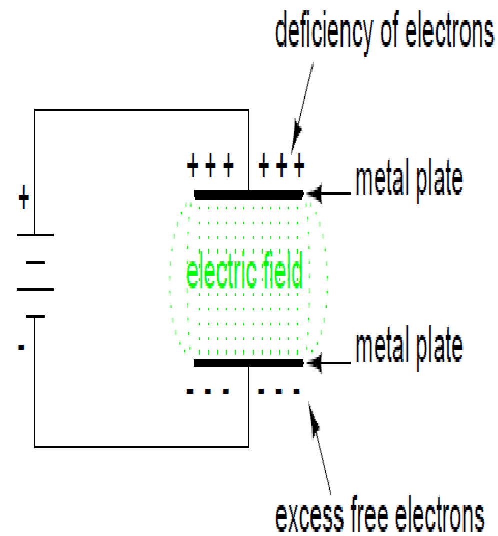
Start capacitors increase a motors starting torque and typically have a high microfarad rating.

Run Capacitors
A run capacitor operates in the same way as a start capacitor, except it remains in the start winding circuit while the motor is running. It provides a signal that is out of phase for added torque during the motor's entire operation. Run capacitors are filled with oil and are designed to dissipate the heat generated by a running motor.

Run capacitors increase a motor's running torque.

Capacitor Operation

When a voltage is applied across the two plates of a capacitor, a concentrated field flux is created between them, allowing a significant difference of free electrons (a charge) to develop between the two plates:



As the electric field is established by the applied voltage, extra free electrons are forced to collect on the negative conductor, while free electrons are ”robbed” from the positive conductor.

This differential charge equates to a storage of energy in the capacitor, representing the potential charge of the electrons between the two plates. The greater the difference of electrons on opposing plates of a capacitor, the greater the field flux, and the greater ”charge” of energy the capacitor will store.

Because capacitors store the potential energy of accumulated electrons in the form of an electric field, they behave quite differently than resistors (which simply dissipate energy in the form of heat) in a circuit. Energy storage in a capacitor is a function of the voltage between the plates, as well as other factors which we will discuss later in this chapter.

A capacitor’s ability to store energy as a function of voltage (potential difference between the two leads) results in a tendency to try to maintain voltage at a constant level. In other words, capacitors tend to resist changes in voltage drop. When voltage across a capacitor is increased or decreased, the capacitor ”resists” the change by drawing current from or supplying current to the source of the voltage change, in opposition to the change.

Notes:______________

Capacitor Operation

Storing Energy

To store more energy in a capacitor, the voltage across it must be increased. This means that more electrons must be added to the (-) plate and more taken away from the (+) plate, necessitating a current in that direction.

Releasing Energy

Conversely, to release energy from a capacitor, the voltage across it must be decreased. This means some of the excess electrons on the (-) plate must be returned to the (+) plate, necessitating a current in the other direction.

Maintaining Charge

A capacitor's tendency to oppose changes in voltage as such: "A charged capacitor tends to stay charged; a discharged capacitor tends to stay discharged." Hypothetically, a capacitor left untouched will indefinitely maintain whatever state of voltage charge that its been left it. Only an outside source (or drain) of current can alter the voltage charge stored by a perfect capacitor.

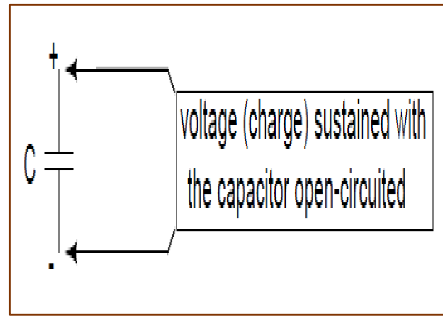
Charging

When the voltage across a capacitor is increased, it draws current from the rest of the circuit, acting as a power load. In this condition the capacitor is said to be charging, because there is an increasing amount of energy being stored in its electric field. Note the direction of electron current with regard to the voltage polarity.

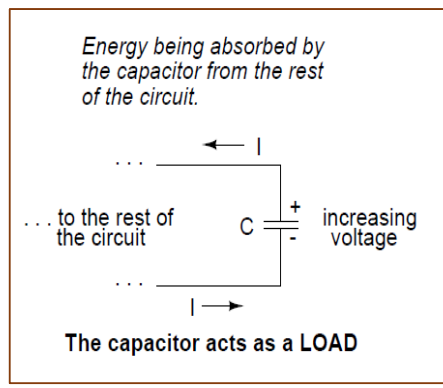
Discharging

Conversely, when the voltage across a capacitor is decreased, the capacitor supplies current to the rest of the circuit, acting as a power source. In this condition the capacitor is said to be discharging. Its store of energy – held in the electric field – is decreasing now as energy is released to the rest of the circuit. Note the direction of electron current with regard to the voltage polarity.

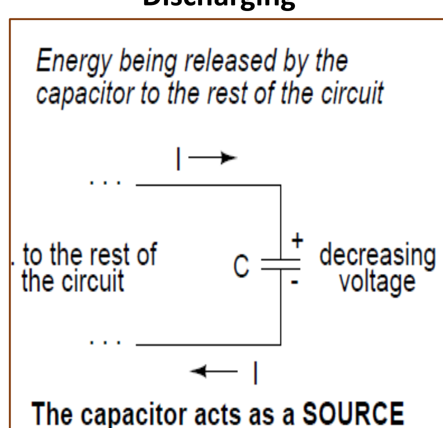
Maintaining Charge



Charging



Discharging



Capacitor Operation

If a source of voltage is suddenly applied to an uncharged capacitor (a sudden increase of voltage), the capacitor will draw current from that source, absorbing energy from it, until the capacitor's voltage equals that of the source. Once the capacitor voltage reached this final (charged) state, its current decays to zero. Conversely, if a load resistance is connected to a charged capacitor, the capacitor will supply current to the load, until it has released all its stored energy and its voltage decays to zero. Once the capacitor voltage reaches this final (discharged) state, its current decays to zero. In their ability to be charged and discharged, capacitors can be thought of as acting somewhat like secondary-cell batteries.

Dielectrics
The choice of insulating material between the plates, as was mentioned before, has a great impact upon how much field flux (and therefore how much charge) will develop with any given amount of voltage applied across the plates. Because of the role of this insulating material in affecting field flux, it has a special name: dielectric. Not all dielectric materials are equal: the extent to which materials inhibit or encourage the formation of electric field flux is called the permittivity of the dielectric.

Capacitance
The measure of a capacitor's ability to store energy for a given amount of voltage drop is called capacitance. Not surprisingly, capacitance is also a measure of the intensity of opposition to changes in voltage (exactly how much current it will produce for a given rate of change in voltage). Capacitance is symbolically denoted with a capital ”C,” and is measured in the unit of the Farad, abbreviated as ”F.” Convention, has favored the metric prefix ”micro” in the measurement of large capacitances, and so many capacitors are rated in terms of micro- Farad values. The symbol for the micro-Farad is µF. Sometimes it is UF.

Condensers
An obsolete name for a capacitor is condenser or condensor. These terms are not used in any new books or schematic diagrams (to my knowledge), but they might be encountered in older electronics literature. Perhaps the most well-known usage for the term ”condenser” is in automotive engineering, where a small capacitor called by that name was used to mitigate excessive sparking across the switch contacts (called ”points”) in electromechanical ignition systems.

REVIEW:
- Capacitors react against changes in voltage by supplying or drawing current in the direction necessary to oppose the change.
- When a capacitor is faced with an increasing voltage, it acts as a load: drawing current as it absorbs energy (current going in the negative side and out the positive side, like a resistor).
- When a capacitor is faced with a decreasing voltage, it acts as a source: supplying current as it releases stored energy (current going out the negative side and in the positive side, like a battery).
- The ability of a capacitor to store energy in the form of an electric field (and consequently to oppose changes in voltage) is called capacitance. It is measured in the unit of the Farad (F).

Multimeter - Capacitance

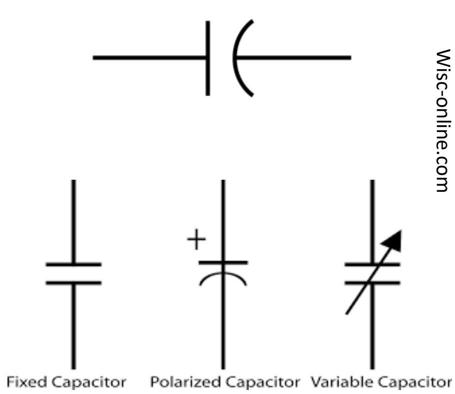
A multimeter determines capacitance by charging a capacitor with a known current, measuring the resulting voltage, then calculating the capacitance.

Warning: A good capacitor stores an electrical charge and may remain energized after power is removed. Before touching it or taking a measurement,

a) turn all power OFF,
b) b) use your multimeter to confirm that power is OFF and
c) c) carefully discharge the capacitor by connecting a resistor across the leads (as noted in the next paragraph). Be sure to wear appropriate personal protective equipment.

To safely discharge a capacitor: After power is removed, connect a 20,000 Ω, 5-watt resistor across the capacitor terminals for five seconds.

Capacitor Schematic Symbols



Start Capacitor

Top Terminals of a run capacitor

10 microfarad run capacitor

Multimeter - Capacitance

How to measure capacitance

Use your multimeter to confirm the capacitor is fully discharged.

1. Use your digital multimeter (DMM) to ensure all power to the circuit is OFF. If the capacitor is used in an ac circuit, set the multimeter to measure ac voltage. If is used in a dc circuit, set the DMM to measure dc voltage.
2. Visually inspect the capacitor. If leaks, cracks, bulges or other signs of deterioration are evident, replace the capacitor.
3. Turn the dial to the Capacitance Measurement mode (Capacitance symbol). The symbol often shares a spot on the dial with another function. In addition to the dial adjustment, a function button usually needs to be pressed to activate a measurement. Consult your multimeter's user manual for instructions.
4. For a correct measurement, the capacitor will need to be removed from the circuit. Discharge the capacitor as described in the warning above.

Note: Some multimeters offer a Relative (REL) mode. When measuring low capacitance values, the Relative mode can be used to remove the capacitance of the test leads. To place a multimeter in Relative mode for capacitance, leave the test leads open and press the REL button. This removes the residual capacitance value of the test leads.

5. Connect the test leads to the capacitor terminals. Keep test leads connected for a few seconds to allow the multimeter to automatically select the proper range.
6. Read the measurement displayed. If the capacitance value is within the measurement range, the multimeter will display the capacitor's value. It will display OL if a) the capacitance value is higher than the measurement range or b) the capacitor is faulty.

Capacitance Measurement Overview

Capacitance measurement overview
Troubleshooting single-phase motors is one of the most practical uses of a digital multimeter's Capacitance Function.

A capacitor-start, single-phase motor that fails to start is a symptom of a faulty capacitor. Such motors will continue to run once operating, making troubleshooting tricky. Failure of the hard-start capacitor for HVAC compressors is a good example of this problem. The compressor motor may start, but soon overheat resulting in a breaker trip.

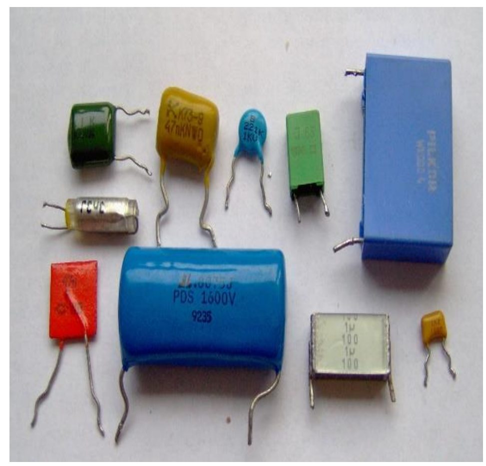
Single-phase motors with such problems and noisy single-phase motors with capacitors require a multimeter to verify properly functioning capacitors. Almost all motor capacitors will have the microfarad value marked on the capacitor.

Three-phase power factor correction capacitors are typically fuse protected. Should one or more of these capacitors fail, system inefficiencies will result, utility bills will most likely increase and inadvertent equipment trips of may occur. Should a capacitor fuse blow, the suspected faulty capacitor microfarad value must be measured and verified it falls within the range marked on the capacitor.

Some additional factors involving capacitance are worth knowing:
•Capacitors have a limited life and are often the cause of a malfunction.
•Faulty capacitors may have a short circuit, an open circuit or may physically deteriorate to the point of failure.
•When a capacitor short circuits, a fuse may blow or other components may be damaged.
•When a capacitor opens or deteriorates, the circuit or circuit components may not operate.
•Deterioration can also change the capacitance value of a capacitor, which can cause problems.

Capacitor Types

Capacitor Types
Capacitors are components designed to take advantage of this phenomenon by placing two conductive plates (usually metal) in close proximity with each other. There are many different styles of capacitor construction, each one suited for particular ratings and purposes. For very small capacitors, two circular plates sandwiching an insulating material will suffice. For larger capacitor values, the ”plates” may be strips of metal foil, sandwiched around a flexible insulating medium and rolled up for compactness. The highest capacitance values are obtained by using a microscopic-thickness layer of insulating oxide separating two conductive surfaces. In any case, though, the general idea is the same: two conductors, separated by an insulator.



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Various Capacitor Types

Commons.Wikimedia.org

Start Capacitor


Kelly Wells

Fan Motor Run Capacitor on Conveyor Oven

Allaboutcircuits.com

Unit 3:
Components

Fundamentals of Electricity

Capacitor Failures

Storing Charge

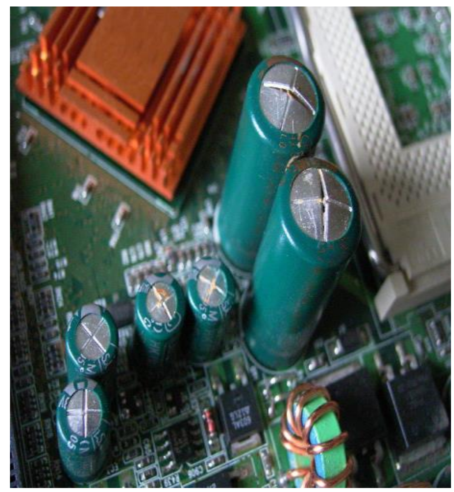
Practically speaking, capacitors will eventually lose their stored voltage charges due to internal leakage paths for electrons to flow from one plate to the other. Depending on the specific type of capacitor, the time it takes for a stored voltage charge to self-dissipate can be a long time (several years with the capacitor sitting on a shelf!).

Start Capacitor Duty

Start capacitors are built to specifications for cyclical duty. They are only meant to operate for short periods of time. If a start capacitor is left in a circuit too long (due to a faulty centrifugal switch or relay), it may damage the motor windings.

Defective Run Capacitors

Be sure that any run capacitors you encounter on service calls are operating properly. Defective run capacitors can cause a motor to draw high current. This could trip the overload protection device or damage the motor.



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Notes:_______________

AC Induction Motor

One of the most common electrical motor used in most applications which is known as induction motor. This motor is also called as asynchronous motor because it runs at a speed less than its synchronous speed. Here we need to define what is synchronous speed. Synchronous speed is the speed of rotation of the magnetic field in a rotary machine and it depends upon the frequency and number poles of the machine. An induction motor always runs at a speed less than synchronous speed because the rotating magnetic field which is produced in the stator will generate flux in the rotor which will make the rotor to rotate, but due to the lagging of flux current in the rotor with flux current in the stator, the rotor will never reach to its rotating magnetic field speed i.e. the synchronous speed. There are basically two types of induction motor that depend upon the input supply - single phase induction motor and three phase induction motor. Single phase induction motor is not a self starting motor which we will discuss later and three phase induction motor is a self-starting motor.

Working Principle of Induction Motor

We need to give double excitation to make a machine to rotate. For example if we consider a DC motor, we will give one supply to the stator and another to the rotor through brush arrangement. But in induction motor we give only one supply, so it is really interesting to know that how it works. It is very simple, from the name itself we can understand that induction process is involved. Actually when we are giving the supply to the stator winding, flux will generate in the coil due to flow of current in the coil. Now the rotor winding is arranged in such a way that it becomes short circuited in the rotor itself. The flux from the stator will cut the coil in the rotor and since the rotor coils are short circuited, according to Faraday's law of electromagnetic induction, current will start flowing in the coil of the rotor. When the current will flow, another flux will get generated in the rotor. Now there will be two flux, one is stator flux and another is rotor flux and the rotor flux will be lagging w.r.t to the stator flux. Due to this, the rotor will feel a torque which will make the rotor to rotate in the direction of rotating magnetic flux. So the speed of the rotor will be depending upon the ac supply and the speed can be controlled by varying the input supply. This is the working principle of an induction motor of either type – single and three phase.

AC Induction Motor

We had mentioned before that single phase induction motor is not a self starting and three phase induction motor is self starting. So what is self starting? When the machine starts running automatically without any external force to the machine, then it is called as self starting. For example we see that when we put on the switch the fan starts to rotate automatically, so it is self starting. Point to be noted that fan used in home appliances is single phase induction motor which is inherently not self starting. How? Question arises How it works? We will discuss it now.

Why is Three Phase Induction Motor Self Starting?
In three phase system, there are three single phase line with 120° phase difference. So the rotating magnetic field is having the same phase difference which will make the rotor to move. If we consider three phases a, b and c, when phase a is magnetized, the rotor will move towards the phase a winding a, in the next moment phase b will get magnetized and it will attract the rotor and then phase c. So the rotor will continue to rotate.

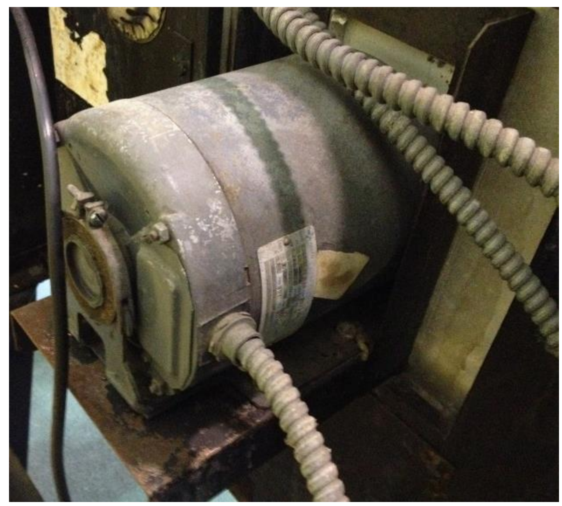
Why Single Phase Induction Motor is not Self Starting?
It will be having only one phase still it makes the rotor to rotate, so it is quite interesting. Before that we need to know why single phase induction motor is not a self starting motor and how the problem is overcome. We know that the ac supply is a sinusoidal wave and it produces pulsating magnetic field in uniformly distributed stator winding. Since pulsating magnetic field can be assumed as two oppositely rotating magnetic fields, there will be no resultant torque produced at the starting and due to this the motor does not run. After giving the supply, if the rotor is made to rotate in either direction by external force, then the motor will start to run. This problem has been solved by making the stator winding into two winding, one is main winding and another is auxiliary winding and a capacitor is fixed in series with the auxiliary winding. This will make a phase difference when current will flow through the both coils. When there will be phase difference, the rotor will generate a starting torque and it will start to rotate. Practically we can see that the fan does not rotate when the capacitor is disconnected from the motor but if we rotate with hand it will start to rotate. So this is the reason of using capacitor in the single phase induction motor. There are several advantages of induction motor which makes this motor to have wider application. It is having good efficiency up to 97%. But the speed of the motor varies with the load given to the motor which is an disadvantage of this motor. The direction of rotation of induction motor can easily be changed by changing the sequence of three phase supply, i.e. if RYB is in forward direction, the RBY will make the motor to rotate in reverse direction. This is in the case of three phase motor but in single phase motor, the direction can be reversed by reversing the capacitor terminals in the winding.

Unit 3:
Components

AC Induction Motor

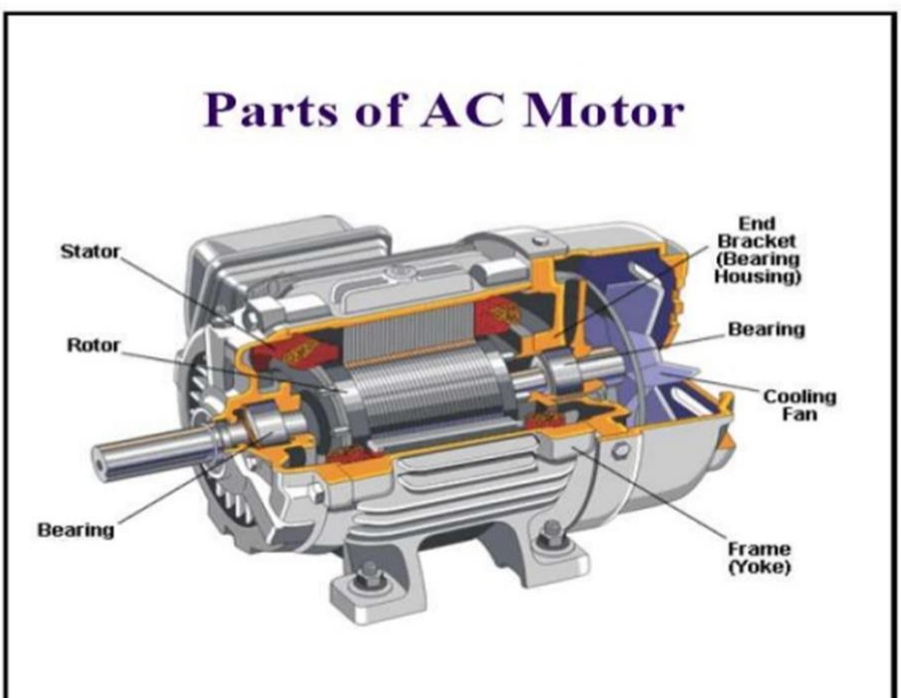
Marineinsight.com

Induction Motor

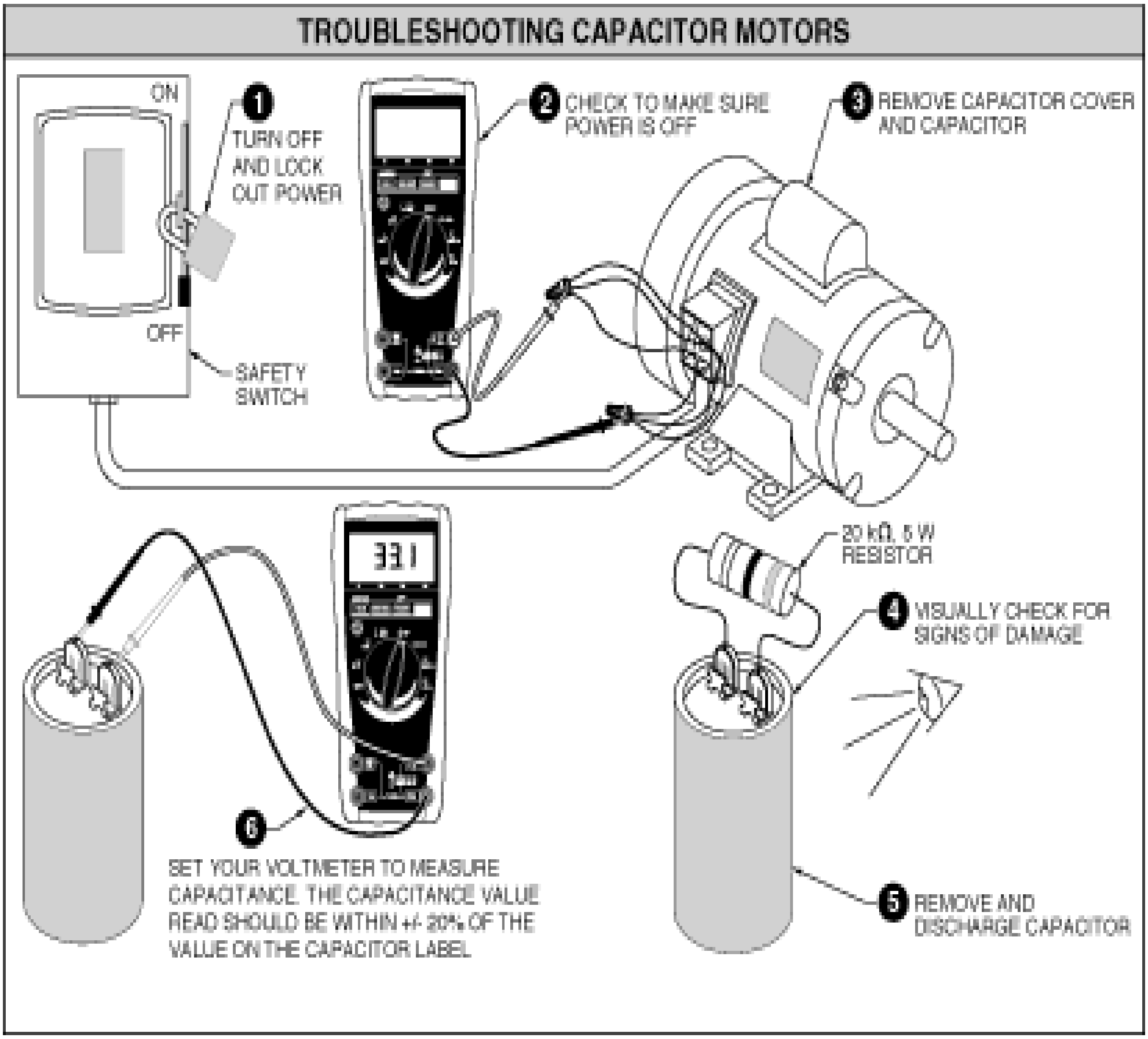


Kelly Wells

Fan Motor on Convection Oven

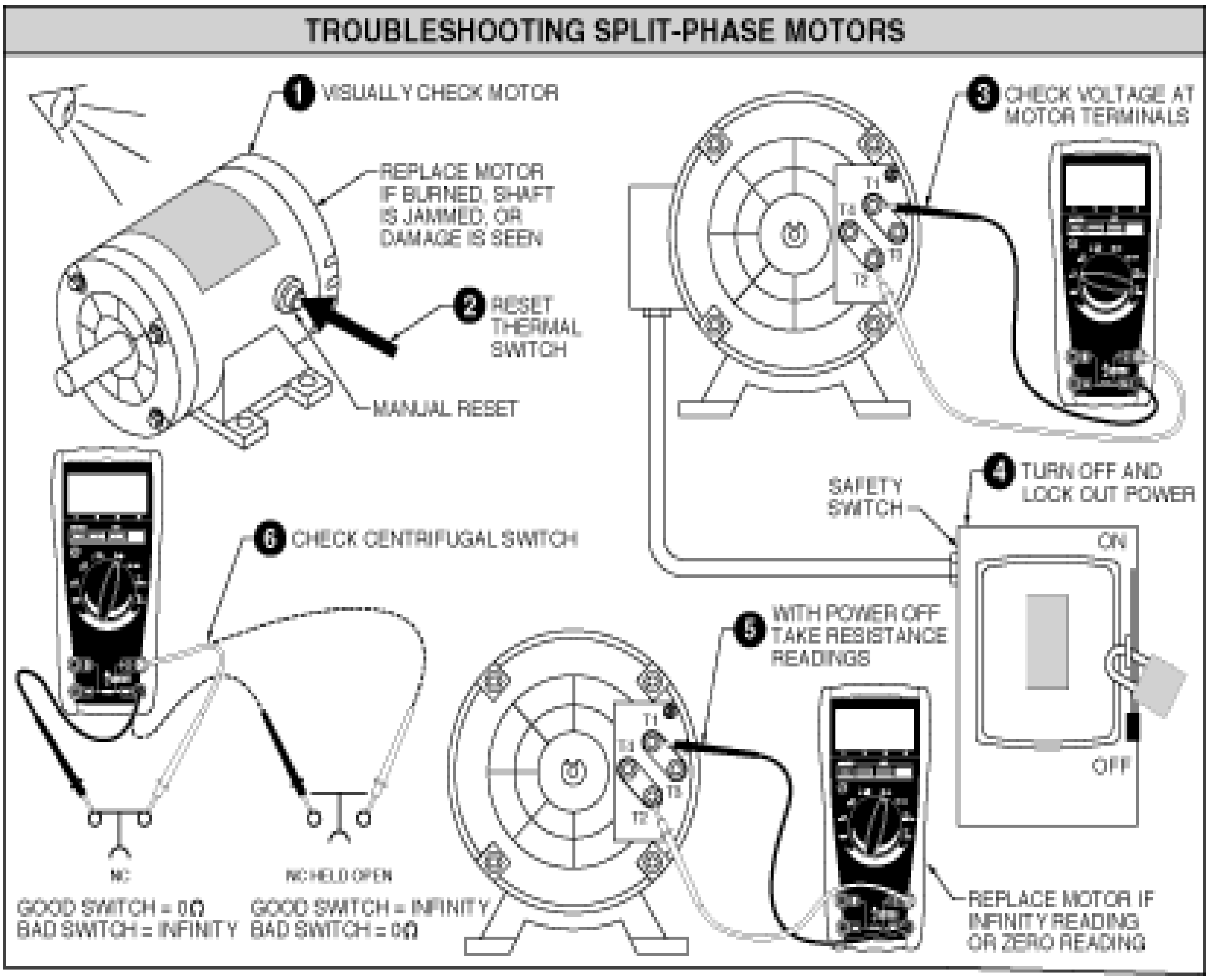


Troubleshooting Motors

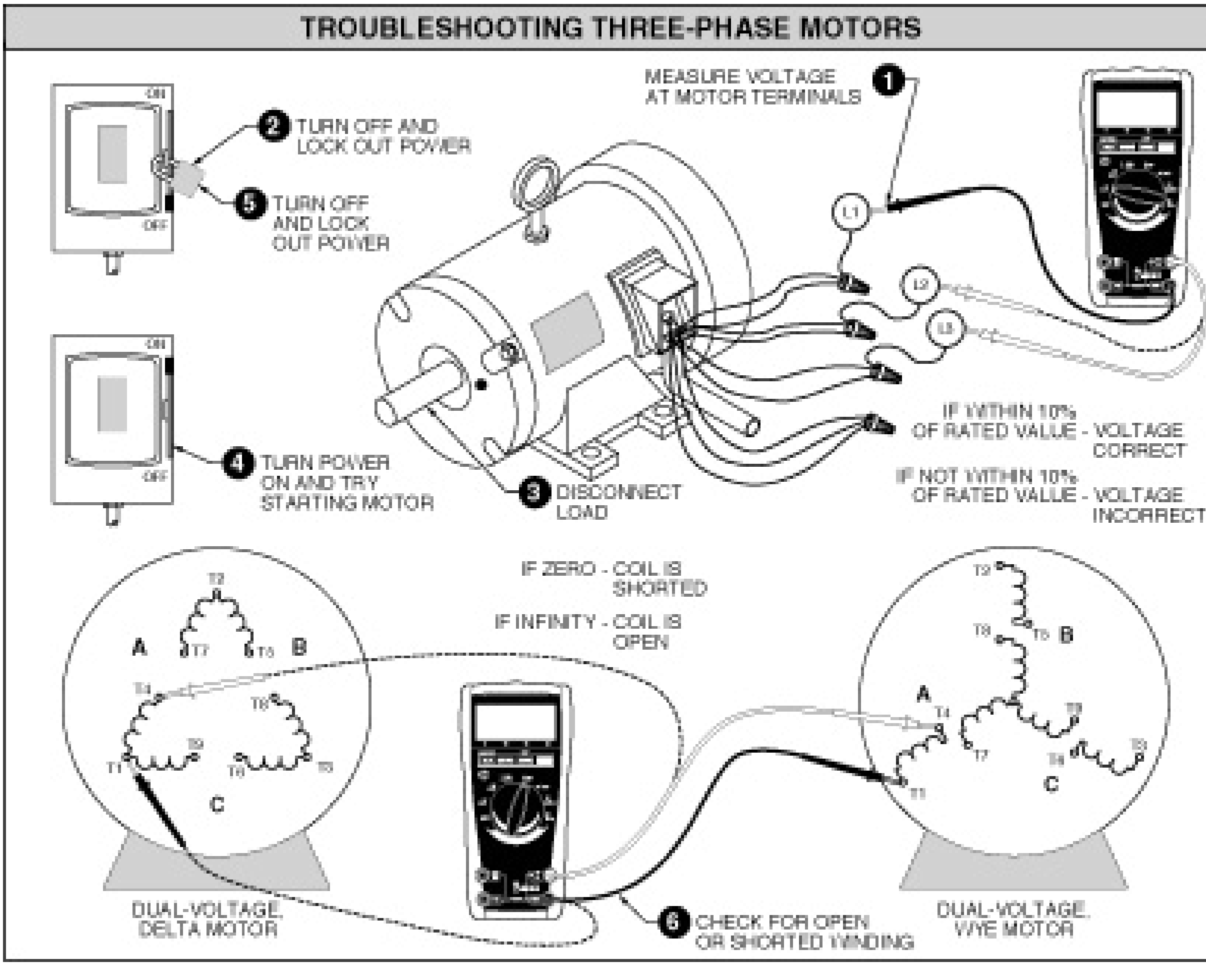


Fluke.com

Troubleshooting Motors



Troubleshooting Motors



Troubleshooting Motors

Basic diagnostic tools

Before you begin, assemble some basic diagnostic equipment for the job. Typical tools used for troubleshooting motor operation problems include an ac voltmeter, ac clamp-on ammeter, ohmmeter and meg-ohmmeter. These tools are used to measure the motor voltage, current and resistance.

Motor overheating

One of the most common sources of motor operating problems is overheating. It's no secret that motors produce heat as a byproduct of their operation. This heat is a result of winding resistance and other inefficiencies in the generation and induction of the magnetic flux used to produce torque at the motor shaft. The rule of thumb for motor life expectancy is "every 10 degrees C rise in motor temperature results in a 50% decrease of motor life." It is important to minimize the adverse effects of overheating.

This is why motors are designed to dissipate heat during normal operation by use of their external surfaces and typically a cooling fan. Other motor configurations are available for improved heat reduction including totally enclosed non vent (TENV), water cooled and air-to-air heat exchangers.

Still, despite the best efforts of the manufacturers, overheating is a common operating problem. Symptoms for motor overheating problems include excess heat on the motor exterior, tripping of the motor overload or drive and motor winding failure.

Unbalanced voltage

Voltage imbalance is a common and damaging source of overheating. A rule of thumb for the effect of voltage imbalance is "the percent of motor temperature rise equals two times the square of the percentage of voltage imbalance." For example, a 3% voltage imbalance can result in an 18% (calculated as: 2 X (3%)2) temperature rise in the motor.

To determine if a voltage imbalance exists, first check the supply voltage to the motor control device when the motor is not running. Set the ac voltmeter to the range for the three-phase voltage of the motor supply. At the line side of the motor control device (power supply side of a motor starter), check and record the voltage phase-to-phase and phase-to-ground for each combination.

The voltage measurements from phase-to-phase should be very close to the same readings. If a voltage imbalance is present on the supply side when the motor is not running, the problem is in the voltage supply. Check out your facility's power system and resolve the supply problem. Problems could include an open fuse, incoming utility imbalance, transformer problems or feed-wire sizing. Voltage measurements from phase-to-ground may vary due to incoming voltage configurations and these measurements may be useful for further troubleshooting.

Troubleshooting Motors

If the voltage supply is okay, next use the ac voltmeter to check the voltage on the load side of the motor control device when the motor is running (motor “T” leads T1 to T2, T2 to T3, T3 to T1, T1 to ground, T2 to ground, and T3 to ground). These measurements will check the voltage going to the motor and the wiring from the motor control device to the motor.

If the voltage imbalance is present only when the motor is running, the problem is in the motor or the wiring from the motor starting equipment to the motor. Remove the power from the motor control device and follow all plant lock-out/tag-out and safety requirements. Using the ohmmeter, check the resistance of the motor leads at the control equipment. This will check the motor and the wires to the motor. Check and record phase-to-phase and phase-to-ground resistances.

The resistance measurements phase-to-phase should be very close for each measurement and within the specifications for the motor as suggested by the manufacturer. Resistance values vary based on motor horsepower and voltage hookup. The resistance from phase-to-ground should be very high for each combination of measurements.

If the phase-to-phase resistance is high, there may be an open winding in the motor, open wire to the motor or a bad connection in the motor connection box. Open the motor connection box, disconnect the motor connections and check the motor windings using the ohmmeter. Determine if the problem is the motor or the feed wires. Replace the motor, feed wires or repair the motor connections at the connection box.

If the phase-to-ground resistance is low, disconnect the motor at the motor connection box and check the motor leads. If the resistance on the motor is low phase-to-ground, there is a short in the motor, and it must be replaced. If the motor resistance to ground is high on the motor leads, check the feed wires. Replace the bad wires or reconnect and insulate the motor connections in the motor connection box to eliminate the short circuit.

If there are no resistance problems found using the ohmmeter use the meg-ohmmeter to test the same series of test measurements as described with the ohmmeter. A meg-ohmmeter tests the wiring with a higher voltage to determine if an intermittent or breakdown in the insulation of the motor windings, motor wires, or motor connections exists.

Motor overload

Motors are designed to run during normal operation within the ratings on the motor nameplate. The nameplate has a full-load amp rating. This rating should not be exceeded during normal operation, however occasional and brief occurrences are typically not a problem. The motor is not designed to remove the heat that is generated at levels above the full load amp rating except for starting and intermittent load surges.

After verifying that the motor voltage and motor resistance are okay, use an ac ammeter to check the motor current. Set the ac ammeter to a level higher than the full load rating of the motor. Affix the ac ammeter clamp around one of the motor wires. Measure and record the amp reading for each phase (T1, T2 and T3).

The amp reading for each phase should be similar. If the amperage reading for each phase is larger than the full load nameplate reading, the motor is overloaded. Check the load for problems such as a jammed load, too much material or bearing failure. The motor may also be sized incorrectly for the load requirements. If the amp readings for each phase are very different, this may indicate a problem with the voltage or a failure in a motor winding or connection. Then check the motor voltage and resistance readings as described earlier.

Environment

Motors require cooling to remove heat generated during operation. If the motor is overheating, check the area around the motor for high ambient temperature conditions. Heat can be transferred to the motor from the environment by radiation, convection and conduction. If the motor is mounted near an oven, burner or other heat source, move the motor to an area away from the heat if possible. Heat can be transferred to the motor through the mechanical connection to a hot load.

Is the motor located in a dirty or dusty environment? Accumulation of dust and dirt on a motor insulates the motor. This will decrease the ability of the motor fan to remove the heat produced by the motor.

Other sources of overheating

Another possibility is that the motor may be running too slow. Motors are designed for running near their nameplate RPM and may run above or below this rating depending on the manufacturer's specifications. When running a motor with a variable frequency drive, motors have a speed range rating at which it effectively removes the heat at the rated load. Motors should offer a constant-torque load speed range for conveyors, augers, extruders, etc., and for variable-torque loads such as centrifugal pumps and blowers. The ratings refer to the speed range capability of the motor below the nameplate RPM rating.

Troubleshooting Motors

When operating a motor on a VFD above the nameplate RPM, the motor output torque capability is reduced. Typical motor torque curves indicate a constant motor horsepower output and a variable torque operation above base speed. The higher the motor speed above base RPM, the less torque available from the motor.

High cycle operation of a motor also adds heat to the motor. When a motor starts, higher current than the full load rating is typically required to begin motor rotation and bring the motor up to speed. If the motor is started and stopped frequently, the motor may not be running long enough at speed for the fan to remove the heat.

Alternatives for removing the heat from a motor include a constant velocity blower fan, ducting outside air to the motor and the use of a heat exchanger.

Low speed or lack of torque

A motor in proper working order should rapidly reach near-nameplate speed when started across the line. If the motor takes a long time to reach the nameplate RPM or has little torque check for the following:

Low voltage — A basic cause of a poor performing motor is low voltage. A low voltage situation does not provide the necessary power to allow the motor to achieve the expected torque rating. If your motor is not generating the required torque for your operation, first check motor voltages as described previously.

Single phase — Single-phase voltage, like low voltage, does not provide the necessary power to develop the torque rating of the motor. Typical motor characteristics may include a motor hum or a motor with very little torque when turning. Again, check motor voltages as described previously.

Excessive vibration — Excessive vibration is as much a symptom as it is a cause of motor operating problems. Excessive motor vibration is usually a sign of either motor or load problems and can lead to premature failure of the motor and the load. The following steps should assist you in discovering and fixing vibration problems:

Misalignment and unbalanced loads — Misalignment between the motor shaft and the load shaft causes unnecessary vibration. Premature bearing failure in the motor and/or the load can result from misalignment. The motor shaft must be centered with the load shaft to optimize operating efficiency. Various tools for motor and load alignment are available such as laser alignment kits. Motors and loads must also be firmly mounted to a base to maintain alignment and minimize vibration from loose mounting hardware.

Load imbalance — Load imbalance is an additional cause of motor vibration. Check the load for unbalanced conditions such as excess material on the outside of the drum, broken fan blades, etc. Clear the material or repair the load and run the equipment again to check for imbalance problems.

Pump cavitation — Pump cavitation is a common cause of excessive pump vibration which may in turn damage the motor. Cavitation is present when the pump is running outside its capabilities. This could include a head pressure that's too low, an impeller that's too large, a pump running too fast or a discharge pressure that's too low. Check with your pump manufacturer to ensure the pump is operating within the design capabilities.

Motor selection and maintenance

Generally, modern electric motors provide long trouble-free service if care is taken in the initial application and routine maintenance of the motor. Correct motor selection and application criteria include:

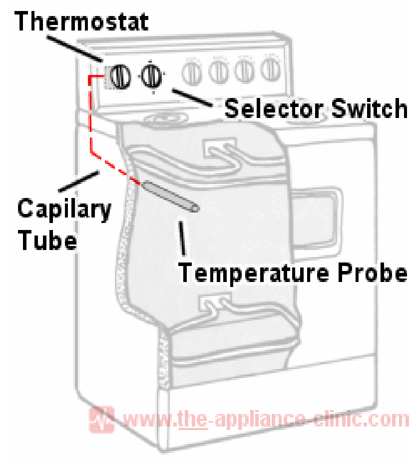
•Voltage
•Horsepower requirement
•Mounting requirements (Foot mount, C-Face mount, etc.)
•Base RPM
•Enclosure type (TEFC, ODP, washdown, etc.)
•Environmental concerns (temperature, moisture, dust, dirt, hazardous, etc.)
•Load type (constant torque, variable torque, high inertia)
•Duty cycle
•Starting method (across the line, VFD etc.)
•Special considerations (regenerative load, positioning, etc.)
•Proper motor maintenance includes regular bearing greasing (do not over-grease), vibration monitoring, cleaning and conditioning monitoring. Proper application and preventive maintenance practices can provide reliable production uptime.

•The Bottom Line...

•Motor operational problems are a common cause of downtime and maintenance headaches.
•Good troubleshooting skills help to identify the root cause of motor problems and avoid their recurrence.
•Take time when handling a motor failure situation to carefully diagnose the situation and gain a complete understanding of the source (or sources) of the problem.
•Analyzing application issues and applying long-term corrective solutions will help to minimize your operational disruptions.

Temperature Controls

Electric Range Oven Temperature Control

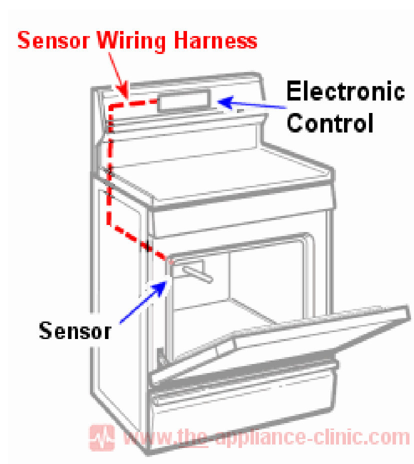


On conventional ranges, the oven temperature is most often controlled by a hydraulic thermostat. That thermostat consists of an electrical switch box mounted in the control panel, a shaft which the temperature adjustment knob attaches onto and a sensor bulb connected to the control body via a capillary tube. The sensor bulb filled with gas is inserted into the oven cavity and held in place my clips. As the sensor is heated by the oven air temperature the gas inside the sensor bulb expands and is forced through the capillary tube to the thermostat body where it actuates electrical contacts which open and close in response to the changing temperatures. When open the thermostat contacts stop power from getting to the oven elements. When closed power is allowed to feed the elements where they generate heat.

Contrary to popular belief an oven does not maintain an exact temperature. The cycles of heating and not can allow the oven temperature to vary by 20 degrees above and below the set temperature. The result is an average oven temperature that the control is set for.

More complex oven designs like self cleaning models may also incorporate an oven selector switch. While the thermostat is responsible for cycling the heat in response to temperature, the selector switch can control whether it is the bake element or broil element doing the heating or both, as in a self clean cycle. There may be additional electrical relays involved in the actual switching of power to the elements depending on the design of the control system utilized in the particular model.

Electronic Range Controls



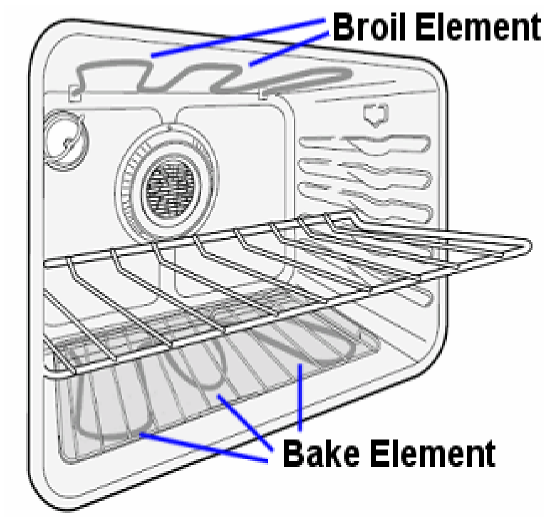
Most newer ranges and ovens use an electronic control system to regulate oven operations. Such a system consist of an electronic control in the control panel and an oven temperature sensor mounted in the oven cavity. The oven temperature sensor is a thermistor which changes resistance depending on ambient temperatures. The sensor is connected to the control by electrical wiring. The control reads the resistance changes in the sensor and reacts, opening and closing electrical relays to switch power to the oven elements on and off. In most cases those relays are an integral part of the electronic control although some control designs use a separate relay board to control the actual switching of power to the elements. On such a system wiring connects the relay board to the main electronic control board.

Electronic controls can be programmed to do all sorts of things it was not possible for a conventional hydraulic thermostat to do. An electronic control can turn the oven elements on at full power (240 volts), half power (120 volts) or mix and match power and element functioning in an attempt to create the best baking solution. Consult the technical data for your particular model to see exactly how your oven was designed to function.

Unit 3:
Components

Electric Range Baking

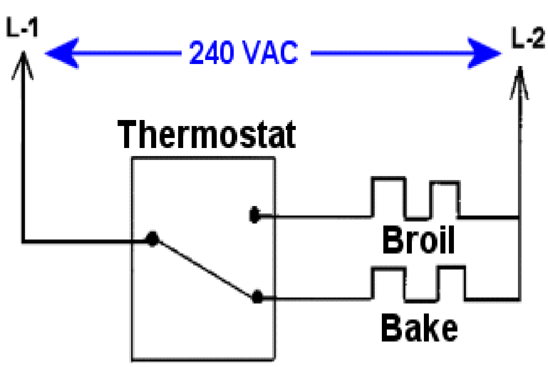
Electric Range Baking



Baking in an electric range is achieved primarily by use of the lower oven element. That element is cycled on an off at full power (240 volts) by the control system to maintain an average (not constant) temperature. The actual oven temperature may vary by 20 degrees above and below the set temperature which results in the average oven temperature being what the control is set for.

Many oven control systems also have a preheat feature designed into them. When initially turned on both bake and broil elements are energized at full power to heat the oven as quickly as possible. Once the set temperature is reached, the broil element is disengaged and only the bake element is cycled on and off to maintain oven temperature.

Lately manufacturers have been trying different things to improve baking. With the advent of electronic controls some manufacturers have designed their controls to power the broil element at half power during bake or to alternate powering the bake and broil elements during a bake cycle. The exact system used in a modern range may be listed with the appliance's 'tech sheet' which should accompany it wiring diagram.

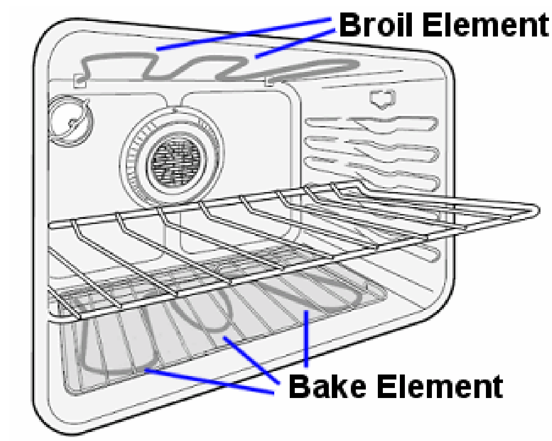


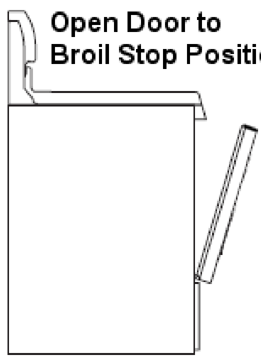
Simplified Oven Circuit

Electric Range Broiling

Electric Range Broiling

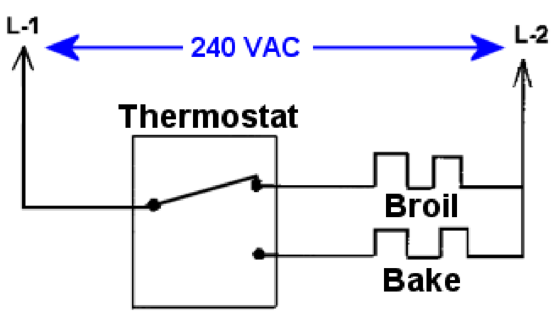
Broiling in an electric range is achieved primarily by use of the upper oven broil element. That element is not temperature controlled and usually stays on 100% of the time at full power (240 volts). Because of this broiling must be done with the door open to allow excess heat to escape or damage to the range can occur.





Vari-broil

Some older dial-type oven thermostats and some newer electronic controls have a vari-broil feature that allows broiling at reduced temperatures. On control systems so equipped, the broil element can be selected to cycle on an off to provide greater flexibility in broiling. Generally, to broil meat well done a lower heat but longer cook time is used. For rare, a higher heat and shorter cooking duration is used.



Simplified Oven Circuit

Unit 3:
Components

Fundamentals of Electricity

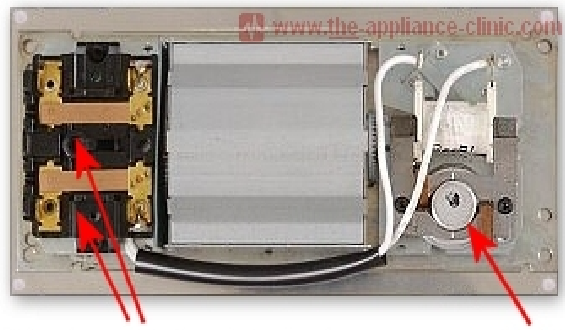
Electric Range Clock Timer

Electric Range Clock Timer Failure

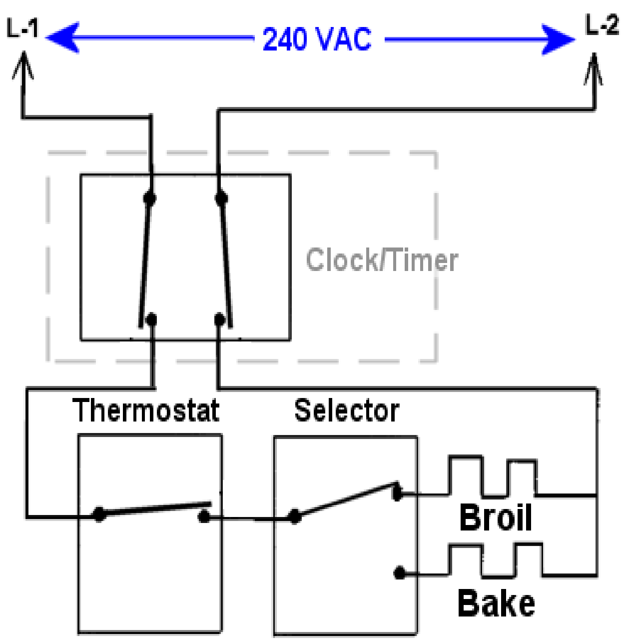
Many ranges have a clock/timer unit which can be set to control the start and stop cooking times automatically. These timer units have electrical contacts which switch power to the oven elements as need be. Those contacts can become damaged though normal wear and tear preventing oven operation. A simple visual inspection can often determine a problem with those contacts. Any signs of arcing or discoloration should have more scrutiny.

The timers can also become mistakenly set to 'auto' preventing manual oven operation. This frequently occurs when being cleaned. Check the owner's manual for how to reset the clock into manual operation.

Rear View of Mechanical Clock/Timer Unit



Notes:___________



Thermostat, Selector, Timer Oven Circuit

Unit 3:
Components

Fundamentals of Electricity

Hands-On Exercises

- ❑ Check a circuit breaker for continuity
- ❑ Check a fuse for continuity
- ❑ Check a switch for continuity and resistance
- ❑ Check a transformer for continuity
- ❑ Check an infinite switch for continuity
- ❑ Check a heating element for continuity and resistance
- ❑ Test a diode
- ❑ Check a relay for continuity
- ❑ Check a contactor for continuity
- ❑ Check a solenoid coil for continuity
- ❑ Test a capacitor
- ❑ Check a motor for continuity
- ❑ Check a thermostat for continuity
- ❑ Identify electrical components on a machine
- ❑ Read a schematic
- ❑ Check voltage at a 120 VAC outlet
- ❑ Check voltage at a 208 VAC outlet
- ❑ Check voltage at a 208 3-Phase outlet
- ❑ Check voltage at breaker panel
- ❑ Check a wire for continuity
- ❑ Connect a series circuit
- ❑ Connect a parallel circuit
- ❑ Connect a series-parallel circuit
- ❑ Solve a circuit

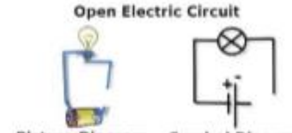
Unit 4:
Circuits

Fundamentals of Electricity

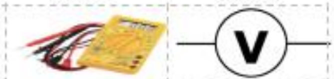
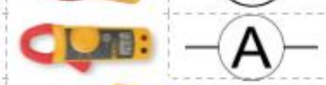
Schematics & Wiring Diagrams

What are schematic symbols?

Schematic symbols are universal symbols used on wiring diagrams and schematics in place of pictures. Symbols make it easier to create and read schematics. Below are some electrical components and their symbols.

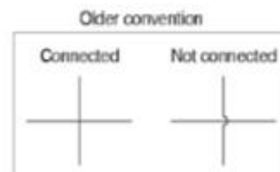


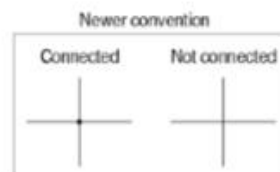
Meter Symbols & Voltage Types

Name	Picture / Symbol
Voltmeter (Voltage)	
Ammeter (Current)	
Ohmmeter (Resistance)	
AC Voltage	
DC Voltage	

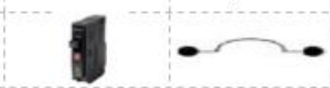
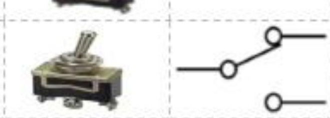
Current Conductors

Earth Ground

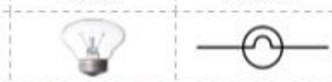
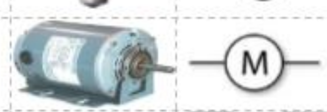
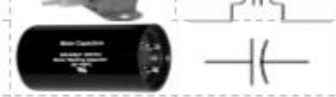




Switching Devices

Name	Picture / Symbol
Circuit Breaker	
Fuse	
Thermostat Temp. Switch	
Push Button Switch	
Single Pole Switch (Open)	
Single Pole Double Throw Switch	
Double Pole Double Throw Switch	

Loads and Other

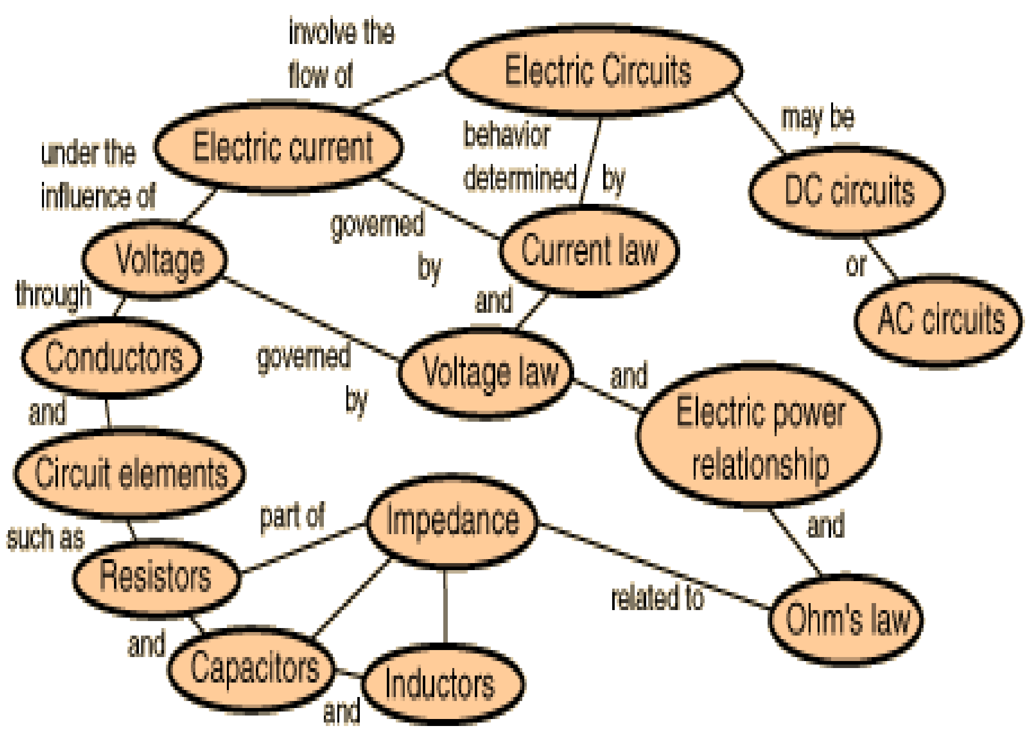
Name	Picture / Symbol
Lamp / Bulb	
Motor	
Transformer	
Capacitor	
Resistor	
Relay	
Thermocouple	

Unit 4:
Circuits

Electrical Circuits

Definition of Electrical Circuit
An electrical circuit is a combination of two or more electrical components which are interconnected by conducting paths. The components may be active or inactive or both. This is a very basic definition of electrical circuit.

Types of Circuits
There are two types of electricity - direct current and alternating current, i.e., DC and AC. The circuit that deals with direct current or DC, is referred as DC circuit and the circuit that deals with alternating current or AC, is generally referred as AC Circuit. The components of the electrical DC circuit are mainly resistive, where as components of the AC circuit may be reactive as well as resistive. Any electrical circuit can be categorized into three different groups - series, parallel and series parallel. So for example, in the case of DC, the circuits can also be divided into three groups, such as series DC circuit, parallel DC circuit and series and parallel circuit.



Electricianeducation.com

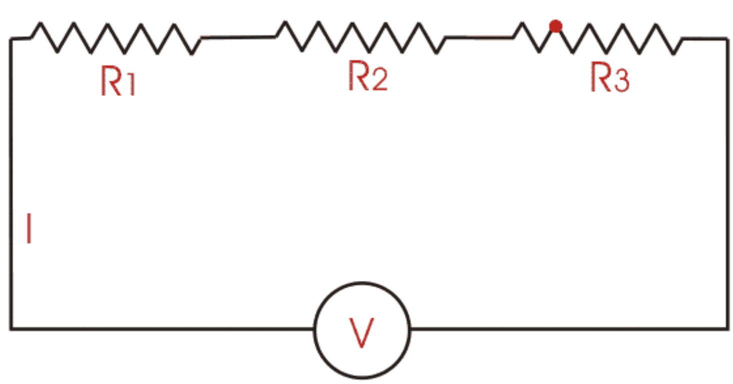
https://www.electrical4u.com/electrical-dc-series-and-parallel-circuit/

Series Circuits

Series Circuit

When all the resistive components of a circuit are connected end to end to form a single path for flowing current, then the circuit is referred as series circuit. The manner of connecting components end to end is known as series connection. Suppose we have n number of resistors R1, R2, R3............Rn and they are connected in end to end manner, means they are series connected. If this series combination is connected across a voltage source, the current starts flowing through that single path. As the resistors are connected in end to end manner, the current first enters in to R1, then this same current comes in R2, then R3 and at last it reaches Rn from which the current enters into the negative terminals of the voltage source. In this way, the same current circulates through every resistor connected in series. Hence, it can be concluded that in a series DC circuit, the same current flows through all parts of the electrical circuit.

Again according to Ohm's law, the voltage drop across a resistor is the product of its electrical resistance and the current flow through it. Here, current through every resistor is the same, hence the voltage drop across each resistor's proportional to its electrical resistance value. If the resistances of the resistors are not equal then the voltage drop across them would also not be equal. Thus, every resistor has its individual voltage drop in a series circuit.



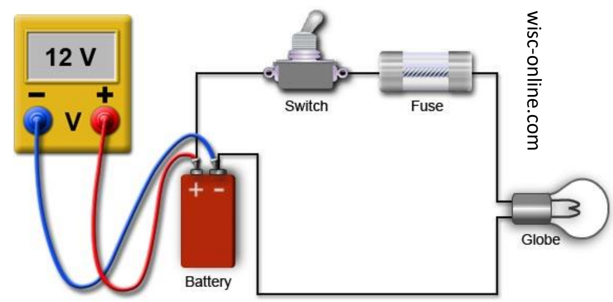
Series Circuit with Three Resistors

https://www.electrical4u.com/electrical-dc-series-and-parallel-circuit/

Unit 4:
Circuits

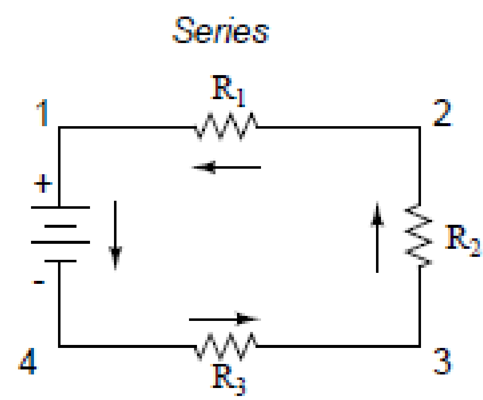
Fundamentals of Electricity

Series Circuits



Circuits consisting of just one battery and one load resistance are very simple to analyze, but they are not often found in practical applications. Usually, we find circuits where more than two components are connected together.

There are two basic ways in which to connect more than two circuit components: series and parallel. First, an example of a series circuit:



Here, we have three resistors (labeled R1, R2, and R3), connected in a long chain from one terminal of the battery to the other.

(It should be noted that the subscript labeling – those little numbers to the lower-right of the letter "R" – are unrelated to the resistor values in ohms. They serve only to identify one resistor from another).

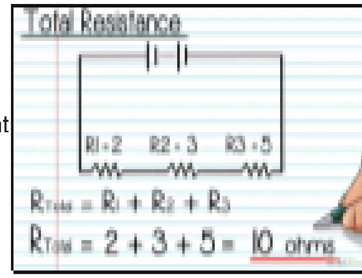
The defining characteristic of a series circuit is that there is only one path for electrons to flow. In this circuit the electrons flow in a counter-clockwise direction, from point 4 to point 3 to point 2 to point 1 and back around to 4.

Unit 4:
Circuits

Fundamentals of Electricity

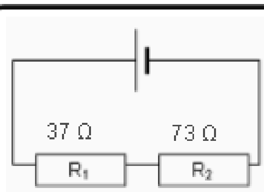
Worksheet – Resistors in Series

What is series circuit resistance?

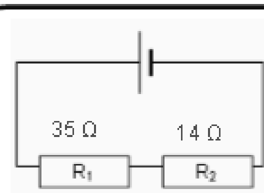


In a series circuit because there is only one path for current flow, the same current flows through all resistors in the circuit. All components in a series circuit see the same amount of current; therefore, each component must be capable of carrying that number of amperes.

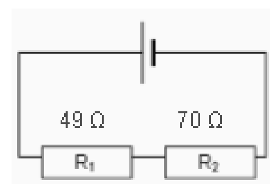
The total resistance of a series circuit is equal to the sum of the resistances across each part of the circuit. RT = R1 + R2



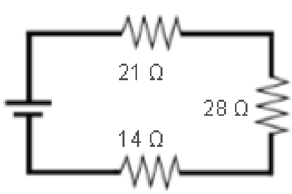
RT = __________ Ω



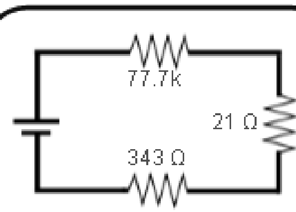
RT = __________ Ω



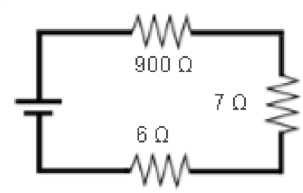
RT = __________ Ω



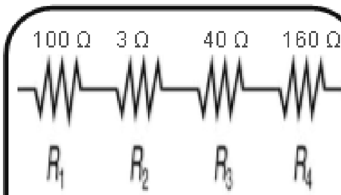
RT = __________ Ω



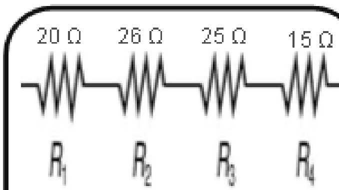
RT = __________ Ω



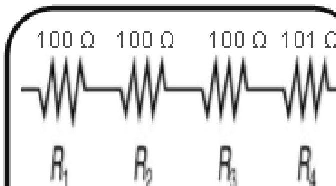
RT = __________ Ω



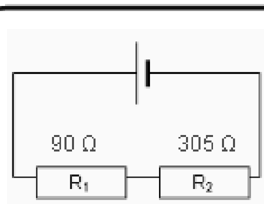
RT = __________ Ω



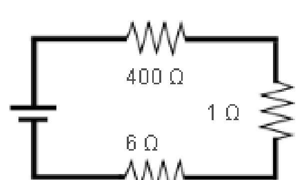
RT = __________ Ω



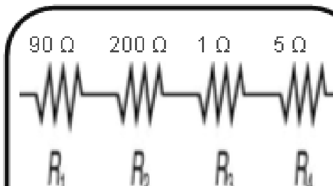
RT = __________ Ω



RT = __________ Ω



RT = __________ Ω



RT = __________ Ω

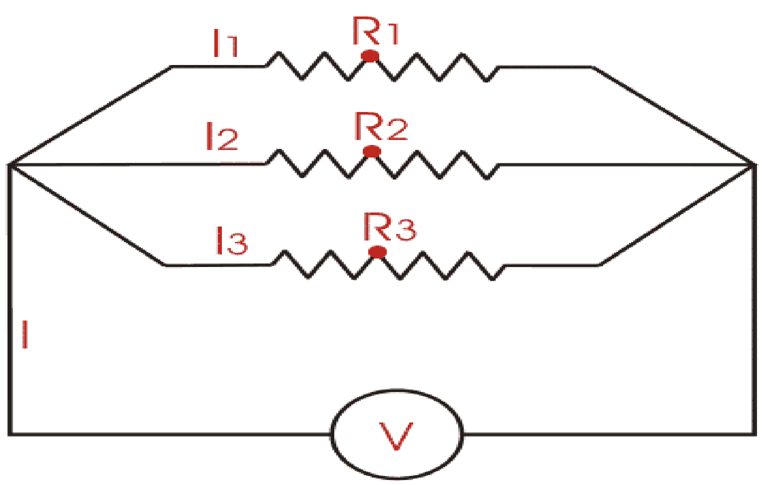
Unit 4:
Circuits

Fundamentals of Electricity

Parallel Circuits

Parallel Circuit
When two or more electrical components are connected in a way that one end of each component is connected to a common point and the other end is connected to another common point, then the electrical components are said to be connected in parallel, and such an electrical circuit is referred as a parallel circuit. In this circuit every component will have the same voltage drop across them, and it will be exactly equal to the voltage which occurs between the two common points where the components are connected. Also in a parallel circuit, the current has several parallel paths through these parallel connected components, so the circuit current will be divided into as many paths as the number of components.

Here, in this electrical circuit, the voltage drop across each component is equal. Again as per Ohm's law, voltage drop across any resistive component is equal to the product of its electrical resistance and current through it. As the voltage drop across every component connected in parallel is the same, the current through them is inversely proportional to its resistance value.



Parallel Circuit with Three Resistors

https://www.electrical4u.com/electrical-dc-series-and-parallel-circuit/

Unit 4:
Circuits

Parallel Circuits

Now, let's look at the other type of circuit, a parallel configuration:

Again, we have three resistors, but this time they form more than one continuous path for electrons to flow.

There's one path from 8 to 7 to 2 to 1 and back to 8 again.

There's another from 8 to 7 to 6 to 3 to 2 to 1 and back to 8 again.

And then there's a third path from 8 to 7 to
6 to 5 to 4 to 3 to 2 to 1 and back to 8 again.

Each individual path (through R1, R2, and R3) is called a branch.

The defining characteristic of a parallel circuit is that all components are connected between the same set of electrically common points.

Looking at the schematic diagram, we see that points 1, 2, 3, and 4 are all electrically common. So are points 8, 7, 6, and 5. Note that all resistors as well as the battery are connected between these two sets of points.

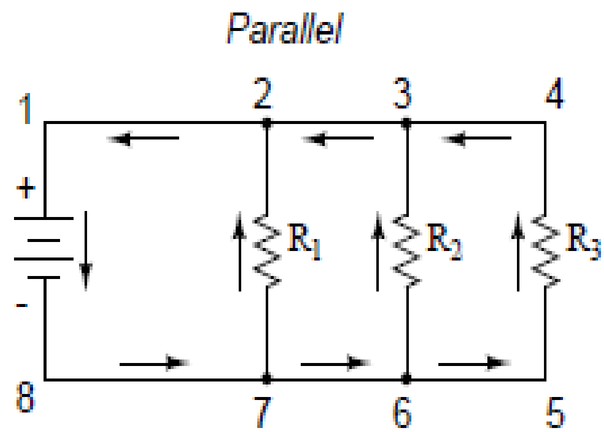
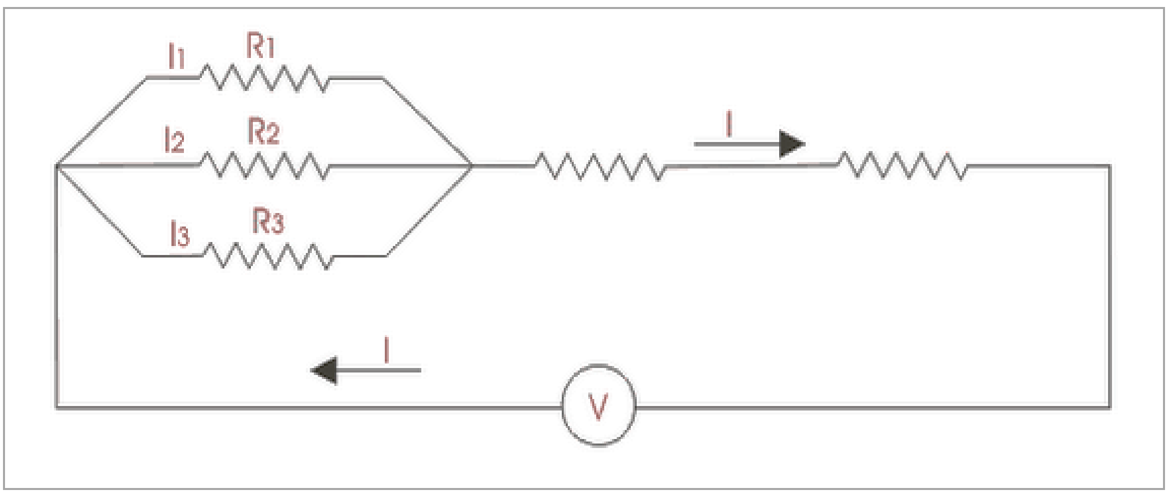


Photo credit:

Allaboutcircuits.com

Series-Parallel Circuits

Series -Parallel Circuit
So far we have discussed series circuit and parallel circuit separately, but in practice, the electrical circuit is generally a combination of both series circuits and parallel circuits. Such combined series and parallel circuits can be solved by proper application of Ohm's law and the rules for series and parallel circuits to the various parts of the complex circuit.

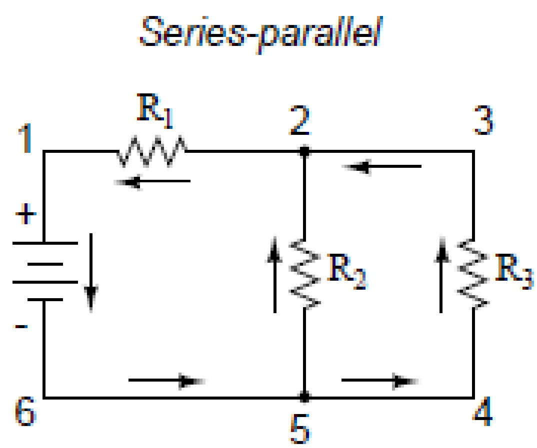


Series-Parallel Circuit with Five Resistors

https://www.electrical4u.com/electrical-dc-series-and-parallel-circuit/

Series-Parallel Circuits

And, of course, the complexity doesn't stop at simple series and parallel either! We can have circuits that are a combination of series and parallel, too:



In this circuit, we have two loops for electrons to flow through: one from 6 to 5 to 2 to 1 and back to 6 again, and another from 6 to 5 to 4 to 3 to 2 to 1 and back to 6 again.

Notice how both current paths go through R1 (from point 2 to point 1).

In this configuration, we'd say that R2 and R3 are in parallel with each other, while R1 is in series with the parallel combination of R2 and R3.

Unit 4:
Circuits

Circuit Characteristics

Series Circuit Characteristics

The following is a list of the characteristics of the series circuit.

1. The current is the same everywhere in the circuit. This means that wherever I try to measure the current, I will obtain the same reading.
2. Each component has an individual Ohm's law Voltage Drop. This means that I can calculate the voltage using Ohm's Law if I know the current through the component and the resistance.
3. Kirchoff's Voltage Law Applies. This means that the sum of all the voltage sources is equal to the sum of all the voltage drops or

   $V_S = V_1 + V_2 + V_3 + \ldots + V_N$
4. The total resistance in the circuit is equal to the sum of the individual resistances.

   $R_T = R_1 + R_2 + R_3 + \ldots + R_N$
5. The sum of the power supplied by the source is equal to the sum of the power dissipated in the components.

   $P_T = P_1 + P_2 + P_3 + \ldots + P_N$

Parallel Circuit Characteristics

The following is a list of the characteristics of the parallel circuit.

1. The current in each component (branch) is the same everywhere in the circuit. This means that wherever I try to measure the voltage, I will obtain the same reading, and this is the supply voltage.
2. Each branch has an individual current path. I can calculate the current using Ohm's Law if I know the voltage across the component and the resistance.
3. Kirchoff's Current Law Applies. This means that the sum of all the voltage sources is equal to the sum of all the voltage drops or

   $I_T = I_1 + I_2 + I_3 + \ldots + I_N$
4. The total resistance in the circuit is equal to inverse the sum of the inverse of the individual resistances.

   $$\frac{1}{R_T} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \ldots + \frac{1}{R_4}$$
5. The sum of the power supplied by the source is equal to the sum of the power dissipated in the components.

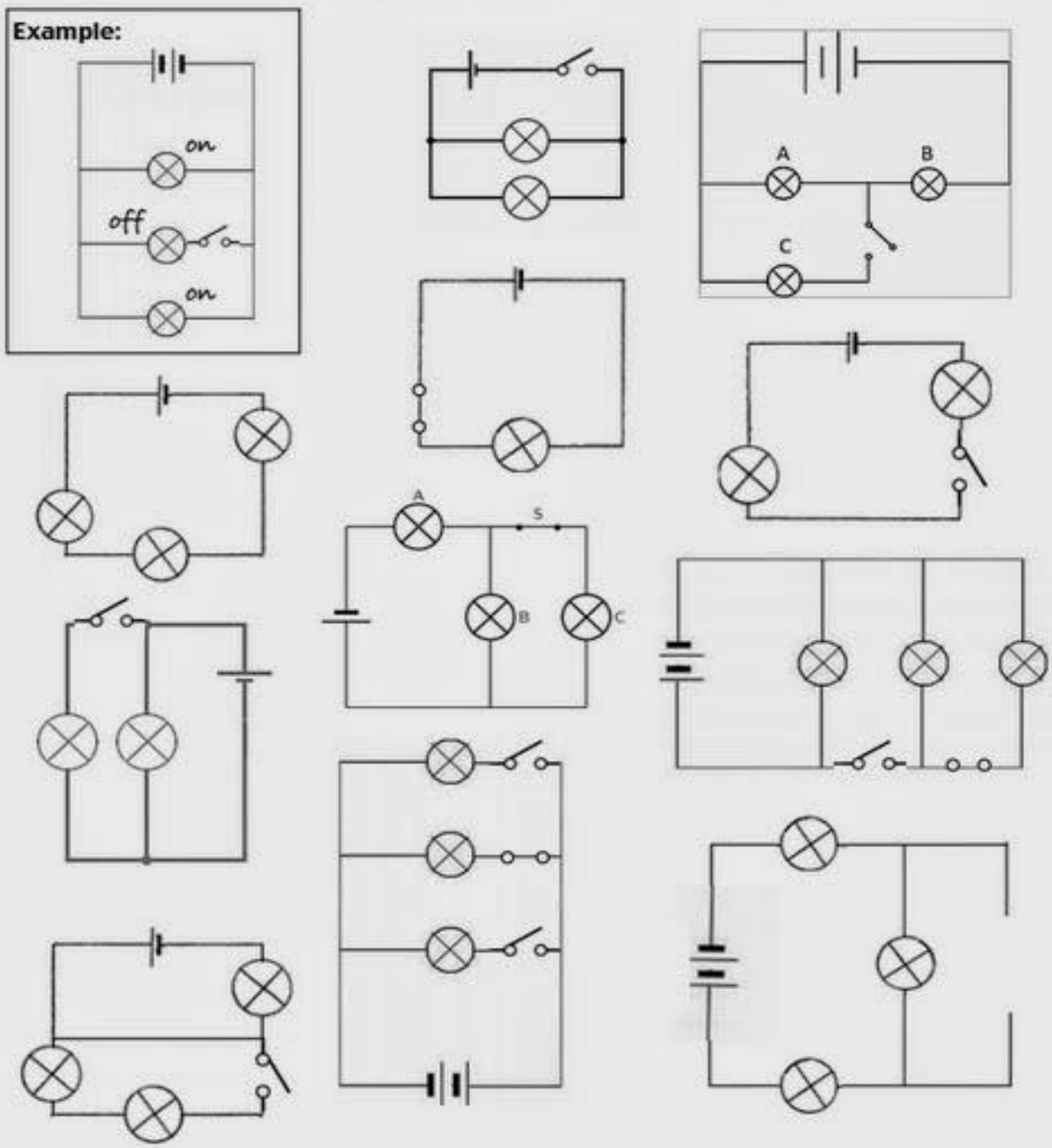
   $P_T = P_1 + P_2 + P_3 + \ldots + P_N$

http://studylib.net/doc/18406917/characteristics-of-the-series-and-parallel-circuit

Worksheets – Challenge Circuits

Challenge Circuits

Determine if the bulb is glowing or not by writing "on" or "off" next to the bulb.

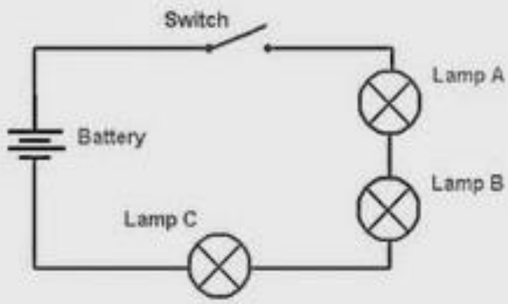


http://teachingthekid.blogspot.com/2015/03/series-or-parallel-circuits.html

Worksheet – Will it Work?

Will it Work?

Look at Circuit 1.



1.Is it a series or a parallel circuit? ______________

2. In its current condition, with the bulbs work? Why?

____

3. The switch is now CLOSED. Will the bulbs work? Why?

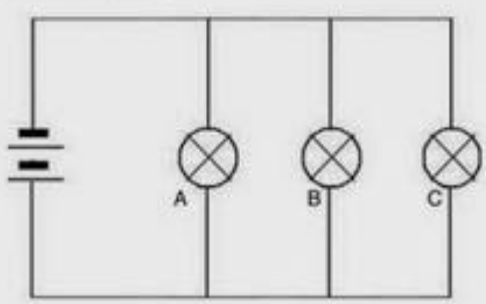
____

4. The switch is CLOSED. Lamp A is broken. Lamp B and C will: glow not glow

5. The switch is CLOSED. Lamp B is broken. Lamp A and C will: glow not glow

6. The switch is CLOSED. Lamp C is broken. Lamp A and B will: glow not glow

Look at Circuit 2:



1.Is it a series or parallel circuit? ______________

2. In its current condition, will the bulbs work? Why?

____

3. Lamp A is broken. Lamp B and C will: glow not glow

4. Lamp B is broken. Lamp A and C will: glow not glow

5. Lamp C is broken. Lamp A and B will: glow not glow

http://teachingthekid.blogspot.com/2015/03/series-or-parallel-circuits.html

Unit 5:
Troubleshooting

Introduction to Troubleshooting

Perhaps the most valuable but difficult-to-learn skill any technical person could have is the ability to troubleshoot a system. For those unfamiliar with the term, troubleshooting means the act of pinpointing and correcting problems in any kind of system. For an auto mechanic, this means determining and fixing problems in cars based on the car's behavior. For a doctor, this means correctly diagnosing a patient's malady and prescribing a cure. For a business expert, this means identifying the source(s) of inefficiency in a corporation and recommending corrective measures.

Troubleshooters must be able to determine the cause or causes of a problem simply by examining its effects. Rarely does the source of a problem directly present itself for all to see. Cause/effect relationships are often complex, even for seemingly simple systems, and often the proficient troubleshooter is regarded by others as something of a miracle-worker for their ability to quickly discern the root cause of a problem. While some people are gifted with a natural talent for troubleshooting, it is a skill that can be learned like any other.

Sometimes the system to be analyzed is in so bad a state of affairs that there is no hope of ever getting it working again. When investigators sift through the wreckage of a crashed airplane, or when a doctor performs an autopsy, they must do their best to determine the cause of massive failure after the fact. Fortunately, the task of the troubleshooter is usually not this grim. Typically, a misbehaving system is still functioning to some degree and may be stimulated and adjusted by the troubleshooter as part of the diagnostic procedure. In this sense, troubleshooting is a lot like scientific method: determining cause/effect relationships by means of live experimentation. Like science, troubleshooting is a mixture of standard procedure and personal creativity.

There are certain procedures employed as tools to discern cause(s) from effects, but they are impotent if not coupled with a creative and inquisitive mind. In the course of troubleshooting, the troubleshooter may have to invent their own specific technique – adapted to the particular system they're working on – and/or modify tools to perform a special task. Creativity is necessary in examining a problem from different perspectives: learning to ask different questions when the "standard" questions don't lead to fruitful answers.

If there is one personality trait I've seen positively associated with excellent troubleshooting more than any other, its technical curiosity. People fascinated by learning how things work, and who aren't discouraged by a challenging problem, tend to be better at troubleshooting than others.

Questions to ask before proceeding

• Has the system ever worked before? If yes, has anything happened to it since then that could cause the problem?

• Has this system proven itself to be prone to certain types of failure?

• How urgent is the need for repair?

• What are the *safety concerns*, before I start troubleshooting?

• What are the process quality concerns, before I start troubleshooting (what can I do without causing interruptions in production)?

These preliminary questions are not trivial. Indeed, they are essential to expedient and safe troubleshooting. They are especially important when the system to be trouble-shot is large, dangerous, and/or expensive.

Sometimes the troubleshooter will be required to work on a system that is still in full operation (perhaps the ultimate example of this is a doctor diagnosing a live patient). Once the cause or causes are determined to a high degree of certainty, there is the step of corrective action. Correcting a system fault without significantly interrupting the operation of the system can be very challenging, and it deserves thorough planning.

When there is high risk involved in taking corrective action, such as is the case with performing surgery on a patient or making repairs to an operating process in a chemical plant, it is essential for the worker(s) to plan ahead for possible trouble. One question to ask before proceeding with repairs is, ”how and at what point(s) can I abort the repairs if something goes wrong?” In risky situations, it is vital to have planned ”escape routes” in your corrective action, just in case things do not go as planned. A surgeon operating on a patient knows if there are any ”points of no return” in such a procedure, and stops to re-check the patient before proceeding past those points. He or she also knows how to ”back out” of a surgical procedure at those points if needed.

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General troubleshooting tips

When first approaching a failed or otherwise misbehaving system, the new troubleshooter often doesn't know where to begin. The following strategies are not exhaustive by any means, but provide the troubleshooter with a simple checklist of questions to ask in order to start isolating the problem. As tips, these troubleshooting suggestions are not comprehensive procedures: they serve as starting points only for the troubleshooting process. An essential part of expedient troubleshooting is probability assessment, and these tips help the troubleshooter determine which possible points of failure are more or less likely than others. Final isolation of the system failure is usually determined through more specific techniques.

Prior occurrence

If this device or process has been historically known to fail in a certain particular way, and the conditions leading to this common failure have not changed, check for this ”way” first. A corollary to this troubleshooting tip is the directive to keep detailed records of failure. Ideally, a computer-based failure log is optimal, so that failures may be referenced by and correlated to a number of factors such as time, date, and environmental conditions.

Example: The car's engine is overheating. The last two times this happened, the cause was low coolant level in the radiator.

What to do: Check the coolant level first. Of course, past history by no means guarantees the present symptoms are caused by the same problem, but since this is more likely, it makes sense to check this first.

If, however, the cause of routine failure in a system has been corrected (i.e. the leak causing low coolant level in the past has been repaired), then this may not be a probable cause of trouble this time.

Recent alterations

If a system has been having problems immediately after some kind of maintenance or other change, the problems might be linked to those changes.

Example: The mechanic recently tuned my car's engine, and now I hear a rattling noise that I didn't hear before I took the car in for repair.

What to do: Check for something that may have been left loose by the mechanic after his or her tune-up work.

Function vs. non-function

If a system isn't producing the desired end result, look for what it is doing correctly; in other words, identify where the problem is not, and focus your efforts elsewhere. Whatever components or subsystems necessary for the properly working parts to function are probably okay.

The degree of fault can often tell you what part of it is to blame.

Example: The radio works fine on the AM band, but not on the FM band.

What to do: Eliminate from the list of possible causes, anything in the radio necessary for the AM band's function. Whatever the source of the problem is, it is specific to the FM band and not to the AM band. This eliminates the audio amplifier, speakers, fuse, power supply, and almost all external wiring. Being able to eliminate sections of the system as possible failures reduces the scope of the problem and makes the rest of the troubleshooting procedure more efficient.

Hypothesize

Based on your knowledge of how a system works, think of various kinds of failures that would cause this problem (or these phenomena) to occur, and check for those failures (starting with the most likely based on circumstances, history, or knowledge of component weaknesses).

Example: *The car's engine is overheating.*

What to do: Consider possible causes for overheating, based on what you know of engine operation. Either the engine is generating too much heat, or not getting rid of the heat well enough (most likely the latter). Brainstorm some possible causes: a loose fan belt, clogged radiator, bad water pump, low coolant level, etc. Investigate each one of those possibilities before investigating alternatives.

Specific troubleshooting techniques

After applying some of the general troubleshooting tips to narrow the scope of a problem's location, there are techniques useful in further isolating it. Here are a few:

Swap identical components

In a system with identical or parallel subsystems, swap components between those subsystems and see whether or not the problem moves with the swapped component. If it does, you've just swapped the faulty component; if it doesn't, keep searching!

This is a powerful troubleshooting method, because it gives you both a positive and a negative indication of the swapped component's fault: when the bad part is exchanged between identical systems, the formerly broken subsystem will start working again and the formerly good subsystem will fail.

I was once able to troubleshoot an elusive problem with an automotive engine ignition system using this method: I happened to have a friend with an automobile sharing the exact same model of ignition system. We swapped parts between the engines (distributor, spark plug wires, ignition coil – one at a time) until the problem moved to the other vehicle. The problem happened to be a ”weak” ignition coil, and it only manifested itself under heavy load (a condition that could not be simulated in my garage). Normally, this type of problem could only be pinpointed using an ignition system analyzer (or oscilloscope) *and* a dynamometer to simulate loaded driving conditions. This technique, however, confirmed the source of the problem with 100% accuracy, using no diagnostic equipment whatsoever. Occasionally you may swap a component and find that the problem still exists, but has changed in some way. This tells you that the components you just swapped are *somehow different* (different calibration, different function), and nothing more. However, don't dismiss this information just because it doesn't lead you straight to the problem– look for other changes in the system as a whole as a result of the swap, and try to figure out what these changes tell you about the source of the problem.

An important caveat to this technique is the possibility of causing further damage. Suppose a component has failed because of another, less conspicuous failure in the system. Swapping the failed component with a good component will cause the good component to fail as well. For example, suppose that a circuit develops a short, which ”blows” the protective fuse for that circuit. The blown fuse is not evident by inspection, and you don’t have a meter to electrically test the fuse, so you decide to swap the suspect fuse with one of the same rating from a working circuit. As a result of this, the good fuse that you move to the shorted circuit blows as well, leaving you with two blown fuses and two non-working circuits. At least you know for certain that the original fuse was blown, because the circuit it was moved to stopped working after the swap, but this knowledge was gained only through the loss of a good fuse and the additional ”down time” of the second circuit.

Another example to illustrate this caveat is the ignition system problem previously mentioned. Suppose that the ”weak” ignition coil had caused the engine to backfire, damaging the muffler. If swapping ignition system components with another vehicle causes the problem to move to the other vehicle, damage may be done to the other vehicle’s muffler as well.

As a general rule, the technique of swapping identical components should be used only when there is minimal chance of causing additional damage. It is an excellent technique for isolating non-destructive problems.

Example 1: You’re working on a CNC machine tool with X, Y, and Z-axis drives. The Y axis is not working, but the X and Z axes are working. All three axes share identical components (feedback encoders, servo motor drives, servo motors).

What to do: Exchange these identical components, one at a time, Y axis and either one of the working axes (X or Z), and see after each swap whether or not the problem has moved with the swap.

Example 2: A stereo system produces no sound on the left speaker, but the right speaker works just fine.

What to do: Try swapping respective components between the two channels and see if the problem changes sides, from left to right. When it does, you’ve found the defective component. For instance, you could swap the speakers between channels: if the problem moves to the other side (i.e. the same speaker that was dead before is still dead, now that its connected to the right channel cable) then you know that speaker is bad. If the problem stays on the same side (i.e. the speaker formerly silent is now producing sound after having been moved to the other side of the room and connected to the other cable), then you know the speakers are fine, and the problem must lie somewhere else (perhaps in the cable connecting the silent speaker to the amplifier, or in the amplifier itself).

If the speakers have been verified as good, then you could check the cables using the same method. Swap the cables so that each one now connects to the other channel of the amplifier and to the other speaker. Again, if the problem changes sides (i.e. now the right speaker is now ”dead” and the left speaker now produces sound), then the cable now connected to the right speaker must be defective. If neither swap (the speakers nor the cables) causes the problem to change sides from left to right, then the problem must lie within the amplifier (i.e. the left channel output must be ”dead”).

Remove parallel components

If a system is composed of several parallel or redundant components which can be removed without crippling the whole system, start removing these components (one at a time) and see if things start to work again.

Example 1: *A "star" topology communications network between several computers has failed. None of the computers are able to communicate with each other.*

What to do: Try unplugging the computers, one at a time from the network, and see if the network starts working again after one of them is unplugged. If it does, then that last unplugged computer may be the one at fault (it may have been "jamming" the network by constantly outputting data or noise).

Example 2: *A household fuse keeps blowing (or the breaker keeps tripping open) after a short amount of time.*

What to do: Unplug appliances from that circuit until the fuse or breaker quits interrupting the circuit. If you can eliminate the problem by unplugging a single appliance, then that appliance might be defective. If you find that unplugging almost any appliance solves the problem, then the circuit may simply be overloaded by too many appliances, neither of them defective.

Divide system into sections and test those sections

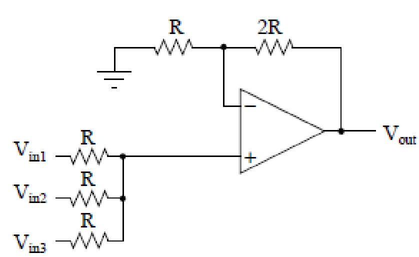
In a system with multiple sections or stages, carefully measure the variables going in and out of each stage until you find a stage where things don't look right.

Example 1: *A radio is not working (producing no sound at the speaker))*

What to do: Divide the circuitry into stages: tuning stage, mixing stages, amplifier stage, all the way through to the speaker(s). Measure signals at test points between these stages and tell whether or not a stage is working properly.

Example 2: *An analog summer circuit is not functioning properly.*

Analog summer circuit



What to do: I would test the passive averager network (the three resistors at the lower-left corner of the schematic) to see that the proper (averaged) voltage was seen at the noninverting input of the op-amp. I would then measure the voltage at the inverting input to see if it was the same as at the noninverting input (or, alternatively, measure the voltage difference between the two inputs of the op-amp, as it should be zero). Continue testing sections of the circuit (or just test points within the circuit) to see if you measure the expected voltages and currents.

Simplify and rebuild

Closely related to the strategy of dividing a system into sections, this is actually a design and fabrication technique useful for new circuits, machines, or systems. It's always easier begin the design and construction process in little steps, leading to larger and larger steps, rather than to build the whole thing at once and try to troubleshoot it as a whole.

Suppose that someone were building a custom automobile. He or she would be foolish to bolt all the parts together without checking and testing components and subsystems as they went along, expecting everything to work perfectly after its all assembled. Ideally, the builder would check the proper operation of components along the way through the construction process: start and tune the engine *before* its connected to the drivetrain, check for wiring problems *before* all the cover panels are put in place, check the brake system in the driveway *before* taking it out on the road, etc.

Countless times I've witnessed students build a complex experimental circuit and have trouble getting it to work because they didn't stop to check things along the way: test all resistors *before* plugging them into place, make sure the power supply is regulating voltage adequately *before* trying to power anything with it, etc. It is human nature to rush to completion of a project, thinking that such checks are a waste of valuable time. However, more time will be wasted in troubleshooting a malfunctioning circuit than would be spent checking the operation of subsystems throughout the process of construction.

Take the example of the analog summer circuit in the previous section for example: what if it wasn't working properly? How would you simplify it and test it in stages? Well, you could reconnect the op-amp as a basic comparator and see if its responsive to differential input voltages, and/or connect it as a voltage follower (buffer) and see if it outputs the same analog voltage as what is input. If it doesn't perform these simple functions, it will never perform its function in the summer circuit! By stripping away the complexity of the summer circuit, paring it down to an (almost) bare op-amp, you can test that component's functionality and then build from there (add resistor feedback and check for voltage amplification, then add input resistors and check for voltage summing), checking for expected results along the way.

Trap a signal

Set up instrumentation (such as a data logger, chart recorder, or multimeter set on ”record” mode) to monitor a signal over a period of time. This is especially helpful when tracking down intermittent problems, which have a way of showing up the moment you've turned your back and walked away. This may be essential for proving what happens first in a fast-acting system. Many fast systems (especially shutdown ”trip” systems) have a ”first out” monitoring capability to provide this kind of data.

Example #1: A turbine control system shuts automatically in response to an abnormal condition. By the time a technician arrives at the scene to survey the turbine's condition, however, everything is in a ”down” state and its impossible to tell what signal or condition was responsible for the initial shutdown, as all operating parameters are now ”abnormal.”

What to do: One technician I knew used a video camera to record the turbine control panel, so he could see what happened (by indications on the gauges) first in an automatic-shutdown event. Simply by looking at the panel after the fact, there was no way to tell which signal shut the turbine down, but the videotape playback would show what happened in sequence, down to a frame-by-frame time resolution.

Example #2: *An alarm system is falsely triggering, and you suspect it may be due to a specific wire connection going bad. Unfortunately, the problem never manifests itself while you're watching it!*
What to do: Many modern digital multimeters are equipped with "record" settings, whereby they can monitor a voltage, current, or resistance over time and note whether that measurement deviates substantially from a regular value. This is an invaluable tool for use in "intermittent" electronic system failures.

Likely failures in proven systems

The following problems are arranged in order from most likely to least likely, top to bottom. This order has been determined largely from personal experience troubleshooting electrical and electronic problems in automotive, industry, and home applications. This order also assumes a circuit or system that has been proven to function as designed and has failed after substantial operation time. Problems experienced in newly assembled circuits and systems do not necessarily exhibit the same probabilities of occurrence.

Operator error

A frequent cause of system failure is error on the part of those human beings operating it. This cause of trouble is placed at the top of the list, but of course the actual likelihood depends largely on the particular individuals responsible for operation. When operator error is the cause of a failure, it is *unlikely* that it will be admitted prior to investigation. I do not mean to suggest that operators are incompetent and irresponsible – quite the contrary: these people are often your best teachers for learning system function and obtaining a history of failure – but the reality of human error cannot be overlooked. A positive attitude coupled with good interpersonal skills on the part of the troubleshooter goes a long way in troubleshooting when human error is the root cause of failure.

Bad wire connections

As incredible as this may sound to the new student of electronics, a high percentage of electrical and electronic system problems are caused by a very simple source of trouble: poor (i.e. open or shorted) wire connections. This is especially true when the environment is hostile, including such factors as high vibration and/or a corrosive atmosphere. Connection points found in any variety of plug-and-socket connector, terminal strip, or splice are at the greatest risk for failure. The category of "connections" also includes mechanical switch contacts, which can be thought of as a high-cycle connector. Improper wire termination lugs (such as a compression-style connector crimped on the end of a solid wire – a definite faux pas) can cause high-resistance connections after a period of trouble-free service.
It should be noted that connections in low-voltage systems tend to be far more troublesome than connections in high-voltage systems. The main reason for this is the effect of arcing across a discontinuity (circuit break) in higher-voltage systems tends to blast away insulating layers of dirt and corrosion, and may even weld the two ends together if sustained long enough.

Power supply problems

These generally consist of tripped overcurrent protection devices or damage due to overheating. Although power supply circuitry is usually less complex than the circuitry being powered, and therefore should figure to be less prone to failure on that basis alone, it generally handles more power than any other portion of the system and therefore must deal with greater voltages and/or currents. Also, because of its relative design simplicity, a system's power supply may not receive the engineering attention it deserves, most of the engineering focus devoted to more glamorous parts of the system.

Active components

Active components (amplification devices) tend to fail with greater regularity than passive (non-amplifying) devices, due to their greater complexity and tendency to amplify overvolt8.6.
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age/overcurrent conditions. Semiconductor devices are notoriously prone to failure due to electrical transient (voltage/current surge) overloading and thermal (heat) overloading. Electron tube devices are far more resistant to both of these failure modes, but are generally more prone to mechanical failures due to their fragile construction.

Passive components

Non-amplifying components are the most rugged of all, their relative simplicity granting them a statistical advantage over active devices. The following list gives an approximate relation of failure probabilities (again, top being the most likely and bottom being the least likely):

• Capacitors (shorted), especially *electrolytic* capacitors. The paste electrolyte tends to lose moisture with age, leading to failure. Thin dielectric layers may be punctured by overvoltage transients.

• Diodes open (rectifying diodes) or shorted (Zener diodes).

• Inductor and transformer windings open or shorted to conductive core. Failures related to overheating (insulation breakdown) are easily detected by smell.

• Resistors open, almost never shorted. Usually this is due to overcurrent heating, although it is less frequently caused by overvoltage transient (arc-over) or physical damage (vibration or impact). Resistors may also change resistance value if overheated!

Likely failures in unproven systems

"All men are liable to error;"
John Locke

Whereas the last section deals with component failures in systems that have been successfully operating for some time, this section concentrates on the problems plaguing brand-new systems. In this case, failure modes are generally not of the aging kind, but are related to mistakes in design and assembly caused by human beings.

Introduction to Troubleshooting

Wiring problems

In this case, bad connections are usually due to assembly error, such as connection to the wrong point or poor connector fabrication. Shorted failures are also seen, but usually involve misconnections
(conductors inadvertently attached to grounding points) or wires pinched under box covers.
Another wiring-related problem seen in new systems is that of electrostatic or electromagnetic interference between different circuits by way of close wiring proximity. This kind of problem is easily created by routing sets of wires too close to each other (especially routing signal cables close to power conductors), and tends to be very difficult to identify and locate with test equipment.

Power supply problems

Blown fuses and tripped circuit breakers are likely sources of trouble, especially if the project in question is an addition to an already-functioning system. Loads may be larger than expected, resulting in overloading and subsequent failure of power supplies.

Defective components

In the case of a newly-assembled system, component fault probabilities are not as predictable as in the case of an operating system that fails with age. Any type of component – active or passive – may be found defective or of imprecise value ”out of the box” with roughly equal probability,
barring any specific sensitivities in shipping (i.e. fragile vacuum tubes or electrostatically sensitive semiconductor components). Moreover, these types of failures are not always as easy to identify by sight or smell as an age- or transient-induced failure.

Improper system configuration

Increasingly seen in large systems using microprocessor-based components, ”programming” issues can still plague non-microprocessor systems in the form of incorrect time-delay relay settings, limit switch calibrations, and drum switch sequences. Complex components having configuration ”jumpers” or switches to control behavior may not be ”programmed” properly.
Components may be used in a new system outside of their tolerable ranges. Resistors, for example, with too low of power ratings, of too great of tolerance, may have been installed.
Sensors, instruments, and controlling mechanisms may be uncalibrated, or calibrated to the wrong ranges.

Design error

Perhaps the most difficult to pinpoint and the slowest to be recognized (especially by the chief designer) is the problem of design error, where the system fails to function simply because it cannot function as designed. This may be as trivial as the designer specifying the wrong components in a system, or as fundamental as a system not working due to the designer's improper knowledge of physics.

I once saw a turbine control system installed that used a low-pressure switch on the lubrication oil tubing to shut down the turbine if oil pressure dropped to an insufficient level. The oil pressure for lubrication was supplied by an oil pump turned by the turbine. When installed, the turbine refused to start. Why? Because when it was stopped, the oil pump was not turning, thus there was no oil pressure to lubricate the turbine. The low-oil-pressure switch detected this condition and the control system maintained the turbine in shutdown mode, preventing it from starting. This is a classic example of a design flaw, and it could only be corrected by a change in the system logic.

While most design flaws manifest themselves early in the operational life of the system, some remain hidden until just the right conditions exist to trigger the fault. These types of flaws are the most difficult to uncover, as the troubleshooter usually overlooks the possibility of design error due to the fact that the system is assumed to be ”proven.” The example of the turbine lubrication system was a design flaw impossible to ignore on start-up. An example of a ”hidden” design flaw might be a faulty emergency coolant system for a machine, designed to remain inactive until certain abnormal conditions are reached – conditions which might never be experienced in the life of the system.

Potential pitfalls

Fallacious reasoning and poor interpersonal relations account for more failed or belabored troubleshooting efforts than any other impediments. With this in mind, the aspiring troubleshooter needs to be familiar with a few common troubleshooting mistakes.

- Trusting that a brand-new component will always be good. While it is generally true that a new component will be in good condition, it is not always true. It is also possible that a component has been mislabeled and may have the wrong value (usually this mis-labeling is a mistake made at the point of distribution or warehousing and not at the manufacturer, but again, not always!).
- Not periodically checking your test equipment. This is especially true with battery powered meters, as weak batteries may give spurious readings. When using meters to safety check for dangerous voltage, remember to test the meter on a known source of voltage both before and after checking the circuit to be serviced, to make sure the meter is in proper operating condition.
- Assuming there is only one failure to account for the problem. Single-failure system problems are ideal for troubleshooting, but sometimes failures come in multiple numbers. In some instances, the failure of one component may lead to a system condition that damages other components. Sometimes a component in marginal condition goes undetected for a long time, then when another component fails the system suffers from problems with both components.
- Mistaking coincidence for causality. Just because two events occurred at nearly the same time does not necessarily mean one event caused the other! They may be both consequences of a common cause, or they may be totally unrelated! If possible, try to duplicate the same condition suspected to be the cause and see if the event suspected to be the coincidence happens again. If not, then there is either no causal relationship as assumed. This may mean there is no causal relationship between the two events whatsoever, or that there is a causal relationship, but just not the one you expected.
- Self-induced blindness. After a long effort at troubleshooting a difficult problem, you may become tired and begin to overlook crucial clues to the problem. Take a break and let someone else look at it for a while. You will be amazed at what a difference this can make. On the other hand, it is generally a bad idea to solicit help at the start of the troubleshooting process. Effective troubleshooting involves complex, multi-level thinking, which is not easily communicated with others. More often than not, ”team troubleshooting” takes more time and causes more frustration than doing it yourself. An exception to this rule is when the knowledge of the troubleshooters is complementary: for example, a technician who knows electronics but not machine operation, teamed with an operator who knows machine function but not electronics.

Introduction to Troubleshooting

Failing to question the troubleshooting work of others on the same job. This may sound rather cynical and misanthropic, but it is sound scientific practice. Because it is easy to overlook important details, troubleshooting data received from another troubleshooter should be personally verified before proceeding. This is a common situation when troubleshooters ”change shifts” and a technician takes over for another technician who is leaving before the job is done. It is important to exchange information, but do not assume the prior technician checked everything they said they did, or checked it perfectly. I've been hindered in my troubleshooting efforts on many occasions by failing to verify what someone else told me they checked.

Being pressured to ”hurry up.” When an important system fails, there will be pressure from other people to fix the problem as quickly as possible. As they say in business, ”time is money.” Having been on the receiving end of this pressure many times, I can understand the need for expedience. However, in many cases there is a higher priority: caution. If the system in question harbors great danger to life and limb, the pressure to ”hurry up” may result in injury or death. At the very least, hasty repairs may result in further damage when the system is restarted. Most failures can be recovered or at least temporarily repaired in short time if approached intelligently. Improper ”fixes” resulting in haste often lead to damage that cannot be recovered in short time, if ever. If the potential for greater harm is present, the troubleshooter needs to politely address the pressure received from others, and maintain their perspective in the midst of chaos. Interpersonal skills are just as important in this realm as technical ability!

Finger-pointing. It is all too easy to blame a problem on someone else, for reasons of ignorance, pride, laziness, or some other unfortunate facet of human nature. When the responsibility for system maintenance is divided into departments or work crews, troubleshooting efforts are often hindered by blame cast between groups. ”It's a mechanical problem . . . Its an electrical problem . . . its an instrument problem . . .” ad infinitum, ad nauseum, is all too common in the workplace. I have found that a positive attitude does more to quench the fires of blame than anything else. On one particular job, I was summoned to fix a problem in a hydraulic system assumed to be related to the electronic metering and controls. My troubleshooting isolated the source of trouble to a faulty control valve, which was the domain of the millwright (mechanical) crew. I knew that the millwright on shift was a contentious person, so I expected trouble if I simply passed the problem on to his department. Instead, I politely explained to him and his supervisor the nature of the problem as well as a brief synopsis of my reasoning, then proceeded to help him replace the faulty valve, even though it wasn't ”my” responsibility to do so. As a result, the problem was fixed very quickly, and I gained the respect of the millwright.

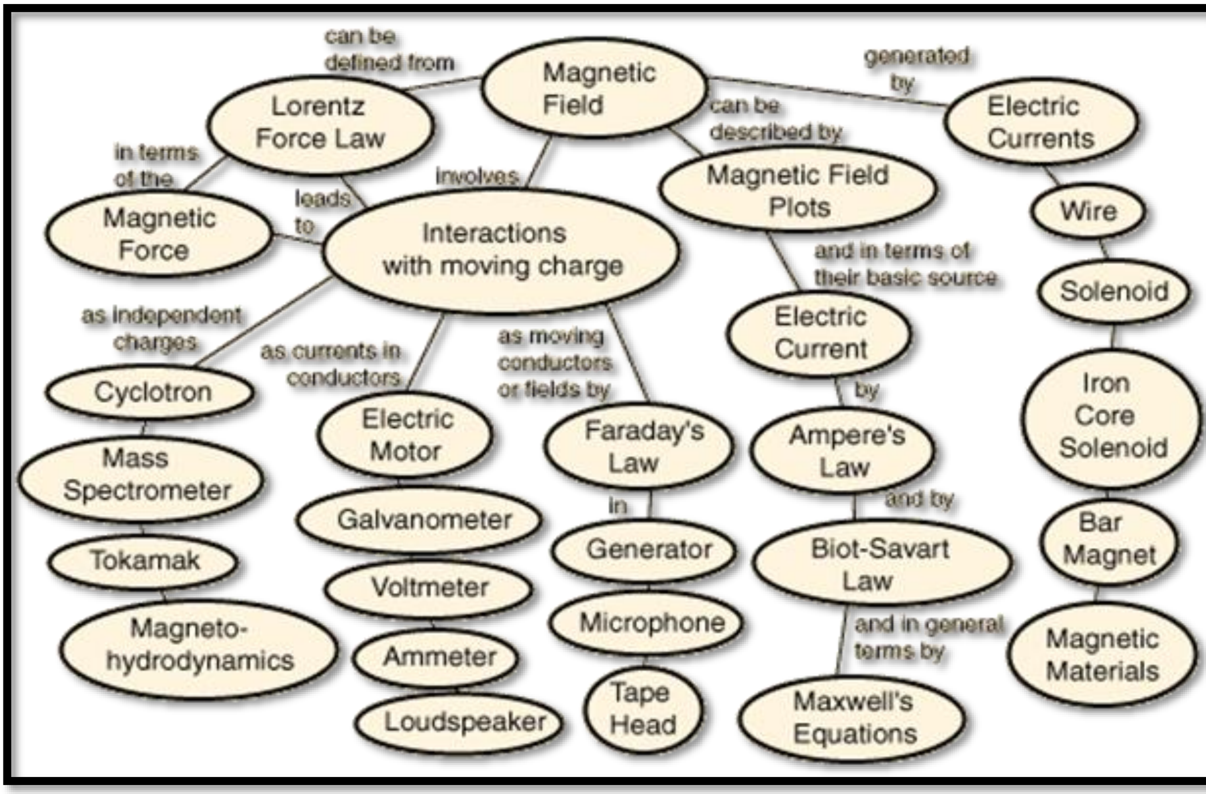
Helpful Websites

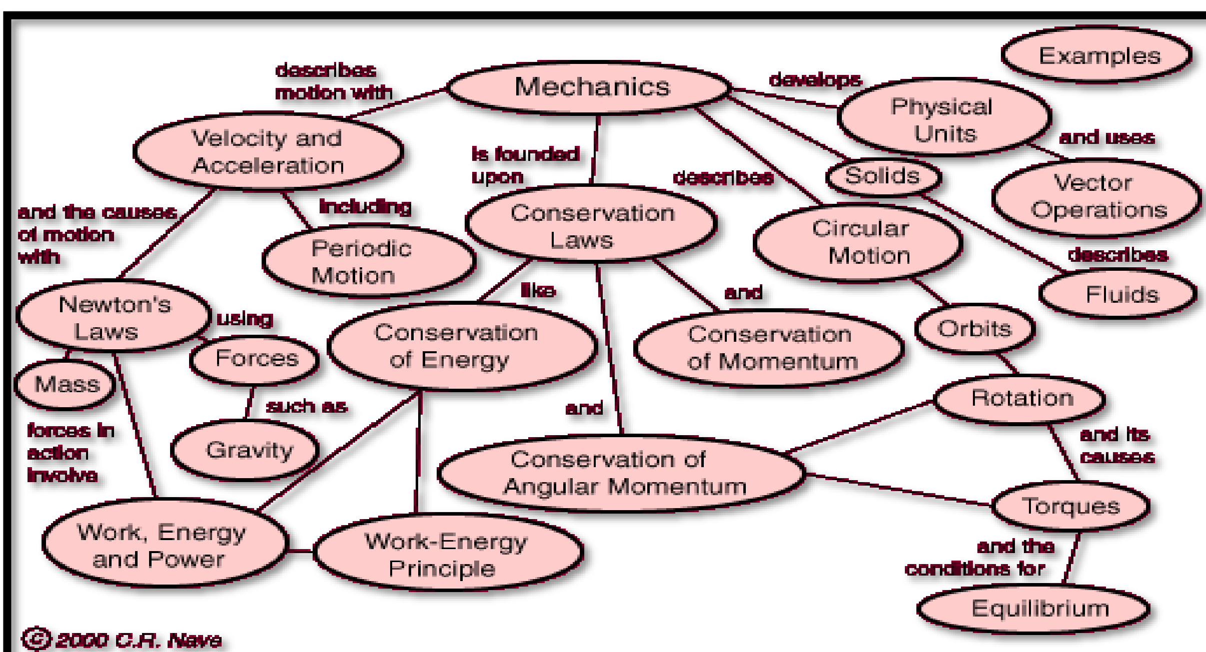
www.allaboutcircuits.com
www.fluke.com
www.electrical4u.com
www.plantengineering.com
www.klein.com
www.applianceassistant.com
www.wisc-online.com
www.galco.com
www.cfesa.com
www.khanacademy.com
www.Alison.com
www.jacquesricher.com/neets

Unit 6:
Extras

Fundamentals of Electricity

Physics Relationships





Commercial Food Equipment Service Technician

Fundamentals of Gas

Introduction to Gas Cooking Equipment

Basic Gas

Fundamentals of Gas

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Unit 1:
Basic Gas
Equipment

Fundamentals of Gas

Cooking with Gas

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Introduction to Gas Systems

Benefits of cooking with gas
There are several reasons why the best chefs, as well as most foodservice operators, prefer natural gas cooking equipment over electric equipment, including:

- Instant on/off and precise heat control
- Reliability and easy, inexpensive maintenance
- High-quality results
- Easy to clean
- 1/3 carbon footprint of electricity, natural gas is the cleanest burning fossil fuel
- And, natural gas gives you more for your energy dollars.

When used properly, new natural gas cooking equipment can save 50 percent or more in operating costs over electric.

Pixabay.com

Appliance Types

Gas Cooking Appliances and their Applications

Ranges
There are two types of ranges, heavy-duty and restaurant style. Top variations for both types include:

Open Burner Range

Open burner ranges are versatile and adaptable. They are basic in all kitchens. Open burners produce from 15,000 to 40,000 Btu of input per burner and have a visible heat source that allows you to make instant and accurate flame adjustments.

Hot Top / French Top Range

A hot top range has a flat, solid 1/4'' to 3/4'' cast iron or steel top. Chefs can choose between two burner configurations: concentric for sautéing in an à la carte line or straight line for boiling, stewing or simmering in a production kitchen.

> **Straight Line –** the burners or heaters are arranged in a straight line longitudinally at the rear of the cooking top, while the front or forward portion is utilized for a working space, taking the place of the usual kitchen table.

Fry and Griddle Tops

These units have a 1/2'' to 1'' rolled steel top with splash guard sides and drip drawer, with burners every 12''. Some griddle plates are chrome plated with a mirror finish which increases heat retention in the plate to lower operating costs. This also reduces flavor transfer between foods and makes for easy clean up. They are basic in most kitchens. The key to a great griddle is heat control across the griddle plate. Taller splash plates protect nearby equipment and keep the heat in the cooking zone. Many have U-shaped burners for maximum heat coverage.

Unit 1:
Basic Gas Equipment

Fundamentals of Gas

Appliance Types

Range Ovens

Many ranges include an oven. Range ovens can be conventional or convection. Convection ovens have a fan inside them to distribute the hot air around evenly.

Deck Oven – Bake/Roast

These are high production gas ovens. They are used for baking and roasting. Pans of food are placed on the hearth.

Convection Oven - an oven that has fans to circulate air around food.

Conventional Oven - does not have a fan; relies primarily on radiation from the oven walls, and to a lesser extent, on natural convection caused by temperature differences within the oven, to transfer heat to food.

Hearth - a brick- or stone-lined fireplace, with or without an oven, used for heating and originally used for cooking food.

Deck Oven – Pizza

In a pizza deck oven, the pizza is placed directly on the stone or metal deck hearth. Usually two or more decks are stacked to provide greater capacity and versatility in the same precious floor space. Pizza deck ovens have a high Btu input and higher temperature controls.

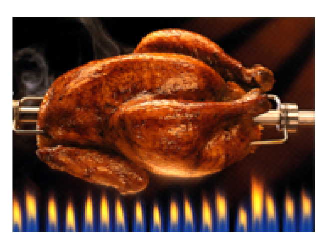
BTU Input - All gas appliances are rated in BTU's/hr Input which approximates the amount of gas consumed on full fire in one hour as expressed in terms of the heat potential of the gas.

Revolving Oven

Revolving ovens are high production pieces that use a Ferris wheel-type assembly to rotate trays within the oven cavity. Trays revolve on pivot mounts attached to two wheels that rotate.

ROTISSERIES

A rotisserie is a slow-turning motor that turns meat over as you cook it. Getting a small, low-horsepower motor to turn over ten unbalanced pounds of roast beast requires some mechanical help, so the motor drives the spit through a gear train.



Spit - a long solid rod used to hold food while it is being cooked over a fire in a fireplace or over a campfire, or roasted in an oven.

Appliance Types

Rack Oven

Product is placed on sheet pans which are loaded on mobile racks. The loaded racks are then rolled into the oven. A rotation system is activated when doors close, providing fast cook times and even browning.

Conveyor Oven

Conveyor ovens move food products through a heated chamber at a constant speed where a high-speed fan distributes heat. These ovens cook two to four times faster than conventional ovens due to their intense temperatures. Heat zones and conveyor speed can be controlled and since they are stackable, they save space.

Convection Oven

Convection ovens are ideal for baking, roasting and broiling. A fan inside the oven moves heated air around the oven interior for rapid defrosting, reheating, roasting and baking.

Hands-On Exercise:

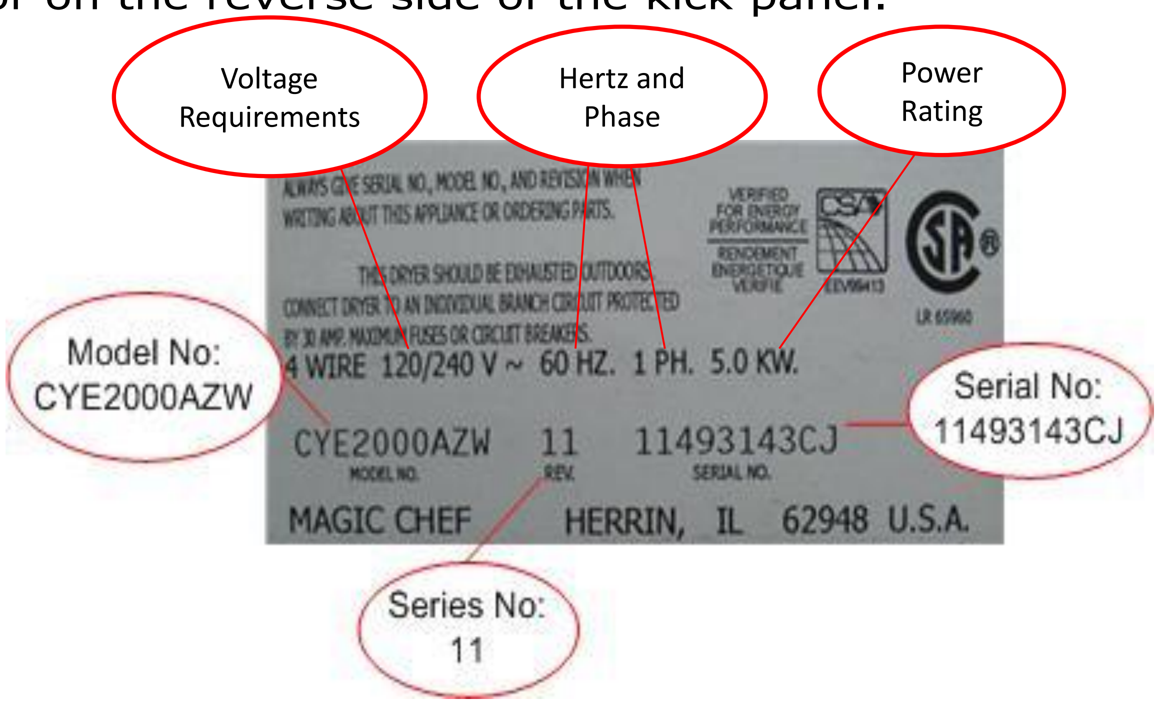
Locate and identify three types of cooking equipment.

- ❑ 1. ________________________
- ❑ 2. ________________________
- ❑ 3. ________________________

Equipment Data Plates

Data Plate / Name Plate / Rating Plate

The data plate is typically a metal plate riveted on the appliance that gives information about the machine such as the manufacturer, model, serial number, voltage requirements, amperage draw, type of gas fuel, gas pressure requirements (W.C), type and amount of refrigerant used (if applicable), etc. Each range is factory equipped for use with the type of gas specified on the range rating plate. The rating plate is located on the back of the machine or on the reverse side of the kick panel.



Hands-On Exercise: Locate and Gather Information on Data Plates

Choose the machines, locate the data plate and find and document the information available. Write N/A if the information is not found on the data plate.

Machine 1 **Machine Type: ___________________**
Manufacturer: _________________________________
Model:_______________________________________
Serial Number:_________________________________
Voltage Requirements: _________________________
Phase: _______________________________________
Amperage: ____________________________________
Wattage: _____________________________________
Refrigerant Type: ______________________________
Amount of Refrigerant: _________________________
Water Column: ________________________________

Machine 2 **Machine Type: ___________________**
Manufacturer: _________________________________
Model:_______________________________________
Serial Number:_________________________________
Voltage Requirements: _________________________
Phase: _______________________________________
Amperage: ____________________________________
Wattage: _____________________________________
Refrigerant Type: ______________________________
Amount of Refrigerant: _________________________
Water Column: ________________________________

Machine 3 **Machine Type: ___________________**
Manufacturer: _________________________________
Model:_______________________________________
Serial Number:_________________________________
Voltage Requirements: _________________________
Phase: _______________________________________
Amperage: ____________________________________
Wattage: _____________________________________
Refrigerant Type: ______________________________
Amount of Refrigerant: _________________________
Water Column: ___________________________

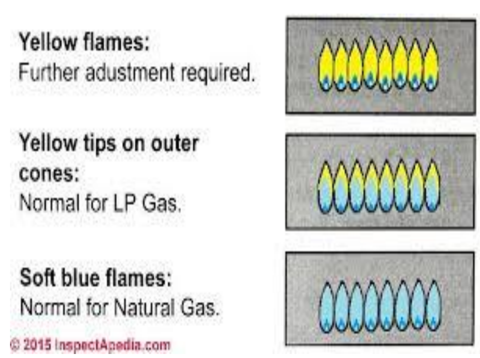
Proper Use and Maintenance

Good maintenance and proper use of equipment
Good maintenance and proper use of gas appliances is essential to prevent exposure to carbon monoxide and fire hazards.

Equipment Inspections
Gas appliances should be inspected annually. This inspection should be documented and performed by an authorized agent.

Fire and Explosion Hazard
Never store or use flammable products in the same room as or near any gas or heat-producing appliances. Flammable products include gasoline, spray paints, solvents, insecticide, adhesives, foggers, varnish, cleaning products and other pressurized containers. This will reduce the risk of flammable vapors being ignited by the main burner flame found in all gas appliances or the pilot flame found in many gas appliances.

Flame Evaluation
If a burner flame is yellow, large and unsteady, the appliance needs to be inspected immediately. Also never store anything near a gas appliance that might interfere with normal appliance airflow.



Proper Clearance
Manufacturers design equipment to have a certain amount of clearance around them for proper and safe operation. See the manufacturer's service manual for recommended clearances.

Unit 1:
Basic Gas Equipment

Fundamentals of Gas

Safety Procedures

Safety is of utmost importance when working with gas equipment. When working with gas equipment there are dangerous hazards involved including:

High Voltage
Gas equipment contains components that require voltages ranging from 120 Volts AC to 480 Volts AC. Always unplug equipment before servicing or removing covers and guards. Perform Lockout-Tagout procedures where necessary. Use insulated electrical tools. Always check for the presence of voltage using a voltmeter before beginning work.

High Pressure
Some steam systems are gas-fired. Pressurized steam systems operate under a pressurized condition. Pressure release in these systems can be extremely dangerous. Pressurized steam can burn you, penetrate your skin, or blow scale particles at you. To protect yourself from pressure, wear safety goggles and gloves. Avoid disconnecting any pressurized lines.

High Temperatures
Working on gas equipment involves working with fire. There is the risk of getting burned with fire or hot product such as fryer oil when servicing gas-fired equipment. Follow gas Lockout-Tagout procedures before servicing gas equipment. Exposed surfaces may be hot to the touch. Wear safety glasses and gloves whenever necessary. Keep loose hair and clothing away from flames.

Heavy Equipment
Cooking equipment is very heavy in many cases. Some equipment weighs several hundred pounds. When moving heavy equipment or parts, have someone help you, use a dolly, forklift, or pallet jack whenever possible. Don't risk it. Back injuries are the number one injury in the commercial equipment industry. **A back injury can end your career**.

Cooking and Temperature

INTRODUCTION TO COOKING AND TEMPERATURE

Cooking and Temperature

To cook food properly, you have to know about temperature. Cooking equipment has temperature control devices such as thermostats. Setting a thermostat at a certain temperature will heat up the cooking space to that temperature. Sometimes you set the oven thermostat at 350 degrees and it heats up to 400 degrees. This means the thermostat is 50 degrees out of calibration. In the food service industry, temperature will be a part of your everyday life. You will use thermometers almost every day. Technicians need to have a good understanding of temperature and its units of measurement. We will begin this session by learning about temperature.

Temperature Definition

A measure of the warmth or coldness of an object or substance with reference to some standard value. The temperature of two systems is the same when the systems are in thermal equilibrium.

Temperature Description

Temperature is the result of the amount of atomic or molecular motion of a substance. The faster the molecules in a substance move, the hotter the temperature. When the molecule movement slows down, the substance gets cooler. There is a temperature at which no molecular movement exists. This is called absolute zero.

Absolute Zero Definition

The temperature of −459.69°F, the hypothetical point at which all molecular activity ceases.

Safe Cooking Temperature Fact Sheet

Safe Cooking Temperatures
Fact Sheet

All food products containing raw animal foods such as eggs, fish, meat, poultry or any combination of these items must be sufficiently cooked until all potentially hazardous germs are destroyed. The minimum internal temperature at which pathogens are destroyed depends upon the type of food being cooked. To ensure that the food products being cooked are safe for human consumption, use the following chart to determine doneness. Remember to use a food thermometer to check the internal temperature of the food before serving.

Food Item	Minimum Temperature
Fruits and vegetables cooked for hot holding	135ºF
Beef and pork roasts, beef steaks, veal, lamb, and commercially-raised game animals	145ºF
Eggs cooked for immediate service	145ºF
Fish and foods containing fish	145ºF
Pork, including ham and bacon	145ºF
Ratites and injected meats	155ºF
Eggs cooked for later service	155ºF
Ground or flaked meats, including hamburger, ground pork, flaked fish, ground game animals, or sausage	155ºF
Poultry and poultry products, including stuffing, stuffed meats, casseroles, and dishes combining raw and cooked foods	165ºF
Stuffed fish	165ºF

Microwave Cooking

When cooking with a microwave oven, the Food Code requires that all potentially hazardous foods containing meat, poultry, fish or eggs shall be cooked to a minimum temperature of 165ºF. In addition, these foods shall be cooked according to the following standards:

1. Rotated or stirred throughout or midway during the cooking process to compensate for uneven distribution of heat;
2. Covered to retain surface moisture;
3. Heated to an internal temperature of at least 165ºF in all parts of the food; and
4. Allowed to stand covered for two minutes after cooking to obtain temperature equilibrium.

Public Notice of Raw or Undercooked Foods

If a food establishment intends to sell raw or undercooked animal foods in a ready-to-eat form, the establishment must inform the consumer of the risks associated with eating these foods with both a "disclosure" and a "reminder" statement.

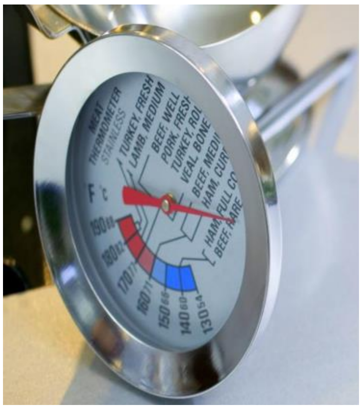
The "disclosure" includes a description of the raw or undercooked animal foods, or by asterisking these foods to a footnote, which states these foods are served raw or undercooked.

The "reminder" shall include a statement that tells consumers that consuming raw or undercooked meats, poultry, seafood, shellfish or eggs may increase their risk of foodborne illness.

For more information about operating a food establishment, contact your local health department.

Temperature Scales

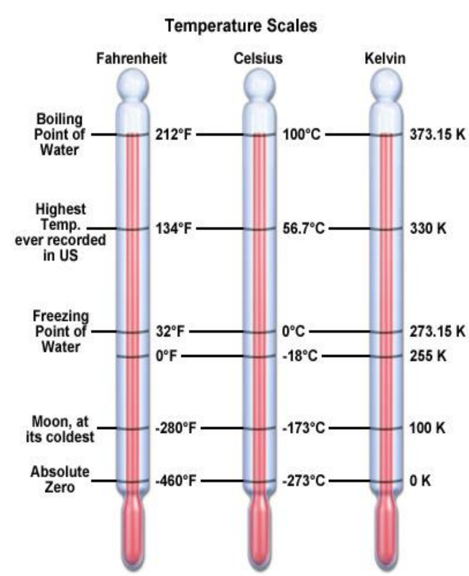
Temperature Scales



Humans are sensitive to a fairly small range of temperatures. We get uncomfortable if the temperature of our surrounding gets too extreme. We don't like to be too cold or too hot. Even though we can sense the temperature that makes us uncomfortable, we are not able to accurately quantify the exact temperature with our senses. This causes us to rely on temperature scales and measuring devices so our observations will match up with others. A temperature scale is divided into increments known as degrees. Temperature gauges allow us to read these increments.

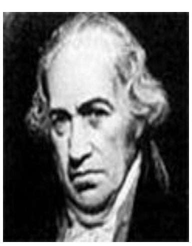
Two Relative Temperature Scales

The most common type of temperature scale is the relative temperature scale. The two most used relative temperature scales used today are Fahrenheit and Celsius. They are named after Daniel Fahrenheit and Anders Celsius.



.com

Daniel Gabriel Fahrenheit (May 24, 1686 - Sept. 16, 1736) was a German physicist and maker of scientific instruments. He is best known for inventing the alcohol thermometer (1709) and mercury thermometer (1714) and for developing the Fahrenheit temperature scale; this scale is still commonly used in the United States.



Fahrenheit spent most of his life in the Netherlands, where he devoted himself to the study of physics and the manufacture of precision meteorological instruments. He discovered, among other things, that water can remain liquid below its freezing point and that the boiling point of liquids varies with **atmospheric pressure**. The Fahrenheit scale is based on 32° for the freezing point of water and 212° for the boiling point of water. The Fahrenheit scale is in general use wherever the English system of units has been adopted.

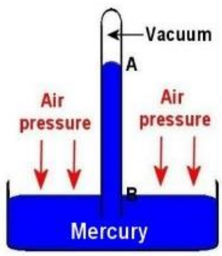
Britannica.com

Unit 2:
Basic Gas
Temperature

Fundamentals of Gas

Temperature Scales

Definition - Atmospheric Pressure



Atmospheric pressure is defined as the force per unit area exerted by an atmospheric column (that is, the entire body of air above the specified area). Also called barometric pressure, Atmospheric pressure can be measured with a mercury barometer (hence the commonly used synonym barometric pressure), which indicates the height of a column of mercury that exactly balances the weight of the column of atmosphere over the barometer. Atmospheric pressure at sea level is 14.696 PSIA.

Anders Celsius (1701-1744) was a Swedish astronomer who invented the Celsius temperature scale (often called the centigrade scale).

Celsius Scale

The Celsius scale is based on 0° for the freezing point of water and 100° for the boiling point of water. Invented in 1742 by the Swedish astronomer Anders Celsius, it is sometimes called the centigrade scale because of the 100-degree interval between the defined points. The Celsius scale is in general use wherever the metric system of units has been adopted, and it is used in scientific work everywhere.

1. Atmospheric pressure is ______________ P.S.I.A.
2. Water freezes at ______ degrees Celsius.
3. Water freezes at ______ degrees Fahrenheit.
4. Water boils at ________ degrees Celsius.
5. Water boils at ________ degrees Fahrenheit.
6. Air pressure all around us is called ________________ __________________.

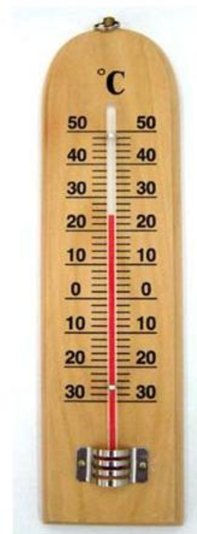
Temperature Measurement

Temperature Measurement Instruments

The most common temperature measurement instrument is a thermometer. There are a variety of styles of thermometers available to the technician. Let's look at a few here.

Liquid-in-glass thermometers

- The liquid-in-glass thermometer is a well-known temperature-measuring instrument that is used in a wide range of applications. The fluid used is usually either mercury or colored alcohol, and this is contained within a bulb and capillary tube.
- As the temperature rises, the fluid expands along the capillary tube and the meniscus level is read against a calibrated scale etched on the tube. The process of estimating the position of the curved meniscus of the fluid against the scale introduces some error into the measurement process and a measurement inaccuracy less than ±1% of full-scale reading is hard to achieve.
- Industrial versions of the liquid-in-glass thermometer are normally used to measure temperature in the range between -200°C up to 1500°C.



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Digital Probe Thermometer

Commons.Wikimedia.org

Infrared Digital Thermometer

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Unit 2:
Basic Gas Temperature

Fundamentals of Gas

How to Read an Oven Thermometer

Oven Thermometers

Oven thermometers are useful tools for cooks who require precise temperatures for their recipes. Because the thermometer that comes built into an oven is not always accurate, an independent oven thermometer can help cooks reach the temperature they desire. The inaccuracy of the internal thermometer on some ovens often amazes individuals. An oven that is off by 50 to 100 degrees can drastically influence the final result. A variety of options help cooks achieve the temperature they need. Users should follow a few simple steps to ensure their oven thermometer produces an accurate readout.

Place Thermometer in the Oven

While this might seem like an elementary step, it is crucial to the accuracy of the thermometer's output. Depending on the size and model of an oven, different sections inside it may actually be different temperatures. To ensure the oven thermometer produces a relevant reading, place it in the middle of the same rack the food cooks on. This decreases the chance that the oven door causes cold air to influence the temperature. It also makes sure the thermometer reads the temperature of the oven where the food cooks. Most oven thermometers come with a hook that allows them to hang conveniently on the rack in the position of choice.

Set Temperature of the Oven

Once the thermometer is properly in place, it is time to set the temperature of the oven. Most ovens have a digital control that allows users to set the temperature in 5-degree intervals. Older oven models have spin dials that set the temperature. Once the oven is set, and an indicator shows that the oven is preheating, it is time to wait.

Preheat the Oven

When the oven is preheating, cooks should not open the door. If the door opens, it releases heat from the oven and causes heating to take longer. When the preheat indicator goes off, or the oven beeps, the oven's internal thermometer is at the preset temperature. At this point, users should keep the door closed, turn the oven light on, and check the thermometer. It is common for the oven thermometer to read lower than what the oven is set at.

Ebay.com

How to Read an Oven Thermometer (Cont.)

Give it Additional Time
Oven thermometers often need additional time to provide an accurate reading. Approximately five minutes after the oven indicates it is preheated, users should check the oven thermometer again. At this point, they can be confident that the reading is accurate.

Adjust Oven Temperature
First-time oven thermometer users are often shocked by the discovery that the internal oven thermometer is not 100 percent accurate. It is common to find that a consumer-level oven is 50 to 100 degrees cooler than the set temperature. This can wreak havoc on a recipe. In order to get the benefit of an oven thermometer and bring the oven to the appropriate temperature, cooks should adjust it by the number of degrees it is off. For example, if the oven is set at 176 degrees Celsius, but the thermometer reads 126 degrees Celsius, the cook should set the oven 50 degrees higher at 226 degrees Celsius. Ovens can be off by different amounts, which makes an oven thermometer an important kitchen tool.

Additional Tips
Additional questions often arise after the first use of an oven thermometer. The accuracy of the thermometer and the effectiveness of the oven are two common concerns. There are simple steps individuals can take to settle both.

Get Two Thermometers
First-time oven thermometer users often wonder if the thermometer is accurate. To ensure the accuracy of the reading, individuals can purchase a second thermometer to place next to the original. If the two thermometers provide identical temperatures, users can cook with confidence knowing the temperature is accurate.

Calibrate the Oven
Some ovens allow owners to calibrate the temperature. To do so, users usually need to pull an oven out from the wall and find a setting on the back. Other digital ovens have navigation controls that calibrate the temperature. This does have limitations, however. If an oven temperature is inaccurate, it is best to use an oven thermometer, even after recalibration.

Ebay.com

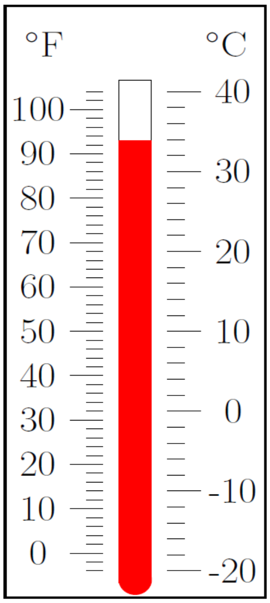
Unit 2:
Basic Gas Temperature

Fundamentals of Gas

Hands-On Exercise: Reading Temperatures

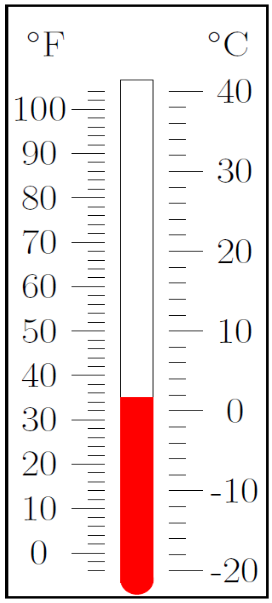
Reading Temperature (A)

Read and record the temperatures in degrees Celsius and degrees Fahrenheit.



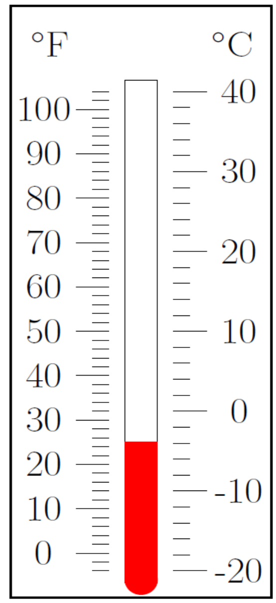
____°C

____°F



____°C

____°F



____°C

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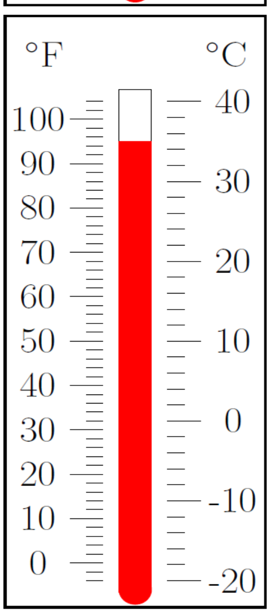
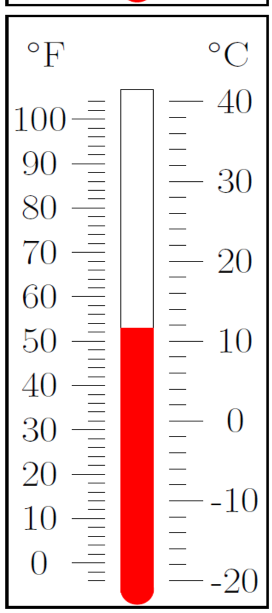


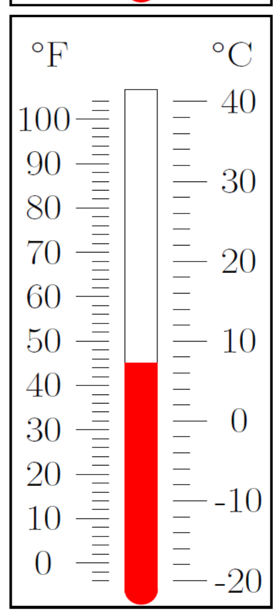
____°C

____°F



____°C

____°F



____°C

____°F

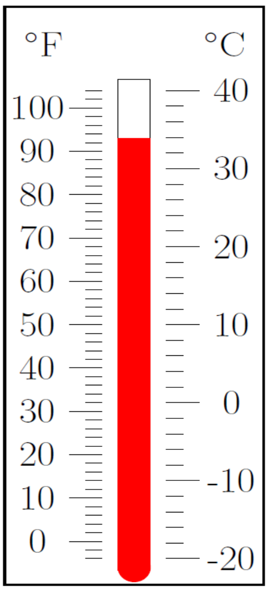
Unit 2:
Basic Gas Temperature

Fundamentals of Gas

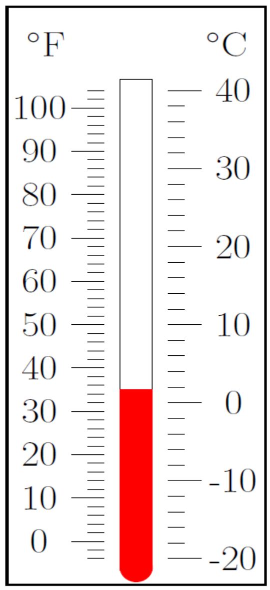
Hands-On Exercise: Reading Temperatures

Reading Temperature (A) Answers

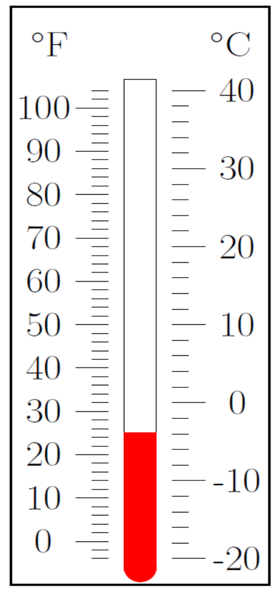
Read and record the temperatures in degrees Celsius and degrees Fahrenheit.



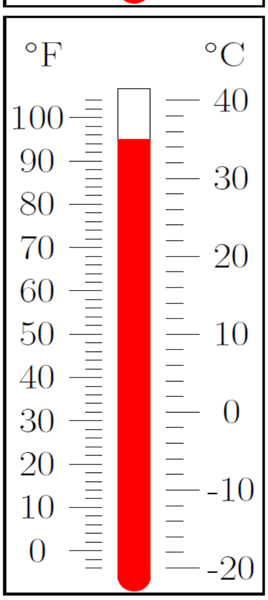
34 °C
93 °F



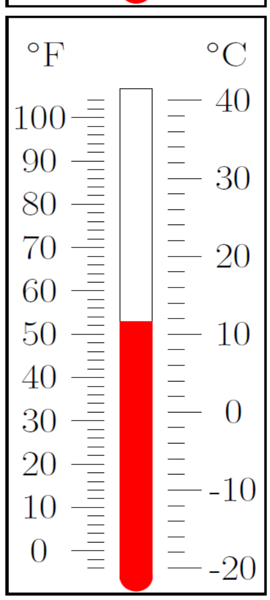
2 °C
35 °F



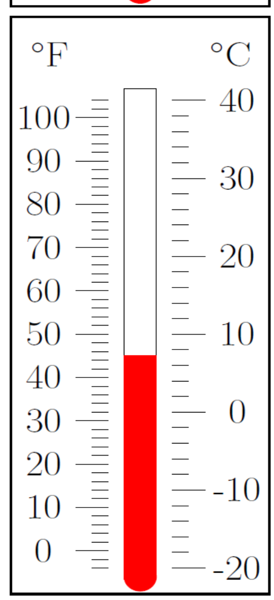
−4 °C
25 °F



35 °C
95 °F



12 °C
53 °F



7 °C
45 °F

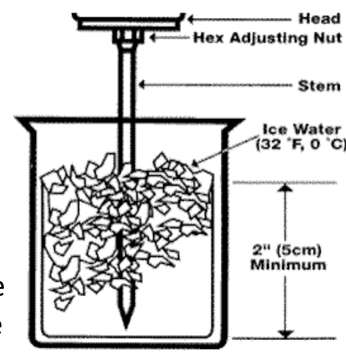
Thermometer Calibration

Analog Thermometer Calibration

Thermometer Basics

Thermometers used frequently must be calibrated frequently (weekly or monthly). Follow manufactures instructions for taking temperatures. Always calibrate a new thermometer, one that has been dropped on a hard surface, or one with a temperature reading that is off by more than +/- 2°F. It is best to test both ice-point and boiling-point calibrations as thermometer sensitivity may differ at extreme ranges.

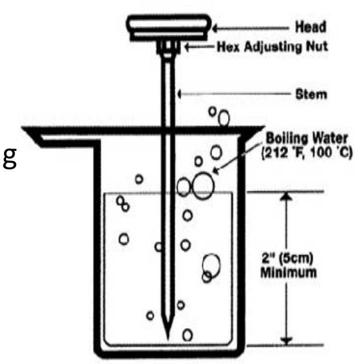
To Calibrate and Adjustable Analog (dial) Thermometer



Clemson.edu

Ice-Point Method

1. Fill a glass with ice and add cold water until the glass is full.
2. Insert the thermometer probe into the center of the glass of ice water. Stir slightly and then wait until temperature has stabilized.
3. The temperature should read 32°F. If it doesn't, locate the calibration nut on the back of the thermostat dial and adjust the temperature so that the dial reads 32°F while the probe is in the water.



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Boiling-Point Method

1. In a deep pan, boil distilled water to a rolling boil. DO NOT REMOVE FROM HEAT.
2. Place the thermometer probe in the center of the rapidly boiling water. Make sure to protect your hands from steam. Do not touch the thermometer to the bottom of the sides of the pan.
3. Wait until temperature indicator on the thermometer is stabilized.
4. The temperature should read 212°F. If it doesn't, locate the calibration nut on the back of the thermostat dial and adjust the temperature so that the dial reads 212°F while the probe is in the water.
5. An adjustment is also necessary for high altitudes. For every 550 feet above sea level, the boiling point of water is 1°F lower than 212°F. For example, at 5,500 feet above sea level, the boiling point of water is 202°F. Thermometers will need to be adjusted accordingly.

Simplydixon.com

Unit 2:
Basic Gas
Temperature

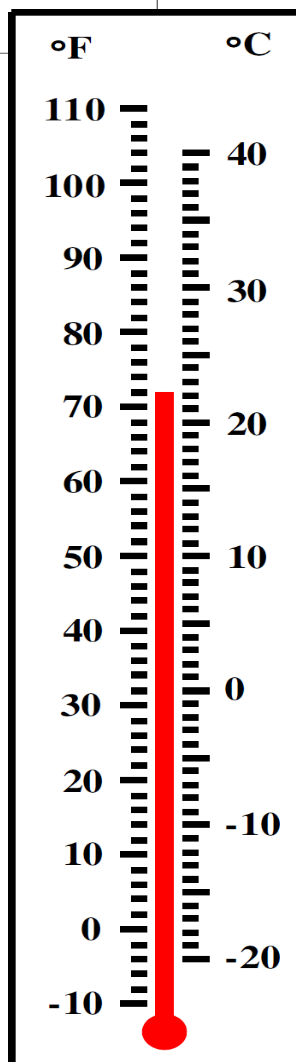
How to Convert Temperatures

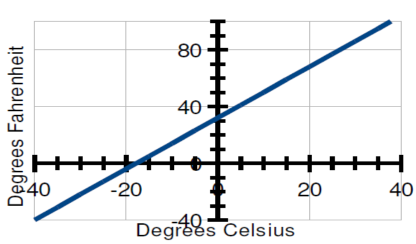
Converting Temperatures (A)

A guide for converting between Celsius and Fahrenheit.

Convert Celsius to Fahrenheit	*Convert Fahrenheit to Celsius*
Multiply °C by 1.8; add 32.	Subtract 32 from °F; divide by 1.8.
$F = C \times 1.8 + 32$	$C = \frac{(F-32)}{1.8}$

Whole Numbers	
°C	°F
40	104
35	95
30	86
25	77
20	68
15	59
10	50
5	41
0	32
-5	23
-10	14
-15	5
-20	-4
-25	-13
-30	-22
-35	-31
-40	-40





Temperature of the Sun
5505 °C or 9941 °F

Boiling Point of Water
100 °C or 212 °F

Human Body Temperature
37 °C or 98.6 °F

Room Temperature
20 °C or 68 °F

Freezing Point of Water
0 °C or 32 °F

Same Value
-40 °C or -40 °F

Absolute Zero
-273 °C or -459.4 °F

Alternate Formulas

$$F = C \times \frac{9}{5} + 32$$

$$C = (F-32) \times \frac{5}{9}$$

Math-Drills.Com

Hands-On Exercise: Converting Temperatures

How to convert between temperature scales
The following formula can be used to convert a temperature from its representation on the Celsius (°C) scale to the Fahrenheit (°F) value:
$^\circ F = 1.8(^\circ C + 32)$.

The following formula can be used to convert a temperature from its representation on the Fahrenheit (°F) scale to the Celsius (°C) value:
$^\circ C = .55(^\circ F - 32)$.

Below is an example of where you might find a need to convert from Celsius to Fahrenheit.

"Dry heat" cooking mode (30 °C to 300 °C)
The hot air circulated at high speed flows around the food from all sides. The meat protein sets immediately, so it remains wonderfully succulent on the inside. Constant hot air at up to 300 °C is not simply a technical detail; the necessary reserve power is there even for full loads. This is the only way to guarantee succulent, browned pan fries, frozen convenience foods or soft bakery products.

Exercise:
Convert 30 degrees Celsius to Fahrenheit
Answer: _______________

Convert 300 degrees Celsius to Fahrenheit
Answer: _______________

Unit 2:
Basic Gas Temperature

Fundamentals of Gas

Hands-On Exercise: Converting Temperatures

Converting Celsius to Fahrenheit (A)

Estimate or convert the temperatures.

-44 °C = ____°F	75 °C = ____°F	-74 °C = ____°F
39 °C = ____°F	90 °C = ____°F	56 °C = ____°F
53 °C = ____°F	-46 °C = ____°F	-11 °C = ____°F
-63 °C = ____°F	73 °C = ____°F	-20 °C = ____°F
-3 °C = ____°F	97 °C = ____°F	11 °C = ____°F
23 °C = ____°F	-88 °C = ____°F	-23 °C = ____°F
43 °C = ____°F	60 °C = ____°F	49 °C = ____°F
67 °C = ____°F	-13 °C = ____°F	-38 °C = ____°F
-74 °C = ____°F	76 °C = ____°F	-13 °C = ____°F
47 °C = ____°F	-11 °C = ____°F	45 °C = ____°F

Hands-On Exercise: Converting Temperatures

Converting Celsius to Fahrenheit (A) Answers

Estimate or convert the temperatures.

-44 °C = -47.2 °F	75 °C = 167 °F	-74 °C = -101.2 °F
39 °C = 102.2 °F	90 °C = 194 °F	56 °C = 132.8 °F
53 °C = 127.4 °F	-46 °C = -50.8 °F	-11 °C = 12.2 °F
-63 °C = -81.4 °F	73 °C = 163.4 °F	-20 °C = -4 °F
-3 °C = 26.6 °F	97 °C = 206.6 °F	11 °C = 51.8 °F
23 °C = 73.4 °F	-88 °C = -126.4 °F	-23 °C = -9.4 °F
43 °C = 109.4 °F	60 °C = 140 °F	49 °C = 120.2 °F
67 °C = 152.6 °F	-13 °C = 8.6 °F	-38 °C = -36.4 °F
-74 °C = -101.2 °F	76 °C = 168.8 °F	-13 °C = 8.6 °F
47 °C = 116.6 °F	-11 °C = 12.2 °F	45 °C = 113 °F

Unit 3:
Basic Gas Fuels

Fundamentals of Gas

Gas Cooking Fuels

GAS FUELS USED IN COOKING APPLIANCES

There are two types of fuel used in cooking equipment: Natural Gas and Propane. Propane is classified as liquid petroleum (L.P) gas. Gas cooking equipment that is permanently setup in restaurants typically use natural gas. Propane is used in locations where natural gas is not available or portability of the equipment is desired (i.e. – Food trucks and portable backyard grills).

Propane Grill

Natural Gas

The first use of gas energy in the United States occurred in 1816, when gaslights illuminated the streets of Baltimore, Md. By 1900, natural gas had been discovered in 17 states. During the years following World War II, expansion of the extensive interstate pipeline network occurred, bringing natural gas service to customers all over the country.

Natural Gas Burner

Notes:

____

____

____

____

____

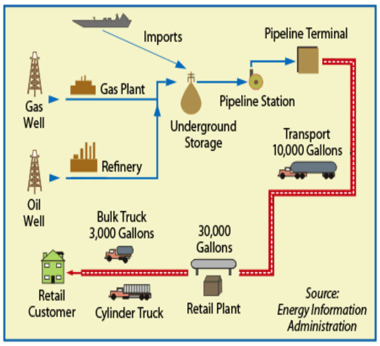
____

Unit 3:
Basic Gas Fuels

Fundamentals of Gas

Gas Distribution

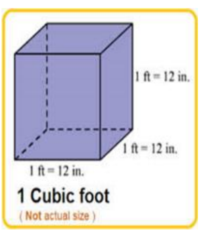
Natural Gas Distribution



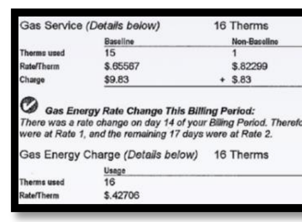
Three segments of the natural gas industry are involved in delivering natural gas from the wellhead to the consumer.

1. Production companies explore, drill and extract natural gas from the ground.
2. Transmission companies operate the pipelines that link the gas fields to major consuming areas.
3. Distribution companies are the local utilities that deliver natural gas to the customer.

Volume



Natural gas is normally sold from the wellhead in the production field to purchasers in standard volume measurements of thousands of cubic feet (Mcf). However, consumer bills are usually measured in heat content or therms.



Gas Service *(Details below)* 16 Therms

	Baseline	Non-Baseline
Therms used	15	1
Rate/Therm	$.65567	$.82299
Charge	$9.83	+ $.83

Gas Energy Rate Change This Billing Period:
There was a rate change on day 14 of your Billing Period. Therefo
were at Rate 1, and the remaining 17 days were at Rate 2.

Gas Energy Charge *(Details below)* 16 Therms

	Usage
Therms used	16
Rate/Therm	$.42706

Therm - One therm is a unit of heating equal to 100,000 Btu.

<u>Hands-On Exercise:</u>

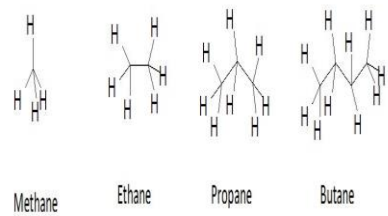
Look up and write down the name of one company involved in three segments of natural gas distribution in your state.

- ❑ Production Company________________________________
- ❑ Transmission Company ______________________________
- ❑ Distribution Company _______________________________

Unit 3:
Basic Gas Fuels

Fundamentals of Gas

Natural Gas

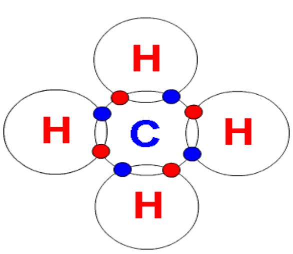


Natural gas has been forming along with oil for millions of years from dead plants and animals. It is usually found in deep underground reservoirs formed by porous rock. Natural gas is a combustible fossil fuel composed almost entirely of methane, but does contain small amounts of other hydrocarbon gases, including ethane, propane, butane, hexane, and pentane.

As recently as 1960, gas was a nuisance by-product of oil production in many areas of the world. The gas was separated from the crude oil stream and eliminated as cheaply as possible. Only after the crude oil shortages of the late 1960s and early 1970s did natural gas become an important world energy source.

Even in the United States the home-heating market for natural gas was limited until the 1930s, when town gas began to be replaced by abundant and cheaper supplies of natural gas, which contained twice the heating value of its synthetic predecessor. Also, when natural gas burns completely, carbon dioxide and water are normally formed. The combustion of gas is relatively free of soot, carbon monoxide, and the nitrogen oxides associated with the burning of other fossil fuels. Natural gas is used extensively in residential, commercial and industrial applications. It is used to heat homes, water, and food. Overall, more than 66 million homes use natural gas.

Describe the characteristics of natural gas and propane
Natural Gas (CHB_{4B}) Characteristics



Natural gas molecules have 1 carbon atom and 4 hydrogen atoms. Natural gas is lighter than air and will dissipate. NG turns from a liquid to a gas at -260°F and ignites at temperatures from 1100°–1200°F. Natural gas is the cleanest burning fossil fuel, producing primarily carbon dioxide, water vapor and small amounts of nitrogen oxides.

Unit 3:
Basic Gas Fuels

Fundamentals of Gas

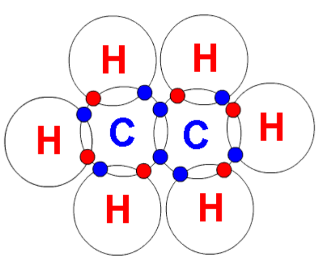
Propane

Propane

Propane, a colorless, easily liquefied, gaseous hydrocarbon (compound of carbon and hydrogen), the third member of the paraffin series following methane and ethane. The chemical formula for propane is C3H8. It is separated in large quantities from natural gas, light crude oil, and oil-refinery gases and is commercially available as liquefied propane or as a major constituent of liquefied petroleum gas (LPG).

Although a gas at ordinary atmospheric pressure, propane has a boiling point of −43.8° F and thus is readily liquefied under elevated pressures. It therefore is transported and handled as a liquid in cylinders and tanks. In this form, alone or mixed with liquid butane, it has great importance as a fuel for domestic and industrial uses and for internal-combustion engines.

Propane ($CB_{3B}HB_{8B}$) Characteristics



Propane (LP) gas molecules have 3 carbon atoms and 8 hydrogen atoms. LP gas is heavier than air and will collect in low spots. Although both natural gas and propane have carbon and hydrogen atoms, the extra atoms in propane make it heavier, create a need for more oxygen to burn and create more BTU. Propane burns hotter than natural gas. Propane turns from a liquid to a gas at −43.8°F and ignites at 842°F.

1. Natural gas ignites at ______ - _______ degrees Fahrenheit.
2. Propane ignites at _____________ degrees Fahrenheit.
3. Natural gas turns from a liquid to a gas at _______ degrees Fahrenheit.
4. Propane turns from a liquid to a gas at _________ degrees Fahrenheit.

Unit 3:
Basic Gas Fuels

Fundamentals of Gas

Gas Characteristics

Composition and properties 19

Natural gas is a hydrocarbon consisting mainly of methane, although it usually also contains a variable percentage of nitrogen, ethane, CO2, H2O, butane, propane, mercaptans and traces of heavier hydrocarbons. Methane is one carbon atom joined to four hydrogen atoms (CH4) and can constitute up to 97% of natural gas.

PHYSICAL AND CHEMICAL PROPERTIES	
Molecular formula	CH4
Molecular weight of mixture	18,2
Boiling point at 1 atmosphere	-160.0 °C
Melting point	-180.0 °C
Vapour density (Air =1) at 15.5	0,61
Liquid density (Water=1) at 0°/4 °C	0,554
Expansion ratio	1 litre of liquid becomes 600 litres of gas
Water solubility at 20 °C	Slightly soluble (0.1 to 1.0%)
Appearance and colour	Colourless, tasteless and with a slight smell of rotten eggs

Characteristics

- Natural gas is consumed as found in nature. From extraction at the deposit to its arrival at homes and points of consumption, natural gas does not undergo any transformation process.
- The simpler molecular structure of natural gas enables a clean burn, so its combustion does not produce solid particles or sulphur.
- Natural gas is one of the cleanest fossil fuel energy sources, as it emits less pollutant gas (SO2, CO2, NOx and CH4) per unit of energy produced.

Hands-On Exercise:

Look up and write down the definition for the following words that are used in the table above.

- ❑ Boiling Point - ____
- ❑ Melting Point - _______________________________________
- ❑ Density - ____
- ❑ Expansion Ratio - _____________________________________
- ❑ Hydrocarbons - _______________________________________

Units of Measurement

Units of Measurement

British thermal unit (BTU) - The amount of energy needed to cool or heat one pound of water by one degree Fahrenheit at atmospheric pressure. Equal to about 1055 Joules.

Joule - The work required to produce one watt of power for one second.

Natural gas, like other forms of heat energy, is measured in British thermal units or Btu.

The British thermal unit is a traditional unit of energy equal to about 1055 joules. One four inch, wooden kitchen match consumed completely generates 1 BTU. A cubic foot of natural gas has about 1,027 Btu.

Specific Heat

$$Q = mC\Delta T$$

Specific heat is the amount of heat needed to raise the temperature of one gram of a substance one degree Celsius. The specific heat of water is very high compared to other substances, so water can store energy longer than most other substances. For example, the Gulf of Mexico remains warm during the night, when air and soil temperatures decrease rapidly. Why is the Southern Hemisphere summer generally cooler than the Northern Hemisphere summer when the Earth is closer to the sun during the Southern Hemisphere summer? Because most of the Southern Hemisphere is water, which regulates the seasonal temperatures.

Hands-On Exercise:

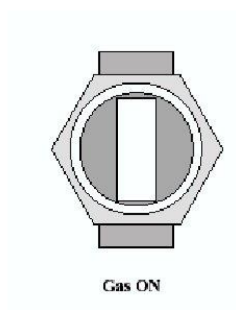
- ❑ Locate the BTU rating on the data plate of a gas appliance.
- ❑ What is the rating? ____________________

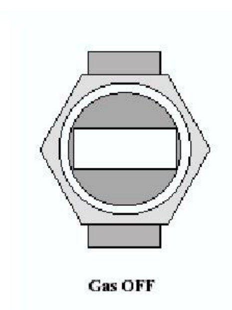
Gas Meters

Outside gas meter

Locate the outside gas meter. In an emergency, every second counts so you don't want to find yourself running around the building trying to locate the meter. You probably won't ever shut off the gas at the outside meter but its best to be prepared in case you have to.

Keep a 12" (or larger) adjustable wrench in your toolkit. Take the adjustable wrench and turn the shut-off valve one-quarter of a turn in either direction, until the valve is crosswise to the pipe (see diagram). Use caution when touching gas shut-off valves and meters. Faulty appliances or faulty electrical wiring could inadvertently introduce electricity to the gas meter.





Hands-On Exercise:

- ❑ Locate the outside gas meter
- ❑ Explain how to shut off the gas at the gas shut off on the meter

Connections and Shut-offs

NATURAL GAS SAFETY

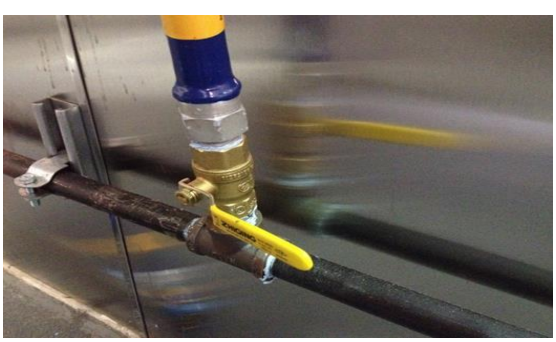
It is important to know where the energy and fuel supplies are for all equipment in case you need to shut them off. You should locate the following before beginning work:

GAS CONNECTIONS

CAUTION: All gas supply connections and any pipe joint compound used must be resistant to the action of propane gases. Each range is factory equipped for use with the type of gas specified on the range rating plate. This rating plate is located on the reverse side of the kick panel.
Connect gas supply to the range. Make sure the pipes are clean and free of obstructions, dirt, and piping compound. Codes require that a gas shutoff valve be installed in the gas line ahead of the range. Ranges are equipped with fixed burner orifices for proper range operation elevation.
On some models, the gas pressure regulator is factory installed on the manifold pipe at the rear of the range, and on some models, the regulator is packaged separately. The arrow on the regulator shows the direction of gas flow.

Inside Gas Shutoff Valves

Be sure to locate the inside gas shutoff valves for the kitchen you are working in and there should also be a gas shut off valve behind each piece of equipment you are working on. There may also be a gas shut off valve on the equipment itself. Verify these valves work before you begin in case they are jammed. You don’t want to discover these valves are jammed when you need them to turn off in an emergency.



<u>Hands-On Exercise:</u>

- ❑ Locate the inside gas shutoff valves

Unit 4:
Basic Gas Installation

Equipment on Castors

Equipment on Casters

For ranges equipped with casters, the installation shall be made with a connector that complies with the Standard for Connectors for Movable Gas Appliances, ANSI Z21.69, and a quick-disconnect device that complies with the Standard for Quick-Disconnect Devices for Use With Gas Fuel, ANSI Z21.41. Provide a gas line strain relief to limit movement of the range without depending on the connector and any quick-disconnect device or its associated piping to limit the range movement. Attach the strain relief to the rear of the range (Fig. 2).

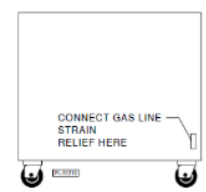
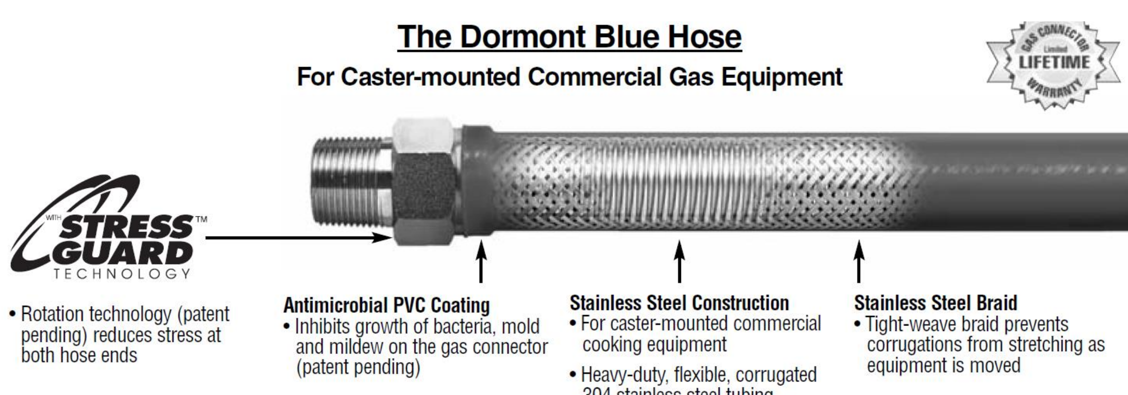


Fig. 2

If it is necessary to disconnect the gas line strain relief, turn off the gas supply before disconnecting. Reconnect this restraint before turning the gas supply on and returning the range to its installation position.

Hands-On Exercise:

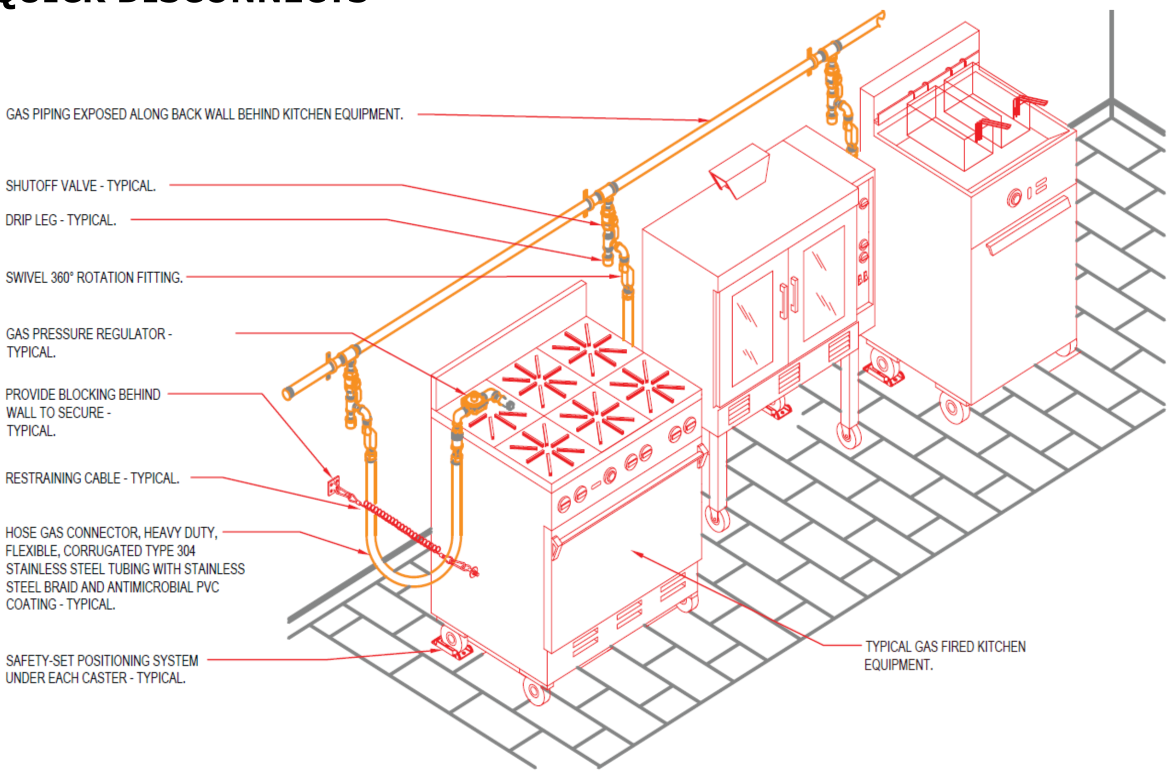
- ❑ Locate a machine on castors and explain to the instructor how the castors are installed.



Unit 4:
Basic Gas Installation

Quick Disconnect Kits

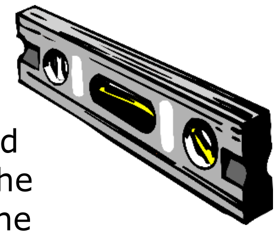
QUICK DISCONNECTS



Hands-On Exercise:

- ❑ Connect a quick-connect disconnect to a gas appliance.
- ❑ Check for gas leaks

Equipment Leveling



Leveling the Equipment
Equipment that is not level can cause cooking to be a challenge. If you try to cook something in the oven and the front of the rack is higher than the back then the liquid (e.g. cake batter) will be deeper in the back than it is in the front and will cook at different rates due to the depth of the product. An unleveled griddle plate will cause items to roll and run. Some machines also require levelness for grease to flow properly to the grease trap. Follow the following steps to properly level a machine.

- ☐ Place a carpenter's level inside the oven cavity across the oven rack.
- ☐ Level the range from front to back and from side to side by turning the adjustable legs. To adjust, tilt the range to one side.
- ☐ Using channel locks, unscrew the adjustable leg insert as required.
- ☐ Repeat this procedure as necessary for each leg.

NOTE: Casters for some ranges are of the non-leveling type. Therefore, the floor surface must be level. If the floor surface is not level, the range will experience cooking problems until it is level.

Hands-On Exercise:
❑ Level a machine

Gas Leak Safety

Gas Leak Safety

Whenever you suspect a gas leak, turn the equipment off, vent the area and then try to find the leak.

If you open or disconnect a gas line, be sure to check for leaks after putting it back together. All gas joints disturbed during servicing must be checked for leaks. Check with a soap and water solution (bubbles). Do not use an open flame to check for leaks. All leaks should be repaired and unused gas lines should be capped off.

Soap Bubble Leak Testing

Spraying bubble soap on fittings is one way of finding a leak. You can also use a cotton dauber to apply the soap solution. If there is a leak at the fitting or line, the gas will blow bubbles in the soap solution.

Leak Prevention

To prevent a fitting from leaking, always use approved thread tape or thread sealant before making connections. Typically thread sealant tape approved for use with natural gas is colored yellow or gray.

When using pipe joint compound, use a product designed for use with natural gas or L.P. gas.

Avoid ignition hazards

Before entering an area where there is a gas leak, turn off radios, pagers, and cell phones, or leave them in your vehicle if possible.

Avoid using doorbells, light switches, matches, lighters, and anything else that can create a spark because a spark can ignite the gas. If you must use a flashlight, turn it on before approaching the area. Also be aware that static discharge can ignite the gas as well as components that automatically come on by themselves, such as thermostats. Even turning on a light switch can create enough of a spark to cause ignition.

Hands-On Exercise:

- ❑ Apply thread tape to a gas pipe

Hands-On Exercise:

- ❑ Check for a gas leak on a gas supply line using soap bubbles.

Safety Procedures

Electrical Circuit Breaker Panel

Know where the circuit breakers are for the equipment you are working on. Use lockout Tagout procedures if you need to turn off the power to work on equipment. Remember that some equipment is hardwired in and the only way to shut off the power is by turning it off at the breaker panel. Look to see if the circuit you are working on is marked. It is risky to start flipping breakers. You may turn off a circuit that is operating a computer or cash register and cause it to lose its data. Check with the manager if unsure. The circuit you are looking for may not even be in the panel where you are looking.

Water Shutoff Valve

Know where the main water shut off to the kitchen is and the shut off for the equipment. Once again, make sure the valves work and are not jammed. Be aware the most valves rarely get used and cheap water valves will break on you so be careful and don't force the valves. If you break it, you may have to pay to have it fixed.

Fire Extinguishers

Before starting work on any piece of equipment, it is important to know where the fire extinguishers and fire alarm levers are.

Safety procedures when working with gas appliances

For safety, a shut-off valve should be installed at every gas appliance. If a leak occurs at a specific appliance, the valve will allow you to turn off the gas at the appliance rather than shutting off all gas service at the meter. Some valves require a wrench to turn them. Clean the equipment whenever possible before beginning work. When possible, allow the equipment to cool down. Wear safety glasses. If equipment was moved during servicing, be sure that it is placed back into position with recommended clearances. Check all electrical, gas, water, steam, and drains before returning equipment back over to the user. Do not work on equipment where the floor is wet. Be sure to follow all Lockout Tagout procedures before servicing equipment.

Unit 5:
Basic Gas Safety

Fundamentals of Gas

Gas Lockout-Tagout

OSHA 29 CFR 1910.147 – Subpart J
This OSHA required procedure establishes the minimum requirements for the lockout of energy isolating devices whenever maintenance or servicing is done on machines or equipment. It shall be used to ensure that the machine or equipment is stopped, isolated from all potentially hazardous energy sources and locked out before employees perform any servicing or maintenance where the unexpected energization or start-up of the machine or equipment or release of stored energy could cause injury.

Compliance With This OSHA Program
All employees are required to comply with the restrictions and limitations imposed upon them during the use of lockout. The authorized employees are required to perform the lockout in accordance with this procedure. All employees, upon observing a machine or piece of equipment which is locked out to perform servicing or maintenance shall not attempt to start, energize, or use that machine or equipment.

Hands-On Exercise:

- ❑ Perform Lockout Tagout procedures on a gas valve

Unit 5:
Basic Gas Safety

Fundamentals of Gas

Carbon Monoxide

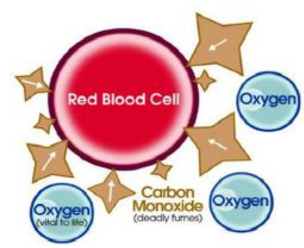
CARBON MONOXIDE

What is CO?

Carbon monoxide, (CO), a highly toxic, colorless, odorless, flammable gas produced industrially for use in the manufacture of numerous organic and inorganic chemical products; it is also present in the exhaust gases of internal-combustion engines and furnaces as a result of incomplete conversion of carbon or carbon-containing fuels to carbon dioxide.

How is CO produced?

For use in manufacturing processes, carbon monoxide is made by passing air through a bed of incandescent coke or coal, or by the reaction of natural gas with oxygen at high temperatures in the presence of a catalyst. The carbon monoxide resulting from these processes generally is contaminated with other substances, such as nitrogen or carbon dioxide, which may be removed if they are undesirable in the intended application.



CO Toxicity

Carbon monoxide's toxicity is a consequence of its absorption by red blood cells in preference to oxygen, thus interfering with the transport of oxygen from the lungs to the tissues, in which it is required. Although accidental carbon monoxide poisoning from natural gas appliances is statistically rare, the existence of carbon monoxide in the home can be caused by improper installation, poor maintenance or other appliance misuse or failure.

Signs and symptoms of carbon monoxide presence

Indication of carbon monoxide poisoning include headache, weakness, dizziness, nausea, fainting, mental confusion, shortness of breath and, in severe cases, coma, weak pulse, and respiratory failure. Carbon monoxide displaces oxygen in the blood, so prolonged exposure can lead to death by asphyxiation. Treatment must be prompt and includes respiratory assistance and the administration of oxygen, often with 5 percent carbon dioxide and sometimes under high pressure. Some people exposed to carbon monoxide poisoning may have mood swings, fatigue, confusion, and memory problems for several weeks after exposure. Some are highly sensitive to CO for the rest of their lives.

Fundamentals of Gas

Hands-On Exercise: Read OSHA Fact Sheet on Carbon Monoxide

OSHA FACT Sheet

Carbon Monoxide Poisoning

What is carbon monoxide?

Carbon monoxide (CO) is a poisonous, colorless, odorless, and tasteless gas. Although it has no detectable odor, CO is often mixed with other gases that do have an odor. So, you can inhale carbon monoxide right along with gases that you can smell and not even know that CO is present.

CO is a common industrial hazard resulting from the incomplete burning of natural gas and any other material containing carbon such as gasoline, kerosene, oil, propane, coal, or wood. Forges, blast furnaces and coke ovens produce CO, but one of the most common sources of exposure in the workplace is the internal combustion engine.

How does CO harm you?

Carbon monoxide is harmful when breathed because it displaces oxygen in the blood and deprives the heart, brain, and other vital organs of oxygen. Large amounts of CO can overcome you in minutes without warning—causing you to lose consciousness and suffocate.

Besides tightness across the chest, initial symptoms of CO poisoning may include headache, fatigue, dizziness, drowsiness, or nausea. Sudden chest pain may occur in people with angina. During prolonged or high exposures, symptoms may worsen and include vomiting, confusion, and collapse in addition to loss of consciousness and muscle weakness. Symptoms vary widely from person to person. CO poisoning may occur sooner in those most susceptible: young children, elderly people, people with lung or heart disease, people at high altitudes, or those who already have elevated CO blood levels, such as smokers. Also, CO poisoning poses a special risk to fetuses.

CO poisoning can be reversed if caught in time. But even if you recover, acute poisoning may result in permanent damage to the parts of your body that require a lot of oxygen such as the heart and brain. Significant reproductive risk is also linked to CO.

Who is at risk?

You may be exposed to harmful levels of CO in boiler rooms, breweries, warehouses, petroleum refineries, pulp and paper production, and steel production; around docks, blast furnaces, or coke ovens; or in one of the following occupations:

- Welder
- Garage mechanic
- Firefighter
- Carbon-black maker
- Organic chemical synthesizer
- Metal oxide reducer
- Longshore worker
- Diesel engine operator
- Forklift operator
- Marine terminal worker
- Toll booth or tunnel attendant
- Customs inspector
- Police officer
- Taxi driver.

What can you do if you suspect someone has been poisoned?

When you suspect CO poisoning, promptly taking the following actions can save lives:

- Move the victim immediately to fresh air in an open area.
- Call 911 or another local emergency number for medical attention or assistance.
- Administer 100-percent oxygen using a tight-fitting mask if the victim is breathing.
- Administer cardiopulmonary resuscitation if the victim has stopped breathing.

Warning: You may be exposed to *fatal* levels of CO poisoning in a rescue attempt. Rescuers should be skilled at performing recovery operations and using recovery equipment. Employers should make sure that rescuers are not exposed to dangerous CO levels when performing rescue operations.

How can employers help prevent CO poisoning?

To reduce the chances of CO poisoning in your workplace, you should take the following actions:

- Install an effective ventilation system that will remove CO from work areas.
- Maintain equipment and appliances (e.g., water heaters, space heaters, cooking ranges) that can produce CO in good working order to promote their safe operation and to reduce CO formation.
- Consider switching from gasoline-powered equipment to equipment powered by electricity, batteries, or compressed air if it can be used safely.
- Prohibit the use of gasoline-powered engines or tools in poorly ventilated areas.

Hands-On Exercise: Read OSHA Fact Sheet on Carbon Monoxide (Cont.)

Carbon Monoxide Poisoning

- Provide personal CO monitors with audible alarms if potential exposure to CO exists.
- Test air regularly in areas where CO may be present, including confined spaces. See *Title 29 of the Code of Federal Regulations* (*CFR*) 1910.146.
- Install CO monitors with audible alarms.
- Use a full-facepiece pressure-demand self-contained breathing apparatus (SCBA) certified by the National Institute for Occupational Safety and Health (NIOSH), or a combination full-facepiece pressure demand supplied-air respirator with auxiliary self-contained air supply in areas with high CO concentrations, i.e., those immediately dangerous to life and health atmospheres. (See 29 *CFR* 1910.134.)
- Use respirators with appropriate canisters for short periods under certain circumstances where CO levels are not exceedingly high.
- Educate workers about the sources and conditions that may result in CO poisoning as well as the symptoms and control of CO exposure.

In addition, if your employees are working in confined spaces where the presence of CO is suspected, you must ensure that workers test for oxygen sufficiency before entering.

What can employees do to help prevent CO poisoning?

Employees should do the following to reduce the chances of CO poisoning in the workplace:

- Report any situation to your employer that might cause CO to accumulate.
- Be alert to ventilation problems—especially in enclosed areas where gases of burning fuels may be released.
- Report promptly complaints of dizziness, drowsiness, or nausea.
- Avoid overexertion if you suspect CO poisoning and leave the contaminated area.
- Tell your doctor that you may have been exposed to CO if you get sick.
- Avoid the use of gas-powered engines, such as those in powered washers as well as heaters and forklifts, while working in enclosed spaces.

What are the OSHA standards for CO exposure?

- The OSHA PEL is 50 parts per million (ppm). OSHA standards prohibit worker exposure to more than 50 parts of the gas per million parts of air averaged during an 8-hour time period.
- The 8-hour PEL for CO in maritime operations is also 50 ppm. Maritime workers, however, must be removed from exposure if the CO concentration in the atmosphere exceeds 100 ppm. The peak CO level for employees engaged in Ro-Ro operations (roll-on roll-off operations during cargo loading and unloading) is 200 ppm.

How can you get more information on safety and health?

OSHA has various publications, standards, technical assistance, and compliance tools to help you, and offers extensive assistance through workplace consultation, voluntary protection programs, grants, strategic partnerships, state plans, training, and education. OSHA's *Safety and Health Program Management Guidelines* (*Federal Register* 54:3904-3916, January 26, 1989) detail elements critical to the development of a successful safety and health management system. This and other information are available on OSHA's website.

- For one free copy of OSHA publications, send a self-addressed mailing lable to OSHA Publications Office, P.O. Box 37535, Washington, DC 20013-7535; or send a request to our fax at (202) 693-2498, or call us at (202) 693-1888.
- To order OSHA publications online at **www.osha.gov**, go to **Publications** and follow the instructions for ordering.
- To file a complaint by phone, report an emergency, or get OSHA advice, assistance, or products, contact your nearest OSHA office under the "U.S. Department of Labor" listing in your phone book, or call toll-free at **(800) 321-OSHA (6742)**. The teletypewriter (TTY) number is (877) 889-5627.
- To file a complaint online or obtain more information on OSHA federal and state programs, visit OSHA's website.

This is one in a series of informational fact sheets highlighting OSHA programs, policies, or standards. It does not impose any new compliance requirements or carry the force of legal opinion. For compliance requirements of OSHA standards or regulations, refer to *Title 29 of the Code of Federal Regulations*. This information will be made available to sensory-impaired individuals upon request. Voice phone: (202) 693-1999. See also OSHA's website at **www.osha.gov**.

U.S. Department of Labor
Occupational Safety and Health Administration
2002

Unit 6:
Basic Gas Piping

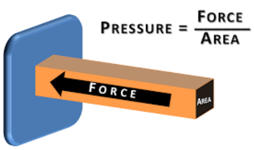
Fundamentals of Gas

Gas Piping and Flow

GAS PIPING AND FITTINGS

Pressure, Flow Rate, Volume, and Pressure drop

Gas Pressure



Pressure is the push provided by the gas supplier. Pressure is created by the force of the gas particles running into a surface. For example, gas particles exert pressure when they collide with the walls of their container.

Flow Rate
Flow rate is affected by pipe size and the length of the pipe. Flow rate is the amount of gas that is supplied to a burner during a specific period of time.

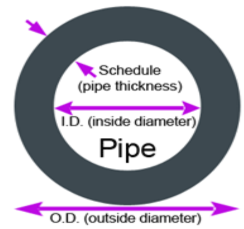
Volume
Volume is the amount of gas supplied and is measured in cubic feet. As the length of pipe increases the cubic feet of gas available decreases. This is due to the resistance created by the pipe. Different charts are available for different pressures and are used to install the gas lines. Refer to the data plate on the equipment for gas volume requirements.

VOLUME DECREASES
PRESSURE INCREASES

Pressure Drop
As gas flows through the pipe, resistance is created which causes its pressure to drop. The longer the pipe, the more resistance there will be which causes the pressure to be lower. Pressure drop is the loss of pressure that occurs due to the resistance of gas flow along the length of pipe.

Gas Density
Density will change with the type of gas and the temperature.

Pipe Length and Size
Pipe length is the total length of pipe needed to deliver gas to a given appliance. Pipes come in different sizes measured in inches or fractions of an inch. The size is the measurement of the inside of the pipe at its widest point. This is known as the inside diameter or ID. The measurement from the outside of the pipe to the outside of the pipe is known as the outside diameter or OD. The thickness of the pipe is known as the schedule. The higher the number of the schedule is, the thicker the pipe, thus the more heavy duty it is. Connecting a large diameter pipe on to a smaller pipe will not make more gas available to the appliance. The most gas that can be delivered through a series of pipe is limited by the smallest diameter pipe.



Unit 6:
Basic Gas Piping

Fundamentals of Gas

Gas Fittings

Multiple Appliance Connections
When multiple appliances are connected to the gas line, the incoming gas supply line must be large enough to provide gas for all the equipment. When planning a pipe installation, start from the appliance that is the furthest away from the gas supply and work back to the gas meter. Obtain the gas requirements from the data plate for each appliance. The total sum of the gas requirements is used to determine the size of the pipe required to meet the needs of each appliance connected to the gas supply.

Pipe Fittings
Pipe fittings are small pieces of pipe and are used to assemble the main sections of the gas line. Fittings allow you to branch off into multiple branches, cap off unused lines, adapt from one size pipe to another, couple two pipes together, or configure the pipe any other way you would like. Pipe fittings, however, do add resistance to gas flow. Piping is assembled using a pipe wrench. Natural gas piping and fittings are typically black or charcoal colored

Common fittings are:

Pipe Wrench

Hands-On Exercise:
Locate and identify the following gas fittings.

- ❑ Union
- ❑ Tee
- ❑ Elbow

Unit 6:
Basic Gas Piping

Fundamentals of Gas

Gas Pressure Loss

Pressure Loss Due to Fittings
Adding a fitting to a gas pipe is the same as adding additional feet of pipe to the line due to the resistance that the fitting creates. Some fittings add more resistance than others. Multiply the number of fittings by the number of feet to get the total length added to a pipe due to fittings.

Pipe size	90° elbow	45° elbow	Tee
3/4″	29	19	49
1″	2.59	1.59	5.259
1-1/4″	3.59	2.09	7.09

The table shows the amount of additional feet and pipe that will need to be added for each type of fitting used.

Cubic Feet of Gas Available in 3/4″ Diameter Pipe				
Length in Feet	10	20	30	40
Available Gas in Cubic Feet	278	190	152	130

Don't forget that every foot of pipe to a machine takes away from the total supply of gas that is delivered into the building.
The size of the pipe and the length of the pipe will govern how much gas can be distributed at a particular pressure or flow rate.
Charts are available that indicate, in cubic feet per hour, the maximum delivery available through a pipe of a particular size.

Hands-On Exercise:

Locate a run of gas pipe and document the number and type of fittings it has.

- ❑ Tee ______
- ❑ Elbow ______
- ❑ Coupler ______
- ❑ Union ______
- ❑ Estimated length of pipe run ______
- ❑ What color was the pipe? _____________ Fittings? ___________

Gas Pressure Charts

Gas charts are written for a pressure rating with a particular pressure drop and at a particular density of the gas.

Natural Gas Supply Piping

Maximum Capacity of Natural Gas Based on a 0.60 specific gravity at a 0.5" WC pressure drop

Pipe Size	kBTU of Natural Gas											
Length	10'	20'	30'	40'	50'	60'	70'	80'	90'	100'	125'	150'	200'
¾"	372	255	205	175	156	142	130	121	114	107	95	86	74
1"	702	482	387	331	293	266	245	228	213	202	179	162	139
1 ¼"	1441	990	795	680	603	546	503	468	439	415	367	332	285
1 ½"	2158	1483	1191	1019	903	819	753	701	658	621	550	499	427
2"	4155	2856	2293	1963	1740	1576	1450	1349	1266	1195	1060	960	822

Propane (LP) Gas Supply Piping

Maximum Capacity of Propane (LP) Gas Based on 11" WC supply pressure at a 1.0" WC pressure drop

Pipe Size	kBTU of Propane												
Length	10'	20'	30'	40'	50'	60'	70'	80'	90'	100'	125'	150'	200'
¾"	567	393	315	267	237	217	196	185	173	162	146	132	112
1"	1071	732	590	504	448	409	378	346	322	307	275	252	213
1 ¼"	2205	1496	1212	1039	913	834	771	724	677	630	567	511	440
1 ½"	3307	2299	1858	1559	1417	1275	1181	1086	1023	976	866	787	675
2"	6221	4331	3465	2992	2646	2394	2205	2047	1921	1811	1606	1496	1260

Exercises

Use the above gas tables to answer the following questions.

1. What diameter of pipe is needed for an 372,000 BTU natural gas appliance located 10' from the meter? ___________
2. What diameter of pipe is needed for an 732,000 BTU LP gas appliance located 20' from the meter? ___________
3. What diameter of pipe is needed for an 460,000 BTU natural gas appliance located 50' from the meter? ___________
4. What diameter of pipe is needed for an 360,000 BTU natural gas appliance located 30' from the meter? ___________
5. What diameter of pipe is needed for an 800,000 BTU natural gas appliance located 10' from the meter? ___________

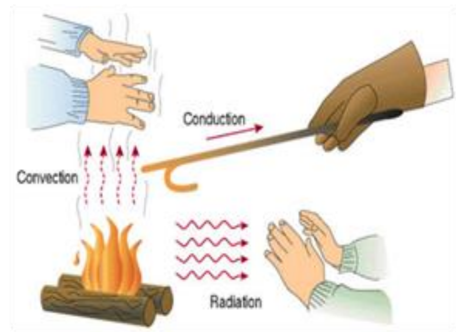
Unit 7:
Basic Gas
Operation

Fundamentals of Gas

Thermal Systems

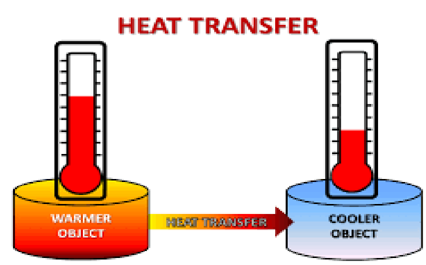
Thermal Systems

Thermal systems maintain a desired temperature in a confined space. An oven is a thermal system. The confined space of the system is called the thermal storage area.



Heat Flow

Heat always flows from a warmer object to a cooler object. This heat flow will occur until the warmer object and the cooler object are the same temperature.



Heat Transfer

There are three methods of heat transfer: conduction, convection, and radiation.

Impingement Ovens 21

An impingement oven uses the same principles of forced air movement to heat as the convection oven. There is little difference between the two, although air impingement cooking is considered to be faster and primarily used in commercial operation. Manufacturers produce the ovens in gas and electric configurations.

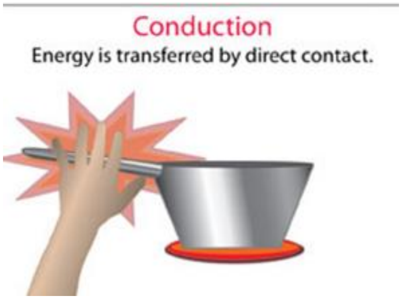
Missionrs.com

Unit 7:
Basic Gas Operation

Fundamentals of Gas

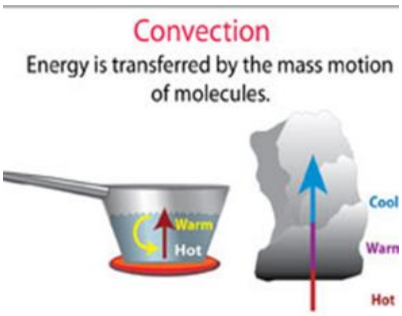
Heat Transfer

Conduction



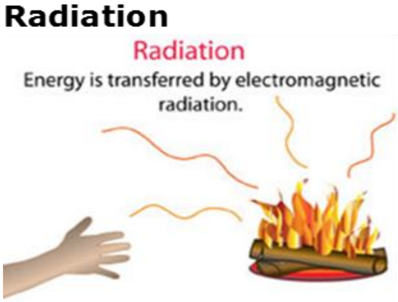
Energy is transferred by the direct contact of molecules, not by the movement of the material. Example: putting your hand on a stove burner. The amount of energy transferred depends on how conductive the material is. Metals are good conductors, so they are used to transfer energy from the stove to the food in pots and pans. Air is the best insulator, so good insulating products try to trap air and not allow it to move.

Convection



Energy is transferred by the mass motion of groups of molecules resulting in transport and mixing of properties. Example: holding your hand over a stove burner. In meteorology, we speak of convection predominantly as that caused by rising currents of warm air. We refer to all other mass motions of air as advection. In cooking equipment, convection ovens have a fan in the oven cavity that moves the air around to distribute the heat over the food.

Radiation



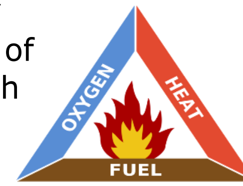
Energy is transferred by electromagnetic radiation
Example: heat felt when standing away from a large fire on a calm night.
Everything that has a temperature above absolute zero radiates energy.
Radiation is not "felt" until it is absorbed by a substance.
It does not require a medium to transfer energy through as do conduction and convection.

Impingement

The Impinger® oven functions by directing high velocity streams of heated air directly on the food products. Because air is the heat source, it is effective even on sensitive foods. Compared to conventional ovens and even convection ovens, the cooking time of products in the Impinger® Conveyor ovens can be as much as two (2) to four (4) times faster. Several factors may affect the cooking time of any special product such as: 1) oven temperature setting, 2) conveyor speed, 3) position of columnating plate in oven, and 4) adjustments of the 2 baffles on the conveyor openings.

Combustion

Combustion



Combustion, a chemical reaction between substances, usually including oxygen and usually accompanied by the generation of heat and light in the form of flame. The rate or speed at which the reactants combine is high, in part because of the nature of the chemical reaction itself and in part because more energy is generated than can escape into the surrounding medium, with the result that the temperature of the reactants is raised to accelerate the reaction even more.

A familiar example is a lighted match. When a match is struck, friction heats the head to a temperature at which the chemicals react and generate more heat than can escape into the air, and they burn with a flame. If a wind blows away the heat or the chemicals are moist and friction does not raise the temperature sufficiently, the match goes out. Properly ignited, the heat from the flame raises the temperature of a nearby layer of the matchstick and of oxygen in the air adjacent to it, and the wood and oxygen react in a combustion reaction. When equilibrium between the total heat energies of the reactants and the total heat energies of the products (including the actual heat and light emitted) is reached, combustion stops. Flames have a definable composition and a complex structure; they are said to be multiform and are capable of existing at quite low temperatures, as well as at extremely high temperatures. The emission of light in the flame results from the presence of excited particles and, usually, of charged atoms and molecules and of electrons. To cook we have to have heat. Next we will discuss three things that have to come together to make fire. Remove one of these things and fire cannot exist. Combustion happens when fuel reacts with oxygen in the air to produce heat.

Three things are needed in order for combustion to happen: heat, oxygen, and fuel.

After these three things come together at the proper ratios a chemical reaction is needed to produce the fire. Burning will continue until the source of heat, oxygen, or fuel is gone. We can remove the heat with fire extinguishers. CO2 extinguishers cool as well as displace oxygen. Water will also absorb heat from a fire. We can remove the fuel source by turning the gas valve off.

Unit 7:
Basic Gas
Operation

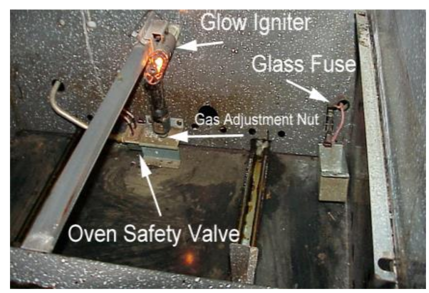
Heat Sources

Heat Sources in Gas Appliances

We have to have enough heat to ignite the gas. Four types of heat sources are: standing pilot, hot surface igniter, glow coil or glow igniter, and high voltage spark igniter.

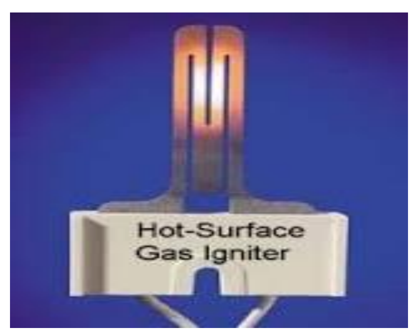
Standing Pilot

Older ovens often employ a small flame in their base called a pilot light. Some pilots burn constantly at a low level; when you turn these ovens on, you feed more gas to the flame, which in turn lights the oven burner.



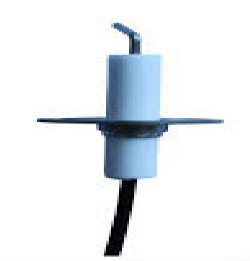
Glow Coil

Gas ovens use either a pilot flame, electronic spark or a glow bar to ignite the gas. A glow igniter (or glow coil) igniter works somewhat like an electric heating coil. Current flowing through it causes it to glow, and when its temperature is high enough, a sensor sends a signal to open the gas valve. The hot igniter then sets the escaping gas aflame.



Hot Surface Igniters

Oven hot surface ignitors are found on many modern ovens to light the gas burner flames. Electricity passes through the Silicon Carbide ignitor and makes it glow red hot.



High Voltage Spark Igniters

High voltage spark igniters are connected to an ignition module which increases its voltage from line voltage to thousands of volts (exact amount depends on equipment). This high voltage creates a spark between the electrodes of the spark igniter and ignites the gas.

Unit 7:
Basic Gas Operation

Fundamentals of Gas

Air Requirements

Oxygen

nitrogen (N_2)	78.084
oxygen (O_2)	20.946
argon (Ar)	0.934
neon (Ne)	0.0018
helium (He)	0.000524
methane (CH_4)	0.0002
krypton (Kr)	0.000114
hydrogen (H_2)	0.00005
nitrous oxide (N_2O)	0.00005
xenon (Xe)	0.0000087

You can't have fire without oxygen. Oxygen comes from the air in the atmosphere. The air we breathe contains around 78% nitrogen, 21% oxygen, 0 to 7% water (humidity) and very small percentages of many other gasses. Bigger fires need larger supplies of oxygen. Different gasses need different amounts of air to get a complete burn without creating carbon monoxide. Fuel gasses require a certain mixture of air and fuel in order to combust.

Natural Gas Oxygen Requirements

Natural gas requires 10 cubic feet of air to burn 1 cubic foot of gas and will produce 1000 BTU of heat. With a burner adjusted properly, the exhaust will contain 1 cubic foot of CO2, 2 cubic feet of water and 8 cubic feet of nitrogen. Improper burner adjustment can produce carbon monoxide instead of CO2.

	Natural Gas	LP Gas
Density	Lighter than Air	Heavier than Air
Air required per cubic foot of gas	10 Cubic Feet (CF)	24 Cubic Feet (CF)
Heat produced by burning 1 CF of gas	1000 BTU	2500 BTU
Specific Gravity	0.60	1.50

LP Gas Oxygen Requirements

LP or Propane gas requires 24 cubic feet of air to burn one cubic foot of gas and will produce 2500 BTU. With a burner adjusted properly, the exhaust will contain 3 cubic feet of CO2, 4 cubic feet of water and 18 cubic feet of nitrogen. Improper burner adjustment can produce carbon monoxide instead of CO2.

Elevation Adjustments

Less dense air has fewer molecules which means less oxygen available for combustion. Due to the air not being as dense at higher elevations, some equipment must be re-rated. This is typically for equipment located at elevations above 2000 feet above sea level.

Hands-On Exercise:

- ❑ Locate the data plate of a gas appliance.
- ❑ What is the fuel used? _______________
- ❑ How many cubic feet of air is needed per cubic foot of fuel? _______________
- ❑ How many BTU's are produced per cubic foot of fuel for this machine? __________

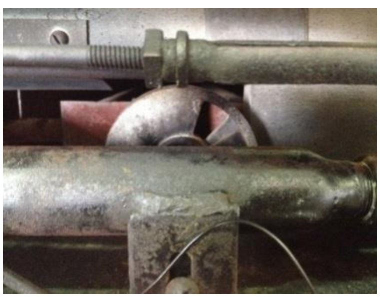
Unit 7:
Basic Gas
Operation

Proper Flames

When using natural gas, the air shutter will be approximately 50% open. On propane (LP) the air shutter will be approximately 90% open.

If the flame is soft, lazy or yellow, there is not enough primary air and the air shutter needs to be opened up. In the event this does not solve the situation, check the burner for obstructions and clear as necessary. If the flame is lifting off the burner, there is too much primary air and the air shutter needs to be closed down (Diagram #5).

If grates, hot tops or oven bottoms have been removed, be sure to recheck flame adjustments with these items in place as the flame characteristics may change and additional adjustments may be necessary. Always recheck burner flames after the grates, hot tops and oven bottoms are in their proper place.



Air Shutter

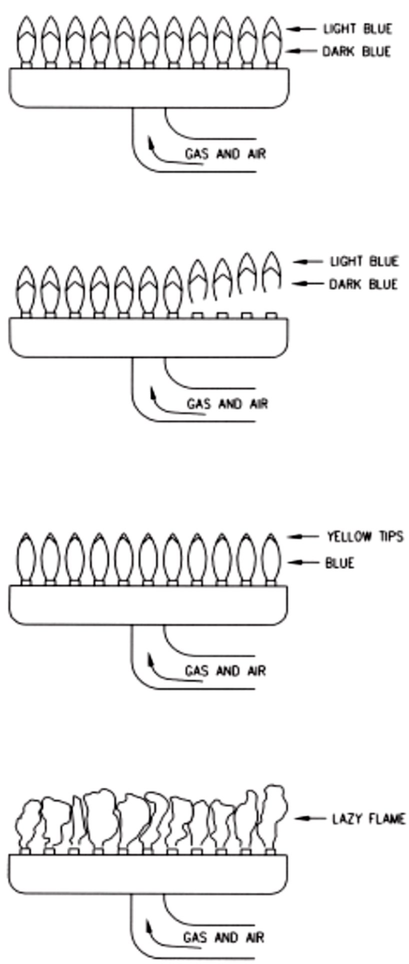


DIAGRAM #5

Hands-On Exercise:

- ❑ Identify proper and improper flames on a gas range.
- ❑ Achieve proper flames by adjusting the shutters.

Unit 7:
Basic Gas Operation

Fundamentals of Gas

Flame Evaluation

Flame Evaluation

The flame of gas range burners should be steady and slightly rounded, with a light-blue tip. The flame should be quiet and should respond to adjustments made at the control knobs. Most burner troubles can be quickly solved by adjusting the air shutter mixer plate, which is located at the end of the burner tube near the knob controls. Turn a small screw on the plate, slide the plate open or closed, and tighten the setscrew.

If the flame is yellow, it's not receiving enough air. To allow more air in, open the plate slightly. If the flame is high or makes a roaring noise, it's getting too much air and you should close the plate slightly.

Hands-On Exercise:

- ❑ Turn on a burner of a gas appliance. What color is the flame? ________________

Products of Combustion

Complete Combustion

When complete combustion occurs while burning natural gas, heat, CO2, and water vapor is created.

Incomplete Combustion

When incomplete combustion occurs while burning natural gas, byproducts that may include carbon monoxide (CO), aldehydes, nitrogen oxides (NOX), total hydrocarbons (THC's), volatile organic compounds (VOC's), hydrogen, carbon dioxide (CO2) and water vapor are released.

Notes:

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Unit 8:
Basic Gas Ventilation

Fundamentals of Gas

Ventilation

Ventilation

Burning natural gas produces exhaust gasses that need to be removed by the process of ventilation. Burning one cubic foot of natural gas produces 11 cubic feet of exhaust gasses that need to be removed (1 cubic foot gas and 10 cubic feet of air). Burning one cubic foot of LP gas produces 25 cubic feet of exhaust (1 cubic foot of gas and 24 cubic feet of air). Code states that all commercial cooking equipment and dish machines that produce smoke, fumes, grease-laden vapors, steam or condensate must be ventilated and exhausted. This includes both natural gas-fired and electric equipment. Keep filters and hoods clean.

Commercial Ventilation System

Hands-On Exercise:

- ❑ Operate a vent hood
- ❑ Turn on/off fans
- ❑ Turn on/off lights
- ❑ Remove/replace cartridges
- ❑ Discuss fire suppression system

HMI – Human Machine Interface

Exhaust – Air Leaving

Ventilation Formula
Depending on local codes, ventilation requirements may vary. A basic formula is as follows: 100 to 150 CFM (cubic feet per minute) per square foot of floor space that the appliance or line up occupies. For example, one standard six burner unit, which measures 36" wide by 38" deep, equals approximately 9 square feet of floor space, therefore 900 to 1,350 CFM of exhaust is required.

Charbroilers
Units with charbroilers may require more CFM exhaust; check with local authorities.

Clearance
The hood should extend a minimum of 6" over all exposed sides of an appliance or line up. Seldom can the units be without rear clearance, so figure 4" in the rear.

Exhaust and Fresh Air
For every cubic foot of gas that is burned, 11 cubic feet of by-products are produced. These by-products must be vented to the outside.
Ventilation systems need to be properly balanced to ensure that all the by-products are exhausted. There must be an adequate supply of fresh air for proper combustion and still a very slight negative pressure in the kitchen.

Compatibility
Sometimes a hood system will be operating perfectly as per its manufacturer’s specifications, however, there is still a problem with the gas cooking appliance. The hood system may not be compatible with the gas appliance under it. In these instances, the service contractor for the hood system and the appliance Servicer will have to work together to attempt to correct the problem. If it is determined that the hood system is not compatible with the appliances under it, it is imperative that this information be communicated to the end user, the dealer and all parties involved.
If the fresh air system (make-up air) is such that ovens and griddles are experiencing fluing problems, there will be component failures due to excessive heat. If the open burners are fluttering or blowing around due to make-up air being directed at the top or front of the unit delayed, no ignition will occur, and the appliance’s performance will be severely affected. If it is determined that any of these conditions exist, the appliance warranty will be voided. Some cities allow the use of a direct vent system in lieu of a motor-driven exhaust system to vent a bake oven.
Check with local authorities.

Range Hoods

Range Hoods

Range hoods provide powered venting to the room. These devices must be installed according to local codes. Many of these units include fire suppression equipment. Newer, energy efficient units may also have heat exchangers to collect the heat from the exhaust and use it to heat water or the kitchen area.

Range Location and Clearance

The range must be kept free and clear of combustible substances. The range, when installed, must have minimum clearance of 6" at the sides and 6" at the back from combustible construction, and 0" at the sides and 0" at the back from non-combustible construction.
The installation location must allow adequate clearances for servicing and proper operation. A minimum front clearance of 40" is required.
The range must be installed so that the flow of combustion and ventilation air will not be obstructed.

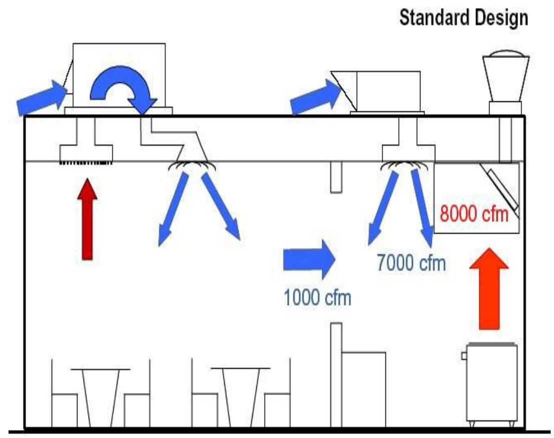
Adequate clearance for air openings into the combustion chamber must be provided. Make sure there is an adequate supply of air in the room suitable for the amount of combustion gas feeding the burners.

Do not permit fans to blow directly at the range. Wherever possible, avoid open windows next to the range. Avoid wall-type fans which create air cross currents within the room.

Hands-On Exercise:

- ❑ Remove and clean vent hood cassettes.
- ❑ Reinstall the vent hood cassettes.

Make-Up Air



Fresh Air Intake / Make-Up Air

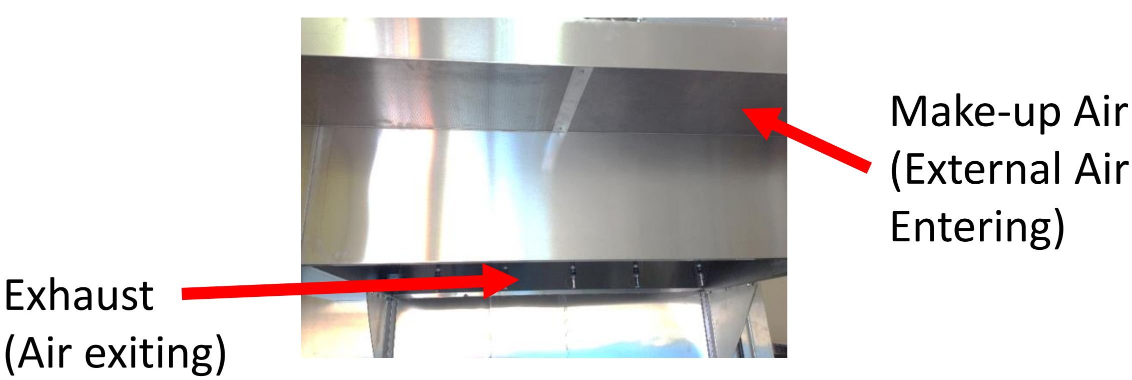
There is a lot of air leaving the kitchen space when the vent hoods are on, so an equivalent amount of fresh air must be brought in to keep the air pressure stable. If the air that has been removed is not replenished, the building could be caused to operate in a vacuum which causes problems and potential safety issues for gas fire equipment.

Negative Pressure

When the pressure inside the building becomes lower than the pressure outside, this is called negative pressure and can create flame issues. It can also create incomplete combustion which can lead to the release of carbon monoxide and unburned hydrogen in the exhaust gasses. This can cause a buildup of explosive hydrogen gas and may lead to fire, injury, or death. To prevent this, a fresh air intake or make up air system is installed to bring in fresh air from the outside.

Flues

Because heat rises naturally, the heat of the fire creates a drafting effect. Air and exhaust flow up the flue and vent to the outside of the building. Sometimes draft diverters are installed to prevent down drafts to prevent problems of high winds pulling heat out of the fire box.



Hands-On Exercise: Calculate square feet and cubic feet of a space

1. What is the square footage of a room that measures 10’ in length and 10’ in width?

   ____

2. What is the square footage of a room that measures 15’ in length and 10’ in width?

   ____

3. What is the cubic footage of a room that measures 10’ in length, 10’ in width, and 10’ in height?

   ____

4. What is the cubic footage of a room that measures 12’ in length, 10’ in width, and 14’ in height?

   ____

5. How many square inches is an oven door that measures 24” in length and 2’ in width?

   ____

6. What is the cubic footage of an oven cabinet that measures 26” in length, 34” in width, and 24” in height?

   ____

7. What is the square footage of a wall that measures 14’ in height and 10’ in width?

   ____

Unit 9:
Ignition

Fundamentals of Gas

Pilot Light Operation

Servicing Pilot Lights
The oven pilot is sometimes located at the back of the oven, sometimes at the front; turn a screw on the pilot ignition unit to adjust the pilot flame height.

Pilot Light Characteristics
One pilot light can serve all the top burners of a gas range. Some ranges have two pilot lights, one for each side of the range and some ranges have a separate pilot for each burner. A correctly adjusted pilot flame is steady and blue, between 1/4 and 1/2 inch high. If the flame goes out repeatedly, or if it's yellow at the tip, it's getting too little air. If there's a space between the flame and the pilot feed tube, it's getting too much air. To correct either condition, turn the pilot adjustment screw on the gas line slightly, as directed by the manufacturer of the range.

Pilot Flame
Most modern gas ranges use an electronic pilot igniter to start the pilot.
If the pilot flame is properly adjusted, but the flame doesn't ignite the burners, the problem is probably in the flash tubes that run from the pilot to the burners. These tubes may be blocked by spilled food from the burners. If this is the case, turn off the power to the range and clean out the tubes using a short piece of wire. Push the wire through the opening until the tube is clear. You may have to disconnect the tube to clear it. After cleaning the tube, replace it in the same position. If the pilot has a switch, the switch may be faulty.

Notes:

Hands-On Exercise:
- ❑ Light a pilot flame on a gas-fired appliance that uses a standing pilot.

Pilot Light Adjustment

Pilot Adjustments

After all connections/fittings have been checked for gas leaks and no leaks are found, the pilots can be lit. Locate each pilot and the corresponding pilot adjustment valve. Light the pilots and adjust them up or down as necessary.
The flame should be only high enough to ignite the corresponding burner within 3 or 4 seconds maximum.
Mushroom head-type pilots are used on open burners, griddles, and hot tops. The flame should be only about the size of a dime. This type of pilot will burn yellow; that is the reason they should be as small as possible and still be able to ignite the burner, within 3 or 4 seconds, maximum

Kelly Wells

Pilot Light next to burner

Orifice Pilots

Orifice pilots with thermocouples or flame switches are used on ovens. The flame should be large enough to completely engulf the tip of the thermocouple/sensor and make the tip of the thermocouple/sensor glow red-hot.
Orifice pilot flames should be sharp, well-defined, two-tone blue when burning natural gas. However, when burning propane (LP), there may be a tiny yellow tip to the flame. This yellow tip should be no more than 10% of the total flame size.

Kelly Wells

Pilot Light valves

Fine Tuning

All gas burners should ignite within 3 to 4 seconds, maximum. All burners are tested at the factory prior to shipment. However, fine tuning adjustments may be necessary to accomplish 3 to 4-second ignition at the installation site**.** Most gas burners have an air shutter. There are two types of air shutters, the cap or disk type, and the sleeve type. The cap or disk type is used on burners with cast iron venturis. The sleeve type is used on tubular steel burners and/or burners with tubular steel venturis. All burners are tested, and the air shutters are set at the factory prior to shipment. However, the factory cannot make the fine tuning adjustments that may be necessary during the actual installation.

Kelly Wells

Shutters

Spark Igniter Operation

In a high voltage spark ignition system, voltage is increased to around 10,000 volts by the ignition module. This high voltage will arc across the spark igniter electrodes.

In a spark ignition system, the spark is created, and then it stops sparking when the flame is lit. These systems also provide a safety system to shut off gas flow if the flame goes out.

Spark Ignition

- Typically used in ranges, ovens, fryers & griddles
- Valve drive & intermittent pilot versions available
- Multiple models available, including flame sensing and non-flame sensing
- Ambient temp: 32ºF (0ºC) to 200ºF (93ºC)

Unit 9:
Hot Surface Igniters

Fundamentals of Gas

Hot Surface Igniter Operation

Hot Surface Igniters
Hot surface ignitors are found on many modern ovens to light the gas flames upon unit start-up. Electricity passes through the Silicon Carbide or the newer Silicon Nitride ignitor and makes it glow red to white hot. As gas flows by the hot surface igniter, the gas ignites. Operating under normal conditions a hot surface ignitor will last for 3 to 5 years (Silicone Nitride lasts about twice as long). During that time ignitors will eventually crack and need to be replaced. Like a light bulb, they are a regular replacement item.

Tip
Sometimes a hot surface igniter may glow red hot and appear to be working. However, it may not be getting hot enough to ignite the gas. Make sure your igniter is designed to heat up to the ignition temperature of the gas you are trying to ignite.

Ignition Temperatures
Natural gas has an ignition point of 1100 to 1200 degrees Fahrenheit. Propane has an ignition point of 842 degrees Fahrenheit.

<u>Hands-On Exercise:</u>
- ❑ Test a hot surface igniter for continuity

Hot Surface Igniter Troubleshooting

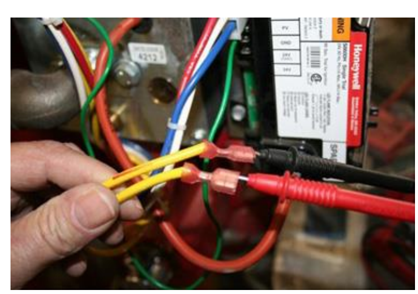
Troubleshooting a Hot Surface Igniter

1. Verify that all wire connections are secure from the oven to the hot surface ignitor.
2. Does the hot surface ignitor have any visible abnormal spots on it.? A burned hot surface ignitor will typically have a white or burned spot when it has failed. This hot surface ignitor failed due to a "bad spot."
3. Does the hot surface ignitor glow when the oven cycles?
4. You will need a multimeter to check the power of the hot surface ignitor. Disconnect the plug going to the ignitor. Use your Multimeter to see if you have 120 volts. Make sure you do this on startup of the oven. After a minute or so it will be timed out. Then you will have to shut the system off and then turn it back on again.

OR

A. You will need a multimeter to check the resistance of the hot surface ignitor. A hot surface ignitor uses resistance just like a light bulb to glow hot in order to light the gas. It typically has a life span of 2 to 3 years depending on the usage and the conditions of the furnace. Set the multimeter so it can properly measure a resistance of 10 to 200 ohms. Disconnect the hot surface ignitor from the control board and measure the resistance. A good hot surface ignitor will have a resistance of 40 to 90 ohms. Greater than 90 ohms indicates a failing or failed hot surface ignitor.

5. If your hot surface ignitor is good, then you need to verify power from the control board or ignition controller. Disconnect the hot surface ignitor and measure the voltage coming from the controller. A good reading is 115 to 120 VAC. If there is no voltage and the thermostat is calling for heat, then the control board or ignition controller needs to be replaced



Unit 10:
Components

Fundamentals of Gas

Regulators

Gas Supply
Gas pressure in interstate distribution pipelines range from 200 – 1500 psi. Then it is regulated to about 3 psi at the local level. This is too high for most appliances so it must be regulated at the gas meter before it comes into the building. This pressure will vary according to the needs of the building. Most gas appliance regulators have a maximum of ½ psi (14” W.C.). Gas pressure must be regulated at the equipment to operate properly. Typical gas pressure for appliances are in the range of 3 – 7” water column. One inch of water column is 0.036 psi and has a volume of 0.00225 oz. per square inch.

Interstate lines	200 – 1500 psi
Local lines	Typically 3 psi
One PSI	27.68” water column
1/2 PSI is approximately	14 inches water column
One inch water column	0.036 psi
One inch water column	0.00225 oz/square inch

Regulators

A pressure regulator keeps the gas entering the stove at a constant pressure of about 1/6 PSI, regardless of fluctuations in the supply pressure. In a cooktop or stove, this pressure regulator feeds a main gas header, or manifold, located under the cooktop. The surface burner gas valves are mounted directly to the gas header. Gas is piped from the header to the various burners, pilots and safety valves, and in some systems, the oven thermostat.

Photo Credit: Kelly Wells

All gas appliances must have a gas pressure regulator installed. In order for the pressure regulator to perform properly, the supply pressure must be greater than the operating pressure. For example, most cities supply 7" to 9" W.C. of natural gas pressure to a building.
Propane (LP) systems should supply 11" to 12" W.C. The appropriate pressure regulator will provide the correct pressure to the unit or line up.
Sometimes even though the gas pressure is correct, the appliance may not be able to function properly because the gas supply piping may be too small and is not able to supply the volume of gas required. It is recommended that the piping be able to supply a minimum of 10% more fuel than the maximum BTU consumption of the appliance or line up.

Regulator Vents and Code

Regulator Vents

All regulators have vents that will vent out the gas in the event of a diaphragm rupture in the regulator. The small hole in the vent acts as a flow limiter which limits the amount of gas that will leak out if the diaphragm ruptures. Since the diaphragm fluctuates to regulate the gas pressure, this vent also acts as an air vent to allow the movement of the diaphragm. If the vent becomes clogged it will prevent the regulator from working properly. Some vents are of the check valve ball style and must be mounted in the horizontal position. Clean vent cap before adjusting.

Code Alert

Gas codes state that if a regulator is inside of a building then the device must be vented over a constantly burning pilot, vented to the outside, or restricted with a flow limiter.

Hands-On Exercise:

- ❑ 1. Locate and identify a gas regulator.
- ❑ 2. Locate the regulator vent

Regulator Adjustments

Regulator Adjustments

Regulators come preset, but should be checked anytime one is installed. To adjust the regulator, remove the protective cap to access the adjustment screw. Turn the screw clockwise to increase the gas pressure and counter clockwise to decrease the gas pressure. It is important to reinstall the protective cap. This cap also prevents gas from leaking in the event of a diaphragm rupture. The adjustment screw cap is also an indicator of the type of gas used. If the cap is silver, natural gas is being used. If the cap is red, LP (Propane) gas is being used. If a conversion from one fuel to another is done, this cap should be changed out to the proper one for the fuel type.

Pressure Regulators

Pressure regulators are used to decrease the incoming gas pressure on the equipment side of the gas line. If pressure regulators are not included on the equipment, they should be added when it is installed. The buildings gas supply line will be ran to the location where the appliance is located and will have a shut off valve where it ends. A gas line is connected to this shut-off valve and ran to the "In" port of the pressure regulator. The "Out" port of the pressure regulator supplies gas to the appliance. If the regulator does not say "In" or "Out", then look for an arrow to indicate the flow of gas. The arrow will be pointing to the "Out" port. The incoming pressure to the regulator can be adjusted to meet the specifications of the equipment by adjusting the adjustment screw on the regulator. You can typically expect to find around 3 – 7 inches of water column supplied to an appliance. You can only decrease the pressure from what the supply pressure is. Regulators will not increase gas pressure above what the supply pressure is from the outside meter. Check the data plate on the equipment for required gas supply pressure. This reading will say W.C (Water column). Example: 4 W.C.
Line regulator bodies are typically riveted together and cannot be rebuilt. Thread sealant approved for the type of fuel used should also be used to prevent gas leaks.

Hands-On Exercise: Adjust a regulator to achieve correct gas pressure

CHECK GAS PRESSURE USING A U-TUBE MANOMETER AND SET USING A REGULATOR ON A RANGE

☐ Position yourself in front of the range.
☐ Turn on the vent hood lights and fan above the range.
☐ Turn on the gas supply and light the top burner pilots.
☐ Determine the target amount of water column by looking at the data plate of the machine.
☐ What is the target water column measurement? _____________ W.C.
☐ Fill the U-tube manometer with tap water until the water level is at zero with the tube upright.
☐ Choose a burner orifice to connect to blow out the pilot next to it so you don't burn yourself. A small amount of gas will escape from this pilot.
☐ Connect the hose from the manometer to the burner orifice you have chosen. The other side of the U shaped tube should be open to the atmosphere.
☐ Open the burner valve. The gas pressure will push on the water causing it to move in the tube.
☐ The U-Shaped tube is numbered on both sides of the zero.
☐ What is the number on the left? ________________
☐ What is the number on the right? _______________
☐ Add the number on the left to the number on the right to get the inches of water column.
☐ What is the gas pressure measurement? ____________________ W.C.
☐ This reading is called "Static" pressure. Static pressure is the pressure when the machine is not being used.
☐ Now turn on three burners on the range. This will use up some of the gas volume.
☐ What is the number on the left? ________________
☐ What is the number on the right? _______________
☐ What is the gas pressure measurement? __________________ W.C.
☐ What happened to the gas pressure? _________________ (increase/Decrease/No Change)
☐ This reading is called the "Dynamic" pressure. Dynamic pressure is the pressure when the machine is being used. If the dynamic pressure is lower or higher than what the data plate calls for, you have found a problem, and you need to adjust the regulator until it matches the data plate requirement.
☐ Does it match your target gas pressure? ______________ (yes/no)

Exercise continued on next page.

Hands-On Exercise: Adjust a regulator to achieve correct gas pressure (Cont.)

□ Obtain a flat head screwdriver.
□ Locate the gas pressure regulator on the machine.
□ Remove the regulator adjustment screw cap.
□ Turn the adjustment screw clockwise ½ turn.
□ What is the gas pressure measurement? __________________ W.C.
□ Did the pressure increase or decrease? ____________________(increase/decrease)
□ Turn the adjustment screw counter clockwise ½ turn.
□ What is the gas pressure measurement? __________________ W.C.
□ Did the pressure increase or decrease? ____________________(increase/decrease)
□ Turn the adjustment screw counter clockwise ½ turn.
□ What is the gas pressure measurement? __________________ W.C.
□ Did the pressure increase or decrease? ____________________(increase/decrease)
□ You should now understand how to adjust gas pressure.
□ Set the gas pressure to the pressure specified on the data plate.
□ Have the instructor verify the gas pressure is correct.

Instructors initials: __________

□ Close the gas valve.
□ Remove the manometer tube.
□ Ensure all pilot lights are lit.
□ Store manometer.
□ Congratulations, you have completed this exercise.

Unit 10:
Components

Fundamentals of Gas

Cooktop Controls

Cooktop Temperature Controls

Temperature control in cooktops is very different from that in ovens. In cooktops, a gas valve varies the flow of gas to the burner. In ovens, the gas is either on or off; the burner cycles on and off to maintain temperature.

Another major difference is that when you turn on a gas cooktop, you can immediately see if it ignites. If it doesn't, you turn off the burner and figure out why. In ovens, since the burner is inside the oven, you cannot immediately see whether the burner has ignited. If it does not ignite, you certainly do not want the gas valve to stay open. This would dump raw unburned gas into the oven and create an explosion hazard.

This creates different ignition and safety needs for cooktops versus ovens. Cooktops use a standing pilot or spark ignition system. Ovens use a standing pilot, spark or glow bar ignition system, and gas safety valves that will not open unless ignition is assured.

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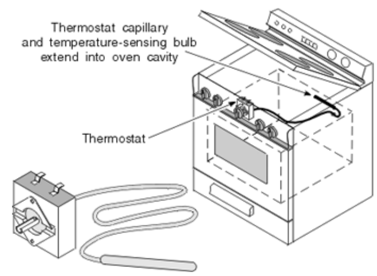
Thermostat Operation

Oven Setting Control

An oven that won't heat or heats unevenly most likely involves a faulty control, thermostat, or timer.

Oven Thermostats



Thermostats control temperature by sensing the temperature and controlling the gas flow to the burner. The sensing element is of the capillary tube style. A bulb holds fluid that also extends to the other end of the capillary tube. As a bulb heats up the fluid expands. This expansion causes a greater pressure at the end of the capillary tube and this pressure is used to gradually close the gas valve. Expansion and contraction of the fluid gives a throttled action that can be used to throttle the gas valve.
Both provide snap shut off of the gas if the temperature needs to be low while using a large burner. These are frequently found on convection ovens where different food products are cooked at different temperatures settings.

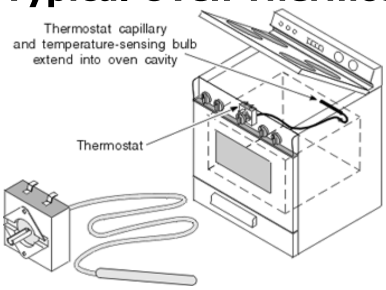
If the oven doesn't heat evenly or doesn't heat at all, the oven thermostat may be malfunctioning. First, determine how much the temperature in the oven is off from the control setting. To do this, put an oven thermometer on a center rack inside the oven and turn the oven on for about 20 minutes, with the thermostat set at any range between 300 degrees and 400 degrees Fahrenheit. If the oven thermometer reads 25 degrees higher or lower than the oven control setting, the thermostat should be recalibrated.

Unit 10:
Components

Fundamentals of Gas

Thermostat Operation

Typical Oven Thermostat



Thermostats are either gas or electric; pressure from the capillary either closes an electrical switch or opens a gas valve.

That is the simplest form of a main control thermostat. If there is an automatic oven cycle, main control thermostats must also be wired through the timer.

Main control thermostats are about the most expensive commonly-replaced parts in an oven. Usually the first thing a novice thinks is that the thermostat has quit working. It should be the last thing you conclude, after you have checked out everything else in the system.

The liquid inside the bulb and capillary of an oven thermostat is usually a mercury or sodium compound or some other such nasty and dangerous stuff. It can literally explode on contact with air. So when you replace an oven thermostat, do not cut open the capillary or bulb, and dispose of the old thermostat properly. The definition of "properly" varies between jurisdictions, but check with your appliance parts dealer or local fire department hazardous materials professionals.

Notes:

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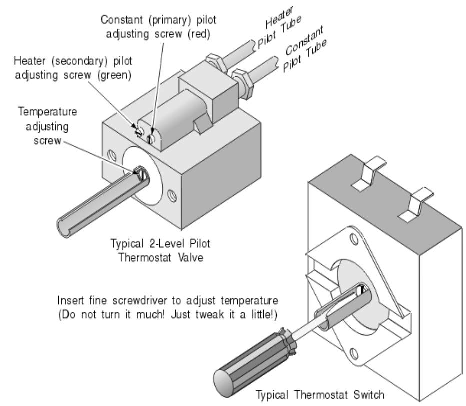
Thermostat Adjustments

ADJUSTING THERMOSTATS



The oven is adjusted by a small adjusting screw in the center of the oven thermostat valve stem. Remember that the thermostat keeps the temperature within a certain range, and usually there will be a 20 or 30-degree differential. In other words, if you set the thermostat at 350 degrees, you want the heating system to cycle on if the temperature is below 340 degrees, and off when the temperature reaches about 360 degrees. Don't forget, too, that heat rises, so the top of the oven might be warmer than the bottom of the oven.

Get a good calibrating thermometer. With nothing else in the oven, place it in the middle of the oven, where you can see it through the oven door glass. Let the burner cycle on and off at least twice, then observe the low temperature (when the burner cycles on) and the high temperature (when the burner cycles off.) Adjusting the screw adjusts both temperatures up or down.

Hands-On Exercise:

Test a thermostat

- ❑ 1. Set thermostat to 325 degrees F.
- ❑ 2. Check for proper temperature using a thermometer

Thermostat Control Body Types

ROBERTSHAW

CONTROL BODY TYPE

Body 1

Body 2
Straight Thru
Shallow Dish Mount

FD Series T'stats are heavy-duty, high capacity gas controls that have either *snap throttle* (FDO) or *throttle* (FDTO) valve action — see "Control Function."

Control Function

Type	Valve Action	Burner Flame Range	Typical Application
FDO	Snap Throttle	Full to Off	Oven (150 to 550°F)
FDTO	Throttle	Full to By-Pass	Oven (Low to 550°F)
FDH	Snap Throttle	Full to Off	Oven (650°F)
FDTH	Throttle	Full to By-Pass	Oven (650°F)
FDL	Snap Throttle	Full to Off	Liquid Fryers
FDTL	Throttle	Full to By-Pass	Liquid Fryers
FDS	Snap Throttle	Full to Off	Surface Griddle
FDTS	Throttle	Full to By-Pass	Surface Griddle

Thermostat Types

BJWA Gas Thermostat

- Combination gas cock & bypass type thermostat
- Typically used in oven, broiler & griddle applications
- Modulating seat action
- Capacity: up to 70k BTU/HR (natural gas)
- Ambient Temp: 32ºF (0ºC) to 350ºF (177ºC)

GS Gas Thermostat

- Snap acting hydraulic thermostat
- Typically used in small ovens, warming cabinets and fryers
- Snap acting from ‘off’ to full gas flow
- Capacity: up to 30k BTU/HR (natural gas)
- Ambient Temp: 32ºF (0ºC) to 200ºF (93ºC)

FD Gas Thermostat

- Heavy duty, high capacity thermostat
- Modulating only or modulating with snap by-pass versions
- Typically used in heavy duty ranges, deck, convection & baking ovens.
- Capacity: up to 100k BTU/HR (natural gas)
- Ambient Temp: 32ºF (0ºC) to 350ºF (177ºC)

Notes:

GS Thermostat

GS SERIES 4290 SERIES GAS THERMOSTATS

The Robertshaw® GS thermostat is a snap-acting hydraulic thermostat and is used to provide temperature control by interrupting gas flow to the burner. The GS gas thermostat is available for a wide variety of applications including small ovens, griddles, brooders, warming cabinets and fryers.

Features and Benefits

- Available in various temperature ranges, with temperature control up to 600°F (316°C)
- Snap-acting from OFF position to full gas flow
- Adjustable bypass key and bypass settings are optional
- Adequate capacity and small size for counter top appliances
- Applicable to use with high capacity gas operated diaphragm valves
- Adapts to limited mounting space
- Bulb and capillary assemblies supplied in copper, nickel plated copper, or stainless steel
- Dials in heat resistant plastic are available
- Available with main burner bypass or pilot outlet

Specifications

- Ambient temperature: 32°F to 300°F (0°C to 93°C)
- Maximum inlet pressure: 0.5 PSI
- Capacity (Natural Gas):
  - 3/8" pipe in and out 30,000 BTU/HR
  - 7/16" tubing in and out 30,000 BTU/HR
  - 1/4" tubing in and out 9,000 BTU/HR
- Agency Certification Numbers:
  - CSA 164327-1195957
  - BSi EN 257 (1992)
  - CE Certification applies only to GSE models
  - Certification EC 87/96/11/MS (2009)
  - CE 0086

FDTO Thermostat

FDTO Type Thermostat[23]

The standard oven uses an FDTO-type, modulating thermostat. When first turned on, the flame comes on full speed, approximately 1 1/4" to 1 1/2" tall. As the temperature approaches the set point, the flame slowly reduces in size. When the temperature is achieved, the flame should be in bypass, approximately 1/8" tall. The bypass flame
will keep the oven temperature constant unless the door is opened and heat is lost.
When the oven needs to recover heat loss, the thermostat will allow the flame to slowly increase in size until the temperature is again at the set point. Usually the thermostat does not require calibration, however it may need to have the bypass flame set at the time of installation. The temperature accuracy of this thermostat is 25°F.

Field recalibration is rarely necessary on new appliances, however older thermostats may require calibration. Recalibration should only be considered when cooking results definitely indicate the thermostat is not maintaining the set temperature. Before attempting recalibration, the temperature should be checked with temperature test instrument or a reliable thermometer.

Standard Oven with FDTO Thermostat [23]

1. Place the test instrument sensor or thermometer in the center of the oven cavity and close the door.
2. Turn oven on, set the thermostat dial to 300 degrees and allow the oven to cycle several times (at least 20 minutes).
3. Turn the thermostat dial back to the lowest temperature setting. Check the bypass flame; it should be 1/8" tall. Adjust bypass as necessary (Diagram #9).
4. Turn thermostat dial back to 325°F and allow 5 minutes for temperature to stabilize. If temperature is more than 20°F different from the dial setting, calibrate as follows.
   - A. Remove dial and loosen the calibration plate screws until the calibration plate moves freely. Gently attach dial and turn until the dial setting matches the actual oven temperature (Diagram #9).
   - B. Hold calibration plate. Gently remove dial and tighten calibration plate mounting screws. Apply adhesive material to calibration screws
   - C. Replace dial and increase temperature 50°F. Allow 10 minutes and recheck the temperature.
   - D. If temperature is still more than 20°F different from the dial setting, the thermostat may need to be replaced.

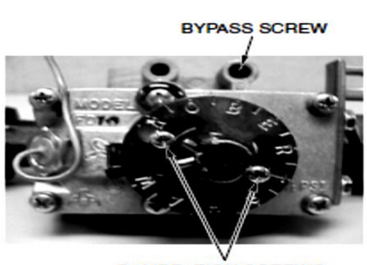


DIAGRAM #9

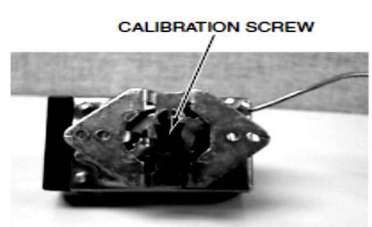


DIAGRAM #10

KX Thermostat

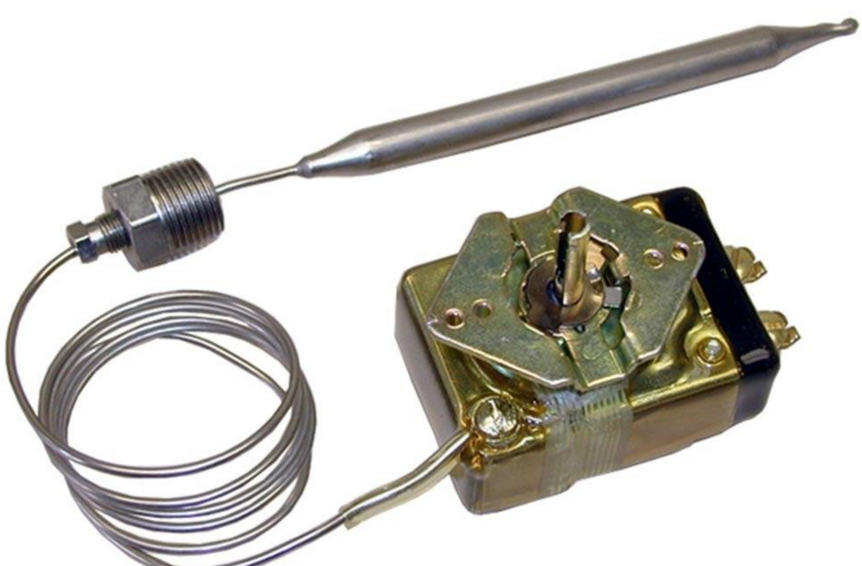
KX-Type Thermostat

Snorkel and electric ignition ovens use a KX-type snap action thermostat. When first turned on, the flame comes on full speed. When it achieves the set temperature, it shuts off. When 10°F to 15°F is lost, the thermostat will come on full speed to recover the heat loss. Due to the fact the thermostat shuts completely off and the oven is constantly venting heat off through the flue, the thermostat will cycle on and off throughout the cooking process.

The temperature accuracy of the KX thermostat is 15°F to 20°F.

Snorkel Oven and/or Electric Ignition Oven with KX Thermostat

1. Place the instrument sensor or thermometer in the center of the oven cavity and close the door.
2. Turn fan switch on. Set temperature dial to 300°F. Allow oven to cycle at least five times (approximately 15 minutes). If the temperature is more than 15°F different from the dial setting, calibrate as follows.
   A. Pull the dial straight off. Turn the calibration screw (Diagram #10) clockwise to decrease temperature or counterclockwise to increase temperature (1/4 turn equals approximately 35°F).
   B. Replace dial and increase temperature 50°F. Allow oven to cycle at least three times and recheck the temperature.
   C. If the temperature is more than 15°F different from the dial setting, the thermostat may need to be replaced.

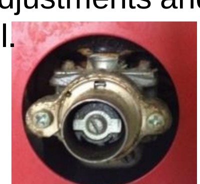


BJWA Thermostat

BJWA Type Thermostat
The thermostat used on griddles is a BJWA modulation type. When first turned on the flame comes on full speed, approximately 3/4" to 1" tall. As the temperature approaches the set point, the flame is slowly reducing in size. When the temperature is achieved, the flame should be in bypass. Bypass flame for griddles should only be big enough to keep the burner lit all the way around, with little blue dots of flame. This type of thermostat by design will allow the temperature to creep if the griddle is left idling, with no product on the griddle, for a minimum of 50°F an hour. Therefore it is imperative that the bypass flame be correct. If the bypass flame is not correct, the temperature will creep to 100°F to 200°F an hour. Temperature accuracy of the BJWA thermostat is 25°F.

NOTE: Calibrations and/or bypass adjustments require a good working knowledge of the components and system as well as specific test instruments and should only be performed by authorized service personnel. When checking calibrations on the BJWA griddle thermostat, it is necessary to begin the procedure when the griddle is cold. Attempting to calibrate the BJWA griddle thermostat from other than a cold start is extremely difficult, as well as time-consuming, and can cause the temperature to be incorrect at a later time.

NOTE: Although the BJWA thermostat is a very simple and basic thermostat, it is somewhat difficult to calibrate due to the fact that once the bypass is set, it must be recognized as in full bypass at the time the temperature reading is taken. Additionally, if the temperature reading is not taken as soon as the thermostat is in full bypass, the temperature will begin creeping up, and a true temperature reading will not be possible.
In the event that a thermostat has to be replaced, use extreme care when handling and installing the sensor probe. Do not kink or severely bend the probe. Do not allow direct flame to come in contact with the probe or the capillary line. Any excess capillary line should be gently coiled up in an area that is away from direct flame and/or working or cleaning areas. Warranty does not cover thermostats that have been rendered inoperative by improper adjustments and/or calibrations or by work being performed by unqualified personnel.



Griddles with BJWA Thermostat

Griddles with BJWA Thermostat

Before attempting recalibration on the BJWA thermostat, a temperatures check must be done from a cold start, before the griddle has been idling and the temperature has had a chance to creep up. All temperature readings and/or calibrations must be performed from a cold start. Thermostats can be rendered inoperative by improper calibration and/or adjustments.

• Clean the griddle plate and make sure there is no carbon buildup on the cooking surface. Carbon buildup will cause a false temperature reading.

• Remove the temperature dials and manifold cover. Locate sensor probes. Temperature readings can only be taken directly over the sensor probes. The sensor probes will be located as follows. Approximately 6“ from the left side splash, then 12" spacing and the last sensor probe will be approximately 6" from the right side splash (Diagram #11).

• Once the left-to-right locations are identified, measure 12" from the front of the cooking surface. That is where the temperature readings will be taken.

• Pull off all the thermostat dials. Using a screwdriver from the back of the dial, push out the center chrome cap of the dial. Replace dial on the thermostat.

• Turn the dial to 300°F. The flame should be approximately 3/4" to 1" tall. Allow about 15 minutes for the plate to heat up.

• Turn the dial to the lowest temperature setting (150°F). Check the bypass flame; it should be only big enough to keep the burner lit all the way around (little blue dots of flame). Adjust as necessary (Diagram #12).

• Take note of the size of the bypass flame, as it will be necessary to recognize when the thermostat is in bypass throughout the calibration process.

• Turn the dial up enough for the flame to come on at least 1/4" tall. When the flame is in bypass, again take a temperature reading in the area previously identified as the probe location. If the temperature is more than 25°F different from the dial setting, calibrate as follows.

• With the dial in place, use a small screwdriver through the opening in the front of the dial locate and depress calibration screw. Do not turn the calibration screw. Rotate the dial to match the actual temperature on the griddle plate. Release the calibration screw.

• Turn the dial to increase the temperature 50°F. Watch flame and as soon as the flame is again in full bypass, take a temperature reading. If the temperature is more than 25°F different than the dial setting, the thermostat may need to be replaced.

• Once the thermostat is determined in calibration, that thermostat should be turned off so as not to cause false readings on the other zones.

• Repeat the process for each thermostat zone.

• Once all the thermostats are calibrated, reassemble the dials and reinstall the manifold cover and the thermostat dials.

Robertshaw BJ Thermostat Installation and Service

Robertshaw®

INSTALLATION DATA
4350 SERIES
COMMERCIAL THERMOSTAT BJ UNI-KIT®

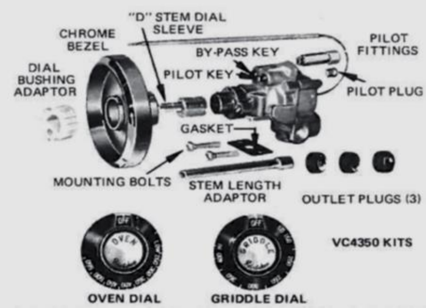
DESCRIPTION

The Robertshaw® 4350 Series Commercial Thermostat Uni-Kit® is designed specifically for heavy-duty commercial oven and griddle "applications. The High-Temperature thermostats with steel bulb and capillary are supplied in these kits.

The thermostat can be mounted in any of the four manifold positions. Rear housing may be rotated as required. Plugs are included with models having four-position outlet tapping.

Four-position dial, stem length adaptor, and chrome bezel are included.

These kits will replace model BJ and BJWA commercial thermostats. Separate kits are available for oven and griddle applications. Kits will also replace earlier Uni-Line models.



INSTALLATION INSTRUCTIONS

> **CAUTION**
> THIS DEVICE SHOULD BE INSTALLED BY A QUALIFIED PERSON WITH DUE REGARD FOR SAFETY AS IMPROPER INSTALLATION COULD RESULT IN A HAZARDOUS CONDITION.

ROTATION OF REAR HOUSING

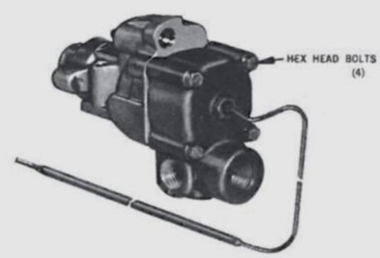
In many applications, rotation or repositioning of the rear housing is not required. If the rear housing on the replacement control is in the desired position proceed to fittings and plugs.

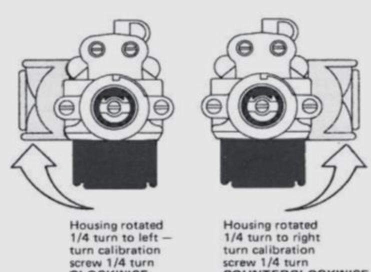
For applications requiring a change in the housing position, proceed as follows:

1. Remove pilot fitting if installed in control.
2. Remove four hex head bolts on rear of control while applying pressure to hold rear housing against main control body housing. (See illustration at right).
3. Rotate rear housing to desired position.
4. Replace and tighten the four hex head bolts.

NOTE: Rotation of the rear housing will also change calibration.

Recalibration of the control after changing rear housing position is easily done at room temperature. View the control from the front using a screwdriver, push in the calibration screw in the center of the gas cock plug. Turn this screw 1/4 turn in the same direction the housing was rotated (viewed from the front). See illustration at right. If housing was rotated 1/4 turn to the side position, the calibration screw must also be turned 1/4 turn in the same direction as the housing was rotated.





FITTINGS AND PLUGS

Install plugs into outlets not required and assemble pilot fitting or plug into pilot outlet. Use a small amount of thread compound on each plug and fitting.

UNCOIL DIASTAT

NOTE: Diastat is liquid filled and sharp bends are to be avoided.

The recommended method to uncoil the diastat is as follows:

Insert a round screwdriver shaft through the center of the diastat coil. Push outward or away from control body to uncoil the diastat smoothly. This method will prevent twisting or crimping.

MOUNTING

Mount control on manifold using new flange nipple gasket and mounting bolts.

Connect outlet and pilot lines as required for the application.

Attach the sensing bulb into its proper location. Again use caution not to twist or crimp the capillary tube.

Robertshaw BJ Thermostat Installation and Service

DIAL ASSEMBLY

Insert "D" stem dial sleeve into front of control and snap in place.

The dial bushing adapts the dial to any of the four control mounting positions. Assemble bushing into dial as follows.

Note stem flat position of dial sleeve. Hold dial with "OFF" position at the top and press dial bushing into back of dial so that "D" opening in bushing will match position of stem flat on dial sleeve. See illustration of bushing assembly at right.

If it is necessary to reposition bushing after it is pressed into dial, push out metal-insert on front of dial with small screwdriver. This will allow bushing to be pushed out the back of the dial.

When addition stem length is required, use the stem length adaptors as follows:

1. Place adaptor on "D" stem and place dial on adaptor.
2. To determine correct adaptor length measure distance from back of dial edge to front of panel. Cut this amount from small end of adaptor.
3. If a tighter dial fit is desired spread the end of the "D" stem and stem length adaptor slightly.

BEZEL INSTALLATION

Bezel and sleeve are installed by sliding center sleeve over dial guide on the front of the control.

If standard sleeve is too short, remove from bezel. Use pliers to apply light pressure and squeeze the adaptor slightly to disengage locking tabs. Install correct length sleeve in bezel.

Bezel index position can be changed to match manifold mounting position of control. Snap sleeve out of bezel as described above, rotate to required position, end snap into bezel.

OPERATING INSTRUCTIONS

ADJUSTMENTS

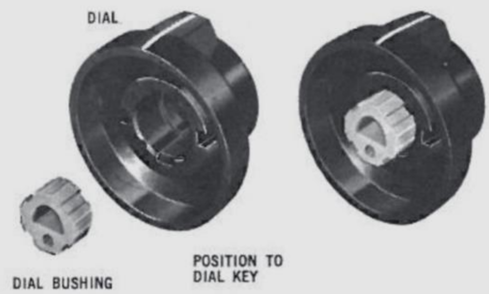
To adjust pilot: (on many applications the pilot is plugged and adjustment is located on safety valve or manifold.)

1. Push dial inward, turn to 300° mark and light the burner.
2. Remove dial. Dial is keyed into place - do not twist or turn it. Grasp the dial at the outer edge and pull straight out.
3. With a screwdriver, turn Pilot Adjusting Key counterclockwise to increase the flame, clockwise to decrease it, until the flame is approximately 3/4" long.
4. Replace dial, turning clockwise until it locks in the "Off" position.

To Adjust By-Pass Flame: (Minimum burner flame)

When the unit reaches the temperature at which the dial is set, the control cuts down the flow of gas to the amount required to keep the unit at that temperature. Always, however, the control must by-pass enough gas to keep the entire burner lit: To maintain this minimum flame, the by-pass must be set carefully and accurately as follows:

1. Light the burner, then turn dial to "High".
2. After 5 minutes, turn dial clockwise to point slightly beyond first mark on dial.
3. Remove dial.



4. With a screwdriver, turn by-pass adjusting key counterclockwise to increase the flame, clockwise to decrease it, until there is a flame approximately 1/8" high over the entire burner.
5. Replace dial, turning clockwise until it locks in the "Off" position.

SERVICE INSTRUCTIONS

To recalibrate control:

This control is a precision instrument. It is carefully calibrated at the factory that is, it is adjusted so that dial settings match actual tempertures. Field recalibration is seldom necessary, and should not be resorted to unless considerable experience with cooking results definitely proves that the control is not maintaining the temperatures to which the dial is set.

Recalibration should not be undertaken, however, until the by-pass flame has been adjusted.

To check temperatures when recalibrating, use a test instrument or a reliable mercury thermometer. Place the thermocouple lead of test instrument in the middle of the oven. Use surface type thermocouple lead for griddles.

If Recalibration is required, use tha following procedure:

1. Set dial to 400° mark and light oven burner. (300° for griddles)
2. After burner has been on about 15 minutes, check temperature. Oven door should be open for as short a time as possible. Use a flashlight, if necessary, to see the thermometer reading clearly.
3. Continue to check temperature, at 5-minute intevals, until two successive readings are within 5 degrees of each other.

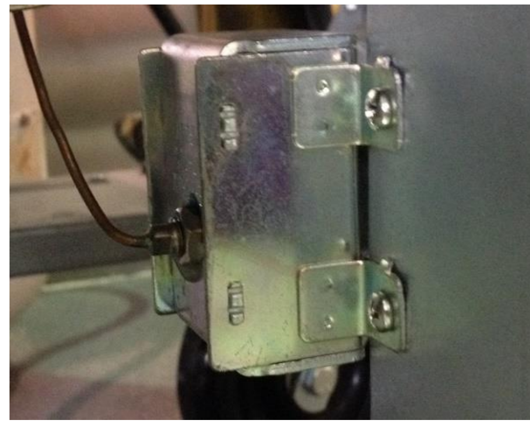
If recalibration is required, the additional steps to be taken are these:

4. Remove dial assembly with "D" type stem.
5. Push calibration stem (in center of gas cock stem) inward with screwdriver, while holding calibration stem firmly in, turn slot clockwise to obtain a lower temperature or counterclockwise for a higher temperature. Each mark on retainer represents 25 degrees. Replace "D" type stem with dial.
6. Check temperature again, as instructed in (2) and (3).

Unit 10:
Components

Fundamentals of Gas

High Limit Switch



Kelly Wells

Ebay.com

High Limit Operation

The high-limit thermostat acts as a normally closed power switch that opens when exposed to temperatures above their preset activation temperature. High limits typically have to be manually reset by pressing a reset button. High limits are typically wired in series with the operating thermostat.

High Limit Application in a Fryer

In the event that a fryer fails to properly control the oil temperature, the high-limit thermostat prevents the fryer from overheating to the flash point. A thermostat stuck in the closed position will keep the burners on continuously which will increase the oil temperature to the point of activating the high limit.

Open or Grounded High Limit

The high-limit thermostat functions as a normally closed switch. If the high-limit is open or grounded, the gas valve coil will not pull in, and no gas will be supplied to the pilot or to the burner manifold.
Check and Corrective Action: Detach the high-limit leads from the gas valve and check for continuity. If the high-limit fails the continuity check, it must be replaced.

Loose/Corroded Wiring Connections

This has the same effect as an open or grounded high-limit. If the gas valve coils do not receive the appropriate voltage from the thermopile, they will not close, and no gas will be supplied to the pilot or to the burner manifold.
Check and Corrective Action: Check wiring connections for corrosion and tightness. Check terminals to verify that they are securely attached to their leads.

Hands-On Exercise:

- ❑ Test a high-limit switch for continuity with a digital multi-meter.

Frymaster.com

Thermocouple Operation

What is a Thermocouple?
A thermocouple is an electrical device that responds to temperature change by a change in voltage output. A thermocouple works to produce a small electrical voltage output by connecting two dissimilar metals. When heated the effect of the two dissimilar metals in contact with one another is the production of an electrical current.

Use of Thermocouple Voltage
This voltage, in turn, can be used to cause a gas valve to open or remain open, or to close, stopping the supply of LP or natural gas fuel should a pilot light or gas flame go out on a heating appliance.

Safety
Shutting down the gas supply to a heating appliance protects against a gas fire or explosion that could occur if a gas regulator valve remains open without proper ignition of the gas flame.

Thermocouple Applications
In general, we think that thermocouples are less accurate and less sensitive temperature sensors than thermistors, but these low-cost and reliable temperature sensing devices have been used successfully in heating equipment such as gas-fired furnaces, boilers, cooking equipment, and water heaters for decades. Thermocouples are also used on gas logs and in gas fireplaces or similar devices.

Types
Thermocouples are produced in a wide range of forms and configurations, in eight or more calibration groups (B,E, J, K, R, S & T) with different temperature ranges including up to very high temperatures such as 3000^{o}F.

Hands-On Exercise:
- ❑ Locate and identify a thermocouple on a machine.

Unit 10:
Components

Fundamentals of Gas

Thermocouple Operation

Thermocouples as Safety Devices
Thermocouples are used as safety devices that will shut off equipment by shutting down the LP or natural gas fuel supply on some gas-fired heating equipment such as gas fired furnaces, gas-fired cooking equipment, gas fired heating boilers, and gas fired water heaters.

Location on Equipment
Typically the thermocouple sensor is mounted right in the flame of the pilot light on gas fired heating equipment.

Connections
The thermocouple on gas-fired heating appliances is mounted to sense the presence of a gas flame or gas pilot flame. It should be placed in the hottest part of the flame which is generally around the top 1/3rd to ½ of the pilot flame. The other end of the thermocouple's tubing connects to a port on the gas regulator or gas valve. Connection to this port should be tight.

Electronic Ignition
But not all of these systems use a thermocouple. Some gas-fired heating equipment relies on an electronic ignition to ignite the flame. Those devices generally will not use a thermocouple. If a thermocouple is used, you'll see a small copper tube (or in some devices an electrical wire) connecting the flame sensor to the valve.

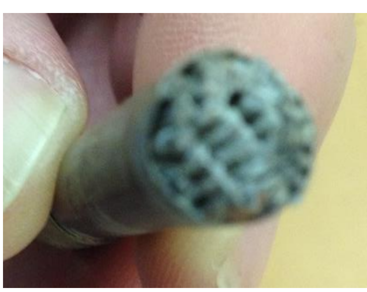
Safety Functions
The thermocouple and safety shutoff do double duty, since on burners that use a pilot flame, the thermocouple senses the pilot flame and won't permit the gas valve to open if the pilot is not lit. (A bad thermocouple itself can prevent a gas furnace or boiler from working - if you can light the flame at the pilot manually, but then the flame goes out when you release the manual gas feed valve, the thermocouple is probably bad).

Thermocouple vs. Thermopile

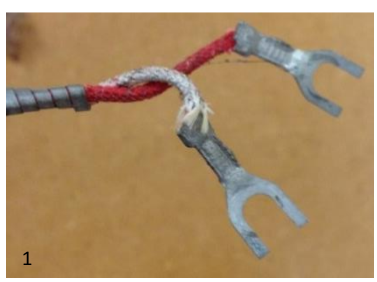
What is the difference between a thermocouple and a thermopile?
Not much for practical purposes, except that when replacing a thermocouple on your heating appliance you should be sure to purchase the proper part.

Visual Differences
A thermopile looks like a thermocouple, and does the same job - sensing a gas flame to function as a safety device. Thermopiles are made by combining multiple thermocouples together in order to produce more electrical current than a basic thermocouple. Externally a thermopile still looks like a single sensing device.

Thermocouple Voltage vs. Thermopile Voltage
Thermocouples produce around 17 - 30 millivolts. When not connected to a load you should expect to see around 30 millivolts. Thermopiles produce around 350 - 750 millivolts. When not connected to a load a thermopile produces around 750 millivolts.



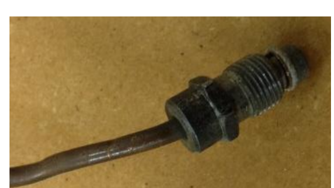
Inside of a thermopile



Thermopile gas valve electrical connections

The part of the thermocouple that sits in the flame

A thermocouple



The part of the thermocouple that connects to the gas valve

Flame Sensor Operation

The flame sensor is a rather simple device located at the burner assembly. It's not much more than a thin, usually bent, metallic rod that sits in front of the flame stream inside the furnace. The purpose of the flame sensor is to confirm to the system that whenever the gas valve is open, a fire is actually present. If a flame is not present, the flame rod will not heat up and therefore will not send current to the ignition module. The ignition module will then shut down power to the gas valve preventing gas from accumulating.

Hands-On Exercise:

- ❑ Test a flame sensor for continuity
- ❑ Clean a flame sensor

Unit 10:
Components

Fundamentals of Gas

Flame Rectification

Today's units react to unsafe conditions in less than a second. This is accomplished through the use of "computerized control modules" and a flame sensing control system known as flame rectification.

With the growing use of ignition control modules, it is imperative that the modern service technicians understand the sequence of operation of the module as well as the phenomenon known as flame rectification. The modern commercial food industry relies on the process.

The safety used in today's ovens is the flame sensor. It is nothing more than a stainless steel rod encased in porcelain. By itself, it does nothing. When attached to a control module, the module sends out an A/C voltage to the sensor. This voltage is always present at the sensor. When the burners ignite, the flame hits this sensor creating a "path to ground through the flame" for the A/C voltage. When this happens, a pulsating D/C signal, in the form of microamps goes back to the control, and the module decides if the signal is strong enough to allow the unit to continue operating. Nominal flame current on today's units are about 1 ½ to 3 ½ microamps. Because this system is "electronic," it reacts to unsafe ignition problems in fractions of seconds instead of minutes.

Internally, in the control module, once the flame is established, current begins flowing in the flame sensing circuit. The current energizes a relay in the control. A minimum amount of current is needed to energize this relay (microamps). When this relay pulls in, one set of contacts open to de-energize the ignition system and another set of contacts closes to keep the main gas valve energized. It is important to know the minimum microamps that are required to "lock in" the control module and keep the unit running.

If the proper amount of microamps is not present, the control will not allow the main valve to remain open and shuts the unit down. Depending on the control, it may or may not go into "retries" to prove that flame was established.

One of the most common causes of flame failure is the sensor. Keep in mind that the control is sending out an A/C voltage signal. If the sensor becomes dirty or corroded, it is like covering the stainless steel probe with insulation and the current can not pass through the flame (ground) and create the D/C signal back to the board. Or, if the wire is cracked or the porcelain is cracked, the voltage "bleeds" off to ground at the point of the "leak" changing the microamp signal to the board and not allowing it to lock in. This is why it is imperative for the MODERN SERVICE TECHNICIAN to have a microamp meter to see if the control module is getting the proper signal. Without this tool, diagnostics becomes very difficult.

It is the ability of the sensor to pass voltage, through the flame to ground, and create a D/C signal back to the board that allows the system to operate. When this signal is not present, the control responds in a fraction of a second to shut the unit down safely.

Since the flame sensor is the primary safety for ignition, the signal should be checked every time a unit is cleaned and serviced. If the signal is getting weak, the sensor should be cleaned. Cleaning it is a fix if the signal does not reach the nominal microamps required by the control. Keep in mind that this is the primary safety in the unit. It is important to make sure that it functions properly.

Unit 10:
Components

Gas Safety Valves

Photo Credit: Kelly Wells

How a Gas Oven Safety Valve Works

Safety valves ensure a gas range's oven won't come on without ignition. Gas ovens, unlike gas cooktops, use a burner hidden from view so you can't see whether the burner has ignited.

To prevent an explosion hazard from an unlit oven burner, ovens feature a gas safety valve that won't open until ignition is assured by means of an electric glow bar, pilot flame or electric spark.

Combination valves are a combination of a gas safety valve and a gas regulator built into one unit.

Baso Valve

Redundant Style Valve

TS Style Valve

Combination Valve

<u>Hands-On Exercise:</u>

- ❑ Locate and identify a gas safety valve

Robertshaw Gas Safety Valves

TS11 Gas Oven Safety

- Typically used in mV oven, broiler & griddle applications
- Cuts off main burner gas flow in event of pilot outage
- Available in 'J' and 'K' versions
- Capacity: up to 210k BTU/HR (natural gas)
- Ambient Temp: 32ºF (0ºC) to 350ºF (177ºC)

7000 Regulated Gas Valve

- Typically used in various commercial applications (e.g. fryers)
- Available for mV up to line voltage applications.
- Capacity: up to 360k BTU/HR (natural gas)
- Higher and lower capacity versions available
- Ambient Temp: 32ºF (0ºC) to 175ºF (79ºC)

7000 BGOR Bleed Gas Valve

- Bleed control valve
- With or without gas cock
- Straight line gas pressure regulation
- Various gas types

Dual Gas Solenoid

- Normally closed solenoid available in single or dual versions
- Capacity: Single up to 119k BTU/HR. Dual up to 110k BTU/HR each outlet, 165k BTU/HR total with both sides open
- 24, 120 & 240 VAC versions available
- Ambient temp: -40ºF (-40ºC) to 275ºF (135ºC)

Robertshaw TS Valve

Robertshaw

TS SERIES THERMOMAGNETIC
1720 SERIES SAFETY VALVES

The Robertshaw® TS Series thermomagnetic safety valve is a control used to cut off the flow of gas to the burner in the event of a pilot outage. The magnet assembly is energized by voltage generated by a thermocouple that is heated by the pilot flame. When this flame is extinguished, the thermocouple voltage decreases until a spring overcomes the magnetic force and closes off both the pilot and main gas. This control can be used for commercial and residential ovens, infrared heaters, chicken and pig brooders, recreational vehicle gas appliances and many more applications requiring automatic safety valves.

Features and Benefits

- 300°F (149°C) ambient temperature rated and 350°F (177°C) versions available
- TS11J - available with separate pilot inlet/outlet tube connections
- TS11K - gas flows from main inlet
- Compatible with other Robertshaw models such as the BJ, FD, and GS series thermostats
- RoHS compliant
- Agency Certifications
  - CSA Certification number 164327-1910372

Specifications

Main Size		Capacities BTU/HR @ 1" WC PD	
Inlet	Outlet	Natural Gas	LP Gas
1/4" Pipe	1/4" Pipe	97,000	157,000
1/2" Pipe	1/2" Pipe	210,000	340,355
7/16" Tubing	7/16" Tubing	99,000	160,599
3/8" Pipe	7/16" Tubing	99,000	160,599
3/8" Pipe	3/8" Pipe	135,000	218,999

Pilot Connections		
Model	Inlet	Outlet
J	1/8" Pipe	1/8" Pipe
J	1/4" Tubing	1/4" Tubing
J	3/16" Tubing	3/16" Tubing
K	NA	1/8" Pipe
K	NA	1/4" Tubing
K	NA	3/16" Tubing

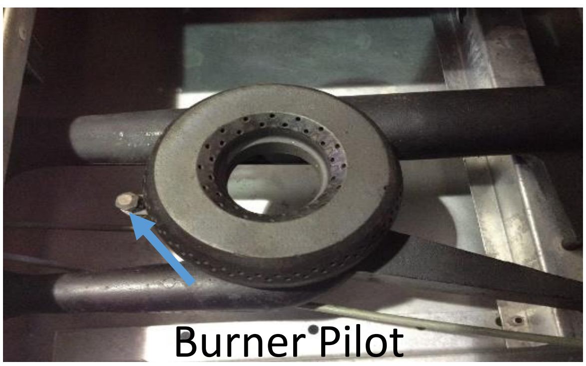
CSA US *An ISO 9001 – 2008 Certified Company*

Robertshaw.com

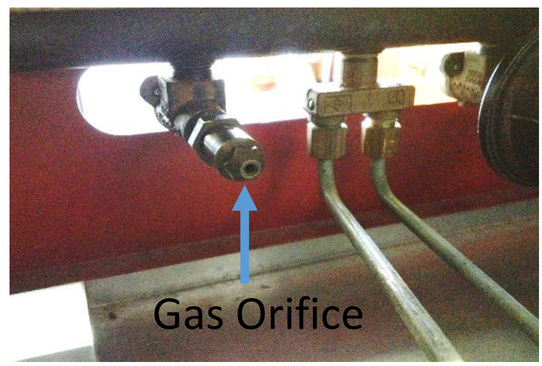
Unit 10:
Components

Atmospheric Burner Operation

An atmospheric burner is typically found on open burner ranges. The end of the burner sets on the fuel orifice. When the gas valve is opened up, fuel flows through the venturi. This creates a vacuum and draws in air (primary air) from the kitchen through holes in the adjustable shutters. The gas air mixture flows through the holes on the burner head and is ignited by the pilot flame at the burner.



Kelly Wells



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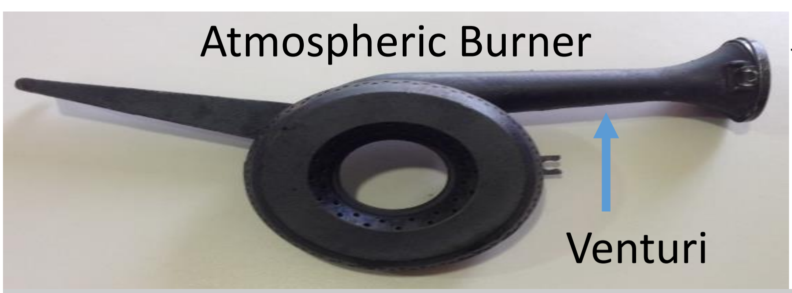

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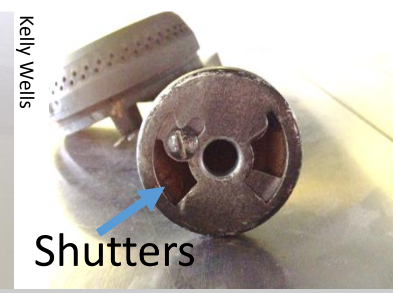
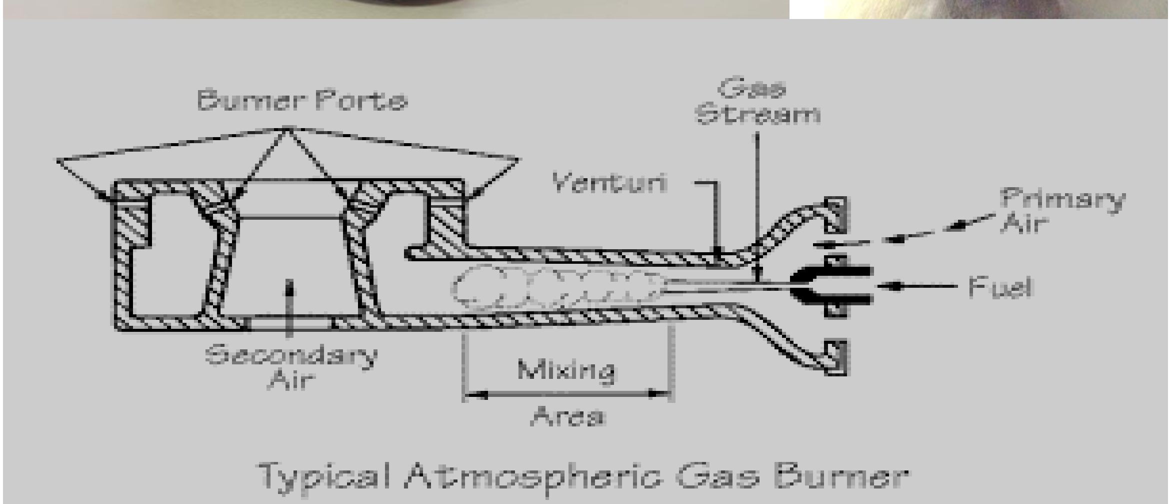




Combustiontechnology.co.za

Unit 11:
Basic Gas Maintenance

Fundamentals of Gas

Cleaning Equipment

Cleaning
Housekeeping/cleaning is a vital part of appliance maintenance. Individual procedures will vary from operation to operation. When properly cleaned and well-maintained, appliances will provide many years of reliable performance. The information provided is intended to provide general information about the cleaning equipment.

Flickr.com

Painted Surfaces
Use a soft cloth with mild detergent and warm water. Wipe off spills as they may occur with a soft cloth and warm water. Do not use abrasives or harsh chemicals on painted surfaces.

Webstaruantstore.com

Stainless Steel Surfaces
Stainless steel is resistant to most cleaners, so detergent or degreasers can be used. Be sure to read the instructions on the product before using it on your appliance. A petroleum-based stainless cleaner/polish may be used on exterior areas that are not near a cooking surface. Abrasive cleansers and/or cleaning pads will scratch the surface.

Flickr.com

Cast Iron Grates
The grates can be cleaned by using a wire brush or a steel wool pad. Also, the grates can be cleaned in a dishwasher, however rust may occur. To help retard rust after water is used, a light coat of cooking oil can be applied to the grate. If oil is applied, the grates will smoke when the burners are used; therefore the oil must be “burned off” before using the burner to cook the product.

Webstaruantstore.com

Cast Iron Hot Tops
The top surface of the cast iron hot top can be cleaned by using a steel wool pad or an abrasive scrubber. Occasionally the bottom side of the hot top should be inspected for carbon and/or soot and cleaned as necessary with a wire brush.

Unit 11:
Basic Gas Maintenance

Fundamentals of Gas

Cleaning Equipment

Standard Oven Interior
The standard oven has a porcelain coating on the bottom (floor) of the cavity as well as the inner liner of the door. These surfaces can be cleaned with a commercial degreaser or oven cleaner. The side walls, ceiling and back wall of the oven cavity is made of aluminized steel, which can be cleaned with a non-caustic cleaner. The use of caustic cleaner will damage the aluminized steel; a detergent-based cleaner is recommended.

Flickr.com

Convection Oven
The entire oven cavity is coated with porcelain and can be cleaned with a commercial degreaser or oven cleaner. The fan cover and blower wheel is made of aluminized steel. Caustic cleaners will damage the aluminized material and should not be used on these parts. Use of water on or near the fan should be minimized.

Commons.Wikimedia.org

Oven Racks and Guides
The racks are chrome plated and can be cleaned in a dishwasher. A steel wool soap pad can be used in conjunction with a commercial degreaser or oven cleaner.

Griddle Plates
Allow the plate to cool to approximately 250°F. Apply a small amount of water on the griddle plate (the amount can be controlled with a spatula). At 250°F the water will boil and loosen the cooking debris, use the spatula to scrape off the stubborn debris. Use a clean towel to wipe up the debris. Use abrasive (griddle stone, griddle screen or a product called Scotch Brick) with oil or water. Use the abrasive to remove the carbon buildup. Wipe the plate with a cloth. Apply a small amount of cooking oil. Spread the oil evenly over the surface.

Katom.com

Vulcanfeg.com

Cleaning Tips

Grill Cleaning

The main purpose of cleaning a griddle plate is to remove the cooking debris and prevent carbon buildup. Product will stick to a new griddle plate due to the fact that steel is porous. After a griddle has been used, the pores of the steel will fill with carbon and the plate will be almost nonstick due to the fact that carbon has filled the pores of the steel plate. However, excessive carbon build up will decrease the performance of the griddle, and there will be taste transfer to the food product. Occasionally (once or twice a year) it is recommended that a commercial grill cleaner be used.

Cleaning Products

Whenever a cleaning product is used, the product instructions must be read, understood and followed. Be extremely careful when using any and all caustic cleaners, as they do pose a safety hazard to the user as well as a potential hazard to any food product that may come in contact with the product itself or the residue. Make sure to thoroughly wash the unit with fresh, clean water before cooking again. Be advised that after a cleaner is used on the plate, product will likely stick until the pores are again filled with carbon. After a grill cleaner has been used, product sticking can be reduced by heating the griddle plate to approximately 300°F, rubbing beef fat on the plate and allowing the grease from the fat to lightly burn into the plate.

Constant Use of Cleaners

Constant use of griddle cleaners will cause a grease-bubbling effect around the perimeter of the griddle plate. This occurs because the splashes are welded to the bottom surface of the griddle plate and there is a slight gap on the cooking surface in which grease will accumulate. Normally this grease will solidify and become carbon; and the carbon will fill the gap. The cleaner will break down the carbon barrier that has been formed, and new grease and/or water residue will bubble up. Therefore this situation can be avoided by allowing the grease to solidify and create a carbon barrier.

Scheduled Maintenance

Scheduled Maintenance
In order to provide maximum performance and proper operation, and to ensure the safety of the operator, all equipment must be serviced at least once a year by an authorized servicer. If for any reason an appliance has not been in use or has been in storage for any time, it is imperative that the unit be inspected by an Authorized Servicer prior to reinstallation and/or operation.

Recommended Service Frequency
- 10 to 12 hours of operation per day, 7 days a week, every 30 to 60 days.
- 8 to 12 hours of operation per day, 5 days a week, every 90 days.
- 4 to 6 hours of operation per day, 5 days a week, every 120 days.
- Limited daily usage, every 180 days.

Inspection Items
- Check for the slightest odor of gas. If detected, locate and correct as necessary.
- Check for valves that are hard to turn or that are seized up.
- Verify that all burners light in 2 or 3 seconds.
- Check that all burner ports are clean.
- Check that burners burn sharp, clean and blue, not yellow. Propane (LP) may have a small yellow tip.
- All pilots are lit and set to the proper height (see pilot adjustment section).
- Look for grease, debris and/or carbon buildup.
- Check all moving parts for ease of movement and/or wear.
- Verify that thermostats are functioning and temperatures are correct.
- Inspect and verify that all panels, covers, racks and rack guides are intact and properly installed and are not binding or falling out.

Problems Found
If any of these items are found to be incorrect, malfunctioning or in need of attention, immediately contact an Authorized Servicer to repair or correct the problem.

<u>Hands-On Exercise:</u>

- [ ] Perform the items listed on the Inspection Items checklist above.

Manometer Types

One of the earliest pressure measuring instruments is still in wide use today because of its inherent accuracy and simplicity of operation. It's the U-tube manometer, which is a U-shaped glass tube partially filled with liquid. This manometer has no moving parts and requires no calibration. Manometry measurements are functions of gravity and the liquid's density, both physical properties that make the U-tube manometer a NIST standard for accuracy.

Manometers are both pressure measurement instruments and calibration standards. They range from simple U-tubes and wells filled with liquid to portable digital instruments with a computer interface.

Manometer Use

As shown in Figure 1, with each leg of a U-tube manometer exposed to the atmosphere, the height of liquid in the columns is equal. Using this point as a reference and connecting each leg to an unknown pressure, the difference in column heights indicates the difference in pressures (see Figure 2).

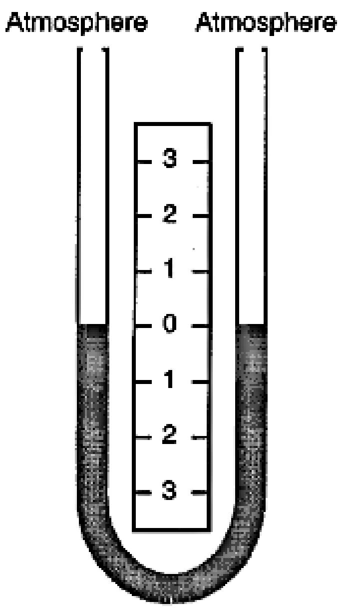


Figure 1. With both legs of a U-tube manometer open to the atmosphere or subjected to the same pressure, the liquid maintains the same level in each leg, establishing a zero reference.

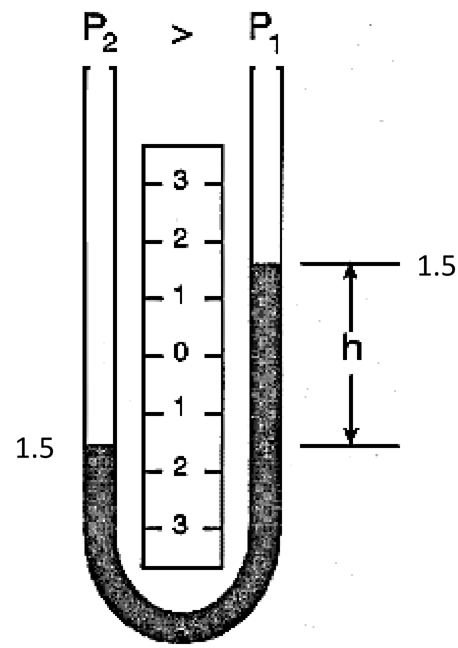


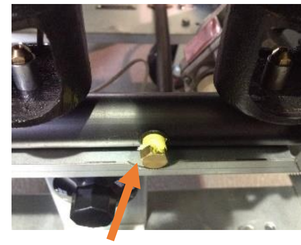
Figure 2. With a greater pressure applied to the left side of a U-tube manometer, the liquid lowers in the left leg and rises in the right leg. The liquid moves until the unit weight of the liquid, as indicated by h, exactly balances the pressure.

To find gas pressure in “inches of water column” add the reading at P2 (which is 1.5 in figure 2) and the reading at P1 (which is 1.5 in figure 2).

P_2 + P_1 = “WC

1.5 + 1.5 = 3” WC (Water Column)

Manometer Use (Cont.)



Manometer Connection Point on a Fryer

The fundamental relationship for pressure expressed by a liquid column is:

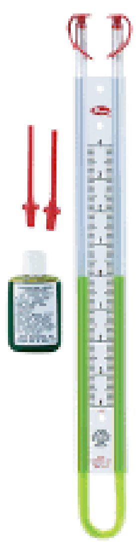
$$\Delta p = P_2 - P_1 = \rho g h$$

where:

Δp = differential pressure
P_1 = pressure at the low-pressure connection
P_2 = pressure at the high-pressure connection
ρ = density of the indicating fluid (at a specific temperature)
g = acceleration of gravity (at a specific latitude and elevation)
h = difference in column heights

The resulting pressure is the difference between forces exerted per unit of surface area of the liquid columns, with pounds per square inch (psi) or newtons per square meter (pascals) as the units. The manometer is so often used to measure pressure that the difference in column heights is also a common unit. This is expressed in inches or centimeters of water or mercury at a specific temperature, which can be changed to standard units of pressure with a conversion table.

All pressure measurements are differential. The reference can be zero absolute pressure (a total vacuum), atmospheric pressure (the barometric pressure), or another pressure. With one leg of a manometer open to the atmosphere (see Figure 3A), the measured pressure is that which exceeds atmospheric pressure, which at sea level is 14.7 psi, 101.3 kPa, or 76 cmHg.



U-Tube Manometer

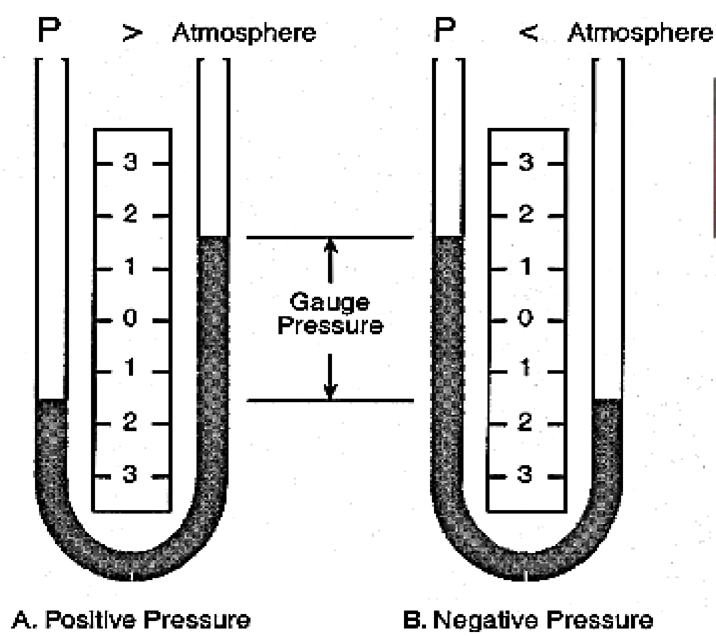


Figure 3. Gauge pressure is a measurement relative to atmospheric pressure and it varies with the barometric reading. A gauge pressure measurement is positive when the unknown pressure exceeds atmospheric pressure (A), and is negative when the unknown pressure is less than atmospheric pressure (B).

Manometer Connection Point at the burner orifice on an open burner range

Digital Manometer

Carbon Monoxide Detectors

What is a Carbon Monoxide Detector?
Carbon Monoxide (CO) Detectors are designed to detect Carbon Monoxide. Most units have a very fast reaction time, and measure CO in parts per million (ppm). Some have electrochemical sensors that are fast enough for walk-around tests. Fast electrochemical sensors helps you find CO sources like cracked heat exchangers or breached flue stacks.

Features
Some features and benefits may include:
- Field-replaceable CO sensor
- Advanced three-pin sensor measures 0 to 1000 ppm CO
- Calibrate / Zero detector to ambient quickly with the ZERO button
- Audio and visual alarms w/mute
- Bright-blue, backlit dual-display with MAX and real-time measurements displayed
- Magnetic hanger for hands-free operation
- Auto Power-Off (APO).

How to Use
Some detectors respond to changes in CO levels in real time.
- Zero the unit outdoors away from any source of CO (will not zero if CO levels are higher than 5ppm)
- Enter the structure
- Walk around and watch the display
- Move toward the area of highest concentration to find the CO source

Carbon Monoxide Detector

Hands-On Exercise:
- ❑ Operate a CO Detector

Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

Combustion Analyzer Operation

Hands-On Exercise:
- ❑ Operate a Combustion Analyzer

We measure it. testo

Light Industrial Combustion Analyzer

testo 330-2G LL

- Measures O_2, CO (up to 8,000 ppm / 30,000 ppm w/ dilution), Nitric Oxide Sensor (optional), draft, ambient and flue temperatures
- Dilution prevents CO sensor overrange, maximizing sensor life
- Optional in-stack zeroing feature eliminates climbing the stack to remove the probe and zero the instrument before restarting measurement
- Pre-programmed fuels, including solid fuel
- Calculates CO_2, efficiency, excess air, CO air free
- O_2 / CO Long-Life Sensors (up to 6 years) 4-year sensor warranty
- On-board instrument diagnostics & quick leak check
- Up to 10 hours continuous operation with rechargeable Lithium batteries

O_2 | CO | amb. CO | CO_2 | Draft Diff. | amb. CO_2 | Effic. | Temp. Diff.

Bluetooth®
(Optional for iOS and Android)

The testo 330-2G LL combustion analyzer offers accurate combustion analysis with colorful charts and graphs that save time and reduce uncertainty during tuning and troubleshooting. Simply set the parameters and watch real time results on the display in either standard "numeric" or "graphic" view during tuning adjustments.

The 330-2G LL provides easy operation with simple icons and intuitive menus. Bluetooth and Bluetooth printer option, a 4-year warranty -- the longest in the market -- and long life O_2 and CO sensors, with an expected sensor life of up to 6 years, makes the 330-2G LL a combustion analyzer that will serve you well.

Additionally the 330-2G LL comes equipped with a Quick Start function - zero start-up time with probe in the flue and the ability to Zero in high stack for sampling without having to climb ladders. The testo Combustion App uses measurement data to create custom reports (including adding photos and comments). Information and reports can be saved as files and / or sent by e-mail in PDF or Excel format.

Other notable features include:
- Data logging up to 2 hours (stores 500,000 readings)
- Differential pressure
- Differential temperature (with optional probes)
- Gas pipe testing: pressure drop, pipe commissioning, etc
- Gas leak (with optional probe)
- Wide temperature range
- USB connectivity to PC with EasyHeat software

Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

General Equipment Safety and Operation

General Equipment Operation

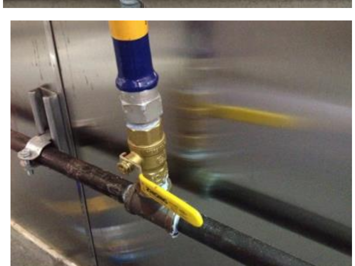
Gas and electric ranges and ovens operate fairly simply, and they're usually easy to repair, mainly because the components are designed for quick disassembly.

Most of the malfunctions that affect gas ranges involve the supply and ignition of gas in the burners and the oven. Most malfunctions that affect electric ranges and ovens involve faulty heating elements. We'll discuss how the main parts should work on gas and electric ranges and ovens and how to service them regularly to avoid larger, more expensive problems. The first step is taking a peek inside to assess the problem.

Caution: Before doing any work on a gas range or oven, make sure it's unplugged, or turn off the electric power to the unit by removing a fuse or tripping a circuit breaker at the main entrance panel or at a separate panel. If there is a grounding wire to the range, disconnect it. Also close the gas supply valve to shut off the unit's gas supply. Follow Lockout Tagout procedures as needed.

Gas Fuel Parts

The different fuels require valves and burners with different orifice sizes, so when ordering parts, make sure you get the right ones for the fuel you are using.



Hands-On Exercise:
Locate gas and electrical supplies

- ❑ 1. Locate a gas meter
- ❑ 2. Locate a gas shut-off valve
- ❑ 3. Locate a breaker panel

Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

Gas Leaks

GAS LEAKS

Gas and Odor

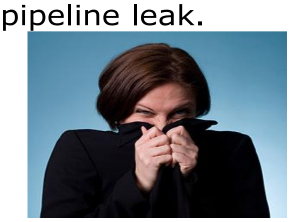
Natural gas and LP are: Colorless, Odorless, and Tasteless.
A chemical odorant that smells like Sulphur is added to the gas by the gas company so it can be detected if there is a leak. This odorant is called Mercaptan.

Mercaptan

Mercaptan stinks. It smells like Sulphur or rotten eggs because it contains Sulphur. In a concentrated form, its smell is almost unbearable.
And it takes only a few parts per million (ppm) of Mercaptan for the average person to wrinkle a nose and say, "What is that smell?" The kind we use blends well with natural gas and, in a gaseous state, has much the same properties as natural gas, so it will also rise and dissipate with natural gas. It is not always used though. If we did not add Mercaptan, it would be hard for you to know that unlit natural gas was coming from your stove after you left the valve turned on and leaks from furnaces and hot water heaters would be nearly impossible to detect without expensive equipment. So, the smell of Mercaptan is a very valuable safety feature.

Recognizing Gas Leaks

Though statistically rare, natural gas pipeline leaks can occur due to natural disasters, damage by third-party contractors or hidden corrosion. That’s why it’s important to learn how to spot — and respond to — a pipeline leak.



- **SMELL the air.**
  We add a distinctive odor to natural gas so that leaks are easier to detect. Not all gas has been odorized, so do not attempt to detect a natural gas leak by smell alone.
- **LISTEN for leaks.**
  A hissing, whistling or roaring sound near a pipeline may indicate escaping natural gas.
- **LOOK for clues:**
  Look for a damaged connection to a gas appliance, dead or dying vegetation over or near a pipeline, dirt spraying in the air, and ponds bubbling, a fire near a pipeline, or an exposed pipeline after an earthquake, fire, flood or other disaster.

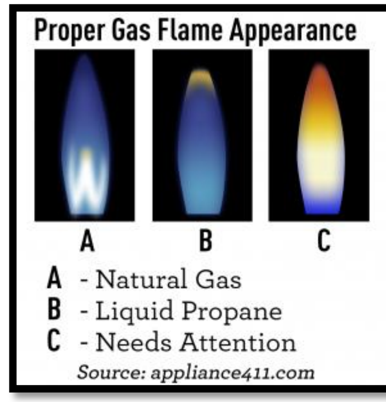
Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

Flame Structure

Combustion Process
Flame Structure

A flame has three cones. The center cone is the un-burnt gas/air mixture. Surrounding it is the inner cone. Combustion is starting here. Combustion produces heat, which cause expansion of the gas/air mixture making the outer cone larger. In the outer cone, the gas/air mixture combines with the secondary air to complete the combustion process. The outer surface of the flame is called the mantle.



Proper Performance

In a properly adjusted burner, all parts of the flame are shades of blue and the flame makes equal contact all around or along the burner. It should be steadily sitting on the burner and not jumping or dancing around. Note: It is normal for LP gas to exhibit yellow tips.

Orange or Red Flames

Orange or red flames are caused when dust particles pass through the flames. This does not affect the quality of the flame and is normally not a problem. Humidity can potential affect the color of the flame as well.

Before and after humidifier

Notes:

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Proper Pilot Flame

Correct Flame	Tip of thermocouple or thermopile 3/8" to 1/2" into pilot flame
Wavy Blue Flame	Draft condition at pilot
Noisy, Lifting Blowing Flame	High gas pressure Wrong pilot orifice
Lazy Yellow Flame	Clogged primary air opening Low gas pressure Clogged pilot orifice
Hard Sharp Flame	High gas pressure Pilot orifice too small
Small Blue Flame	Wrong pilot orifice size Low gas pressure Clogged pilot tube

Hands-On Exercise:

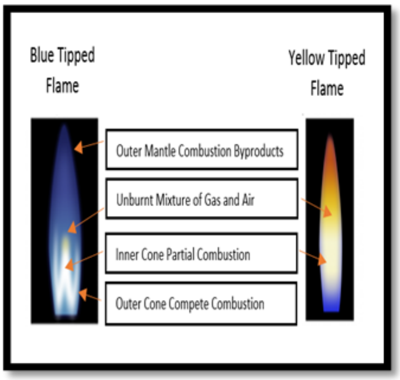
- ❑ Light the burner pilots on an open burner range
- ❑ Light an oven pilot
- ❑ Duplicate the scenarios in the possible cause column and compare your results with the possible cure.

Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

Improper Flames

Improper Flame Performance



Yellow Tipping

When using natural gas, the yellow tipping of flames in the outer cone is caused when there is a reduction of primary air. The shortage of air in the air/fuel mix results in un-burnt fuel. Yellow tips are caused by incomplete combustion and is caused by carbon passing through the flame. This can usually be resolved by adjusting the primary air shutters on the burner to increase air flow. Lint or debris blocking the primary air flow can also be the culprit. Also check for correct gas pressure.

Soot

Yellow flames that produce soot (carbon) forms can be problematic. Soot is formed when yellow flames touch a cool surface before the carbon is burned off. Soot creates a cleaning headache and can start to clog up ventilation flues.

Lifting Flame

Flames that lift off the burner, or may be flickering or noisy, may be caused excessive primary air. Excessive primary air can allow un-burnt fuel to be released. If this happens, adjust the shutters slowly until the flame settles down. This condition may also be caused by too much gas pressure. Check the gas pressure using a manometer and set it to the water column amount specified on the equipment data plate.

Floating Flames

Lack of secondary air (air around the burner) will cause the flames to float up in search of oxygen. This can be caused by poor ventilation (restricted flues) or lack of make-up air (fresh air). This may also occur at higher elevations where the air is less dense. These flames can release un-burnt fuel and may eventually go out.

Unit 12:
Basic Gas Troubleshooting

Fundamentals of Gas

Air Shutter Adjustment

The efficiency of the oven depends on a delicate balance between the air supply and the volume of gas. Whenever this balance is disturbed, poor operating characteristics and excessive gas consumption will occur.

The gas mixer balance is controlled by an air shutter on the front of the oven burner. A yellow streaming flame on the burner is an indication of insufficient air. To correct this condition, loosen the screw locking the shutter into position. Rotate the air shutter open until the burner flame begins to lift from the burner, then close the shutter slightly down again and lock it into place (Fig's. 5 & 6).

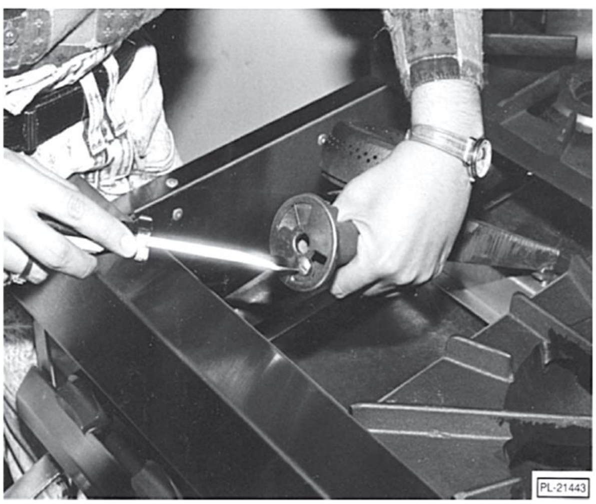


Fig. 5

Fig. 6

<u>Hands-On Exercise:</u>

- ❑ Locate and identify the air shutters on an open burner range.
- ❑ Adjust the air shutters on an burner

Notes:

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Thermocouple Troubleshooting

Common Thermocouple Related Issues 30

- ❑ A bad replacement thermocouple or one that was bent, kinked, damaged during installation
- ❑ Thermocouple not properly connected at the control, e.g. the sensor connector not fully screwed-in
- ❑ Thermocouple sensor tip not properly mounted, secured in the flame path
- ❑ Sudden drafts - equipment may be installed outdoors or in a shelter exposed to wind.
- ❑ Low gas pressure - weak flame
- ❑ Inadequate combustion air - very dangerous, can be fatal
- ❑ Dirt on the equipment Dirt or debris or insects (spiders) clogging the pilot orifice or pilot light gas tube
- ❑ Bad or dirty thermocouple - Short cycling or unexplained on-off cycling of heating equipment

<u>Hands-On Exercise:</u>

- ❑ Test a thermocouple for millivolt production with a DMM.

Notes:

Gas Troubleshooting Tips

Troubleshooting Tips for Gas

Condition	Possible Cause	Possible Cure
Delayed Ignition	1.Improper ignition location 2.Pilot flame too small 3.Burner ports clogged 4.Low outlet pressure	1.Reposition ignition source 2.Check orifice and clean 3.Clean burner ports 4.Adjust pressure regulator
Failure to Ignite	1.Main gas "Off" 2.Poor electrical connections 3.Defective gas valve 4.Defective thermostat	1.Open manual valve 2.Check, clean, & tighten 3.Replace with new 4.Replace with new
Burner won't turn "Off"	1.Poor thermostat location 2.Defective gas valve 3.Defective thermostat	1.Relocate thermostat 2.Replace with new 3.Replace with new

- When all else fails… check gas supply is in the "ON" position

<u>Hands-On Exercise:</u>

- ❑ Duplicate the scenarios in the possible cause column and compare your results with the possible cure.

Flame Troubleshooting Tips

Condition	Possible Cause	Possible Cure
Flame Too Large	1. Outlet pressure too high 2. Defective regulator 3. Orifice too large	1. Change gas valve 2. Change regulator 3. Change orifice
Noisy Flame	1. Excessive primary air 2. Noisy pilot 3. Burr in orifice	1. Adjust air shutter 2. See Proper Pilot Flame slide 3. Remove burr or replace orifice
Yellow Tip Flame	1. Too little primary air 2. Clogged burner ports 3. Misaligned orifice	1. Adjust air shutter 2. Clean burner ports 3. Realign orifice and burner
Floating Flame	1. Blocked venting 2. Insufficient primary air	1. Inspect vent and clean 2. Adjust air shutter

Hands-On Exercise:

- ❑ Duplicate the scenarios in the possible cause column and compare your results with the possible cure.

Troubleshooting Common Problems

Problem	**Probable Cause**
Oven will not hold temperature.	• Thermostat out of calibration. • Bypass flame too high or too low. • Oven door not closing properly.
Oven slow to heat.	• Low gas pressure. • Wrong orifice. • Vent in pressure regulator blocked. • Oven door not closing properly.
Oven will not recover.	• Bypass flame too low. Low gas pressure. • Vent in pressure regulator blocked. • Oven door not closing properly.
Product (in oven) not cooking evenly.	• Wrong orifice. • Unit not level. • Burner deflector or oven bottom warped. • Door not closing properly. • Product placement improper. • Gas pressure fluctuating.
Product (in oven) dried out.	• Temperature too high or too low. • Thermostat out of calibration. • Too long of a baking time.
Griddle will not hold temperature.	• Thermostat out of calibration. • Bypass flame too high. • Vent in pressure regulator blocked. • Gas pressure fluctuating. • Wrong dial on thermostat.

Troubleshooting Common Problems

Problem	Probable Cause
Griddle will not heat evenly.	• Unit not level. • Wrong orifice. • Flue obstructed. • Gas-to-air ratio incorrect. • Burner ports obstructed.
Product sticking to griddle.	• Temperature too high. • Griddle not reseasoned after cleaning. • Excessive carbon buildup on griddle.
Burner valves hard to turn.	• Valve lubricant dissipated. • Valve core/plug scored. • Dirt/debris in valve. • Valve stem or knob rubbing on front panel.
Top burner will not light.	• Wrong orifice. • Gas-to-air ratio incorrect. • Incorrect gas pressure. • Vent in pressure regulator blocked. • Pilot burner positioned incorrectly. • Burner ports obstructed. • Obstruction in venturi. • Make-up air/drafts directed toward burner. • Water or grease in burner. • Pilot flame too big or too small.

Troubleshooting Common Problems

Problem	Probable Cause
Oven burner will not light.	• Pilot flame too low or not lit. • Pilot burner not positioned properly. • Wrong burner orifice. • Gas pressure incorrect. • Vent in pressure regulator blocked. • Gas-to-air ratio incorrect. • Draft or air movement around oven burner. • Oven burner obstructed. • Oven burner baffle out of position. • Oven burner not on orifice correctly.
Oven pilot outage.	• Pilot orifice obstructed. • Low gas pressure. • Insufficient gas volume. • Vent in pressure regulator blocked. • Oven flue obstructed or disturbed by draft. • Poor pilot flame. Pilot burner deteriorated. • Draft or breeze near floor. • Burner box cover missing. • Excessive door slamming. • Thermocouple MV output low. • Failed safety valve.
Griddle will not recover.	• Thermostat swing beyond specification. • Thermostat out of calibration. • Wrong orifice. Low gas pressure. • Thermostat sensor not in correct position. • Gas-to-air ratio on burner incorrect. • Bypass flame too low to keep burner lit. • Product volume beyond griddle capacity. • Product placement incorrect.

Troubleshooting Common Problems

Problem	Probable Cause
Gas odor.	• One or more pilots not lit. • Quick disconnect fitting not properly engaged. • A burner is not on the orifice fitting properly. • Poor combustion on one or more burners. • A burner is not completely lighting. • Loose and/or broken gas line or fitting. • Leak in gas connector hose. • Pressure regulator ruptured.
Oven pilot will not light (standard oven).	• Air not purged from gas lines. • Red button not depressed long enough. • Pilot orifice clogged. • Incorrect pilot orifice. • Excessive air movement in pilot area. • Failed safety valve. • Failed thermocouple.
Oven pilot will not light (with spark ignition).	• Failed spark module. • Broken or deteriorated spark wire. • Door seal missing.

Notes:

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Troubleshooting Common Problems

Problem	Probable Cause
Charbroiler will not heat evenly.	• Valves turned on too high. • Incorrect orifice. • Orifice obstructed. • Gas pressure too high. • Radiants warped. • Burners deteriorated. • Gas pressure fluctuating. • Grates obstructed with cooking/product debris.
Repeated component failure.	• Improper use of appliance. • Fluing problem. • Poor housekeeping. • Water damage. • Not properly installed. • Make-up air/draft problem. • Insufficient exhaust. • Repairs made using incorrect/non-OEM parts. • Gas pressure too high. • Power surge. • Poor electrical ground.

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Troubleshooting Common Problems

Problem	Probable Cause
Stainless steel turning blue.	• Direct flame hitting panel. • Temperature hitting over 500°F.
Stainless steel turning brown.	• Product spill-over not removed and burning. • Grease-laden air being cooked on surface.
Paint peeling or flaking.	• Surface being hit by direct flame. • Exposed to harsh cleaner/chemical. • Exposed to grease and/or acidic juices.
Griddle plate turning blue.	• Temperature hitting over 500°F. • Thermostat out of calibration. • Failed thermostat.
Griddle plate turning black.	• Too high of a cooking temperature. • Product residue burning on plate. • Temperature hitting over 500°F. • Thermostat out of calibration. • Failed thermostat.

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Improper Fryer Burner Troubleshooting

Burners Light on One Side Only
If the burner lights on one side only, the probable causes are a missing or misaligned rear deflector or improper burner manifold pressure. Clogged burner orifices are usually the cause of gaps in burner firing.

Fluctuating Flame Intensity
Fluctuating flame intensity is normally caused by improper or fluctuating incoming gas pressure, but may also be the result of variations in the kitchen atmosphere. Variation in the kitchen atmosphere is usually caused by air conditioning and/or ventilation units starting and stopping. As the units start and stop, the pressure in the kitchen may change. Changes in airflow patterns can also affect flame intensity. If the incoming gas pressure is correct and stable, check for variations in the kitchen atmosphere.

Flame Rollout
Flames “rolling” out of the fryer are usually an indication of negative pressure in the kitchen. Air is being sucked out of the fryer enclosure and the flames are literally following the air. If negative pressure is not the cause, check for high burner manifold gas pressure. An obstructed flue, which prevents the fryer from properly exhausting, may also be the cause.

Noisy Burner
An excessively noisy burner, especially with flames visible above the flue opening, may indicate that the burner gas pressure is too high, or it may simply be that the gas valve vent tube is blocked. If the gas pressure is correct and the vent tube in unobstructed, the gas valve regulator is probably defective.

Slow Recovery Rates
Occasionally a burner may apparently be operating correctly, but nevertheless, the fryer has a slow recovery rate (the length of time required for the fryer to increase the oil temperature from 250ºF to 300ºF (121ºC to 149ºC). The primary causes of this are low burner manifold pressure and/or misaligned or missing deflector targets. If both of these causes are ruled out, the probable cause is a gas valve regulator that is out of adjustment.

Additional Hands-On Exercises

- ❑ Troubleshoot a gas safety valve
- ❑ Adjust a combination safety valve to achieve correct gas pressure for the appliance.
- ❑ Read through an open burner range service manual
- ❑ Start up an open burner range
- ❑ Troubleshoot an open burner range
- ❑ Shut down an open burner range
- ❑ Read through a fryer service manual
- ❑ Start up a fryer
- ❑ Troubleshoot a fryer
- ❑ Shut down a fryer
- ❑ Read through a convection oven service manual
- ❑ Start up a convection oven
- ❑ Troubleshoot a convection oven
- ❑ Shut down a convection oven

Unit 13:
Basic Gas
Extras

Helpful Website Links

www.Robertshaw.com
www.Honeywell.com
www.Vulcanequipment.com
www.Blodgett.com
www.emersonclimate.com
www.lincolnfp.com
www.testo.com
www.frymaster.com
www.cfesa.com

Commercial Food Equipment Service Technician

Fundamentals of Steam

Introduction to Steam Cooking Equipment

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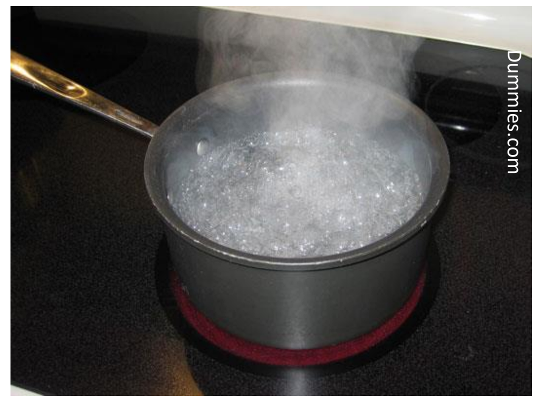
Unit 1:
Introduction to
Steam Systems

Fundamentals of Steam

What is Steam?

What is Steam?

Steam is an invisible gas that's generated by heating water to a temperature that brings it to the boiling point of 212 degrees F at atmospheric pressure.
When this happens, water changes from a liquid to a gas.
So, steam is the gas form of water.



Conversely, when heat is removed from steam, it loses its ability to stay a gas and condenses back into water. We refer to the resulting liquid as condensate.

Hands On Exercise:

- [ ] Create Steam by Boiling Water

Cooking with Steam

Why Cook with Steam

©Ebay.com

Steaming is a method of cooking using steam. This is often done with a food steamer, a kitchen appliance made specifically to cook food with steam, but food can also be steamed in a wok. Steaming is considered a healthy cooking technique that can be used for many kinds of food.

Steam Cooking Method

Steam cooking is extremely fast and efficient and is done so mostly through latent heat and not the 212 degree sensible heat. Steaming works by boiling water continuously, causing it to vaporize into steam; the steam then carries heat to the nearby food, thus cooking the food. The food is kept separate from the boiling water but has direct contact with the steam, resulting in a moist texture to the food.

Benefits of Cooking with Steam

©onlymyhealth.com

Cooking with steam preserves flavor, texture, colors, and nutrients better and 212 degree atmospheric steamers preserve all of these characteristics. Overcooking or burning food is easily avoided when steaming it. Individuals preferring to avoid additional fat intake may prefer steaming to methods which require cooking oil. Steaming also results in a more nutritious food than boiling, because fewer nutrients are leached away into the water, which is usually discarded.

www.wiikipedia.com

Unit 2:
Steam Science

Fundamentals of Steam

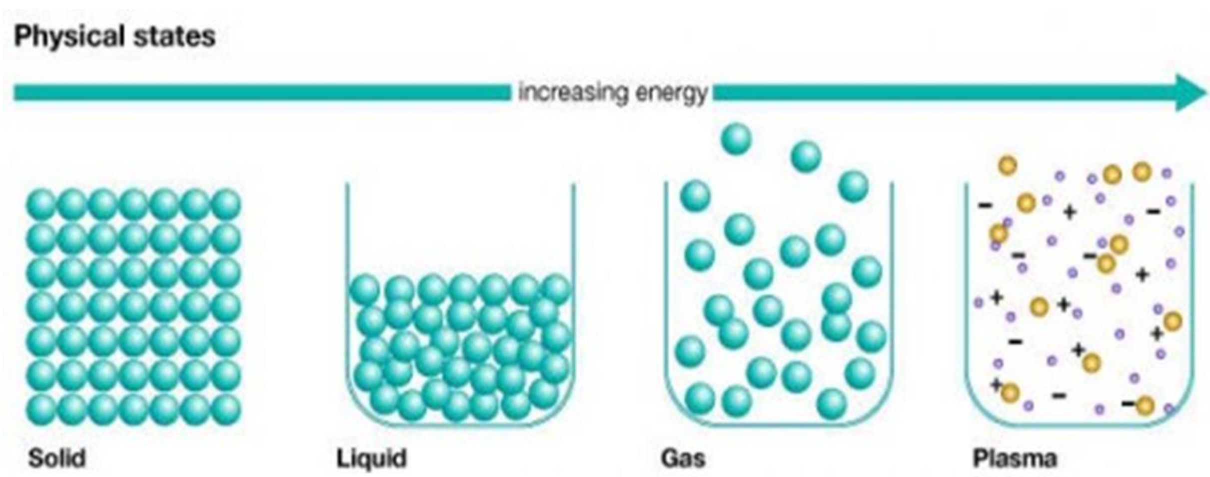
Physical States of Matter

Matter can exist in different states. Four states are shown below:

- Solid
- Liquid
- Gas
- Plasma

A fifth state of matter exists called Bose-Einstein Condensate (groups of atoms that behave as one).

In the food service equipment industry, we only deal with solids, liquids, and gases.



Solid: The molecules that make up a solid are arranged in regular repeating patterns. They are held firmly in place but can vibrate within a limited area.

Liquid: The molecules that make up a liquid flow easily around one another. They are kept from flying apart by attractive forces between them. Liquids assume the shape of their containers.

Gas: The molecules that make up a gas fly in all directions at great speeds. They are so far apart that the attractive forces between them are insignificant.

Plasma: At the very high temperatures of stars, atoms lose their electrons. The mixture of electrons and nuclei that results is the plasma state of matter.

Unit 2:
Steam Science

Fundamentals of Steam

Introduction to Vapor and Steam

What is Vapor?

Vapor is a gas. There is no significant physical or chemical difference between a vapor and a gas. A vapor is a substance in gaseous state, at a condition where it is ordinarily a liquid or a solid.

©Dupont.com

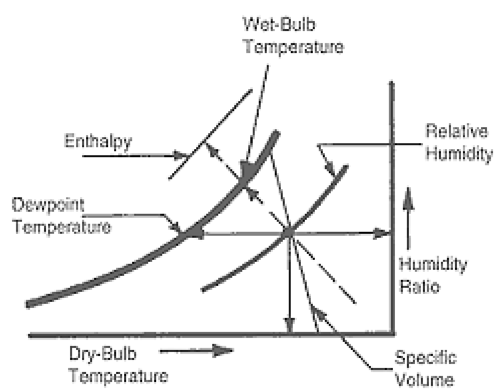
Moisture

The most common example of a vapor is steam (water vaporized during boiling or evaporation). The water vapor in the atmosphere is invisible and is often called **moisture**. Knowledge about moisture in air is important for the design of air-condition applications like HVAC systems and industrial dryers.

©Maintenancetechnology.com

Air Psychrometrics

Moist air technology is often called Air Psychrometrics. Evaporation from a fluid takes place when liquid molecules at the liquid surface have enough momentum to overcome the intermolecular cohesive forces and escape to the atmosphere. When heat is added to a liquid the molecular momentum and the evaporation of the liquid is increased. A reduction of the pressure above a liquid reduces the momentum needed for molecules to escape and evaporation is increased. Increased pressure above a liquid reduces evaporation. This can be observed as the lower water boiling temperature at higher altitudes.



©Web.uconn.edu

http://www.engineeringtoolbox.com/vapor-steam-d_609.html

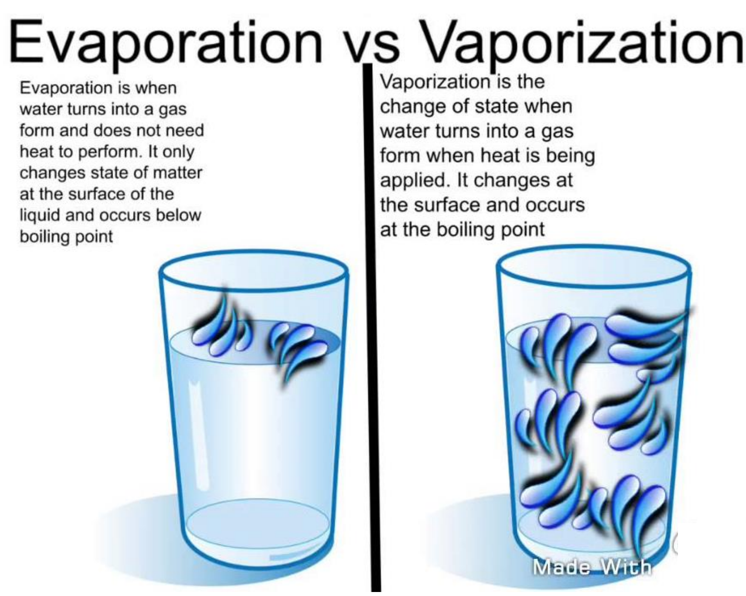
Vaporization

Vaporization

Vaporization is the conversion of a liquid to a gas. Vaporization can occur through either evaporation or boiling.

Because the particles of a liquid are in constant motion they frequently collide with each other, transferring energy when they do so. This energy transference has little net effect beneath the surface, but when enough energy is transferred to a particle near the surface; it may gain enough energy to be knocked completely away from the sample as a free gas particle. This process is called evaporation and it continues as long as liquid remains. It is interesting to note that a liquid cools as it evaporates. The energy transferred to surface molecules, which causes their escape, is carried away from the remaining liquid sample.

When enough heat is added to a liquid that vapor bubbles form below the surface of the liquid, we say that the liquid is boiling. The temperature at which a liquid boils is variable. Boiling point is dependent upon the pressure the substance is under. A liquid under higher pressure will require more heat before vapor bubbles can form within it. At high altitudes, there is less atmospheric pressure pressing down on the liquid, so it will boil at a lower temperature. The same amount of liquid at sea level is under a greater atmospheric pressure and will boil at a higher temperature.



http://www.livescience.com/46506-states-of-matter.html

Unit 2:
Steam Science

Fundamentals of Steam

Terms Related to Vapor and Steam

Common terms in connection with vapor and steam:

Boiling
Boiling is the formation of vapor bubbles within a fluid. Boiling is initiated when the absolute pressure in a fluid reaches vapor pressure.

Saturated Vapor
Vapor at the temperature of the boiling point corresponding to its pressure.

Wet Saturated Vapor
A wet saturated vapor carries liquid globules in suspension. A wet saturated vapor is a substance in the gaseous state which does not follow the general gas law.

Dry Saturated Vapor
A dry saturated vapor is free from liquid particles. All particles are vaporized - any decrease in vapor temperature or increase in vapor pressure, condensates liquid particles in the vapor. A dry saturated vapor is a substance in the gaseous state which does not follow the general gas law.

Super-heated Vapor
In super-heated vapor the temperature is higher than the boiling point temperature corresponding to the pressure. The superheated vapor can not exist in contact with the fluid, nor contain fluid particles. An increase in the pressure or decrease in the temperature will not - within limits - condensate out liquid particles in the vapor. Highly superheated vapors are gases that approximately follow the general gas law.

High Pressure Steam
Steam where the pressure greatly exceeds the atmosphere pressure.

Low Pressure Steam
Steam of which the pressure is less than, equal to, or not greatly above, atmospheric pressure.

http://www.engineeringtoolbox.com/vapor-steam-d_609.html

Evaporation

Conditions that Affect Evaporation

What Causes Evaporation?

While evaporation is a straight forward process of liquid water turning into water vapor, there are other conditions that can have an effect on the rate of evaporation. These conditions are:

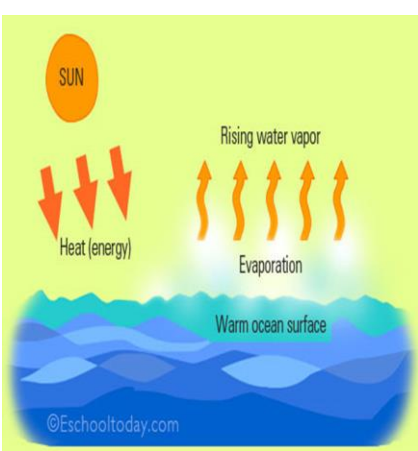
• Pressure: The higher the pressure, the slower the evaporation because there is more pressure on the surface of the water keeping the molecules in place. If pressure is removed, the molecules can more freely launch themselves.

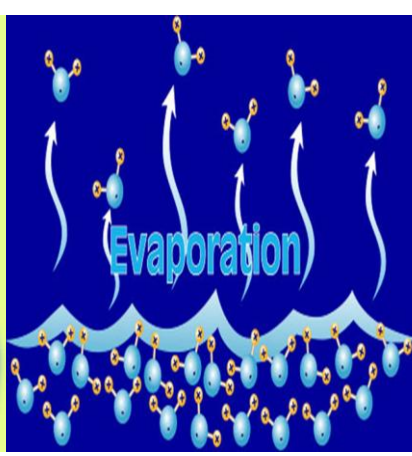
• Concentration: If the air is already very humid, it will take much longer for a cup of water to evaporate than if there is no water in the air at all. The more concentration, the slower the evaporation rate.

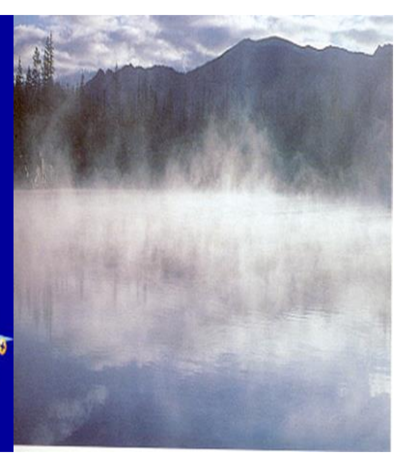
• Density: If a substance is more dense, the evaporation rate is slower. This is why alcohol evaporates faster than water, while water evaporates faster than mercury. Alcohol is less dense than water which is less dense than mercury.

• Surface Area: If all of the heat is only hitting an area 1 inch by 1 inch, there is only going to be room for 1 inch by 1 inch of molecules to make the phase change. If heat is hitting 1 mile by 1 mile, more water vapor will be formed. The more surface area, the faster evaporation.

While evaporation is always going on, it was found that there is only about 3 millimeters of water evaporated daily on average. In warmer areas, the amount might be more. In colder areas, the amount might be less. It is because of evaporation that the Earth doesn't get too hot. The heat on the Earth rises up and cools as it goes higher into the atmosphere.







http://www.tech-faq.com/what-causes-evaporation.html

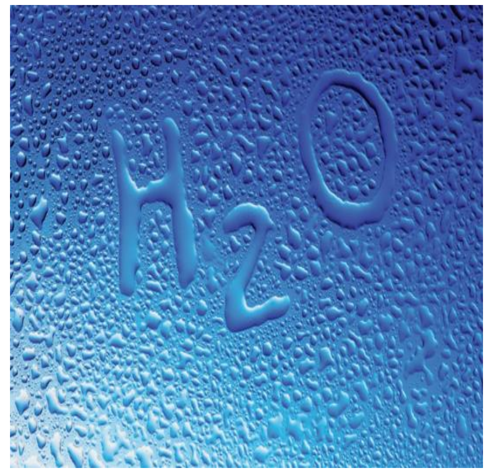
Unit 2:
Steam Science

Fundamentals of Steam

Condensation

Condensation

Condensation is the process of water vapor cooling down to form a liquid again. In steam cooking it is the process of steam vapor changing to water as it cools.



©kingofwallpapers.com

Condensation is when a gas transforms into a liquid. Condensation occurs when a gas has been cooled or compressed to the point where kinetic energy of the particles can no longer overcome the intermolecular forces. An initial cluster of particles initiates the process which tends to further cool the gas so that condensation continues.

http://www.livescience.com/46506-states-of-matter.html

©gettyimages.com

Water vapor in air around glass hits cold glass and condenses to liquid

©hombuilding.co.uk

Water vapor in air due to hot shower heating up the air comes in contact with cold mirror and turns from a vapor to a liquid.

Unit 3:
Steam Safety

Fundamentals of Steam

Steam Safety

Safety is of utmost importance when working with steam equipment. When working with steam equipment there is dangerous hazards involved including:

High Voltage
Steam equipment contains components that require voltages ranging from 120 Volts AC to 480 Volts AC. Always unplug equipment before servicing or removing covers and guards. Perform Lockout-Tagout procedures where necessary. Use insulated electrical tools. Always check for the presence of voltage using a voltmeter before beginning work.

High Pressure
Pressurized steam systems operate under a pressurized condition. Pressure release in these systems can be extremely dangerous. Pressurized steam can burn you, penetrate your skin, or blow scale particles at you. To protect yourself from pressure, wear safety goggles and gloves. Avoid disconnecting any pressurized lines.

High Temperatures
To create steam we have bring water to the boiling temperature of 212F. These temperatures can scald the skin. There is also the risk of getting burned with fire when servicing gas-fired steamers. Follow gas Lockout-Tagout procedures before servicing gas equipment. Exposed surfaces may be hot to the touch. Wear safety glasses and gloves whenever necessary.

Toxic Chemicals
Chemicals harmful to humans are used to clean scale from steam equipment. Some of these chemicals are poisonous and caustic. It is important to protect yourself from these chemicals by wearing rubber gloves that protect you from these chemicals if they spill or get sprayed on you. You should also wear safety glasses or a face shield to protect your face and eyes from chemical splashes.

Heavy Equipment
Cooking equipment is very heavy in many cases. Some equipment weighs several hundred pounds. When moving heavy equipment or parts, have someone help you, use a dolly, forklift, or pallet jack whenever possible. Don't risk it. Back injuries are the number one injury in the commercial equipment industry. **A back injury can end your career**.

HACCP Safety Standards

HAACP Safety Standards

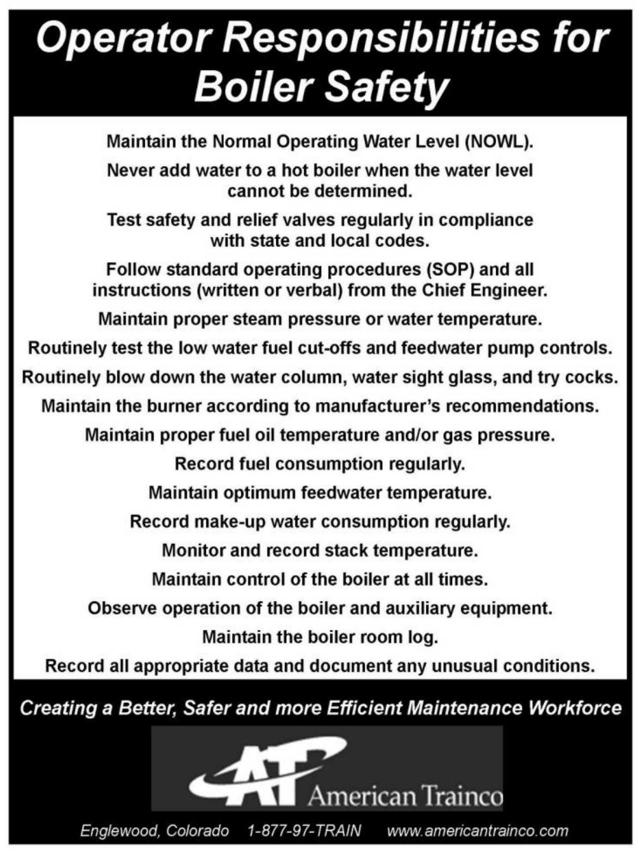
Foodsafety.com.au

Hazard Analysis and Critical Control Points (HAACP) system, the concept of “preventing a problem before it occurs”, is becoming the international norm for food safety. Certain key steps within food preparation processes are critical to the safety of the final product. They can be identified by conducting a systematic hazard analysis for the food and its preparation process. These critical points and their successful management are the basis of the HACCP approach. Whereas previous systems relied on spot-checking, this system provides controls for specific critical points.

There are seven steps to a HACCP system:

1. Assess the hazards
2. Identify critical control points
3. Set up control procedures and standards for critical control points
4. Monitor the critical control points
5. Take the proper corrective actions
6. Establish effective record keeping
7. Verify the system is working

A well-run HACCP system can control each critical point to eliminate hazards.



Hands On Exercise: Steam Safety Quiz

Steam Safety Quiz

1. Burn hazards on the job may include contact with steam, flame, hot equipment, and certain chemicals.
    a. True
    b. False

2. Some chemicals used to clean steam equipment can be:
    a. poisonous
    b. caustic
    c. Both A and B

3. Once you have tripped the breaker, there is no need to check for voltage at the equipment with a voltmeter before beginning work.
    a. True
    b. False

4. The number one industry related injury in the commercial food equipment repair industry is
    a. blindness.
    b. hearing loss.
    c. back injuries.

5. Steam equipment can operate on voltages up to 480 volts AC.
    a. True b. False

6. Safety goggles should be worn when servicing steam equipment.
    a. True
    b. False

7. Following lockout-tagout procedures can insure equipment energy will not be released during servicing of equipment.
    a. True
    b. False

8. Avoid disconnecting _____________ lines.
a. pressurized
b. unpressurized

Answers: 1. a, 2. c, 3. b, 4. c, 5. a, 6. a, 7. a, 8. a

Unit 4:
Steam Cooking Equipment

Fundamentals of Steam

Steam Cooking Equipment Types

Convection

Cleveland offers a full range of models and sizes—6, 10 and 16 pan—in both gas and electric.

Countertop

Available in 3, 5 or 6 pan models—the power you need in the convenience of a counter top model.

Pressure

Cleveland offers a complete range of pressure steamers from 2 to 4 compartments. These pressure steamers feature direct steam mounted on open or cabinet bases.

Table Top Models

The power and flexibility you need at a size that makes sense—choose from a full range. Equipment stands can also be found within this category.

Floor Models

23 models, available in gas or electric, a full range of capacities—Cleveland is the steam leader and known for quality, reliability and efficiency.

Mixer Kettles

For high-volume food production, Cleveland's complete line up of mixer kettles is the answer. Available in gas or electric and a wide variety of capacities to choose from.

Hands On Exercise:

- ❑ Locate and identify a steam cooking appliance

Equipment Specifications

Specifications
Specifications give the owner/installer guidelines and requires related to utilities that are recommended for proper operation of the equipment. The graphic shows sample specifications from a convection steamer.

Gas Line Pressures
Note that machine has different operating and incoming pressure and that the pressures are dependent on the type of gas fuel used.

Electrical
Electrical specifications include voltage, amperage draw, frequency, and phase requirements.

Water
Water specifications include supply pressure and water quality requirements

Hands On Exercise:

- ❑ Locate the data plate on an appliance.
- ❑ Does it have the voltage requirements? ___________

SPECIFICATIONS

Gas Line Pressures

- Operating Pressure
  Natural - Recommended 2.5" W.C.
  Propane - Recommended 10.0" W.C.
- Incoming Pressure
  Natural - Recommended 7.0" W.C. min.
  Propane - Recommended 11.0" W.C. min.

Burner Air Pressure

0.4" W.C.

Electrical

Voltage: 120/60/1

Amps: 2.5 Amps

Frequency: 50/60 Hz

Water Supply

Supply pressure: 20-60 psig

Hardness*: Less than 3 grains

Silica: Less than 13 ppm

Total Chloride: Less than 4.0 ppm

pH Range: 7 to 8

Undissolved Solids: Less than 5 microns

(*17.1 ppm = 1 grain of hardness)

Hands On Exercise: Service Connections

Below is an example of service connections required for a gas steam boiler cabinet. Please answer the following questions as found in this information.

Unless otherwise specified, Field Wire Electrical Connection to be 120 Volts, 60 Hertz single phase with grounding wire.

DRAIN: 2"IPS piped to open floor drain. No Solid Connection.

COLD WATER: 3/8" O.D. tubing at 25-50 PSI(170-345 kPa)

GAS CONNECTION: 3/4"IPS supply line required. Natural Gas : min.7" (178mm) Water Column. Propane : min.11" (279mm) Water Column.

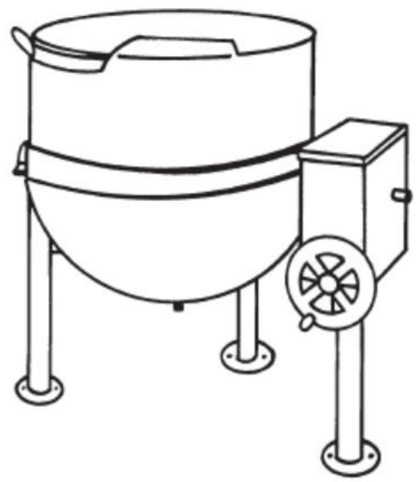
STEAM TAKE-OFF: 3/4"IPS.

1. What is the required voltage? _______________ volts
2. What is the required electrical frequency? _____________ Hz.
3. Is the voltage supply single phase or three phase? ___________________
4. Is a drain required? ____________ If so, what size? ______________
5. What does IPS stand for? ______________ _____________ ______________
6. Does the machine connect to a hot or cold water supply? _________________
7. What does O.D stand for? ___________________ ___________________
8. What size water line is required? _____________
9. What does PSI stand for? ______________ _______ ____________ ___________
10. What is the minimum natural gas pressure? ______________ inches of water column.
11. What is the minimum propane gas pressure? _____________ inches of water column.
12. What pipe size is needed for the steam take off? ___________ IPS

Appliance Types

Steam-jacketed kettles

A steam-jacketed kettle is a pot within a pot, with steam trapped in the space between the walls. Kettles are either fully jacketed (walled) or partially jacketed (walled). They are available in either floor, wall or counter mounted. Tilting kettles are available and called trunnion. Steam is supplied from a self-contained boiler or from a shared or remote source. A major benefit of the steam jacketed kettle is that it cooks extremely fast without scorching or hot spots. Kettles are ideal for soups, sauces, pie fillings, poultry, vegetables, meat fillings, stews, gravies, boiling bagels, pastas, rice, reheating pouch prepared food and cook chill casings. Anything that is normally cooked on the stove top can be done faster, better and using much less energy.



Steam jacketed kettle

Notes:

Unit 4:
Steam Cooking Equipment

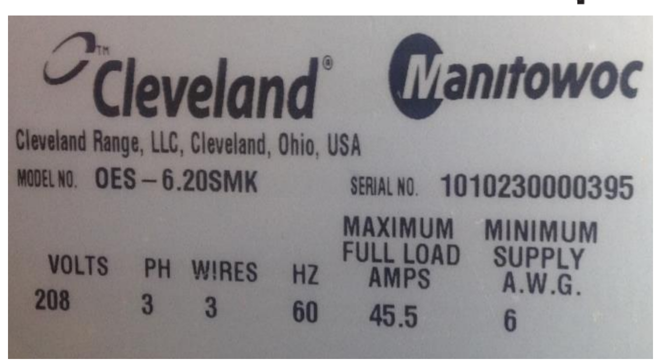
Combi Ovens

Combi ovens

The combi oven is like having three units in one footprint: a pressureless steamer, convection oven and convection oven with steam injection. You can choose the cooking method that meets your cooking needs rather than scheduling around the limitations of the equipment. Use the convection oven for baking, roasting and broiling; pressureless steam for vegetables, eggs, seafood and gentle reheating. Apply benefits of both convection and steam cooking in the combi mode for crusty breads, juicy meats, poultry, fish and baked dishes. Programmable recipes and self-cleaning options add more value by providing consistent, high-quality products and reducing labor.

Combi oven

Front View of Cleveland Combi Oven



Combi Oven Data Plate

Combi Oven Control Panel

Combi Ovens

Tips for efficient use of combi ovens

Combi ovens allow for multi-step programming. For example: Set the convection mode to 450 F to quickly brown a turkey for 10 minutes, then drop the temperature to 300 F and use the combi mode for 50 minutes to complete cooking. Once an operator perfects a recipe, it can be saved for future use.

Combi cooking will require adjustments to normal procedures. A general rule is to reduce the cooking temperature 50° from your conventional cooking temperature and check your food in half the normal time. By keeping notes on the procedures, you will soon know what combination of time and temperature works best to produce the desired results.

For greatest efficiency, load oven to capacity whenever possible.

Preheat the oven for 5 to 8 minutes and turn off as soon as cooking is complete.

To change from the convection or combi mode to steam mode, reduce the oven cavity temperature by opening the door and turning on the fan for 5 to 10 minutes.

Do not cover foods, because covering inhibits the cooking process.

Care

To maintain operating efficiency and extend the life of your natural gas combi oven:

Many manufacturers offer a self-cleaning cycle and most have a water spray arm for easier cleaning.

Regulator Maintenance

De-lime boiler units regularly to keep the steam boiler and generator free of mineral deposits. How often you de-lime will depend on your oven usage and how hard your water is.

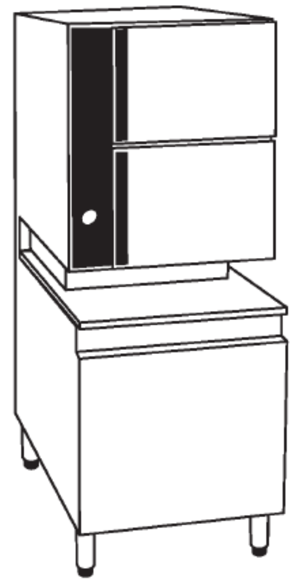
Wipe up spills in the cavity daily.

Use the steam mode to loosen oven soil.

Always follow manufacturer’s cleaning and maintenance instructions.

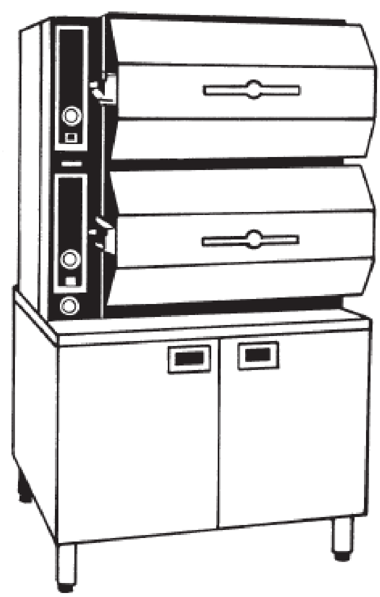
Compartment Steamers

Pressureless /atmospheric steamer
Compartment steamers are available in either boiler, boilerless, or connectionless models. Steam that is provided by a boiler can be part of the steam unit (self-contained), shared with other equipment, or come from a central boiler (direct steam). Because it provides a constant exchange of fresh steam, there is no transfer of flavors so dissimilar foods such as seafood and rice can be cooked at the same time. It is also ideal for frozen products and on-line cooking. Cooking is done at zero pressure (i.e. the term pressureless) and therefore the door can be opened at any time during the cooking cycle.



Pressureless steamer

Pressure steamer
Steam in this unit is pressurized, usually from 5 to 15 psi. For each pound of pressure, the temperature will rise 3° above 212 F. These steamers must be depressurized and the steam allowed to escape before opening the door. They are ideal for large production cooking such as commissaries, schools, health care or prep lines.



Pressure steamer

Boilerless/connectionless
Compartment steamers are also available in boilerless models or connectionless. The boilerless units produce steam when water comes in contact with heat exchanger tubes. Some models incorporate gas heated steam generating reservoirs and some use infrared burners. Connectionless units are boilerless with no water connection. Water is manually placed into the steamers and removed at the end of the day. These units are ideal for locations where water hook up is unavailable or too costly. The advantage of both units is
that there is no boiler to maintain.

Centerpointenergy.com/foodservice

Commercial Steamers

Commercial steamers provide an easy, fast way to prepare large quantities of food. Steaming offers good nutrient retention, short cook times, and ease of preparation; little attention is needed from the chef, food can be cooked and served in the same pan, and cleanup is simple. Steamers are versatile appli-ances that can be used to prepare almost any food that does not require a crust. Delicate vegetables such as asparagus and broccoli are cooked without damage, frozen foods are defrosted and cooked in one step, and hard-to-cook meats such as beef ribs can be par-cooked more quickly and with less weight loss than oven roasting.

Figure 8-1.
Two-compartment convection steamer on self-contained base.
Photo: Fisher-Nickel, inc.

In appearance, the compartment steamer resembles an oven. The cavity is typically rectangular on atmospheric steamers, and may be oval or round on pressure steamers. The door is "gasketed" and windowless. Controls are front-mounted. Figure 8-1 shows a typical two-compartment steamer atop a boiler base.

Steamers come in a variety of configurations, including countertop models, wall-mounted models and floor models mounted on a stand, pedestal or cabi-net-style base. A steamer may consist of one to four stacked cavities. The cavity is usually designed to accommodate a standard 12 by 20-inch (300 mm x 500 mm) hotel pan. Smaller steamers may be designed for use with one-third size pans, and some large steamers can hold several 18 by 26-inch (460 mm x 660 mm) baking trays.

The steam itself can be produced several ways. Many compartment steamers have an external (with respect to the cooking compartment) electric, gas, or service-steam powered boiler that produces potable steam under pressure. This pressurized steam is delivered to the cooking compartment as demanded by the control settings. However, in the case of a pressureless steamer (see Figure 8-1), the compartment is openly connected to a condensate drain and the steam environment within the compartment cannot sustain a pressure above atmospheric (both raw steam and condensate exit the cooking cavity

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through this drain). In the case of a pressure steamer, only condensate is allowed to drain. Thus the cooking cavity is allowed to build up to the operating pressure of the boiler. In the larger boiler-based designs, there may be additional steam capacity (referred to as a power-take-off or PTO) to power other appliances such as a steam-jacketed kettles installed along side the steamer.

Steam also may be produced by a steam generator located within (or directly connected to) the cooking cavity. This method differs from the boiler-based steamers in that the steam is produced at (or slightly above) the compartment operating pressure (i.e., atmospheric pressure). This strategy is not used for pressure steamers.

A steamer may produce steam by boiling water poured directly into the cooking compartment prior to operation (this is the simplest form of an internal steam generator, typically referred to as a "connectionless" steamer). Heating elements are located either beneath the compartment's floor or placed directly in the bottom of the compartment. Gas burners, placed below the compartment, may produce steam in the same fashion.

Steam may be supplied from an external source (e.g., centralized building steam). If this steam is clean, it can be routed directly to the steamer compartments. Otherwise, it can be run through a heat exchanger and used to generate potable steam from clean water.

Boiler-based and conventional steam-generator type steamers require a drain line, water line, and a connection to an energy source—typically gas or electricity. Self-contained units typically have boilers that fill automatically. Condensate from the cavity is directed to a drain tube, where it is cooled by a stream of water before flowing into the sewer (In many areas it is against code to drain water above 140°F). The new generation of "connectionless" steamers require no such connections beyond the electrical (or gas) hook up. Water is poured into the bottom of the cooking compartment and periodically refilled during the course of operation. When operation is suspended, the water is drained from the cavity into a pan or bucket.

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Cooking Process & Steamer Types

Cooking Process

Steam cooking exploits the latent energy that steam at 212°F (100°C) carries, which is six times greater than water at the same temperature. When steam condenses on the surface of cold food, it transfers this latent energy to the food. If the pressure inside the steamer compartment rises, the steam can reach higher temperatures and deliver more energy to the food. This is the mechanism behind pressurized steamers, which may cook food faster than pressureless (atmospheric) steamers.

As with baking, a layer of insulating vapor can form around food in a still steamer cavity. The natural convection inside the cavity tends to strip away this insulating layer of air, but it has a limited ability to do so. If food is tightly packed, or if the steamer is fully loaded with pans, convection is impeded and cooking slows down. The last few years have seen the addition of a fan to some steamers. Forced convection in a steamer (e.g., via steam being injected from the boiler) has the same effect as it does in a convection oven, namely stripping away the insulating layer of vapor around the food to speed cooking and provide even heat throughout the steamer cavity.

Types of Steamers

There are two basic categories of steamers on the market, pressureless (atmospheric) and pressurized. Each type is available in gas, electric and direct-steam models.

Pressureless Steamer

Pressureless steamers, also commonly referred to as "atmospheric" steamers, maintain the cooking compartment at close to atmospheric pressure (between 0 and 2.9 psig (0 and 20 kPa)). They generally employ a large cooking cavity to facilitate the circulation of steam around the food product. Because these steamers operate at or near atmospheric pressure, the door may be safely opened at any point during the cooking cycle to check the product. Many atmospheric steamers employ a fan for forced convection steaming, to produce shorter cook times and even cooking throughout the compartment under full-load conditions.

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Pressure Steamers & Advanced Steamer Technologies

Pressure Steamer

Figure 8-2.
Two-compartment pressure steamer.
Photo: Fisher-Nickel, inc.

Pressure steamers employ a closed system to allow the steam to build pressure inside the cooking compartment. These steamers are easily identifiable by their smaller compartments and heavy locking doors (see Figure 8-2). Although these steamers may cook smaller batches of food than pressureless steamers, cook times can be shorter, and energy efficiency higher, depending on the food product.

Low-pressure steamers typically operate between 3 and 9 psig (20 and 62 kPa). These are high-volume steamers that are often used in schools and hospitals. High-pressure steamers generally have smaller compartments and operate at 10-15psig (70-105 kPa). Although they hold less food, they may cook up to twice as fast as a low-pressure steamer. Pressure steamers require precise cook times because the food product cannot be checked while the steamer is operating.

Advanced Steamer Technologies

Pressureless steamers vary in their technological complexity. In addition to the three primary designs (boiler, steam-generator, and connectionless), manufacturers have employed different strategies for improving performance and reducing energy consumption. These emerging technologies include convection, vacuum pumps, close-system design, connectionless designs, compartment insulation and a stand-by mode.

Convection. Turbulent steam strips away the insulating layer next to the food, for faster cooking that is more even throughout the cavity. There are two basic methods of producing this forced convection. Some manufacturers inject steam into the cavity through jets in the cavity wall, while others use a fan to circulate the steam within the compartment.

Vacuum Pumps. Vacuum pumps have been used to reduce the pressure within the cooking compartment and lower the cooking temperature. This technology is promoted to reduce cook times and be gentler on delicate food products.

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Closed System. One manufacturer employs a unique steam-control system that monitors pressure fluctuations within the cooking compartment, which reflects how much steam is being condensed on the food during the cooking process. As pressure builds in the compartment and less steam condenses, the unit's steam generator will suspend steam production. Only when the compartment pressure lowers, indicating that the food has absorbed heat from the steam, will the steam-generator reactivate.

Connectionless Design. "Connectionless" steamers have a water reservoir in the bottom of the cooking compartment in lieu of a water connection. The reservoir is manually filled and drained. Connectionless steamers have an advantage in that no steam leaves the cooking cavity during operation (except through a compartment vent). Thus, steam that does not condense on the food remains within the cavity, thereby significantly improving the steamer's energy performance. This strategy also mitigates some of the difficulties associated with boiler maintenance, and allows easier access for cleaning. Figure 8-3 shows a typical connectionless steamer. One manufacturer of a connectionless steamer incorporates a vacuum that reduces the temperature of steam (below 212°F) to provide a more "gentle" cooking event.

Figure 8-3.
Connectionless steamer.
Photo: Stellar Steam.

Compartment Insulation. Improved insulation around the cooking compartment reduces heat loss to the kitchen and can have a significant effect on standby (idle) energy consumption.

Standby Mode. Some manufacturers maintain a steam generator stand-by temperature just below boiling (typically, 180 to 200°F). This allows the appliance to produce steam 10-30 seconds after the steamer is loaded with food product and is a practical alternative to turning the steamer off between uses. Cook times may be slightly longer than if the steamer had been held at full input, as the cavity also absorbs heat. The increase in cook time depends on when the steamer was last used (leaving residual heat in the walls of the cavity.)

Controls

Steamer manufacturers offer a wide range of control packages. Some units are equipped with only the necessary controls for operation: an on/off switch, water-refill light, and simple timer. Others have an array of features such as

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boiler temperature, high- and low-power modes, idle/hold modes and other energy-saving settings. Timers can also terminate the cooking process to ensure that food product is not over cooked. Boiler-based units may also incorporate maintenance-indicator lights and an automated boiler blow-down mechanism to cleanse the heating elements or burner tubes of scale and sediment.

Some steamers use compensating timers, which automate defrosting and cooking. As an example, consider a load of frozen fish being cooked in a steamer with a compensating timer. Cavity temperature is monitored, and the timer does not begin to count down until the compartment nears 212°F (100°C), a temperature that corresponds to the frozen food having mostly thawed. At this point, the timer-preset with the desired cook time for a thawed food product has "compensated" for the food's initial condition, whether it was frozen or thawed (as well as the cavity's initial condition, cold or preheated). In a pressure steamer, the drain valve would close at this point and pressurized cooking would begin. [1]

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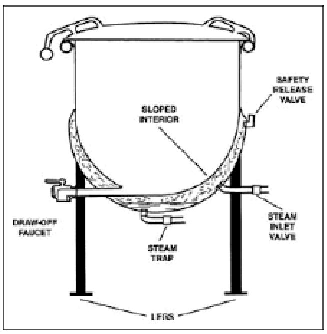
Unit 4:
Steam Cooking Equipment

Fundamentals of Steam

Steam Jacketed Kettle

Introduction



Steam kettles are an improved, self-contained version of the large stockpot used for range top cooking. And they are put to many of the same tasks. Steam kettles are often used to boil pasta, simmer sauces, stocks and stews. But, steam kettles offer a huge increase in productivity, convenience and energy efficiency. Steam-kettle cooking can be partially automated and closely controlled, far more so than cooking on a range top.

Steam kettles are enclosed by an outer wall, or jacket, containing raw steam. This steam jacket typically extends from the bottom of the kettle to between half and two-thirds of the distance to the rim. The circulation of steam inside the jacket provides even heating to the contents of the kettle. The pressure of the steam, which may be from 1 to 50 psig (7 to 345 kPa), determines the maximum temperature of the kettle.

Cooking Process

Steam kettles cook by conduction: heat passes directly from the wall of the kettle into the food. This is the most common mode used for tasks like boiling and simmering large quantities of food product. Depending on the pressure of the steam in the jacket, the maximum temperature of the kettle may be 212-300°F (100-150°C). Some kettles have additional connections to the jacket for cold water, which allows the kettle to first cook the food and then chill the food.

Because kettles heat evenly, they need less supervision than a pot on the stove. A variety of controls allow the cooking process to be further simplified and automated. Manufacturers offer devices to measure the amount of water flowing into the kettle, timers to start cooking unattended and signal the end of the cook time, automatic valves to control cooking and chilling, and mixers to eliminate the need to check or stir the food.

Operators also use steam kettles for heating food up (e.g., rethermalizing precooked food and heating prepared sauces), boiling bagels and spaghetti, and for simmering long-cooking items such as chili. Cooking events may last

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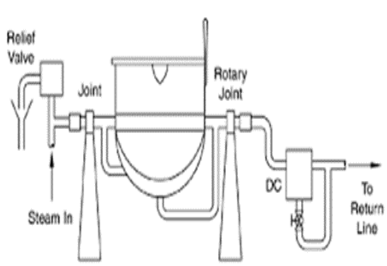
Types of Kettles

from a few minutes to several hours, and take place at temperatures from 150°F to 300°F (70 to 150°C). Reliance on steam kettles in institutional operations such as hotels and university kitchens is diminishing as menu preparation changes from batch cooking to accommodate the "fresh" concept so popular in today's market. Many are moving towards cooking food items in other pieces of equipment such as combis and steamers, as batch cooking smaller quantities defines production. However, this trend is offset by the fact that the kettle is one of the primary appliances used within cook-chill systems for rethermalizing food received from a central commissary.

Types of Kettles

Manufacturers offer a variety of steam kettles for commercial food service: direct steam and self-contained, tilting and stationary, floor-, wall- and countertop-mounted. All are available in gas and electric models. Many have a building service steam option for institutional facilities.

Capacity ranges from 1 quart to 200 gallons (1 to 760 liters). The source of steam may be a boiler built into the housing or base of a "self-contained" type kettle, or an external steam supply for "direct-steam connect" type kettles. Many smaller capacity (i.e. less than 60 gal (230 L)) steam kettles are mounted on pivots so that they may be tilted for pouring. Some manufacturers offer accessories such as timers and mixer attachments to automate steam kettle cooking. Kettles may be mounted on the wall, on a cabinet, pedestal or open-style base, or on a countertop.



Direct Steam Kettles

In all kettles, steam enters the jacket and condenses on the kettle wall, transferring heat into the kettle and condensing back into water. The source of steam varies. Direct steam kettles are supplied with steam from an external boiler. While this makes the design of the kettle itself simpler, it incurs some additional maintenance. The kettle may need to be "blown down" once a day or more to eliminate condensate build-up in the steam supply line. This process is usually manual, although some kettles offer systems that take care of the condensate automatically.

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Self-Contained Kettles & Styles

Self-Contained Kettles

Self-contained kettles have a closed steam system. The jacket is filled with distilled water and steam is supplied by a gas or electric boiler contained in a housing on the kettle's stand. This complicates design and increases the price of the kettle, but makes steam kettles available to kitchens of any size and with any configuration of gas and electrical plumbing. Maintenance of the steam jacket is simple. There is generally a sight glass to inspect water level, and the jacket occasionally requires manual venting or refilling.

Figure 9-1.
Floor-mounted tilting self-contained steam kettle.
Photo: Southbend

Tilting and Stationary Kettles

Tilting kettles simplify the task of decanting a large volume of food product. Tilting kettles range in size up to 100 gal (380 L), and are available in all configurations of steam source and mounting style. The kettle is generally tilted with a hand-operated wheel (Figure 9-1), but in some cases an electric motor is used. The kettle is counterbalanced so that it may stop and remain in any position as it tilts. Tilting kettles are also provided with a pouring lip to guide the food into steamer pans or other serving dishes. Additionally, larger units may have a tangent draw-off valve at the bottom of the kettle. This allows food such as spaghetti to be drained before decanting.

Stationary kettles do not tilt, but are usually equipped with a draw-off tangent valve at the bottom of the kettle. The largest steam kettles, those between 100 and 200 gal (380 and 760 L) capacity, are available only as stationary models.

Mounting Style

Smaller steam kettles, generally less than 10 gal (40 L) capacity, may be available in countertop models. Countertop kettles are available in gas heated-, electric-heated and direct-steam configurations, and are generally tilting-type kettles.

Wall-mounted kettles may be stationary or mounted on trunnions for tilting. They are generally direct steam kettles, and often are installed as part of a

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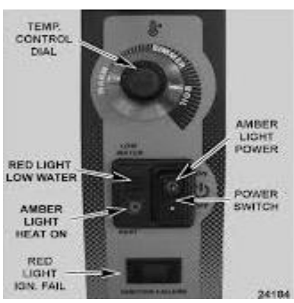
battery of appliances. Kettles of one-quart to 100-gallons (1-400 L) capacity are available in wall-mounted configurations.

Floor-mounted models may be from 10-200 gal (40-800 L), direct or self contained, tilting or stationary. The kettle may be mounted on a pedestal or on an open or cabinet-style base.

Controls



Steam-kettle controls are generally simple, consisting typically of a power switch and a pressure dial. Smaller kettles may use thermostats to control cycling, while larger kettles use a pressure sensor in the jacket.

Some manufacturers offer optional lines of accessories including electronic controls that start and stop kettle cooking and/or chilling operations automatically. Systems are also available to automate boiler maintenance operations.

Advanced Steam Kettle Technologies

Insulated Steam Kettles

One manufacturer has introduced a line of insulated steam kettles. The insulated jacket will reduce heat losses from the bottom and sides of the kettle, which in turn increases efficiency, lowers energy consumption and reduces heat flow into the kitchen.

Thermal Fluid Kettles

This type of kettle circulates a thermal fluid through the jacket instead of steam. This increases the temperature range of kettles significantly, with the manufacturer reporting cooking temperatures of up to 360°F (182°C) versus a more typical peak of 300°F (150°C) with high-pressure steam. This may make it possible to cook additional items such as braised meats in a steam kettle.

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Water Requirements

WATER REQUIREMENTS

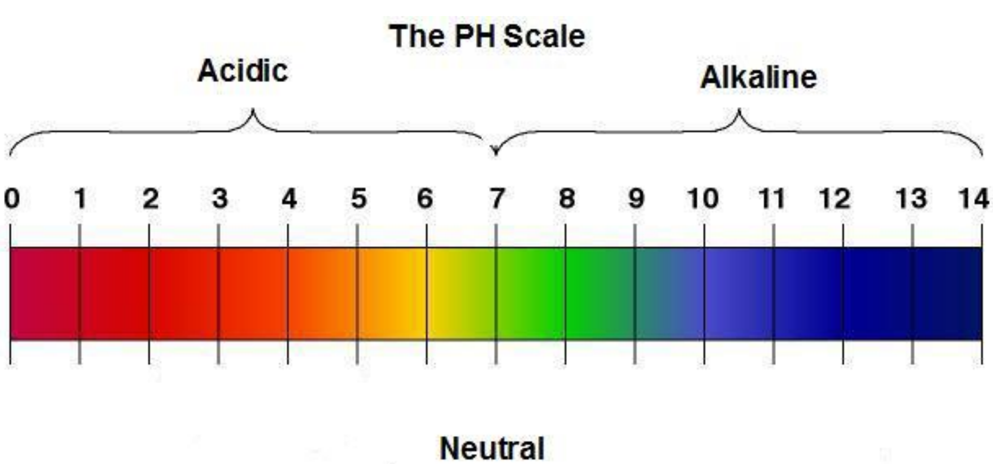
As with all steam related products, water filtration and regular filter replacements, coupled with routine deliming, are required. Your local Service office can recommend a water treatment system to meet the needs of your local water conditions. Contact your local service representative for water treatment offerings.

Proper water quality can improve the taste of the food prepared in the oven, reduce liming and extend equipment life. Local water conditions vary from one location to another. The recommended proper water treatment for effective and efficient use of this equipment will also vary depending on the local water conditions. Ask your municipal water supplier for details about your local water supply prior to installation.

Dynamic Water Pressure	Hardness	Silica	Total Chlo-ride	pH Range	Chlorine & Chloramine	Alkalinity	TDS	Undissolved Solids
30-80 PSIG	2-4 grains	< 13 ppm	< 30 ppm	7-8	0 ppm	< 20 ppm	< 60 ppm	< 5 microns

pH of Water

Water with a pH < 7 is considered acidic and with a pH > 7 is considered basic. The normal range for pH in surface water systems is 6.5 to 8.5 and for ground water systems 6 to 8.5. Alkalinity is a measure of the capacity of the water to resist a change in pH that would tend to make the water more acidic. The measurement of alkalinity and pH is needed to determine the corrosiveness of the water.



Unit 5:
Water Systems

Fundamentals of Steam

Water Quality

Water quality impacts equipment performance and maintenance – not to mention the taste of beverages and foods. No matter what role you hold in the foodservice industry, you'll find answers to your water quality issues through these collected resources.

Converter for hardness of water
Hardness of water is a measure for the content of calcium and magnesium in water. The small contribution of magnesium usually is expressed as calcium as in the degrees of hardness (at the top) and the concentrations of Ca2+, CaO and CaCO3 (at the bottom). Unfortunately, the classification of the degrees of hardness to water quality (soft, slightly hard, hard, very hard) is different in many countries.

Hard Water Hardness Calcium Magnesium Water Corrosion Mineral Scale
Water described as "hard" is high in dissolved minerals, specifically calcium and magnesium. Hard water is not a health risk, but a nuisance because of mineral buildup on fixtures and poor soap and/or detergent performance. Water hardness above 4.0 grains per gallon should be treated by a water conditioner (water softener and/or in-line water treatment). Water hardness below 2.0 grains per gallon may also require a water treatment system to reduce potential corrosion. Water treatment has been shown to reduce costs associated with machine cleaning, reduce deliming and reduce corrosion of metallic surfaces.

Water Hardness Scale		
Grains/Gal	mg/L or PPM	Classification
Less than 1	Less than 17.1	Soft
1-3.5	17.1-60	Slightly Hard
3.5-7	60-120	Moderately Hard
7-10	120-180	Hard
Over 10	Over 180	Very Hard
1 gpg = 17.1 mg/L = 17.1 ppm		

Total Dissolved Solids (TDS)
Elevated total dissolved solids can result in your water having a bitter or salty taste; result in incrustations, films, or precipitates on fixtures; corrosion of fixtures, and reduced efficiency of water filters.

Unit 5:
Water Systems

Fundamentals of Steam

Hands On Activity: Water Quality

Below is an example of service connections required for a gas steam boiler cabinet. Please answer the following questions as found in this information.

WATER QUALITY STATEMENT

Water quality is the major factor affecting the performance of your appliance. If you are unsure of water quality, consult a local water treatment specialist and have the water analyzed. Your water supply must be within these general guidelines:

Total dissolved solids	Less than 60 PPM
Total alkalinity	Less than 20 PPM
Silica	Less than 13 PPM
Chlorine	Less than 1.5 PPM
pH Factor	7.0-8.5

Water which fails to meet these standards should be treated by installation of a water conditioner.

FAILURE OR MALFUNCTION OF THIS APPLIANCE DUE TO POOR WATER QUALITY IS NOT COVERED UNDER WARRANTY.

1. What is the acceptable TDS level? ______________________________
2. What does PPM stand for? _____________ ______________ _________________
3. What is the acceptable total alkalinity? __________________
4. What is the acceptable Silica level? _______________________
5. What is the acceptable Chlorine level? ____________________
6. What is the acceptable pH Factor range? ___________________________
7. What equipment will resolve issues with water that does not meet the above requirements? ____________________ ____________________________
8. What does O.D stand for? ____________________ ___________________
9. Will poor water quality void the appliance warranty? _________________
10. Does water quality affect the performance of the appliance? __________

Deliming / Descaling

Lime and Scale 23

Lime and scale are big problems for steam cooking equipment. To prevent equipment issues excessive lime and scale must be removed on a regular basis. The following is how to delime a Vulcan convection steamer.

DELIMING THE GENERATOR

WARNING: READ AND FOLLOW THE INSTRUCTIONS ON THE DELIMING MATERIAL PACKAGE. AVOID CONTACT WITH SKIN AND EYES. WEAR PLASTIC OR RUBBER GLOVES AND SAFETY GOGGLES WHEN HANDLING. WASH THOROUGHLY AFTER HANDLING. IF DELIMING SOLUTION COMES IN CONTACT WITH THE SKIN OR EYES, RINSE THOROUGHLY WITH CLEAN WATER.

WARNING: THE STEAMER AND ITS PARTS ARE HOT. USE CARE WHEN OPERATING, CLEANING OR SERVICING THE STEAMER. THE COOKING COMPARTMENT CONTAINS LIVE STEAM. STAY CLEAR WHEN OPENING DOOR.

Items Required (not provided)

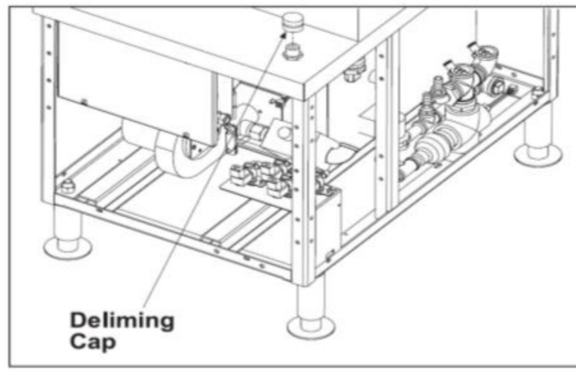
- Deliming material.
- Funnel.
- Plastic or rubber gloves.
- Safety goggles or face shield.
- Measuring cup.
- 1 gallon container for mixing deliming solution.
- Petrol-Gel Lubricant or equivalent food grade grease for coating deliming port threads.

NOTE: Deliming solution may cause the surface of aluminum measuring tools to tarnish or etch.

C24GA (Automatic Drain)
11 US GAL Capacity Steam Generator.

NOTE: This procedure is not intended to take the place of a water treatment program.

1. Turn power switch off. Wait 5 minutes for steam generator to completely drain and the drain valve to close.
2. Turn cooking timers to off.
3. Prepare deliming solution according to the instructions on the deliming material package. Follow all manufacturers' instructions.
4. Remove delime port cap on top of unit and insert funnel into delime port.



5. Pour deliming solution into the steam generator slowly to avoid spillage.
6. Remove funnel from delime port then rinse port with clean water.
7. Lightly coat delime port threads with Petrol-Gel then install delime port cap. Cap must be installed and tightened securely at all times.
8. Turn power switch on. When ready light comes on, allow steamer to remain on for 40 minutes.
9. After 20 minutes, turn cooking timers on for 1 minute to delime the steam tubes and nozzles.
10. After 40 minutes, turn power switch off and allow steam generator to completely drain, 5 minutes.
11. Rinse steam generator with clean water:
    A. Turn power switch on. When ready light comes on, turn cooking timers on for 30 seconds to rinse the steam tubes and nozzles.
    B. Turn power switch off and allow steam generator to completely drain.
    C. Turn cooking timers to off.
    D. Repeat steam generator rinse one time.
12. Clean exterior and interior using a mild solution of soap and water. Rinse with clean water then dry with a soft cloth. Leave compartment doors open when not in use.
13. The steamer is ready for operation or shutdown.

Corrosion

Corrosion is a complex series of reactions between the water and metal surfaces and materials in which the water is stored or transported.

The corrosion process is an oxidation/reduction reaction that returns refined or processed metal to their more stable ore state. With respect to the corrosion potential of YOUR drinking water, the primary concerns include the potential presence of **TOXIC Metals** , such as lead and copper; deterioration and damage to the plumbing, and aesthetic problems such as: bitter taste, and greenish-blue stains around basins and drains.

The primary health concern is the potential for the presence of elevated levels of lead and copper in the water. The primary source of the lead includes the use of lead pipes, lead lined tanks, and use of 50/50 lead/tin solder. Because of the concern with lead, the EPA banned the use of high lead solders in 1986. The primary source of copper is the leaching of copper from the piping used to convey the water throughout the business. In some cases, the water is so corrosive that the interior plumbing system needs to be changed and completely replaced with PVC piping, PEX, or other materials.

Corrosion will occur anywhere a galvanic cell or field can be or has established. To establish the field all that is needed is two dissimilar metals that are connected directly or indirectly by an electrolyte, such as water. This is the same chemical reaction that occurs within a battery.

http://www.water-research.net/index.php/drinking-water-issues-corrosive-water-lead-copper-aluminum-zinc-and-more

Unit 5:
Water Systems

Corrosion

Nearly all metals will corrode to some degree. The rate and extent of the corrosion depend on the degree of dissimilarity of the metals and the physical and chemical characteristics of the media, metal, and environment. In water that is soft, corrosion occurs because of the lack of dissolved cations, such as calcium and magnesium in the water. In scale forming water, a precipitate or coating of calcium or magnesium carbonate forms on the inside of the piping. This coating can inhibit the corrosion of the pipe because it acts as a barrier, but it can also cause the pipe to clog. Water with high levels of sodium, chloride, or other ions will increase the conductivity of the water and promote corrosion. Corrosion can also be accelerated by:

1) low pH (acidic water) and high pH (alkaline water)- For high alkalinity water - it is possible that a chemical scale may form that would help to protect against corrosion, but if a bacteria becomes established the scale, such as SRB (sulfur reducing bacteria), you may experience a problem related to Microbiologically Induced Corrosion (MIC).

2) high flow rate within the piping can cause physical corrosion;

3) high water temperature can increase biological rate of growth and chemical corrosion;

4) oxygen and dissolved CO2 or other gasses can induce corrosion;

5) high dissolved solids, such as salts and sulfates, can induce chemical or bio-chemical corrosion;

6) If the mass ratio (CMSR) of chloride to sulfate is > 0.2, but < 0.5 there is an elevated concern, but if the CMSR is > 0.5 and the alkalinity of the water is less than 50 mg CaCO3/L the concern should be significant;

7) corrosion related bacteria, high standard plate counts, and electrochemical corrosion can result in pinhole leaks and isolated corrosion and aesthetic water quality problems, and

8) presence of suspended solids, such as sand, sediment, corrosion by-products, and rust can aid in physical corrosion and damage and facilitate chemical and biochemical corrosion.

If it is necessary to flush or run your cold water in the morning for a few minutes before you drink because the water has a bitter taste, YOUR Water is probably CORROSIVE. If you see blue-green stains in your basins or some staining along the joints of your copper piping, YOUR Water is probably CORROSIVE. As corrosive water stands or seats in pipes or tanks, it leaches metals from the piping, tanks, well casing, or other metal surfaces that water is in contact. If you see pink standing on the waters edge - this may not be corrosion, but pink bacteria. Pink bacteria is an airborne bacteria.

http://www.water-research.net/index.php/drinking-water-issues-corrosive-water-lead-copper-aluminum-zinc-and-more

Pipes and Tubing

Pipes

The purpose with a pipe is the transport of a fluid like water, oil or similar, and the most import property is the capacity or the inside diameter.

NPS DN pipes

For a ASME/ANSI B 36.10 Welded and Seamless Wrought Steel Pipe the inside diameter (ID) of a NPS 2 inches pipe with schedule 40 is 2.067“ and schedule 80 is 1.939“.
The inside diameters are close to 2" and the nominal diameter is related to the inside diameter. Outside diameter are 2.375" for both schedules.

Pipe Schedule

Since the outside diameter of a single nominal pipe size is kept constant the inside diameter of a pipe depends on the "schedule" or “thickness” of the pipe. The schedule and actual thickness of a pipe varies with size of the pipe. Example - the thickness of a 2" schedule 40 pipe is 0.154" and the thickness of a 6" schedule 40 pipe is 0.280".

Sizing Terminology

It is common to identify pipes in inches by using NPS or "Nominal Pipe Size". The metric equivalent is called DN or "diametre nominel". The metric designations conform to International Standards Organization (ISO) usage and apply to all plumbing, natural gas, heating oil, and in addition to miscellaneous piping used in buildings. Note - the use of NPS does not conform to American Standard pipe designations where the term NPS means "National Pipe Thread Straight".
Nominal Bore (NB) may be specified under British standards classifications along with schedule or wall thickness.
The tolerances are looser to pipes compared with tubes and pipes are often less expensive to produce than tubes.

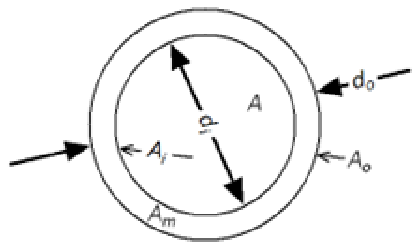
Tubes

The nominal dimensions of tubes are based on the outside diameter. If we look at Copper Tubes - ASTM B88 the outside diameter of a 2" pipe is 2.125", relatively close to 2".

NPS DN tubes

The inside diameter of a tube depends on the thickness of the tube. The thickness is often specified as gauge. If we look at Copper Tubes - ASTM B88 the wall thickness of 0.083"of a 2" pipe is gauge 14.
Tolerances are commonly higher with tubes compared to pipes and tubes are often more expensive to produce than pipes.

Formulas: Cross Sectional Pipe Area



engineeringtoolbox.com

Cross Sectional inside Pipe Area

Cross-sectional inside area of a pipe can be calculated as

$$A = \pi \, (d_i / 2)^2$$

$$= \pi \, d_i^{\,2} / 4 \quad (1)$$

where

A = cross-sectional inside area of pipe (m^2, in^2)

d_i = *inside diameter (m, in)*

Cross Sectional Pipe Wall Area

The cross-sectional wall area - or area of piping material - can be calculated as

$$A_m = \pi \, (d_o / 2)^2 - \pi \, (d_i / 2)^2$$

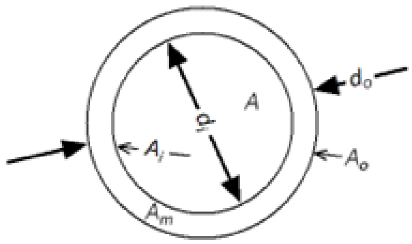
$$= \pi \, (d_o^{\,2} - d_i^{\,2}) / 4 \qquad (2)$$

where

A_m = *cross-sectional wall area of pipe* (m^2, in^2)

d_o = *outside diameter (m, in)*

Formulas: Pipe Weights



engineeringtoolbox.com

Weight of Empty Pipes

Weight of empty pipes per unit length can be calculated as

$$w_p = \rho_m A_m$$

$$= \rho_m (\pi (d_o / 2)^2 - \pi (d_i / 2)^2)$$

$$= \rho_m \; \pi (d_o^2 - d_i^2) / 4 \qquad (3)$$

where

w_p = weight of empty pipe per unit length (kg/m, lb/in)

ρ_s = density of pipe material (kg/m^3, lb/in^3)

Weight of Liquid in Pipes

Weight of liquid in pipes per unit length can be calculated as

$$w_l = \rho_l A$$

$$= \rho_l \pi (d_i / 2)^2$$

$$= \rho_l \pi d_i^2 / 4 \qquad (4)$$

where

w_l = weight of liquid in pipe per unit length of pipe (kg, lb)

Weight of Pipe filled with Liquid

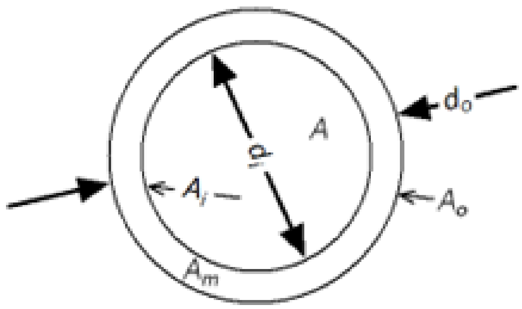
Weight of pipe filled with liquid per unit length can be calculated as

$$w = w_l + w_p \qquad (5)$$

where

w = weight of pipe and liquid per unit length of pipe (kg, lb)

Formulas: Surface Area of Pipes



engineeringtoolbox.com

Outside Surface Area of Pipes

Outside surface area of steel pipes per unit length can be calculated as

$$A_o = 2\ \pi\ (d_o / 2)$$

$$= \pi\ d_o \qquad (6)$$

where

A_o = *outside area of pipe - per unit length of pipe (m^2, in^2)*

Inside Surface Area of Pipes

Inside surface area of steel pipes per unit length can be calculated as

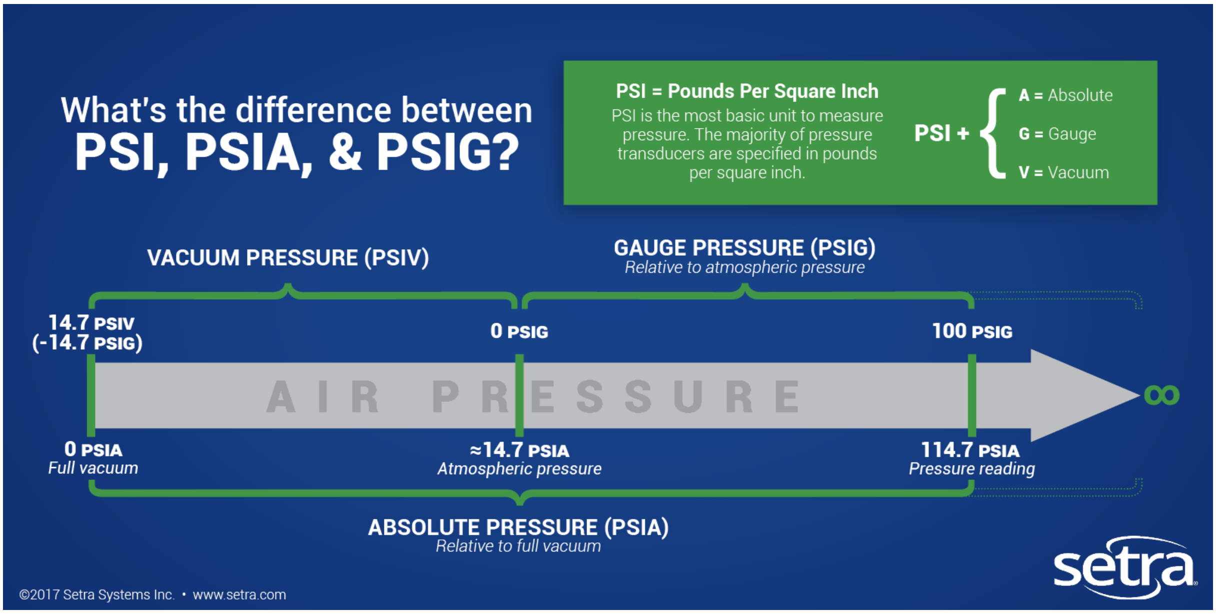
$$A_i = 2\ \pi\ (d_i / 2)$$

$$= \pi\ d_i \qquad (7)$$

where

A_i = *inside area of pipe - per unit length of pipe (m^2, in^2)*

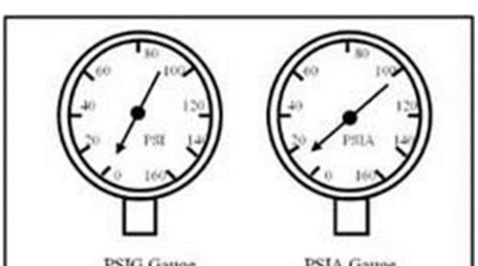
Gauge vs. Absolute Pressure



Absolute pressure is zero-referenced against a perfect vacuum, so it is equal to gauge pressure plus atmospheric pressure.

Gauge pressure is zero-referenced against ambient air pressure, so it is equal to absolute pressure minus atmospheric pressure.

Differential pressure is the difference in pressure between two points.



Hands On Exercise:

- ❑ Read a Pressure Gauge
- ❑ What is the pressure? __________ P.S.I

____________ kPa

Unit 7:
Pressure

Fundamentals of Steam

Effects of Pressure on Temperature

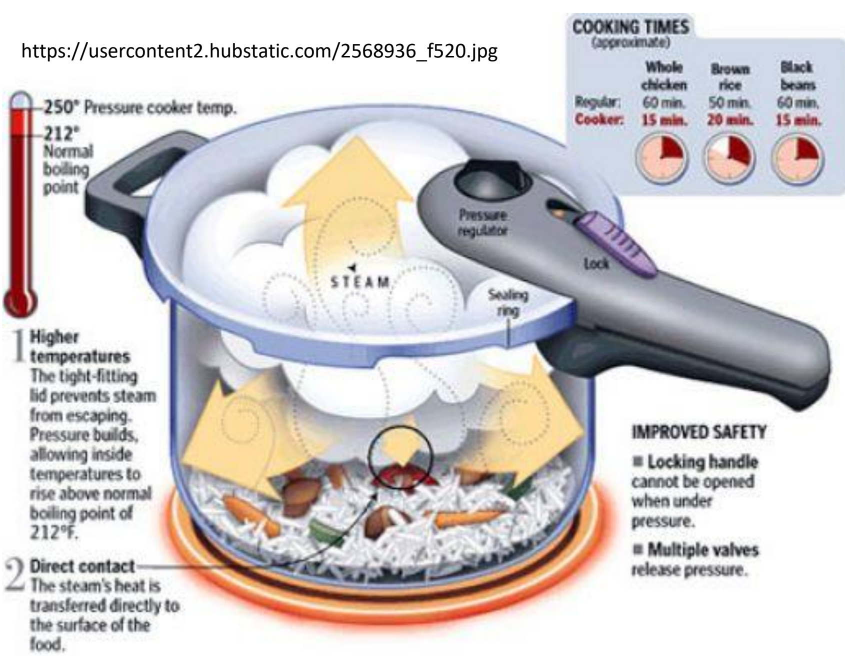
Overview

Temperature and pressure are directly proportional to each other. This means that as the temperature decreases, the pressure also decreases, and as the temperature increases, the pressure increases. One way to think of this is if you increase the speed of the molecules –by increasing their temperature- the force of the molecules hitting their container increases and this increases the pressure. This relationship is called Gay-Lussac's Law and makes up part of the ideal gas law.

Theory

When the speed of a gas's molecules increases, the gas molecules hit their container more often. The more frequently the gas impacts the container walls, the higher the pressure. So, as temperature increases, the pressure also increases. If the gas cools, the impacts are less frequent and the pressure decreases.
This relationship can be described using mathematics as well. Mathematically, Gay-Lussac's Law states that $P/T = k$, where k is any constant.
This relationship explains why race car tires are not filled with as much air as normal tires. At the high speeds of race cars, the air inside the tires heats up, causing the pressure to increase. Tires with too high a pressure have less contact with the road and are more easily damaged. So, the cold tire pressure for a race car is lower than a normal car. As air sinks, it encounters higher pressures and the temperature increases. This characteristic of gases leads to the definition of potential temperature. The potential temperature is the temperature a parcel of air would have if it was moved to 100,000 Pa, although this definition does not require volume to be held constant.

https://usercontent2.hubstatic.com/2568936_f520.jpg



A pressure cooker is an example of Gay Lussac's law as the temperature increases causing the pressure to increase above the food that's being cooked which makes it faster to be cooked.

Unit 7:
Pressure

Common Conversion Formulas

To convert between inches of mercury $(inHg)$ and kilopascals (kPa), use the formulas below:

$$P_{kPa} = 33.8639 \times \left(\frac{P_{inHg}}{10}\right)$$

$$P_{inHg} = 0.295300 \times P_{kPa}$$

To convert between inches of mercury $(inHg)$ and pounds per square inch (psi), use the formulas below:

$$P_{psi} = 0.491154 \times P_{inHg}$$

$$P_{inHg} = 2.03602 \times P_{psi}$$

To convert between kilopascals (kPa) and pounds per square inch (psi), use the formulas below:

$$P_{psi} = 0.145038 \times P_{kPa}$$

$$P_{kPa} = 6.89476 \times P_{psi}$$

Unit 7:
Pressure

Fundamentals of Steam

Hands On Exercise: Convert between Hg, kPa and PSI

1. 10 inHg = __________kPa
2. 15 inHg = __________kPa
3. 20 inHg = __________kPa
4. 25 inHg = __________kPa
5. 30 inHg = __________kPa
6. 10 kPa = __________inHg
7. 15 kPa = __________inHg
8. 20 kPa = __________inHg
9. 25 kPa = __________inHg
10. 30 kPa = __________inHg
11. 10 inHg = __________psi
12. 15 inHg = __________psi
13. 20 inHg = __________psi
14. 25 inHg = __________psi
15. 30 inHg = __________psi
16. 10 psi = __________inHg
17. 15 psi = __________inHg
18. 20 psi = __________inHg
19. 25 psi = __________inHg
20. 30 psi = __________inHg
21. 10 psi = __________kPa
22. 15 psi = __________kPa
23. 20 psi = __________kPa
24. 25 psi = __________kPa
25. 30 psi = __________kPa

Unit 8:
Steam
Properties

Flash Steam

What is Flash Steam?
When hot condensate or boiler water, under pressure is released to a lower pressure, part of it is re-evaporated, becoming what is known as flash steam.

Flash Steam

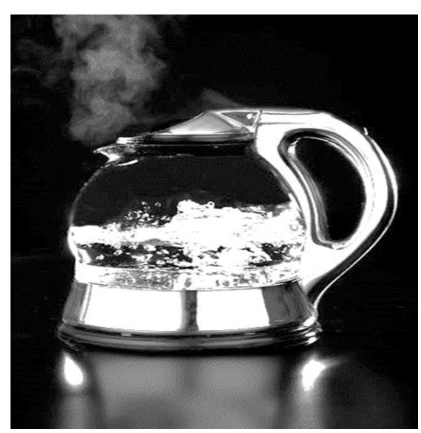
Why is it important?
This flash steam, which normally would be wasted, is important because it contains heat that can be used for other operations.

How is it formed?
When water is heated at atmospheric pressure, its temperature rises until it reaches 212F, the highest temperature at which water can exist at this pressure. Additional heat does not raise the temperature, but converts the water to steam.

Sensible heat
The heat absorbed by the water in raising its temperature to the boiling point is called "sensible heat" or heat of saturated liquid.

Water under pressure
If water is heated under pressure, however, the boiling point is higher than 212F, so the sensible heat required is greater. The higher the pressure, the higher the boiling temperature and the higher the heat content. If pressure is reduced, a certain amount of sensible heat is released. This excess heat will be absorbed in the form of latent heat, causing part of the water to "flash" into steam.

Saturated Steam
The state in which steam contains only the amount of heat energy required to maintain the vapor state. Any loss of heat energy from saturated steam will cause it to begin condensing.



Saturated Steam

Unit 8:
Steam Properties

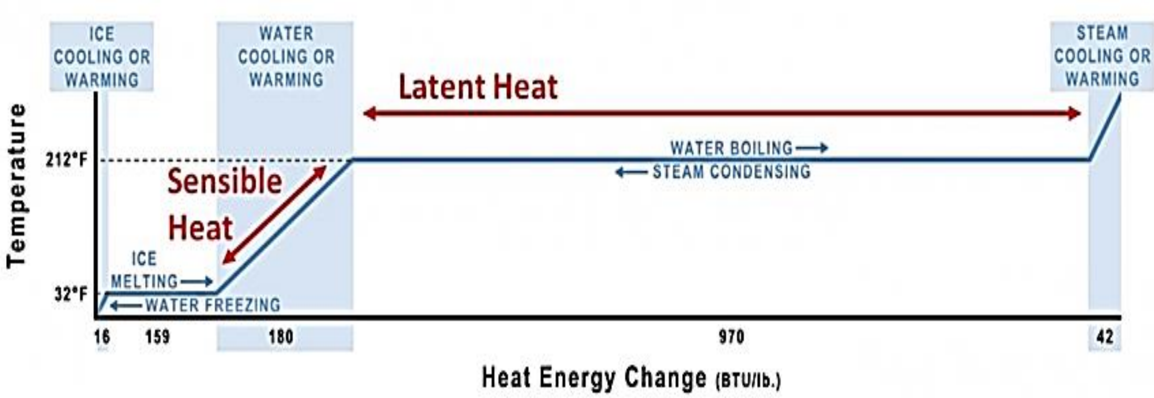
Latent Heat

Latent heat, energy absorbed or released by a substance during a change in its physical state (phase) that occurs without changing its temperature. The latent heat associated with melting a solid or freezing a liquid is called the heat of fusion; that associated with vaporizing a liquid or a solid or condensing a vapor is called the heat of vaporization. The latent heat is normally expressed as the amount of heat (in units of joules or calories) per mole or unit mass of the substance undergoing a change of state.

Ice cubes melting as their temperature rises. During melting, the ice absorbs latent heat, which is used to change the state of the water from ice to liquid water. While the ice is absorbing latent heat, its temperature is not changing.

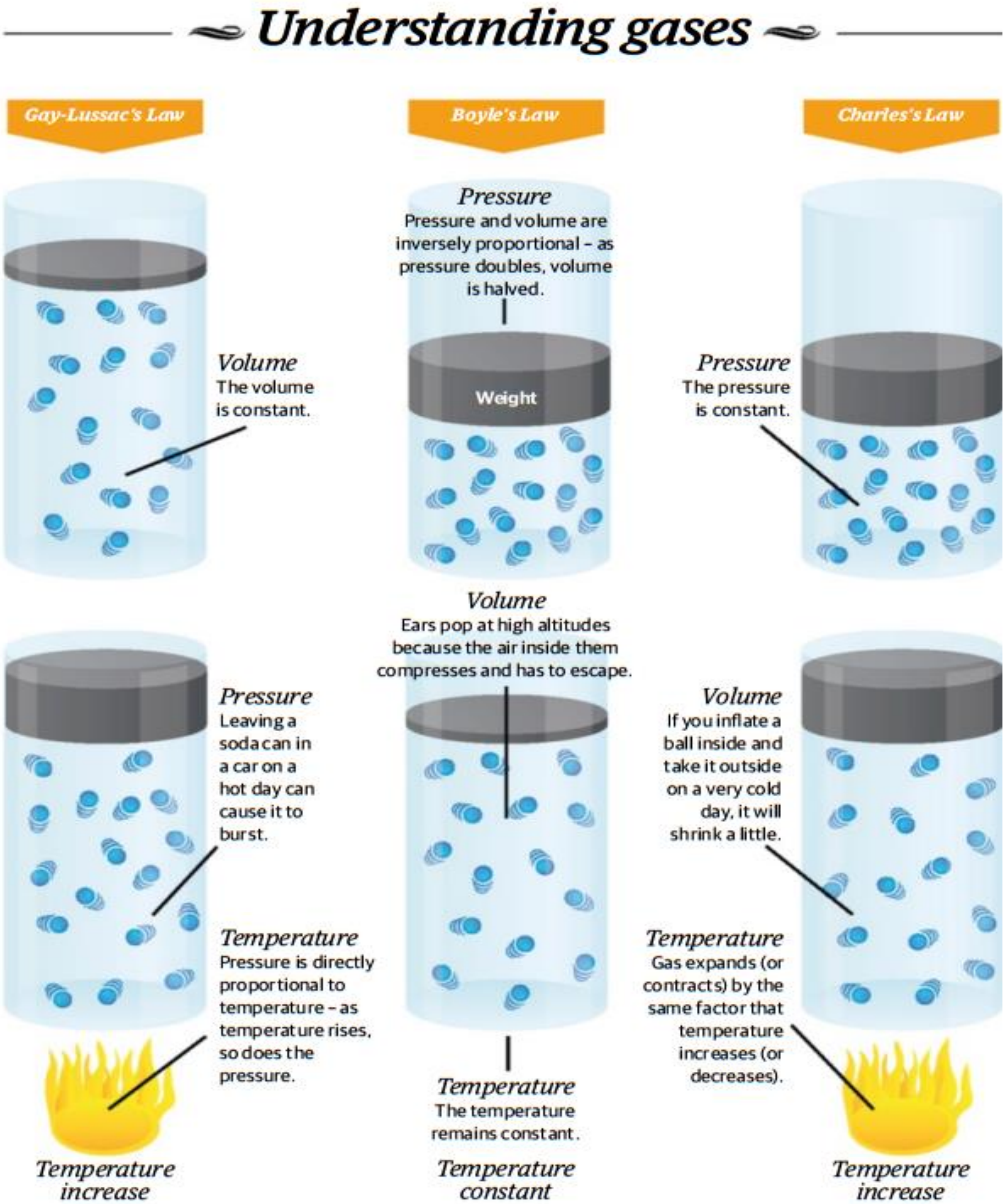
Ice cubes melting as their temperature rises. During melting, the ice absorbs latent heat, which is used to change the state of the water from ice to liquid water. While the ice is absorbing latent heat, its temperature is not changing.

For example, when a pot of water is kept boiling, the temperature remains at 100 °C (212 °F) until the last drop evaporates, because all the heat being added to the liquid is absorbed as latent heat of vaporization and carried away by the escaping vapor molecules. Similarly, while ice melts, it remains at 0 °C (32 °F), and the liquid water that is formed with the latent heat of fusion is also at 0 °C. The heat of fusion for water at 0 °C is approximately 334 joules (79.7 calories) per gram, and the heat of vaporization at 100 °C is about 2,230 joules (533 calories) per gram. Because the heat of vaporization is so large, steam carries a great deal of thermal energy that is released when it condenses, making water an excellent working fluid for heat engines.



https://www.britannica.com/science/latent-heat

Various Gas Laws



http://mechanicalgalaxy.blogspot.com/2014/07/different-laws-on-gas-gay-lussacs-law.html

Steam Tables

What are steam tables?
The heat quantities and temperature/pressure relationships referred to in this section are take from the Properties of Saturated Steam table.

Definition of Terms Used
Saturated Steam is pure steam at the temperature that corresponds to the boiling temperature of water at the existing pressure.

Absolute and Gauge Pressures
Absolute pressure is pressure in pounds per square inch (psia) above a perfect vacuum. Gauge pressure is pressure in pounds per square inch above atmospheric pressure, which is 14.7 psia. Gauge pressure (psig) plus 14.7 equals absolute pressure. Or, absolute pressure minus 14.7 equals gauge pressure.

Pressure/Temperature Relationship
For every pressure of pure steam there is a corresponding temperature. E.g. The temperature of 250 psig pure steam is always 406F.

Heat of Saturated Liquid
This is the amount of heat required to raise the temperature of a pound of water from 32F to the boiling point at the pressure and temperature shown. It is expressed in British thermal units (Btu).

Latent Heat or Heat of Vaporization
The amount of heat (expressed in Btu) required to change a pound of boiling water to a pound of steam. This same amount of heat is released when a pound of steam is condensed back into a pound of water. This heat quantity is different for every pressure/temperature combination.

Total Heat of Steam
The sum of the Heat of the Liquid and Latent Heat in Btu. It is the total heat in steam above 32F.

Specific Volume of Saturated Liquid
The volume per unit of mass in cubic feet per pound.

Specific Volume of Saturated Steam
The volume per unit mass in cubic feet per pound.

How the Table is Used
In addition to determining pressure/temperature relationships, you can compute the amount of steam that will be condensed by any heating unit of known Btu output. Conversely, the table can be used to determine Btu output if steam condensing rate is known.

Unit 8:
Steam Properties

Steam Tables

Chart 1135

Armstrong

Properties of Saturated Steam

	Gauge Pressure	Abso. Press. (psia)	Steam Temp. (°F)	Heat of Sat. Liquid (Btu/lb)	Latent Heat (Btu/lb)	Total Heat of Steam (Btu/lb)	Spec. Vol. of Sat. Liquid (cu ft/lb)	Spec. Vol. of Sat. Steam (cu ft/lb)
Inches of Vacuum	29.743	0.08854	32.00	0.00	1075.8	1075.8	0.016022	3306.00
	29.515	0.2	53.14	21.21	1063.8	1085.0	0.016027	1526.00
	27.886	1.0	101.74	69.70	1036.3	1106.0	0.016136	333.60
	19.742	5.0	162.24	130.13	1001.0	1131.0	0.016407	73.52
	9.562	10.0	193.21	161.17	982.1	1143.3	0.016590	38.42
	7.536	11.0	197.75	165.73	979.3	1145.0	0.016620	35.14
	5.490	12.0	201.96	169.96	976.6	1146.6	0.016647	32.40
	3.454	13.0	205.88	173.91	974.2	1148.1	0.016674	30.06
	1.418	14.0	209.56	177.61	971.9	1149.5	0.016699	28.04
PSIG	0.0	14.696	212.00	180.07	970.3	1150.4	0.016715	26.80
	1.3	16.0	216.32	184.42	967.6	1152.0	0.016746	24.75
	2.3	17.0	219.44	187.56	965.5	1153.1	0.016768	23.39
	5.3	20.0	227.96	196.16	960.1	1156.3	0.016830	20.09
	10.3	25.0	240.07	208.42	952.1	1160.6	0.016922	16.30
	15.3	30.0	250.33	218.82	945.3	1164.1	0.017004	13.75
	20.3	35.0	259.28	227.91	939.2	1167.1	0.017078	11.90
	25.3	40.0	267.25	236.03	933.7	1169.7	0.017146	10.50
	30.3	45.0	274.44	243.36	928.6	1172.0	0.017209	9.40
	40.3	55.0	287.07	256.30	919.6	1175.9	0.017325	7.79
	50.3	65.0	297.97	267.50	911.6	1179.1	0.017429	6.66
	60.3	75.0	307.60	277.43	904.5	1181.9	0.017524	5.82
	70.3	85.0	316.25	286.39	897.8	1184.2	0.017613	5.17
	80.3	95.0	324.12	294.56	891.7	1186.2	0.017696	4.65
	90.3	105.0	331.36	302.10	886.0	1188.1	0.017775	4.23
	100.0	114.7	337.90	308.80	880.0	1188.8	0.017850	3.88
	110.3	125.0	344.33	315.68	875.4	1191.1	0.017922	3.59

Steam Tables

PSIG

Gauge Pressure	Abso. Press. (psia)	Steam Temp. (°F)	Heat of Sat. Liquid (Btu/lb)	Latent Heat (Btu/lb)	Total Heat of Steam (Btu/lb)	Spec. Vol. of Sat. Liquid (cu ft/lb)	Spec. Vol. of Sat. Steam (cu ft/lb)
120.3	135.0	350.21	321.85	870.6	1192.4	0.017991	3.33
125.3	140.0	353.02	324.82	868.2	1193.0	0.018024	3.22
130.3	145.0	355.76	327.70	865.8	1193.5	0.018057	3.11
140.3	155.0	360.50	333.24	861.3	1194.6	0.018121	2.92
150.3	165.0	365.99	338.53	857.1	1195.6	0.018183	2.75
160.3	175.0	370.75	343.57	852.8	1196.5	0.018244	2.60
180.3	195.0	379.67	353.10	844.9	1198.0	0.018360	2.34
200.3	215.0	387.89	361.91	837.4	1199.3	0.018470	2.13
225.3	240.0	397.37	372.12	828.5	1200.6	0.018602	1.92
250.3	265.0	406.11	381.60	820.1	1201.7	0.018728	1.74
	300.0	417.33	393.84	809.0	1202.8	0.018896	1.54
	400.0	444.59	424.00	780.5	1204.5	0.019340	1.16
	450.0	456.28	437.20	767.4	1204.6	0.019547	1.03
	500.0	467.01	449.40	755.0	1204.4	0.019748	0.93
	600.0	486.21	471.60	731.6	1203.2	0.02013	0.77
	900.0	531.98	526.60	668.8	1195.4	0.02123	0.50
	1200.0	567.22	571.70	611.7	1183.4	0.02232	0.36
	1500.0	596.23	611.60	556.3	1167.9	0.02346	0.28
	1700.0	613.15	636.30	519.6	1155.9	0.02428	0.24
	2000.0	635.82	671.70	463.4	1135.1	0.02565	0.19
	2500.0	668.13	730.60	360.5	1091.1	0.02860	0.13
	2700.0	679.55	756.20	312.1	1068.3	0.03027	0.11
	3206.2	705.40	902.70	0.0	902.7	0.05053	0.05

*Abstracted from Keenan and Keyes, THERMODYNAMIC PROPERTIES OF STEAM, by permission of John Wiley & Sons, Inc.

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Chart 1135 5/10 7.5M

Unit 8:
Steam
Properties

Fundamentals of Steam

Hands On Exercise: Steam Tables

*Use the Steam Tables to find the answers to the 25 following questions. Your answer **must** include the decimal points and unit of measurement (e.g. – (970.0 Btu/lb).*

1. If the steamer pressure gauge reads 0.0 PSIG, what is the PSIA pressure? ___________________
2. If the steamer pressure gauge reads 0.0 PSIG, what is the steam temperature? _____________
3. If the steamer pressure gauge reads 0.0 PSIG, what is the latent heat? ___________________
4. If the steamer pressure gauge reads 0.0 PSIG, what is the heat of the saturated liquid? ___________________
5. If the steamer pressure gauge reads 5.3 PSIG, what is the PSIA pressure? ___________________
6. If the steamer pressure gauge reads 5.3 PSIG, what is the steam temperature? _____________
7. If the steamer pressure gauge reads 5.3 PSIG, what is the latent heat? ___________________
8. If the steamer pressure gauge reads 5.3 PSIG, what is the heat of the saturated liquid? ___________________
9. If the steamer pressure gauge reads 15.3 PSIG, what is the PSIA pressure? ___________________
10. If the steamer pressure gauge reads 15.3 PSIG, what is the steam temperature? _____________
11. If the steamer pressure gauge reads 15.3 PSIG, what is the latent heat? ___________________

Producing Steam

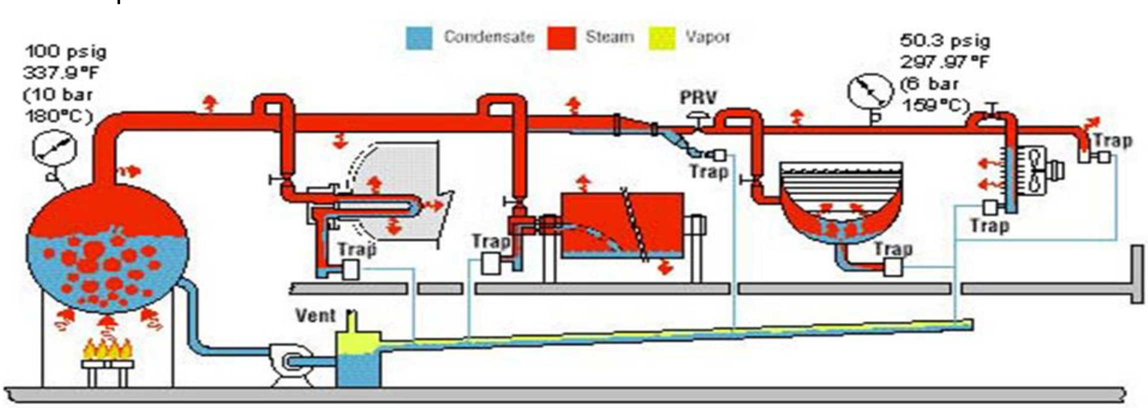
Producing Steam
Most industrial steam systems are closed systems. When water vaporizes to become steam in the boiler, the expansion pressurizes the system. Steam is forced out of the boiler by its own pressure and is carried by piping to whatever devices are to be employed for heating or processing. The pressure changes within the system provide transportation for the steam and also affect its physical properties. It is convenient and helpful to think of the typical steam system as a loop with four distinct sections: generation, distribution, heat transfer, condensate return.

1. Generation
During this stage - in the boiler - heat is applied to water to raise its temperature.
After the water has vaporized, the resulting steam moves into the second stage of the steam loop:

2. Distribution
This is simply the movement of the steam within a closed system to its point of use.
The use, whatever that happens to be, is called Heat Transfer.

3. Heat Transfer
This is the third stage. In the heat transfer portion of the steam loop, the heat of the steam is, well, transferred. In other words, it is put to work doing countless jobs.
A little later in this lesson, we'll discover three separate methods whereby steam's heat is transferred. As the steam gives up its heat through heat transfer or use, it condenses or changes its state - this time from a gas back into a liquid. This is called condensate.

4. Condensate Return
This is the job of a simple device called a steam trap. The fourth and final section of the steam loop is Condensate Return.



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Boiler Information

The gas boiler is designed to ASME Code and approved as a steam heating boiler restricted to operation at pressure not to exceed 15 psi.

The gas boiler may be in a 24" cabinet base rated at 140,000 or 200,000 BTU, 36" cabinet base rated at 200,000, 250,000 or 300,000 BTU, operational on Natural or Propane gas. Boilers may have optional electronic ignition and CSD1 controls.

Installation Codes and Standards
The boiler must be installed in accordance with:
Gas installation to conform to local codes, or in absence of local codes, with the National Fuel Gas Code - ANSI Z223.1/NFPA 54. In Canada installation to be in accordance with CSA B149.1 Natural Gas and Propane Installation Code.
1. The appliance and its individual shut off valve must be disconnected from the gas supply piping system during any pressure testing of that system at pressures in excess of ½ psig (3.5 kPa).
2. The appliance must be isolated from the gas supply piping system by closing its individual manual shut off valve during any pressure testing of the gas supply piping system at test pressures equal to or less than ½ psig (3.5 kPa).
Electrical grounding must be provided in accordance with local codes, or in the absence of local codes, with the National Electrical Code ANSI/NFPA 70. In Canada, installation must be in accordance with the Canadian Electrical Code CSA C22.2.

ASME – American Society of Mechanical Engineers

PSI – Pounds Per Square Inch

PSIG – Pounds Per Square Inch Gauge

BTU – British Thermal Unit

kPa – Kilo Pascal's

ANSI – American National Standards Institute

NFPA – National Fire Protection Association

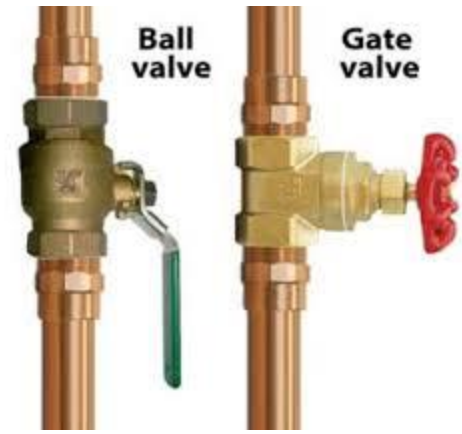
Hands On Exercise:

- ❑ Get an introduction to a code book by looking through one for a few minutes. Find some codes on boilers and discuss.

Unit 9:
Steam Systems

Water Supply Connection

Water Supply Connection
The incoming cold water supply connection, at the rear of the steamer cabinet, requires 3/8" tubing and water pressure of 25-50 psi. A manual shut-off valve must be provided convenient to the appliance; this valve should be open when the boiler is in operation.



Happyhiller.com

FAILURE OR MALFUNCTION OF THIS APPLIANCE DUE TO POOR WATER QUALITY IS NOT COVERED UNDER WARRANTY.

Drain Connections
The steamer drain (2" IPS) should be piped to a floor drain near the steamer. There should be no solid drain connection; an “open gap” between the steamer and the floor drain is required. Steam equipment usually has copper drain lines that drain into the main floor drains.

Superiordrain.com

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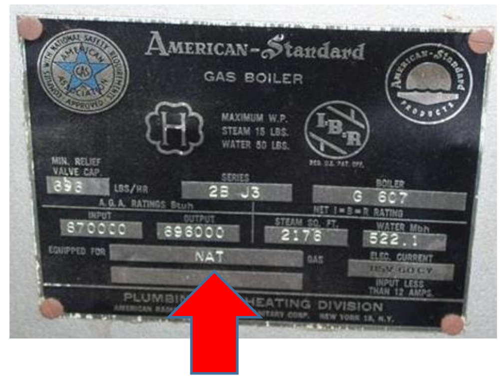
Gas Connection

Gas Connection

1. The data plate on the cabinet door of the boiler indicates the type of gas your unit is equipped to burn. **DO NOT** connect to any other gas type. Keep the appliance area free and clear from combustible substances. Do not obstruct the flow of combustion and ventilation air.
2. A 3/4" NPT line is provided at the rear for the connection. Each boiler is equipped with an internal pressure regulator which is set at 3.5" W.C. manifold pressure for natural gas or 10.5" W.C. for LP gas. Use the 1/8" pipe tap on the burner manifold for checking pressure.



Natchi.org

Gas Boiler Data Plate Displaying Gas Type

An adequate gas supply is necessary. Undersized or low pressure lines will restrict the volume of gas required for satisfactory performance. A steady supply pressure, between 7" W.C. and 14" W.C. for natural gas and 11" W.C. and 14" W.C. for propane gas is recommended.

Rsoultionmpt.com

¾" NPT Flexible Gas Hose

With all units operating simultaneously, the manifold pressure on all units should not show any appreciable drop. Fluctuations of more than 25% on natural gas, and 10% on propane gas, will create pilot problems and affect burner operating characteristics. Codes require that a gas shut-off valve be installed in the gas line prior to the steamer.
Make sure the pipes are clean and free of obstructions, dirt, and piping compound.

CAUTION: The pipe thread compound used when installing pipes must be a type that is resistant to the action of liquified petroleum or propane gases.

WARNING: Prior to start-up, check all joints in the gas supply line for leaks. Use soap and water solution. Do not use an open flame.

Equipment Location Air Flow

The installation location must be kept free and clear of combustibles. Do not obstruct the flow of combustion and ventilation air. Clearance from combustible construction must be a minimum of 3 inches from the sides and 6 inches from the back. The appliance should be installed on a noncombustible floor. Provide adequate clearances for cleaning, maintenance, service and proper operation.

Sufficient air should be allowed to enter the room to compensate for the amount of air removed by any ventilating system and for combustion of the gas burners. Do not obstruct the air flow into and around the appliance. Do not obstruct the flow of flue gases from the flue duct located at the rear and above the cabinet. Position the appliance in its final location. Check that there are sufficient clearances to service the controls, for door swings, etc., so there will be no problem in making the required supply and drain connections.

Allow enough space between any other piece of equipment or a wall for service access. Service on the cabinet base may require access to the left and/or right side panels.

Notes:

Unit 9:
Boilers

Normal Boiler Operating Cycle Example

Normal Boiler Operating Cycle

Water Fill Cycle

On the initial filling of the boiler, the reset switch must be activated to initialize the safety lockout circuit. Once the water in the boiler has reached the proper level, the level control will stop the flow of water to the boiler. As water is consumed in the production of steam, the level control will replenish water to the boiler.

Firing Cycle

The gas valve is controlled by pressure sensing devices. On initial operation of the boiler, steam generation should reach 11 psi in approximately 15 minutes. At this point the "Operating Pressure" switch will close the gas valve. When pressure drops to 9 psi, the pressure switch opens the gas valve and ignition should occur.

Should the pressure rise to more than 14.5 psi the "Override pressure switch" will open the override solenoid valve, releasing the excess steam.

Condensing Drain

A thermostat is located in the drain assembly and is activated by the temperature of steam. The thermostat opens the cooling solenoid valve, supplying water to the drain to condense the steam.

Automatic Blowdown Valve

If the unit has an automatic blowdown valve, it is activated by the main power switch. The boiler will drain should the main power switch be turned "OFF."

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Unit 9:
Steam Systems

Safety Lockout Conditions

High Temperature Condition
A high temperature safety device is installed on the boiler. Should the temperature exceed the limit of this device, the boiler will be shut down and be put in a state of lockout. The “Temperature” pilot light (Red), and the “Standby” pilot (amber), will come on.

High Pressure Condition

A high pressure safety switch is installed on the boiler. Should the pressure exceed the limit of this device, the boiler will be shut down and be put into a state of lockout. The “Pressure” pilot light (Red), and the Stand By pilot (amber), will come on. Should this device fail to operate, the safety relief valve will open.

Low Water Condition

A second low water safety cut off is supplied with the boiler. Should the water level fall below normal operating levels, this device will activate and put the boiler in a state of lockout. The “Low Water” pilot light (Red), and the “Stand By” pilot (amber) will come
on.

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Boiler Safety Devices

Learn the difference between safety- and relief valves
Each boiler requires some sort of pressure-relieving device. They are referred to as either a safety, relief or safety relief valve. While these names are often thought of as interchangeable, there are subtle differences between them. According to the National Board of Boiler and Pressure Vessel Inspectors, the following are the definitions of each:

•**Safety valve** - This device is typically used for steam or vapor service. It operates automatically with a full-opening pop action and recloses when the pressure drops to a value consistent with the blowdown requirements prescribed by the applicable governing code or standard.

• **Relief valve** - This device is used for liquid service. It operates automatically by opening farther as the pressure increases beyond the initial opening pressure and recloses when the pressure drops below the opening pressure.

•**Safety-relief valve** - This device includes the operating characteristics of both a safety valve and a relief valve and may be used in either application.

•**Temperature and pressure safety relief valve** -This device is typically used on potable water heaters. In addition to its pressure-relief function, it also includes a temperature-sensing element which causes the device to open at a predetermined temperature regardless of pressure. The set temperature on these devices is usually 210°.

https://heatinghelp.com/systems-help-center/learn-the-difference-between-safety-and-relief-valves/#sthash.cRPlaUVg.dpuf

Steam safety valve

Directindustry.com

The Purpose of a Safety Valve

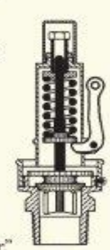
1909

"The function of the safety valve is two fold: (A) it gives notice of the highest pressure permissible; (B) it gives alarm that more water or less fuel is needed."

"It limits the working pressure under ordinary conditions."
– *American Society of Mechanical Engineers Transactions*, 1909

The safety valve "Should be compared with the steam gauge frequently to see that it works accurately."
– *The Young Engineer's Guide*, 1899

"Safety valves should be set at the working pressure of the boiler."
– Consolidated Ashcroft Hancock Co., 1928

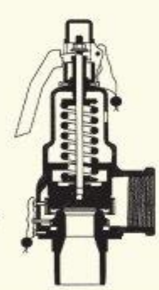


TODAY

"A PRV (pressure relief valve) is a safety device intended to protect life and property if all other safety measures fail."
– Anderson Greenwood Crosby, 2001 (safety valve manufacturer)

"Avoid excessive 'popping' of the safety/relief valve as even one opening can provide a means for leakage."

"Avoid having the operating pressure too near the set pressure. A differential of 10% is recommended."
– Kunkle catalog no. 85, 1985



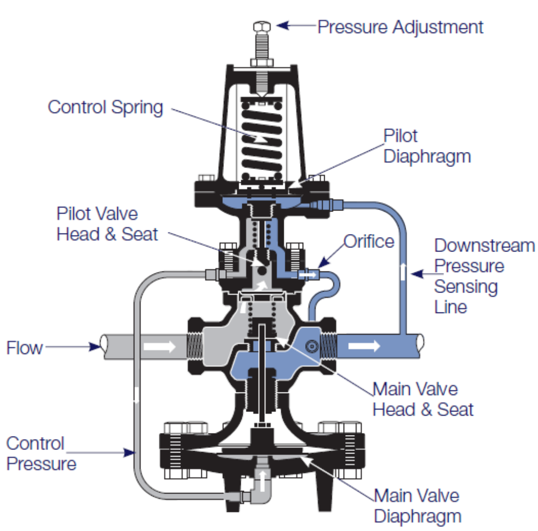
Pressure Reducing Valves

For steam and industrial fluids
A well designed steam system will produce clean dry steam in the boiler house ready for delivery at high pressure through the distribution network. This maximizes the potential to generate and supply saturated steam of the best quality at the lowest overall cost. The majority of applications however require a reduction in pressure at the point of use.

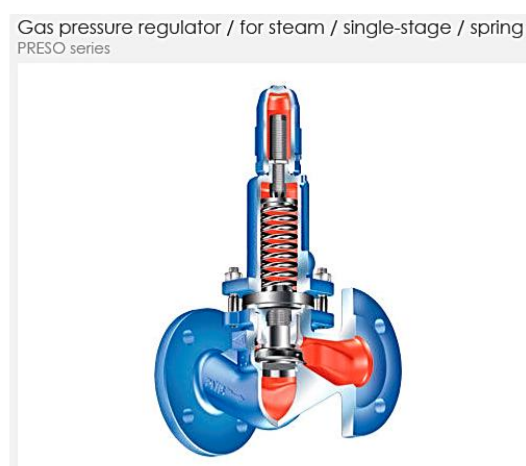
The benefits of this include:
• A reduction in the capital cost of equipment.
• Operating costs will decrease by reducing flash steam.
• Saturated steam pressure is directly related to temperature. Controlling the pressure will therefore automatically control the temperature avoiding the need for additional temperature control equipment.
• The flexibility to supply steam at the optimal pressure for each individual application.

However, there are some applications that have a need to sense and control upstream of the valve to maintain or disperse excess pressure in the distribution pipeline in order to safeguard the equipment using it - this requires a back pressure regulator.

Two main groups of pressure control valves are available for either pressure reduction or back pressure applications:
• Self-acting, requiring no external power or input.
• Pneumatically & Electrically Actuated with either a pneumatic or electrical control system.



spiraxsarco.com



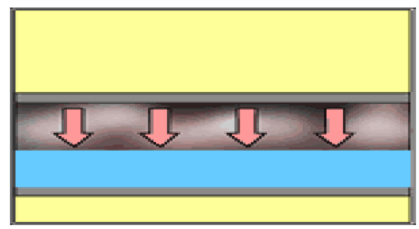
Directindustry.com

Unit 9:
Steam Systems

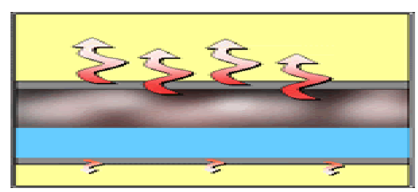
Fundamentals of Steam

Condensate Management

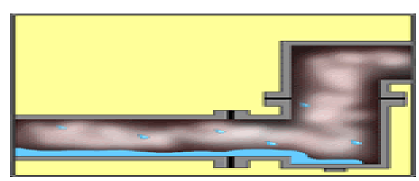
Condensate Management
When you're working with heat transfer in a steam system, it's inevitable that you end up with a by-product called condensate. Accumulation of this by-product is unavoidable, forming as a result of radiation and heat transfer.
Once the steam has given up its valuable latent heat, condensate must be removed immediately.
Management of condensate accumulation and distribution is an important element in an efficient steam system.



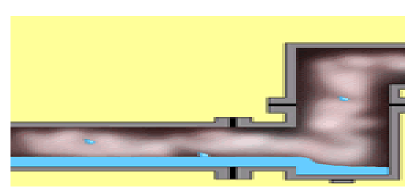
Heat Content of Condensate
Condensate takes up space that steam cannot penetrate, under normal conditions.
Steam contains more than 5 times the heat of condensate at atmospheric pressure, though this ratio falls as pressure increases.



Condensate Heat Transfer
Due to condensate's lack of latent heat, areas of a heat exchanger filled with condensate transfer much less heat than those areas filled with steam.



Condensate Accumulation
Heat is continuously flowing from the steam to the water, causing more steam to become condensate.



Accumulation and Effect on Efficiency
Condensate is water formed when steam has reverted from its gaseous state to a liquid. Managing condensate is essential if you want to maximize your steam system's efficiency.

Notes:

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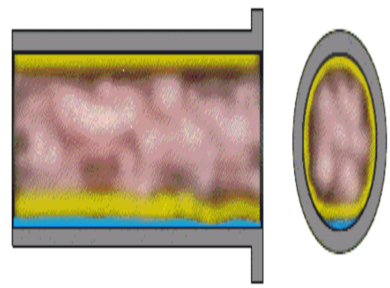
Condensate Management

Corrosion

Corrosion occurs in systems where non-condensables are allowed to combine with retained condensate. The most familiar form of corrosion results from the oxidation of iron in the presence of water to form ferric acid. You probably know it as common rust.

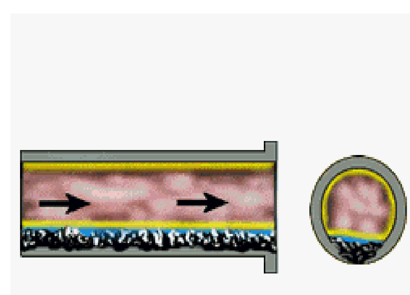
Rust



Armstronginternational.com

In a steam heating system, differences in temperature increase electron flow.
Because water is an electrolyte, it conducts electrons from the anode to the cathode, polarizing them chemically and electrically. The ions of the water combine with the ions of the metal at its surface. Ferrous oxide is formed at the anode, then combines with atmospheric oxygen to form ferric acid, or rust.

Pitting and Scaling



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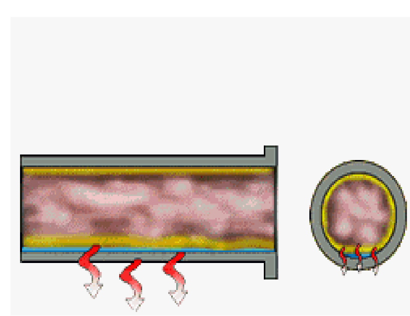
Corrosion can occur in several ways, depending on the oxygen content, alkalinity, temperature and other factors of the water. The damage caused by corrosion can range from pitting in certain areas to scaling, in which the entire surface area becomes affected.
Large pieces of scale can flake off, drifting downstream until they become lodged in small orifices and cause blockage.

Carbonic Acid



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An even more damaging form of corrosion results from the creation of a highly corrosive compound called carbonic acid. As condensate cools within the system, a chemical reaction combines it with carbon dioxide, forming carbonic acid. Carbonic acid within a steam system can completely dissolve piping and equipment.($CO_2 + H_2O = H_2CO_3$)
As long as the condensate remains hot, carbonic acid is not formed. The carbon dioxide behaves like any other non-condensable.

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Unit 9:
Steam Systems

Steam Traps

An Introduction to Steam Traps

A simple, economical steam system consists of certain basic components:

1. A boiler that generates steam
2. Piping that delivers steam from the boiler and returns condensate to the boiler
3. a heat exchanger where heat is transferred to perform work

Steam Trap Function

A steam trap is a device that automatically senses the difference between steam, non-condensable gases and condensate. It assures retention of steam within the system, while removing condensate and non-condensables.

Steam Trap Design

There are several different kinds of steam trap designs, varying according to application demands and requirements.

Types of Steam Traps

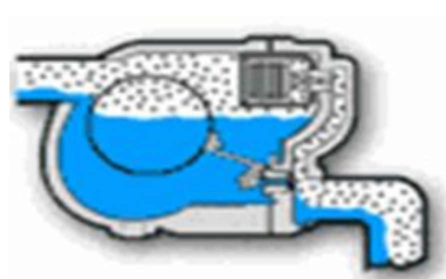
An effective steam trap maximizes the efficiency of a steam system in three ways:

1. It keeps the system filled with dry steam
2. It removes by-products (condensate and air) from the system that form insulating barriers that prevent efficient and effective heat transfer.
3. It makes the hot condensate available for recycling, reducing both waterside care and energy costs at the boiler

The two most common types of steam traps in the Commercial Food Equipment Industry are:

Mechanical Traps

Mechanical traps operate by using the difference in density between steam and condensate. A float within the trap detects the variance in weight between a gas and a liquid.



Mechanical Steam Trap

Thermostatic Traps

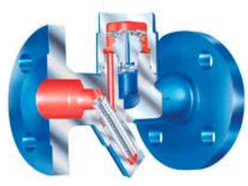
Thermostatic traps detect the variation in temperature between steam and condensate at the same pressure. The sensing device operates the valve in response to changes in the condensate temperature and pressure.

Thermostatic Steam Trap

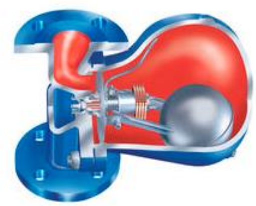
Various Steam Component Design

Steam trapping

Condensate drain / automatic / mechanical / bimetallic
CONA B series



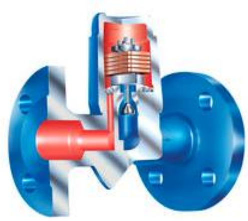
Condensate drain / automatic / thermostatic
CONA-M series



Condensate drain / automatic / variable-area
CONA S series

Condensate drain / automatic / heat-recovery
CONA TD series

Condensate drain / manual / thermostatic
CONA All-in-one

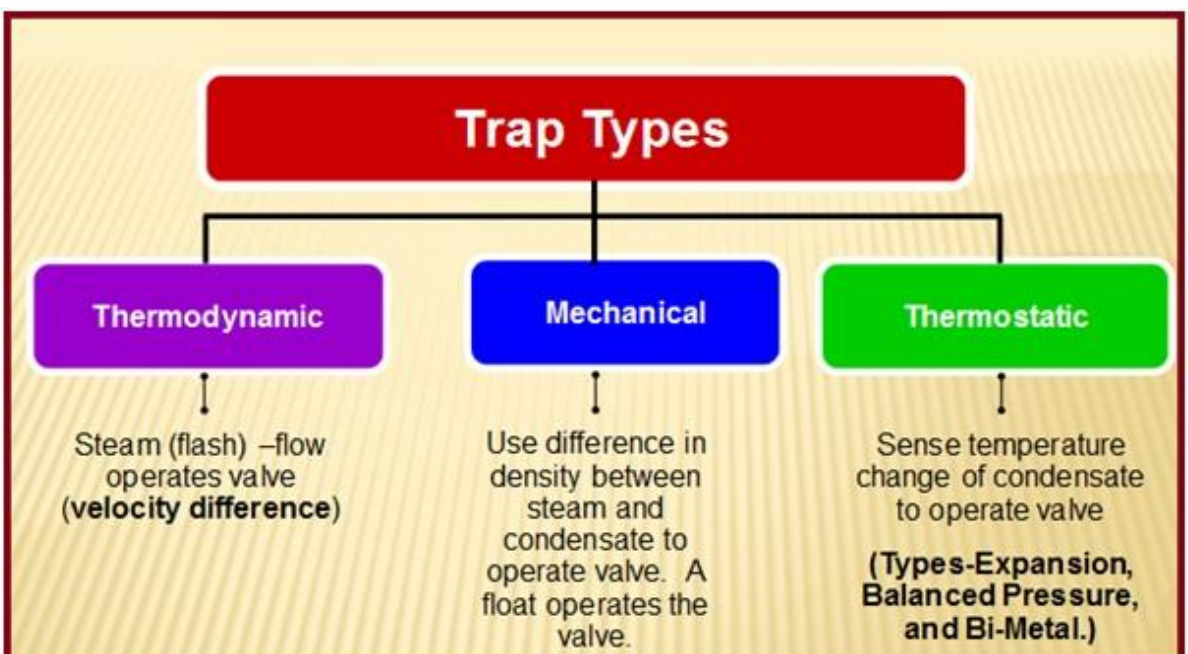


Condensate drain / automatic / mechanical / bimetallic
CONA B ANSI series

Check Valves

Piston check valve / stainless steel
CHECKO-V series

Disc check valve / wafer
CHECKO-D series

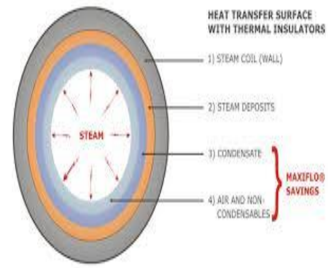


Unit 9:
Steam Systems

Non-Condensable Gases

Non-Condensables

In the world of steam heating system management, non-condensables are fluids that remain in a gaseous state all the way through normal temperature/pressure ranges.



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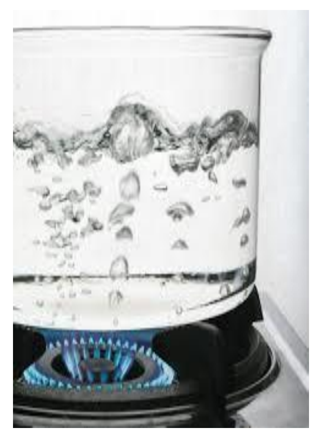
Primarily, we're concerned with three kinds of non-condensables:

- The mixture of atmospheric gases generally known as AIR
- oxygen
- carbon dioxide

How non-condensables enter the system

Non-condensables are introduced into the system in two ways. First, non-condensables can enter the boiler through the make-up water. Non-condensables often exist as dissolved gases. To understand what a dissolved gas is, think of it this way - when you boil water on the stove, you see gas bubbles expand and rise to the surface long before the water actually boils. These are non-condensable gases. Impurities in the makeup water that are released during thermal breakdown can release non-condensables into a system.
Another way non-condensables can enter a system is in the form of air being pulled in from the atmosphere. Air can get in through leaks in equipment or piping. This happens most often when the system is shut down and the steam pressure falls below the atmospheric pressure.



Vacuum Breakers

Non-condensables can be introduced into a system through vacuum breakers. These devices prevent a vacuum from forming inside the steam space. Vacuum breakers prevent steam pressure from falling below atmospheric pressure. They allow air to enter the steam space, preventing a vacuum and controlling the temperature by mixing cooler air with the steam. When a steam system shuts down, a vacuum can form as the remaining steam condenses. Vacuum breakers prevent this from happening and allow the force of gravity to drain the condensate. Unless air needs to be retained in the steam space in order to control the temperature, all non-condensable gases should be removed to get maximum efficiency from the heat exchanger and to prevent water hammer and corrosion. Some types of steam cooking equipment use vacuum breakers.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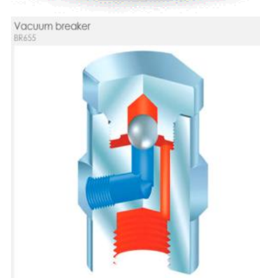

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Unit 10:
Troubleshooting

Fundamentals of Steam

Atmospheric Burner Basics

Some steam cooking equipment is gas fired. This section will give you an overview of the basics of gas burners.

ATMOSPHERIC BURNER BASICS

Common Problems and Corrections

Primary air, burning speed, port size, and depth of the port are several factors affecting flame stability. Flames on a burner tend to stabilize at a point where flow velocity out and burning speed back are equal. This balance of flow velocities and burning speed explain why flames change when the primary air or the gas input rate are adjusted. Natural gas burns at the rate of 25 inches per second. By comparison, propane burns at 32 inches per second and hydrogen at 112 inches per second.

Yellow Flames:

Bunsen type flames should be completely blue. If not enough primary air is supplied, yellow tips appear in the flames. Normally 50 percent of the air required for complete combustion is drawn in through the primary air opening.

Recognizing Yellow Flames:

Do not confuse yellow tips with red or orange streaks, which sometimes appear in flames. These color streaks are due to dust and other impurities being consumed in the flame and represent no problem with the adjustment.

Results of Yellow Flames:

Yellow tipped flames indicate incomplete combustion. This condition is aggravated when the flames impinge on a cooler surface. Yellow flames produce free carbon (soot), and that can be a nuisance. On open burners, the cooking pan's exterior becomes blackened from the soot and difficult to clean. On a hot top, soot acts as an insulator and retards heat transfer. If allowed to accumulate, the soot blocks the natural venting process required to maintain complete combustion.

Correcting Yellow Flames:

Yellow flames are caused by a lack of sufficient primary air. This condition may be due simply to an incorrect air shutter adjustment. A burner orifice out of alignment with the mixer tube will reduce primary air inspiration by lowering the gas velocity in the mixer tube (common on commercial cooking equipment). Correct by aligning the orifice with the mixer tube. A burr or debris on the orifice can also cause reduced gas velocity creating yellow flames on the burner.

Blowing or Lifting Flames:

When blowing flames occur, part of the flame lifts or "dances" on the burner port. This may occur on a few or all of the ports of a burner. The flames will blow off the burner ports when the flow velocity of the air/gas mixture from a port exceeds the flame velocity. The flame cannot stabilize at the burner port, as in normal operation.

Recognizing Blowing Flames:

Lifting flames rise from the ports to burn some distance above the port. In some cases, these flames will drop back to the port and lift again intermittently. If the flames lift from a number of ports they may create a distinct flame noise.

Results of Blowing Flames:

The noise created may cause the user to complain. A more serious condition, incomplete combustion, will occur when there is a tearing or distortion of the flame pattern.

Correcting Blowing Flames:

The simplest way to stop burner flames from blowing is to reduce the primary air. This will be effective only if the burner gas is supplied at the rated input for the burner.

Other Causes of Blowing Flames:

Contamination of primary or secondary air (air surrounding the burner flame) may cause the burner flame to blow or lift away from the burner. A typical example of this condition is when oven products of combustion leak into the range top burner area. Lifting of top burner and pilot flames are caused by the contaminated air (oxygen deficient) surrounding the burner head. In extreme cases this problem can cause pilot outage and difficulty keeping the burner lit on low flame.

Flashback:

When flashback occurs in a burner, the air/gas mixture ignites inside the burner to burn near the orifice. This burning in the mixer tube usually creates a roaring noise like a blowtorch.

Results of Flashback:

Any flashback condition should be avoided. The burning action inside the mixer tube does not get enough air. Combustion is incomplete, producing odors and carbon (soot), which clogs the inside of the burner.

Atmospheric Burner Basics (Cont.)

Correcting Flashback:

Reducing primary air to the burner usually can eliminate flashback on ignition or during burner operation. The input rate may be too low or the orifice may have been enlarged, thereby reducing the gas velocity. Burner valves that fail to shut off completely can also be a source of burner flashback. Repair or replace the valve. A common occurrence with a commercial range top-burner is the build-up of excessive grease or debris inside the burner that can slow the gas/air mixture down and cause flashback to occur.

Fluctuating Flames:

This condition usually indicates a non-uniform gas pressure.

Recognizing Fluctuating Flames:

Lengths of the burner flame may increase and decrease (fluctuate) over a short period of time with no burner readjustment. Burner flame lifting may also be associated with flame fluctuation.

Results of Fluctuating Flames:

Fluctuating flames do not usually create any immediate problems, such as incomplete combustion, unless the flame impinges on a cool surface. This condition should be corrected since it warns of possible future problems.

Correcting Fluctuating Flames:

Unsteady gas pressure causes flames to fluctuate. Usually the condition indicates a problem with the gas pressure regulator (most common), sticking gas meter or a faulty gas service regulator. Water or other liquids in the gas supply line can also cause the gas pressure to fluctuate.

Smothering Flames:

Smothering occurs most often in an enclosed area such as the burner compartment of an oven or burners under a hot top. Smothering flames are lazy looking. The flame does not display well-defined cones and appears to be "reaching" for the air. They are quiet flames, which roll around in the combustion chamber, sometimes completely off the burner ports.

Recognizing Smothering Flames:

The difference between smothering flames and lifting (blowing) flames should be clearly understood. Both conditions are undesirable, but the causes and corrective steps are different in each case. Blowing or lifting flames are well defined, hard and may create a blowing noise. Cutting back on the primary air usually stops a flame from lifting.

Results of Smothering Flames:

Smothering flames indicate incomplete combustion. They point to a dangerous condition that requires prompt action. If the secondary air supply is reduced or contaminated, the flame searches for clean air in order to burn off all the fuel. This may cause the flame to extend out of the burner compartment area as it searches for air.

Correcting Smothering Flames:

The equipment may be overrated (too much input). If this is the case, the flue outlet area provided for the correct input may be too small for the increased gas rate. Check the found gas rate against the rating plate. If the equipment is found to be over gassed, de-rating may be necessary to correct the problem. Other conditions may cause poor venting and lead to smothering flames. Check and clear the flue. Make sure that there is adequate secondary air available to the area supporting combustion.

Flame Rollout or Delayed Ignition: Flame rolls out of the combustion chamber or burner area when the burner is turned on.

Results of Flame Rollout or Delayed Ignition:

Flame rollout may create a fire hazard and will scorch appliance finishes, burn wiring and damage controls. The gas in the burner mixer may be ignited, producing flashback.

Correcting Flame Rollout or Delayed Ignition:

The basic cause of delayed ignition is the pilot being out of position, or a pilot adjusted too low for rapid ignition. Lack of air due to over-rating of the burners may be the cause. Drafts or blockage of the flue is another possible cause. Defective gas controls that open too slowly can also contribute to this condition by not supplying a volume of gas needed for proper ignition.

https://www.socalgas.com/documents/innovation/fsec/2012%20Equipment%20Maintenance%20for%20Optimum%20Efficiency%20Handout.pdf

Gas Boiler Troubleshooting

Below are some areas to consider when troubleshooting gas boilers.

WARNING: The boiler and its parts are hot. Use care when operating, cleaning, or servicing the boiler.

BURNERS PRODUCE CARBON DEPOSITS

1. Wrong size orifices.
2. Burner air not adjusted properly.
3. Wrong gas supply.
4. Incorrect pressure at supply.

PILOT DOES NOT LIGHT

1. Gas supply to unit is OFF.
2. Power supply is OFF.
3. Gas control knob is OFF.
4. Dirty or loose wire connection to module - clean and/or tighten.
5. Ignitor cable, shorting out - check that it is not in contact with metal or damaged; may require replacement.
6. Defective control or module.
7. Unit has gone into 100% lockout - turn off and try again in five minutes.
8. Dirty flame sensor - clean with emery cloth.
9. Cracked ceramic insulator - replace pilot burner/ignitor sensor.
10. Too much draft.

BURNER DOES NOT COME ON

1. Gas supply to unit is “OFF”.
2. Manual shut off valve is “OFF”.
3. Power supply is “OFF”.
4. Faulty valve or ignition module.
5. Pilot out.
6. Pilot may require flame adjustment.
7. Water level has not been reached in boiler. Check water supply is on, check water level control.
8. If water at proper level, check relay which energizes pressure switch and gas control.
9. Pressure switch may need to be replaced if relay is operating.
10. Gas control may also require replacement if energized but not operating.

Gas Boiler Troubleshooting (cont.)

WARNING: The boiler and its parts are hot. Use care when operating, cleaning, or servicing the boiler.

SAFETY RELIEF VALVE BLOWS

1. Defective valve.
2. Pressure too high, pressure switch requires adjustment (lower) or may be defective.

WATER NOT BEING SUPPLIED TO BOILER

1. Water supply is “OFF”.
2. Defective water fill Solenoid Valve.
3. Water level control clogged or defective, unable to operate fill valve.
4. Check that drain valve is closed.
5. Supply water pressure too low.

BOILER SLOW TO HEAT UP

1. Lime build up - contact service.
2. Wrong size orifice(s) or gas supply.

Notes:

Unit 10:
Troubleshooting

Fundamentals of Steam

Vulcan 24GA Convection Steam Sequence of Operations

TROUBLESHOOTING SEQUENCE OF OPERATION

STEP	FUNCTION	DESCRIPTION
1	Power On	Power Switch is switched to the on position.
2	Fill Stage 1	Boiler fills with fast fill water valve, (3.7 GPM).
3	Low Level Probe Confirmation	Low Level Probe, (LLCO), is confirmed then power is applied to burner system, fast fill valve is turned off.
4	Burner Operation	Power is supplied to operating pressure switch.
5	Blower	Blower is turned on by operating pressure switch.
6	Blower Pressure Switch	Blower air pressure switch is closed when fan is up to speed, (0.35" to 0.4" WC) and supplies 24 VAC to the ignition module.
7	Pilot Ignition	Module turns on spark ignition and supplies power to combination valve pilot valve, (PV & PV/MV terminals).
8	Flame Sense	Flame sense probe confirms pilot flame.
9	Main Burner	Ignition module supplies power to gas combination control valve, (MV & PV/MV terminals), burner ignites.
10	Generator Initial Heat Up	Generator heats up.
11	Fill Stage 2	Generator 190°F thermostat supplies signal to water level control to continue filling with trickle valve, (0.25 GPM).
12	Generator Full	Boiler will fill till high water probe is confirmed.
13	Ready	Operating pressure switch activates ready light and supplies timer motor power at 3.5 to 4.0 PSI.
14	Full Pressure	Generator burner system is terminated at 3.5 to 4.0 PSI.
15	Low Pressure	Generator burner system will turn on at 2.5 to 3.5 PSI and operate till generator pressure reaches 3.5 to 4.0 PSI.
16	Water Level	Water level is electronically controlled between the upper and middle probe operating the trickle fill valve, 0.25 GPM.
17	Cooking	Timer is set and door switch is closed power will be supplied to steam valve, cavity drain valve relay, and cook light.
18	Cold Water Condensate	Thermostat located in drain assembly will supply power to cold water condensate valve to maintain drain temp below 140°F.
19	End Cook Cycle	Timer supplies power to buzzer, removes power from steam valves, cook light, & cavity drain valve relay.
20	Power Off	Power Switch is switched to the off position.
21	Power Down	Power is removed from burner and water level controls.
22	Drain	Power is supplied to drain timer, drain valve is powered for approximately 16 minutes.

Vulcan 24GA Convection Steam Troubleshooting Chart

C24GA SERIES CONVECTION STEAMERS - TROUBLESHOOTING

TROUBLESHOOTING CHART

SYMPTOM	POSSIBLE CAUSES
Compartment leaks steam or water around door.	1. Steamer not level. 2. Worn or damaged gasket. 3. Cavity rear strainer clogged. 4. Drain line obstructed. 5. Drain not to an open gap drain.
Cold water condenser not operating properly.	1. Cold water condenser solenoid inoperative or plugged. 2. Lack of water supply. 3. Cold water condenser thermostat malfunction. 4. No power to cold water condenser solenoid. 5. Plugged spray nozzle.
Steam visible inside compartment when unit is not in cook mode.	1. Steam supply solenoid not fully closing (clogged or dirty). 2. Timer contacts 1 & 3 closed.
Heat coming on without water in.	1. Scale on water level probes (shorted to ground). 2. Retention of water in probe canister assembly.
Pressure relief valve opening or leaking.	1. Cycling pressure switch set too high. 2. Pressure relief valve malfunction. 3. Dirt or scale on valve seat.
Generator will not heat or build pressure.	1. Incorrect input voltage. 2. Generator not filled. 3. Water Level Control malfunction. 4. Water too "pure" for probes to properly conduct electricity. 5. Cycling pressure switch open or set too high or set too low. 6. High limit thermostat open. 7. Power switch malfunction.
Steam output low or slow cooking.	1. Blocked steam injector ports. 2. Steam solenoid valve not fully opening or blocked. 3. Steam intake shut-off valve closed. 4. Cycling pressure switch malfunction or needs adjustment. 5. Steam header line (supply) blockage. 6. Pressure relief valve leaking. 7. Steam supply lines leaking badly. 8. Steam strainer clogged. 9. Superheater plumbed incorrectly. 10. Superheater cracked or clogged.
Unit leaks water.	1. Loose water, steam or drain line connections (top or base). 2. Water line connection clamp leaking.
Generator water level too high.	1. Fast fill or slow fill solenoid does not shut off. 2. High level probe dirty or scaled (open circuit). 3. Water level control malfunction.

Vulcan 24GA Convection Steam Troubleshooting Chart

C24GA SERIES CONVECTION STEAMERS - TROUBLESHOOTING

SYMPTOM	POSSIBLE CAUSES
Generator does not fill.	1. Water supply not on.
	2. Fill solenoid not opening or plugged.
	3. Water level control malfunction.
	4. Filter clogged.
Timer motor does not run.	1. Door open.
	2. Door switch inoperative.
	3. Timer not getting power.
	4. Timer motor inoperative.
	5. Ready light circuit malfunction.
Door not closing properly.	1. Door latch assembly malfunction or out of adjustment.
	2. Striker adjustment.
Door won't open or hard to open.	1. Latch won't release.
	2. Door held shut by internal vacuum due to improper drain connection.
	3. Striker adjustment.
	4. Door held shut by internal pressure.
Buzzer not operating.	1. Timer malfunction.
	2. Buzzer malfunction.
Burner won't light or won't stay lit.	1. Gas not on.
	2. Combustion air pressure switch malfunction.
	3. Ignition module not receiving power.
	4. Unit not properly grounded and/or polarity of incoming power is incorrect on automatic ignition systems.
	5. Low incoming gas pressure.
	6. Ignition module malfunction.
	7. Gas combination control valve malfunction.
	8. Generator not filling.
	9. Water level control malfunction.
	10. Water too "pure" for probes to properly conduct electricity.
	11. Generator pressure switch open or set too low.
	12. Supply line gas pressure too low.
	13. Ignition module malfunction.
	14. Obstruction in gas orifice.
Pilot not lit or goes out.	1. Gas not on.
	2. Low incoming gas pressure.
	3. Flame sense current too low; dirty or failed pilot assembly.
	4. Burners ignite too violently.
	5. Flame sense wire connection corroded.
	6. No sparking.
	7. Wrong pilot assembly used.

Vulcan 24GA Convection Steam Troubleshooting Chart

C24GA SERIES CONVECTION STEAMERS - TROUBLESHOOTING

SYMPTOM	POSSIBLE CAUSES
Spark igniter not sparking.	1. Incorrect spark gap setting. 2. Poor ground between pilot bracket and burner. 3. Loose, broken or damaged lead wires (including ground) from ignition module to ignitor. 4. Ignitor boot on ignition cable loose, damaged or missing causing excessive ignition voltage leakage. 5. Ceramic flame rod insulator on ignitor cracked or damaged from extreme heat. 6. Ignition module not receiving power. 7. Ignition module malfunction. 8. Combustion burner not operating. 9. Air pressure switch.

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Steam Jacketed Kettle Tips

STEAM JACKETED KETTLES

Energy-Efficiency Tips

1. The use of a water treatment system is highly recommended to minimize scaling.
2. Steam cooking is fast compared to other cooking methods. Use a timer to prevent overcooking and wasted energy.
3. Use the lid whenever possible.
4. Clean and maintain the boiler for direct connected steamers to maintain performance and conserve energy.

Cleaning Tips

1. Clean kettle as soon as possible, preferably while it is still warm.
2. Scrape and flush out food residues.
3. Use a sponge, cloth or plastic brush to thoroughly clean the inside of the kettle.
4. Rinse kettle and all draw-off valve parts thoroughly with hot water, then drain completely.
5. It is recommended that the kettle be sanitized just before use.
6. Cleanse front and sides of the kettle with a damp cloth and shine with a stainless steel cleaner.
7. Blow down boiler daily, or as recommended by manufacturer.
8. Have boilers cleaned and checked annually, or as recommended by the manufacturer.

Safety Tips

1. Check jacket vacuum and proper water level, as specified by manufacturer's instructions.
2. Never leave a sanitizer in contact with stainless steel surfaces longer than 10 minutes. Longer contact can cause corrosion.
3. Keep the inside of the control console clean and dry.
4. If the steam boiler is running for eight hours or longer, it should be drained or blown down twice daily or as recommended by the manufacturer.

Notes:

https://www.socalgas.com/documents/innovation/fsec/2012%20Equipment%20Maintenance%20for%20Optimum%20Efficiency%20Handout.pdf

Steam Jacketed Kettle Tips

Air and Water

Direct-fired kettles need to be regularly checked for air and water. Air in the jacket acts as an insulator and slows kettle heating. When the kettle is cold, the pressure/vacuum gauge should read a negative or vacuum. A positive reading or a reading near zero indicates that there is air in the jacket. Discharges from the safety valve prior to reaching operating temperature can also indicate there may be air in the jacket.

To remove air from the jacket, allow the kettle to heat. Make sure there is water or product in the kettle. When the pressure gauge shows a pressure reading of 3 to 5 psi, release the air by opening the safety valve for a few seconds then releasing it and allowing it to snap shut. This step can be repeated until there is only a steam discharge. Caution should be taken to protect exposed skin from steam burns. It is best if the discharge opening of the safety valve is piped away a few inches from the valve and terminates with an elbow or pipe nipple angled down. The safety valve should be tested in a like manner following the manufacturer's recommendations. (Minimum once a month–usually more often is required.)

Each day before the kettle is placed into operation, check the water level. The water level should be between the minimum (min) and maximum (max) markers on the sight glass. Over time, water will need to be added to the jacket due to minor steam losses or water drain-off. Water in the jacket is treated to protect the metal surfaces from damage and the formation of lime and scale. Each manufacturer either offers or recommends a specific product for treating of the replacement water. The water must be tested to ensure that the pH level meets the recommendations found in the operator manual before it is added to the jacket.

The kettle will have a port for the purpose of adding water to the jacket. Allow the kettle to cool down so the pressure/vacuum gauge reads a negative showing there is a vacuum in the jacket. After making sure the valve located on the fill port is closed, remove the plug. Insert a funnel in the port and fill the funnel with treated water. Open the valve on the fill port and allow the vacuum to draw water into the jacket. Do not allow the funnel to empty, as air will be drawn into the jacket. Check the water level in the sight glass and repeat this step as needed until the proper water level is restored.

Indirect-fired kettles have steam supplied from a remote boiler or central plant and require very little in the way of routine maintenance. The safety valve should be tested each day as the unit is placed into operation. This is done with a positive reading showing on the pressure gauge by opening the safety valve until steam is released and allowing the valve to snap shut. Caution should be taken to protect exposed skin from steam burns. It is best if the discharge opening of the safety valve is piped away a few inches from the valve and terminates with an elbow or pipe nipple angled down.

Every couple of months (more often when subjected to heavy use), check the draw-off faucets, valves and piping for leaks. Check the steam pressure-reducing valve to ensure it is in good condition and is functioning properly. Check the steam piping and the condensate piping, the valves and the traps for leaks and obstructions. Repairs should be done as soon as possible when dealing with pressurized steam.

Cleaning the Kettle's Cooking Surface

The kettle's surface can be damaged by the sharp edges of spatulas or other utensils. To avoid scratching or nicking, heavy metal scrubbers, wire brushes, or steel wool pads should be avoided when cleaning.

Routine cleaning of the kettle can be accomplished with a mixture of hot water and soap or an appropriate detergent. Rinse the kettle thoroughly and drain after cleaning. Soaking and then scrubbing with a non-metal brush, sponge, plastic spatula, or rubber scraper should remove food products that become stuck to the kettle's surface. It is important not to use abrasive materials that can leave scratches and allow bacteria to grow. When the equipment needs to be sanitized with a chlorine product, it is very important not to allow the chlorine to stay in contact with the stainless steel for more than 10 (ten) minutes, as longer contact can cause corrosion.

Mineral deposits or the film left by hard water can be removed by the use of a deliming agent. However, consult the manufacturer's literature for the proper product. Thoroughly rinse and drain the unit before future use. Caution: a deliming solution not suited for cooking equipment could etch the surface and render the kettle unusable.

https://www.socalgas.com/documents/innovation/fsec/2012%20Equipment%20Maintenance%20for%20Optimum%20Efficiency%20Handout.pdf

Steam Jacketed Kettle Spec. Sheet

BLODGETT®

KPS-DS
Direct Steam Pedestal Stationary Kettle

KPS-DS PEDESTAL BASE STATIONARY KETTLE

Project ______________________

Item No. ______________________

Quantity ______________________

- ❑ Model KPS-20DS - 20 gallon (76 litres) direct steam pedestal stationary kettle
- ❑ Model KPS-30DS - 30 gallon (114 litres) direct steam pedestal stationary kettle
- ❑ Model KPS-40DS - 40 gallon (151 litres) direct steam pedestal stationary kettle
- ❑ Model KPS-60DS - 60 gallon (227 litres) direct steam pedestal stationary kettle
- ❑ Model KPS-80DS - 80 gallon (303 litres) direct steam pedestal stationary kettle
- ❑ Model KPS-100DS - 100 gallon (380 litres) direct steam pedestal stationary kettle

CONSTRUCTION
- ■ Water resistant construction
- ■ 304 stainless steel construction with #4 satin finish
- ■ 316 stainless steel interior cooking surface for added corrosion resistance for 20, 30 and 40 gallon
- ■ Stainless steel pedestal base with four 7/16" holes evenly spaced for securing to the floor
- ■ Hemispherical design on bottom of kettle for superior heat circulation

STANDARD FEATURES
- ■ 2" (50mm) sanitary draw off valve
- ■ Hinged stainless steel cover on 20, 30 and 40 gallon kettles
- ■ Spring assist hinged stainless steel cover on 60, 80 and 100 gallon kettles
- ■ Stainless steel faucet bracket
- ■ One year parts and labor warranty*

* *For all international markets, contact your local distributor.*

OPTIONS AND ACCESSORIES
(AT ADDITIONAL CHARGE)

- ■ Etched markings
  - ❑ Gallons
  - ❑ Litres
- ■ Draw Off valves and accessories
  - ❑ 3" (76mm) draw off valve
  - ❑ 3" (76mm) dairy valve
  - ❑ Perforated strainer for draw off
  - ❑ Solid stainless steel disc for draw off valve
- ■ Faucets
  - ❑ Single pantry faucet with swing spout
  - ❑ Double pantry faucet with swing spout
- ■ Covers
  - ❑ Two piece hinged cover
  - ❑ Spring assist hinged stainless steel cover for 20, 30 and 40 gallon kettles
- ❑ Tri-basket assembly
- ❑ 316 stainless steel liner for 60, 80b and 100 gallon
- ❑ 50 PSI (345 kPa) high pressure operation for higher cooking temperature
- ❑ Steam control valve
- ❑ Strainer hook
- ❑ Graduated measuring strip
- ❑ Steam trap assembly consisting of steam trap, steam inlet, check valve, and line strainer
- ❑ Correctional package

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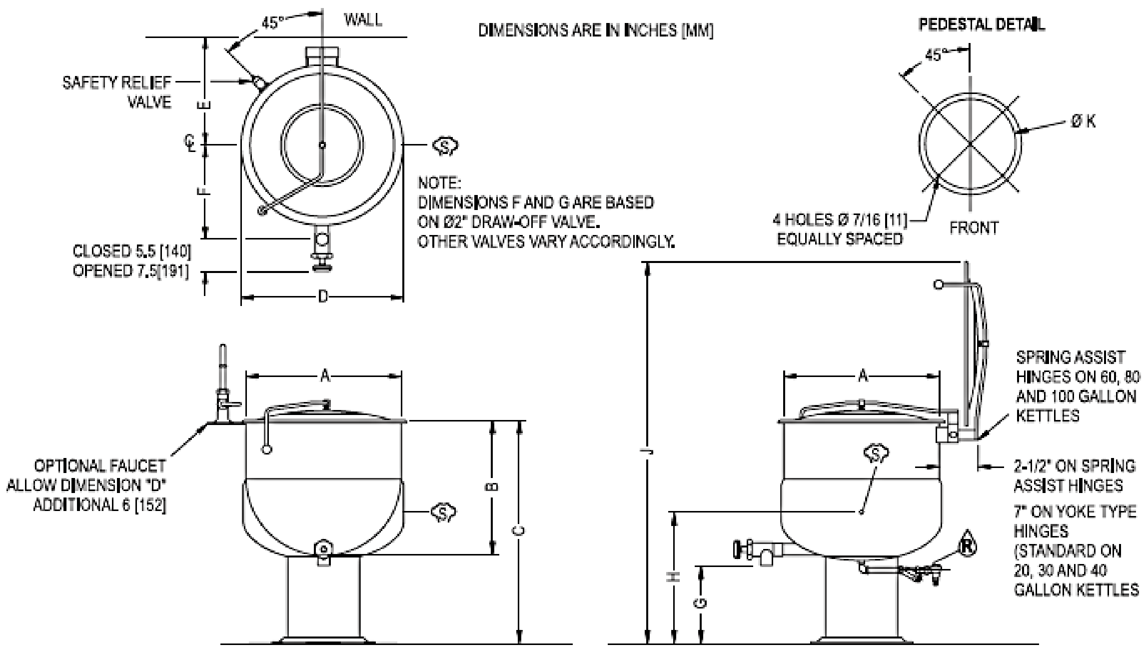
BLODGETT
www.blodgett.com
44 Lakeside Avenue, Burlington, VT 05401 • Phone: (802) 658-6600 • Fax: (802) 864-0183

Steam Jacketed Kettle Spec. Sheet

BLODGETT®

KPS-DS PEDESTAL STATIONARY KETTLE

APPROVAL/STAMP



PIPING REQUIREMENTS:

Steam Supply	3/4" IPS (19 mm)
Condensate Return	1/2" IPS (13 mm)

STEAM PRESSURE:

Minimum	5 PSI (34 kPa)
Maximum	35 PSI (241 kPa) standard kettle
	50 PSI (345 kPa) optional high pressure kettle

Pressure reducing valve required if incoming steam pressure exceeds the kettle rating.

SHIPPING INFORMATION:

Approx. Weight:

KPS-20DS	205 lbs. (93 kg)
KPS-30DS	230 lbs. (104 kg)
KPS-40DS	240 lbs. (109 kg)
KPS-60DS	315 lbs. (143 kg)
KPS-80DS	360 lbs. (163 kg)
KPS-100DS	410 lbs. (186 kg)

NOTE: The company reserves the right to make substitutions of components without prior notice.

BLODGETT
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Printed in U.S.A. NOTE: FOR COMMERCIAL USE ONLY P/N S00025 Rev E (9/12)

Unit 11: Steam Jacketed Kettles

Fundamentals of Steam

Steam Jacketed Kettle Operation

Cleveland

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› KET-T: Electric steam kettle, tilting

50 PSI STEAM JACKETED KETTLE (3.5 Bar boiling Pan), 2/3 STEAM JACKETED, HIGH SPEED COOKING, (3,6,12 GALLONS, 11, 23, 0r 45 (Liters)

CLEVELAND, electric Steam kettle (boiling pan), Table Type, self-contained, tilting. 2/3 steam jacketed, type 304 Stainless Steel kettle and supports. Jacket rated at 50 psi (3.5 Bar) with Safety Valve, Permanently filled Steam Jacket, Splash Proof Solid State Temperature (±1° C) and Safety Control System in plug-in Module including L.E.D. indicators. Marine Lock. Optional Lift Off Cover, Hot & Cold Water Faucet and ST 28 Equipment Stand

Home / Products / Steam Jacketed Kettles / Table Top Models / KET-T: Electric steam kettle, tilting

Features | Technical Specifications | Accessories | Videos | Downloads

Manual Tilting
Balanced design

Self-Contained
Easily installed - needs only an electrical hook-up

50 PSI (3.5 Bar) Steam Jacket Rating for faster cooking
Steam jacket filled with treated water, venting and/or refilling is not required

Controls
Accurate, consistant solid state temperature controls (mechanical thermostate not as accurate) - less than ±1°C variance (ideal for simmering). Operating temperature range from 145° - 260°F (63°C - 127°C) Control panel includes:LED indicator for heat cycle, LED indicator for low water Power ON/OFF switch, Adjustable temperature control dial

Water Resistant Controls
Splash-proof construction

Pouring Lip
Large pouring lip for high capacity and chunky products.

Rolled Rim
Re-inforced rolled rim design prevents damage to kettle rim, eliminates "bar rim designs"

Heating Elements
Welded-in heating elements, (holds vacuum better, won't leak or loose water)

Easily Cleaned
Kettle and all exterior surfaces are of type 304 stainless steel with an #4 finish

Pressure Gauge
Rear mounted easy access pressure gauge and pressure relief valve to prevent tampering. Color coded easy to read pressure gauge with "green" and "vent air zone"

Jacket Rating
50 psi steam jacket rating for higher cooking temperatures

Safety Valve
50 psi

Water Level Control
Solid state water level control (no sight glass gauge to break or leak)

Element Cover
Splash proof element cover with a double gasket seal

Marine Lock
Self locking marine type tilting mechanism prevents accidental spills. Balanced design makes it easy to tilt

Standard voltage
208-240 volts, 60 Hz, 3 phase, 3 wire. Model KET-6 and KET-12 are field rewirable to single phase

Steam Jacketed Kettle Operation

PRODUCTS | SERVICE | SALES | VIDEOS | NEWS | RESOURCES

› KET-T: Electric steam kettle, tilting

50 PSI STEAM JACKETED KETTLE (3.5 Bar boiling Pan), 2/3 STEAM JACKETED, HIGH SPEED COOKING, (3,6,12 GALLONS, 11, 23, 0r 45 (Liters)

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Home / Products / Steam Jacketed Kettles / Table Top Models / KET-T: Electric steam kettle, tilting

Features | **Technical Specifications** | Accessories | Videos | Downloads

STEAM JACKETED KETTLE, MODEL KET-T (3,6,12 GALLONS) ELECTRIC TILTING KETTLE

W x D x H	" x " x " cm x cm x cm
Weight	180 lb 81.6 kg
Power Output	0.00
Primary Power Input	208-240 V x 60 Hz x 3 PH
Certifications	CE UL NSF UL

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Cleveland Kettle Manual

Operators Manual

Electric Table Top Kettles
Installation & Operation

For units built after April 2010

KET-3-T
KET-6-T
KET-12-T
KET-20-T
TKET-3-T
TKET-6-T
TKET-12-T

For your future reference.
Model # ______________________
Serial # ______________________

Model # & Serial #.

Read the manual thoroughly.
Improper installation, operation or maintenance can cause property damage, injury or death.

Cleveland
1333 East 179th St., Cleveland, Ohio, U.S.A. 44110
Ph: 216.481.4900 Fx: 216.481.3782
www.clevelandrange.com

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Manitowoc

Cleveland Kettle Manual

FOR YOUR SAFETY
Do not store or use gasoline or any other flammable liquids and vapours in the vicinity of this or any other appliance.

WARNING: Improper installation, adjustment, alteration, service or maintenance can cause property damage, injury or death. Read the installation and operating instructions thoroughly before installing or servicing this equipment.

This appliance is not to be used by persons with reduced physical, sensory or mental capabilities, or lack of experience and knowledge, unless they have been given supervision or instruction concerning use of the appliance by a person responsible for their safety.

This appliance is not for use by children and they must be supervised not to play with it.

Post in a prominent location, instructions to be followed in the event the user smells gas. This information shall be obtained by consulting your local gas supplier.

Do not obstruct the flow of combustion and ventilation air.
Retain this manual for your reference.

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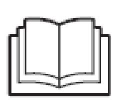
FOR YOUR SAFETY / POUR VOTRE SÉCURITÉ / PARA SU SEGURIDAD

Hazard warnings are for your safey. Absence of a warning does not mean the hazard is not present. Unforeseen actions may result in unanticipated hazards.

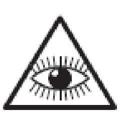
Les avertissements de danger sont pour votre sécurité. L'absence d'un avertissement ne signifie pas que le danger n'est pas présent. Les actions imprévues peuvent entraîner des dangers imprévus

Las advertencias sobre los peligros son para su seguridad. La ausencia de una advertencia no significa que el peligro no está presente. Las acciones imprevistas podrían resultar en peligros no anticipados.

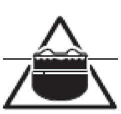
IMPORTANT / IMPORTANT / IMPORTANTE



Read the manual thoroughly. Improper installation, operation or maintenance can cause property damage, injury or death. / Lisez le manuel attentivement. Une mauvaise installation, utilisation ou maintenance peut causer des dommages matériels, des blessures ou la mort. / Lea detenidamente el manual. La instalación, la operación o el mantenimiento incorrectos pueden ocasionar daños a la propiedad, lesiones o la muerte.

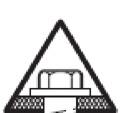


Inspect unit daily for proper operation. / Inspectez l'unité tous les jours pour son bon fonctionnement. / Inspeccione diariamente el funcionamiento correcto de la unidad.



Do not fill kettle above recommended level marked on outside of kettle. / Ne remplissez pas la chaudière en excès du niveau recommandé marqué sur la chaudière. / No llene la marmita arriba del nivel recomendado marcado fuera de la marmita.

Floor may become slippery from product spillage. / Déversement de produit peut causer de plancher à être glissante. / Derrame de producto puede causar piso a ser resbaladizo.



Unit must be anchored as per manual. / Unité doit être ancrée selon les directives du manuel. / Unidad debe estar fijado según el manual.

CAUTION / ATTENTION / PRECAUCIÓN

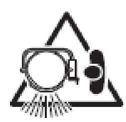
Keep clear of pressure relief discharge. / Restez à l'écart de la soupape de sureté. / Permanezca alejado de la descarga de presión.

Keep hands away from moving parts and pinch points. / Gardez les mains loin des pièces mobiles et des points de pincement. / Mantenga las manos lejos de piezas movibles y puntos de presión muy localizada.

Surfaces and product may be hot! Wear protective equipment. /Les surfaces et le produit peuvent être chauds! Portez un équipement de protection. / ¡Las superficies y el producto pueden estar calientes! Utilice equipo protector.

Hot! / Chauds ! / ¡Caliente!

Do not climb, sit or stand on equipment. /Il ne faut pas monter, s'asseoir ni se tenir debout sur l'équipement. /No subirse, ni sentarse ni pararse sobre el equipo.

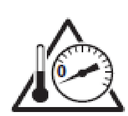


Stand clear of product discharge path when discharging hot product. / Écartez-vous du chemin de décharge d'un produit chaud. / Permanezca alejado de la ruta de descarga del producto al vaciar producto caliente.

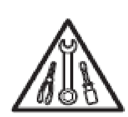
Do not lean on or place objects on kettle lip. / Ne vous appuyez pas et ne placez pas d'objets sur le bec de la chaudière. / No se apoye o coloque objetos en el borde de la marmita.

SERVICING / ENTRETIEN / SERVICIO

Remove electrical power prior to servicing. / Coupez l'alimentation électrique avant l'entretien. / Desconecte la energía eléctrica antes de darle servicio.



Ensure kettle is at room temperature and pressure gauge is showing zero or less prior to removing any fittings. / Assurez-vous que la chaudière est à température ambiante et que le manomètre est à zéro ou moins avant de retirer des accessoires. / Asegúrese de que la marmita esté a temperatura ambiente y el manómetro esté mostrando cero o menos antes de retirar cualquier accesorio.



Have a qualified service technician maintain your equipment. / Demandez à un technicien en entretien et en réparation qualifié d'effectuer l'entretien de votre équipement. / Haga que un técnico de servicio calificado mantenga su equipo.

Cleveland Kettle Manual

POSITIONING

Units must be positioned on a firm, level stand that has been bolted in place, or existing counter top, and bolted in place.

For mounting, these models are supplied with four threaded bushings welded to the underside of the base.

The first installation step is to refer to the Specification Sheets or Specification Drawings for detailed clearance requirements and mounting hole locations of the kettle. If you don't have access to a specification sheet, check the bottom of the kettle for location of threaded mounting bushings.

CLEARANCE REQUIREMENTS

Model #	Back*	Left Side	Right Side
KET-3-T	0	0	0
KET-6-T	6"	0	0
KET-12-T	6"	0	0
KET-20-T	9"	0	0
TKET-3-T	7 1/8"	0	0
TKET-6-T	7 1/8"	0	0
TKET-12-T	9 7/8"	0	0

* From back of mounting base.

POUR PATHS

Kettle Size	Min.	Max.
3 Gallon	15 1/2"	32"
6 Gallon	17 1/4"	36"
12 Gallon	18"	38"
20 Gallon	22"	45"

Countertop Models

1. Drill mounting holes. If mounting to a Cleveland stand holes are already predrilled.
2. Position the unit in its permanent location.
3. Once positioned permanently secure the unit to the mounting surface with the hardware provided.
4. Seal around base of unit with silicone sealant.
5. Remove protective material covering stainless steel surfaces.

KET-20-T Leg Type Models

For floor type leg mount models position on a firm, level sur face, level using adjustable feet and bolt two flanged feet in place. Once the kettle is secure, screw tilt handle into the threaded hole provided at the right of kettle.

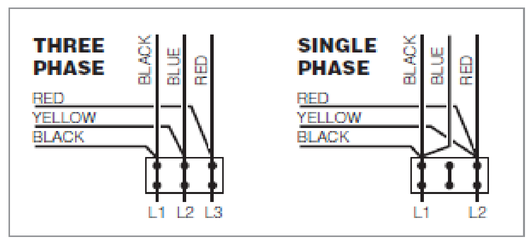
ELECTRICAL

ENSURE THE ELECTRICAL SUPPLY MATCHES THE KETTLE'S REQUIREMENTS AS STATED ON THE RATING LABEL.

Install in accordance with local codes and/or the National Electric Code ANSI/NFPA No. 70 (USA) or the Canadian Electric Code CSA Standard C22.2 (Canada). A separate fused disconnect switch must be supplied and installed. The kettle must be electrically grounded by the installer.

A wiring diagram is affixed to the underside of the console cover.

Remove the four screws securing the console cover and remove the cover. Using a water tight fitting feed permanent copper wiring through the cut-out in the rear or bottom of the console, and fasten to the three connection terminal block, which is mounted on the top of the console's control panel. Be sure to connect the ground wire to the separate ground terminal connector (ground lug). Replace console cover and secure it with the four screws.



The kettle is wired for 3-phase operation at the factory. For single phase operation, rewire the terminal block to that shown in the above diagram.

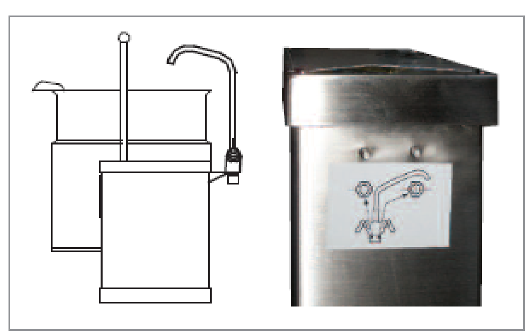
Note: Ensure main power is turned off before connecting wires.

WATER FOR JACKET

The sealed jacket of the electric kettle is precharged with the correct amount of a water based formula, and therefore, no water connection is required to the kettle jacket.

FAUCET SPOUT

The kettle can be equipped with optional hot and/or cold water faucet, requiring 1/2" copper tubing as supply lines. Mount faucet bracket to the rear of the unt or studs provided. Assemble faucet onto bracket and check for leaks.



Cleveland Kettle Manual

INSTALLATION CHECKS

Although the kettle has been thoroughly tested before leaving the factory, the installer is responsible for ensuring the proper operation of kettle once installed.

Visual Checks

1. Check unit is bolted in place.
1. Check Marine Lock. See Marine Lock Testing Procedure.
2. Check Tilting:
   A/ Handle is in place and firmly tightened.
   B/ Kettle tilts smoothly and freely.
3. Insure there are:
   A/ Four screws securely holding the console cover.
   B/ The bottom cover is in place and held with a nut.

Performance Checks

1. Supply power to the kettle by placing the fused disconnect switch to the "ON" position.

2. Before turning the kettle on, read the Vacuum/Pressure Gauge. The gauge's needle should be in the green zone. If the needle is in the "VENT AIR" zone, follow Kettle Venting Instructions.
3. Turn the kettle's ON/OFF Switch/Solid State Temperature Control to "1" (Min.). The Heat Indicator Light (Green) should remain lit, indicating the element is on, until the set temperature is reached (130°F/54°C). Then the green light will cycle on and off, indicating the element is cycling on and off to maintain temperature.
4. Tilt the kettle forward. After a few seconds the Low Water Indicator Light (Red) should be lit when the kettle is in a tilted position. This light indicates that the element has automatically been shut off by the kettle's safety circuit. This is a normal condition when the kettle is in a tilted position.
5. Raise the kettle to the upright position. The Low Water Indicator Light (Red) should go out when the kettle is upright.
6. Turn the ON/OFF Switch/Solid State Temperature Control to "10" (Max.) and allow the kettle to preheat. The green light should remain on until the set temperature (260°F/127°C) is reached. Then the green light will cycle ON and OFF, indicating the element is cycling ON and OFF to maintain temperature. Fill the kettle with cold water to the steam jacket's welded seam. Refer to the Temperature Range Chart for the time required to bring the water to a boil.
7. When all testing is complete, empty the kettle and turn the ON/OFF Switch/Solid State Temperature Control to the "OFF" position.

CLEANING

After installation the kettle must be thoroughly cleaned and sanitized prior to cooking. See Cleaning Instructions.

Notes:

Cleveland Kettle Manual

OPERATING THE KETTLE

1. Before turning kettle on, read the Vacuum/Pressure Gauge. The gauges needle should be in the green zone. Once heated, the kettle's normal maximum operating pressure is approximately 10-12 psi, while cooking a water base product.
2. Ensure that the electrical service to the kettle is turned on at the fused disconnect switch.

Temperature Control Setting	Approximate Product Temperature °F	°C
1. (Min.)	130	54
2.	145	63
3.	160	71
4.	170	77
5.	185	85
6.	195	91
7.	210	99
8.	230	110
9.	245	118
10. (Max.)	260	127
NOTE: Certain combinations of ingredients will result in temperature variations		

Temperature Range Chart

3. Preheat the kettle by turning the ON/OFF Switch/Solid State Temperature Control to the desired temperature setting (see above "Temperature Range Chart"). The Heat Indicator Light (Green) will remain lit, indicating the burner is lit, until the temperature setting is reached. When the green light goes off, the heaters are off, and preheating is complete.

NOTE: When cooking egg and milk products, the kettle should not be preheated, as products of this nature adhere to hot cooking surfaces. These types of food should be placed in the kettle before heating is begun.

4. Place food product into the kettle. The Heat Indicator Light (Green) will cycle on and off indicating the elements are cycling on and off to maintain the set temperature.

NOTE: Do not fill kettle above recommended level marked on outside of kettle.

NOTE: The Low Water Indicator Light (Red) should not be lit when kettle is in upright position during operation. This light indicates that the elements have been automatically shut off by the kettle's safety circuit. It is, however, normal for the red light to come on when the kettle is in a tilted position.

5. When cooking is completed place ON/OFF Switch/Solid State Temperature Control to the "OFF" position.
6. Pour the contents of the kettle into an appropriate container by tilting the kettle forward. Care should be taken to pour slowly enough to avoid splashing off the product.

NOTE: As with cleaning food soil from any cookware, an important part of kettle cleaning is to prevent food from drying on. For this reason, cleaning should be completed immediately after cooked foods are removed.

APPROXIMATE BOILING TIMES

Kettle Capacity	Minutes
3 gallon/11 litre	15
6 gallon/23 litre	20
12 gallon/45 litre	25
20 gallon/80 litre	40

Approximate Boiling Times

The accompanying chart shows approximate times required for electric kettles of various capacities to boil water. The ON/OFF Switch/Solid State Temperature Control must be set at "10" (Max.) throughout the heatup period. Water will boil about 1/3 faster if the kettle is filled only to the outer steam jacket's welded seam, resulting in a kettle filled to 2/3 capacity.

MARINE LOCK

Your unit is equipped with a marine lock to prevent accidental tilting. The following procedure should be used to tilt the kettle.

1. Grasp the tilt handle.
2. Hold the latch down to unlock tilting mechanism.
3. Pull the handle to tilt kettle.
4. To lock, return the kettle to its upright position and push handle back.

NOTE: Inspect lock daily to ensure it is free moving and does not bind or stick. Clean lock if necessary (see Cleaning Instructions for details

CLEANING INSTRUCTIONS


CARE AND CLEANING

Cooking equipment must be cleaned regularly to maintain its fast, efficient cooking performance and to ensure its continued safe, reliable operation. The best time to clean is shortly after each use (allow unit to cool to a safe temperature).

WARNINGS


Chloride Cleaners

Do not use detergents or cleansers that are chloride based or contain quaternary salt.


Wire Brush & Scrapers

Do not use a metal bristle brush or scraper.


Steel Pads

Steel wool should never be used for cleaning the stainless steel.


High Pressure Spray Hose

Unit should never be cleaned with a high pressure spray hose.


Stagnant Water

Do not leave water sitting in unit when not in use.

CLEANING INSTRUCTIONS

1. Turn unit off.
2. Remove drain screen (if applicable). Thoroughly wash and rinse the screen either in a sink or a dishwasher.
3. Prepare a warm water and mild detergent solution in the unit.
4. Remove food soil using a nylon brush.
5. Loosen food which is stuck by allowing it to soak at a low temperature setting.
6. Drain unit.
7. Rinse interior thoroughly.
8. Using mild soapy water and a damp sponge, wash the exterior, rinse, and dry.

NOTES

- For more difficult cleaning applications one of the following can be used: alcohol, baking soda, vinegar, or a solution of ammonia in water.
- Leave the cover off when the kettle is not in use.
- For more detailed instructions refer to Stainless Steel Equipment Care and Cleaning (www.nafem.org/resources/stainlesssteelfinal.doc) on Nafem's website (www.nafem.org).

Notes:

Cleveland Kettle Manual

PREVENTATIVE MAINTENANCE

FOR MAINTENANCE AND REPAIRS CONTACT YOUR AUTHORIZED MANITOWOC SERVICE AGENCY AND HAVE A QUALIFIED SERVICE TECHNICIAN MAINTAIN YOUR EQUIPMENT.

Refer to maintenance procedurees and parts list manual for detailed maintenance and testing instructions.

DAILY PRE-STARTUP INSPECTION

1. Kettle tilts smoothly.
2. Pressure Gauge (**E**) is in the green when unit is cold.
3. Green Light (**F**) comes on when unit is energized.
4. Red Light (**G**) comes on when unit is tilted (tilting models only).

SIX MONTH SERVICE INSPECTION

1. Perform daily startup inspection.
2. Grease bearings on both trunnions.
3. Fasteners securing panels are in place and tight.
4. Perform pressure relief valve periodic test (see PRESSURE RELIEF VALVE TESTING).
5. Insure there are four screws firmly holding down the cover. If not replace screws and/or missing or worn nylon anchor nuts.
6. Check the bottom cover gasket is in place and not cracked.
7. Unit is bolted in place.

YEARLY SERVICE INSPECTION

1. Perform six month service inspection.
2. Check kettle maximum temperature setting (see CALIBRATING PROCEDURE).
3. Perform safety inspection using SAFETY INSPECITON CHECKLIST found in the MAINTENANCE PROCEDURES.

Fundamentals of Steam

Wells Countertop Warmer Manual Overview

001

WELLS MANUFACTURING
10 Sunnen Dr., St. Louis, MO 63143
telephone: 314-678-6314
fax: 314-781-2714
www.wellsbloomfield.com

Model SW10T

OWNERS MANUAL

WELLS COUNTERTOP WARMERS with THERMOSTAT CONTROL

MODELS
SMPT, SMPTD
SMPT27, SMPTD27
SW10T
TMPT, TMPTD
HMPGW

Model SMPT

Includes
INSTALLATION
USE & CARE
EXPLODED VIEW
PARTS LIST
WIRING DIAGRAM

Model TMPT

IMPORTANT: DO NOT DISCARD THIS MANUAL
This manual is considered to be part of the appliance and is to be given to the OWNER or MANAGER of the restaurant, or to the person responsible for TRAINING OPERATORS of this appliance. Additional manuals are available from your WELLS DEALER.

THIS MANUAL MUST BE READ AND UNDERSTOOD BY ALL PERSONS USING OR INSTALLING THIS APPLIANCE. Contact your WELLS DEALER if you have any questions concerning installation, operation or maintenance of this equipment.

p/n 2M-**303305** Rev. K

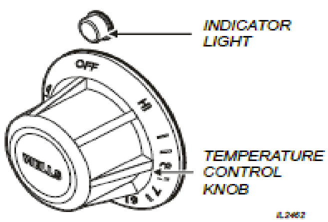
M001 **15**1006

Unit 12:
Countertop Warmers

Fundamentals of Steam

Wells Countertop Warmer Manual Overview – Features & Operating Controls

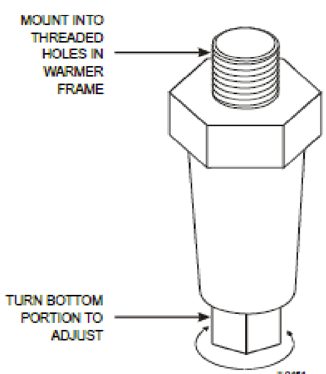
FEATURES & OPERATING CONTROLS



A. THERMOSTAT

1. On thermostatically controlled warmers, power is applied to the heating element according to the control knob position and the actual temperature at the temperature sensing thermobulb.
2. The desired temperature is controlled by rotating the temperature control knob. The knob has a numeric scale, where higher numbers correspond to higher temperature.
3. On warmers equipped with an indicator light, the light will glow when the thermostat is calling for heat (i.e. the element is energized).
4. The TEMPERATURE CONTROL KNOB will rotate approximately 300°, and will reach a "stop" at both ends. The OFF position is marked.

NOTE: The dial position is an indication of the temperature setting. Actual temperature will vary depending upon the type of product and food consistency.



B. ADJUSTABLE LEGS

1. Countertop warmers are equipped with adjustable legs. These legs allow for:
   a. leveling the warmer
   b. ventilation around the warmer, and
   c. cleaning under the warmer.
2. Adjustable legs are supplied with the warmer, the legs **MUST** be properly installed before the warmer is placed into operation.

Notes:

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Hands On Exercise:

- ❑ Identify a countertop warmer
- ❑ Locate the thermostat
- ❑ Locate the indicator light
- ❑ Locate the data plate
- ❑ Model: ____________________
- ❑ Serial #: ____________________
- ❑ Voltage: ____________________
- ❑ Amps: ____________________

Wells Countertop Warmer Manual Overview – Precautions & General Info

PRECAUTIONS AND GENERAL INFORMATION

This appliance is intended for use in commercial establishments only.

This appliance is intended to hold pre-heated food for human consumption. No other use is recommended or authorized by the manufacturer or its agents.

Operators of this appliance must be familiar with the appliance use, limitations and associated restrictions. Operating instructions must be read and understood by all persons using or installing this appliance.

Cleanliness of this appliance is essential to good sanitation. Read and follow all included cleaning instructions and schedules to ensure the safety of the food product.

Disconnect this appliance from electrical power before performing any maintenance or servicing.

This appliance is not jet stream approved. Do not direct water jet or steam jet at this appliance, or at any control panel or wiring.
Do not splash or pour water on, in or over any controls, control panel or wiring.

Exposed surfaces of this appliance can be hot to the touch and may cause burns.

Do not operate this appliance if the control panel is damaged.
Call your Authorized Wells Service Agent for service.

The technical content of this manual, including any wiring diagrams, schematics, parts breakdown illustrations and/or adjustment procedures, is intended for use by qualified technical personnel.

Any procedure which requires the use of tools must be performed by a qualified technician.

This manual is considered to be a permanent part of the appliance.

This manual and all supplied instructions, diagrams, schematics, parts breakdown illustrations, notices and labels must remain with the appliance if it is sold or moved to another location.

This appliance is made in the USA. Unless otherwise noted, this appliance has American sizes on all hardware.

WARNING: SHOCK HAZARD

All servicing requiring access to non-insulated electrical components must be performed by a factory authorized technician.

DO NOT open any access panel which requires the use of tools. Failure to follow this warning can result in severe electrical shock.

CAUTION: RISK OF DAMAGE

DO NOT connect or energize this appliance until all installation instructions are read and followed. Damage to the appliance may result if these instructions are not followed.

CAUTION: HOT SURFACE

Exposed surfaces can be hot to the touch and may cause burns.

AGENCY LISTING INFORMATION

Refer to the product nameplate for the specific appliance for agency listings. In general:

This appliance conforms to NSF Standard 4 for sanitation only if installed in accordance with the supplied Installation Instructions.

UL Listed warmers are U Listed under UL File E6070.

NSF STD 4

UL Listed E6070

Unit 12: Countertop Warmers

Fundamentals of Steam

Wells Countertop Warmer Manual Overview - Operation

OPERATION

WET OR DRY OPERATION for WARMERS

1. Carefully read the description of the warmer operation on the specification sheet.
2. a. Most warmers are designed for WET OR DRY operation.
   b. Warmers may be used wet, or may be used dry. However warmers may NOT be used wet-to-dry or dry-to-wet unless they have been allowed to cool to room temperature between the change in wet or dry operation.
   c. Wells Manufacturing recommends operating WET for consistent food heating.
   d. If your wet-operation warmer is allowed to run dry, turn it OFF and allow to cool to room temperature before adding water.
3. If the warmer is to be used for WET operation, add approximately 1" of hot tap water before turning the warmer on. Use of hot water will allow a faster preheat.
   a. Check the water level frequently and add hot water as necessary to prevent the warmer from running dry. Do not add water to the warmer if it has run dry.
   b. If your wet-operation warmer is allowed to run dry, turn it OFF and allow to cool to room temperature before adding water.
   4. Damage caused by allowing a wet-operation warmer to run dry, is NOT covered by warranty. Damage caused by adding water to a dry warmer when hot is NOT covered by warranty.

PRE-HEATING THE WARMER

1. Place desired pan(s) or inset(s) with appropriate adapter top on warmer.
   a. Insets are available as accessories in 2½ qt., 4qt., 7 qt., and 11 qt. sizes with lids and adapter tops.
   b. For dry operation, a 6" deep pan or inset is recommended.
2. Turn temperature control to HI or highest temperature setting.
3. Allow warmer to preheat for approximately 30 minutes, then set the control for the desired temperature. Be sure to keep the warmer covered during preheat and operation.

OPERATION

1. Always use an inset. **DO NOT** place food directly into the warmer.
2. Check water level in wet-operation warmer frequently during use. Running warmers dry will lower the temperature of the food in the insert pan, and may damage the warmer.
3. Alternating between wet and dry operation in any individual warmer is not recommended.
4. **DO NOT** use metal tools, steel wool, or caustic or abrasive cleanser to clean warmer pan.

CAUTION: HOT SURFACE

Exposed surfaces can be hot to the touch and may cause burns.

CAUTION: SHOCK HAZARD

DO NOT splash or pour water onto control panel or wiring.

Always use an inset.

DO NOT place food directly into the warmer.

Always pour hot water into the warmer before it is preheated. **DO NOT** pour water into a dry, heated warmer. This may damage the unit.

DO NOT put ice into a warmer pan. This will cause condensation on the inside of the warmer. Damage caused by condensation is **NOT** covered by warranty.

Stir thick food items frequently to keep food heated uniformly.

Keep insets covered to maintain food quality and temperature.

Wells Countertop Warmer Manual Overview – Daily Cleaning Instructions

CLEANING INSTRUCTIONS

CAUTION: SHOCK HAZARD

Do NOT splash or pour water into or over any control panel or wiring.

CAUTION: SHOCK HAZARD

Disconnect warmer from electric power before cleaning

CAUTION: BURN HAZARD

Allow warmer to cool completely before cleaning.

CAUTION: SHOCK HAZARD

DO NOT submerge warmer in water.

DAILY CLEANING INSTRUCTIONS

PREPARATIONS: Turn control knob(s) to OFF. Unplug the warmer. Allow warmer to cool before proceeding. Remove any insets, pans and/or adapter tops Drain or remove water from well if used for wet operation.

FREQUENCY: Minimum - daily.

TOOLS:
Mild Detergent
Solution: 10 Parts Warm Water to 4 Parts Vinegar
Plastic Scouring Pad
Clean Cloth or Sponge

1. Wipe entire unit down using a clean cloth or sponge and mild detergent.
2. Use a plastic scouring pad to remove any hardened food particles or mineral deposits.

   IMPORTANT: DO NOT use steel wool for cleaning.
3. Rinse warmer thoroughly with a vinegar and water solution to neutralize all detergent cleanser residue.
4. Inspect warmer tank for damage. Damage to the outer body may allow grease and water to leak into insulation and heating element, causing a potential fire and/or electric shock hazard. Contact your Authorized Wells Service Agency to inspect the warmer if you suspect water or grease contamination.
5. Add proper amount of warm water. Reconnect warmer to electric power. Turn control knob(s) ON and check for proper operation.

Notes:

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001 p/n 2M-303305 Owners Manual CT Warmers / Thermostat Control

Wells Countertop Warmer Manual Overview – Weekly Cleaning Instructions

CLEANING INSTRUCTIONS (continued)

WEEKLY CLEANING INSTRUCTIONS

PREPARATIONS: Remove any insets, pans and/or adapter tops. Drain or remove water from well if used for wet operation.

FREQUENCY: Weekly, or whenever lime or scale is seen accumulating on the sides of the warmer pans.

TOOLS: Commercial Delime Cleaner
Plastic Scouring Pad
Clean Cloth or Sponge

CAUTION: CHEMICAL BURN HAZARD

Deilimng chemicals may be caustic. Wear appropriate personal protective equipment. Follow cleaner manufacturer's instructions for safest use.

1. Add water to pans until water is at normal operating level (1" - 1 1/2" deep) or covers accumulated scale.
2. Heat water to maximum temperature (190°F or higher).
3. Pour contents of one package of commercial delime cleaner into each warmer pan. Stir to dissolve cleaner. Turn heat control OFF. Cover pans.
4. Allow solution to soak at least one hour, or overnight for heavy scale buildup.
5. Drain hot water from pans. Scrub with a plastic scouring pad. Rinse thoroughly with hot water, then dry.
6. Refill pans with hot tap water and resume operation.
7. Heavy scale buildup may require additional treatments.

Notes:

Wells Countertop Warmer Manual Overview - Troubleshooting

TROUBLESHOOTING SUGGESTIONS

SYMPTOM	POSSIBLE CAUSE	SUGGESTED REMEDY
No power to warmer	Circuit breaker off or tripped	Reset circuit breaker
	Unit not plugged in	Make sure unit is plugged in to power receptacle
Warmer will not heat	Temperature control not set	Set control to desired temperature
	Internal damage	Contact you Authorized Wells Service Agency for repairs
Warmer trips circuit breaker	Pan leaking or other internal damage	Contact your Authorized Wells Service Agency for repairs
	Internal damage	Contact your Authorized Wells Service Agency for repairs
Warmer slow to heat	Mineral deposits on pan acting as a insulator	Clean pan(s) with delime cleaner
	Connected to wrong voltage	Verify supply voltage - must match voltage on warmer nameplate
	Too much water	Remove water from pan until 1" of water remains in pan

There are no user-serviceable components in this appliance.
In all instances of damage or malfunction, contact your Authorized Wells Service Agency for repairs.

Hands On Exercise:

- ☐ Simulate "Tripped circuit breaker" scenario
- ☐ Simulate "Unit not plugged in" scenario
- ☐ Simulate "Temperature control not set" scenario
- ☐ Check voltage at wall outlet

Notes:

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Wells Countertop Warmer Manual Overview – Care of Stainless Steel

MAINTENANCE INSTRUCTIONS

CARE OF STAINLESS STEEL

Stainless steel is a marvelous material: strong, lustrous and low maintenance. With a minimum of care, it will normally retain its beauty and durability for the life of the equipment. In some applications, however, special care is required in order to maintain stainless steel's special properties.

External components, such as cabinets and control panels, are finished with a grain pattern. This pleasing finish is best maintained by cleaning with a non-abrasive cleanser applied with a soft cloth. Rub only in the direction of the grain. In the absence of visible grain, rub only along the longest axis of the appliance.

Restore stainless steel's luster by applying a polish specifically made for stainless steel. Spray on, wipe off with a soft cloth, rubbing in the direction of the grain.

Never use metal implements, wire brushes, abrasive scratch pads or steel wool to clean stainless steel.

Warmer pans, insets and other vessels are subject to a harsher environment. Wells Manufacturing uses an very high quality stainless steel (#304DDQ) for our food warmer pans. Even the highest quality stainless steel, however, is mostly iron, and will rust, pit and corrode under the following conditions:

- **Poor Water Quality:** Hard water (water with a high content of dissolved minerals) will leave mineral deposits when allowed to dry. Calcium (lime) can buildup on heated surfaces, even under water. If left unattended, hard water spots and lime buildup can lead to rusting, corrosion and pitting.
- **Contact with Chlorides:** Chlorides (specific compounds of chlorine) are found in food, table salt and many cleansers. Chlorides can attack the surface of stainless steel, resulting in corrosion and pitting.

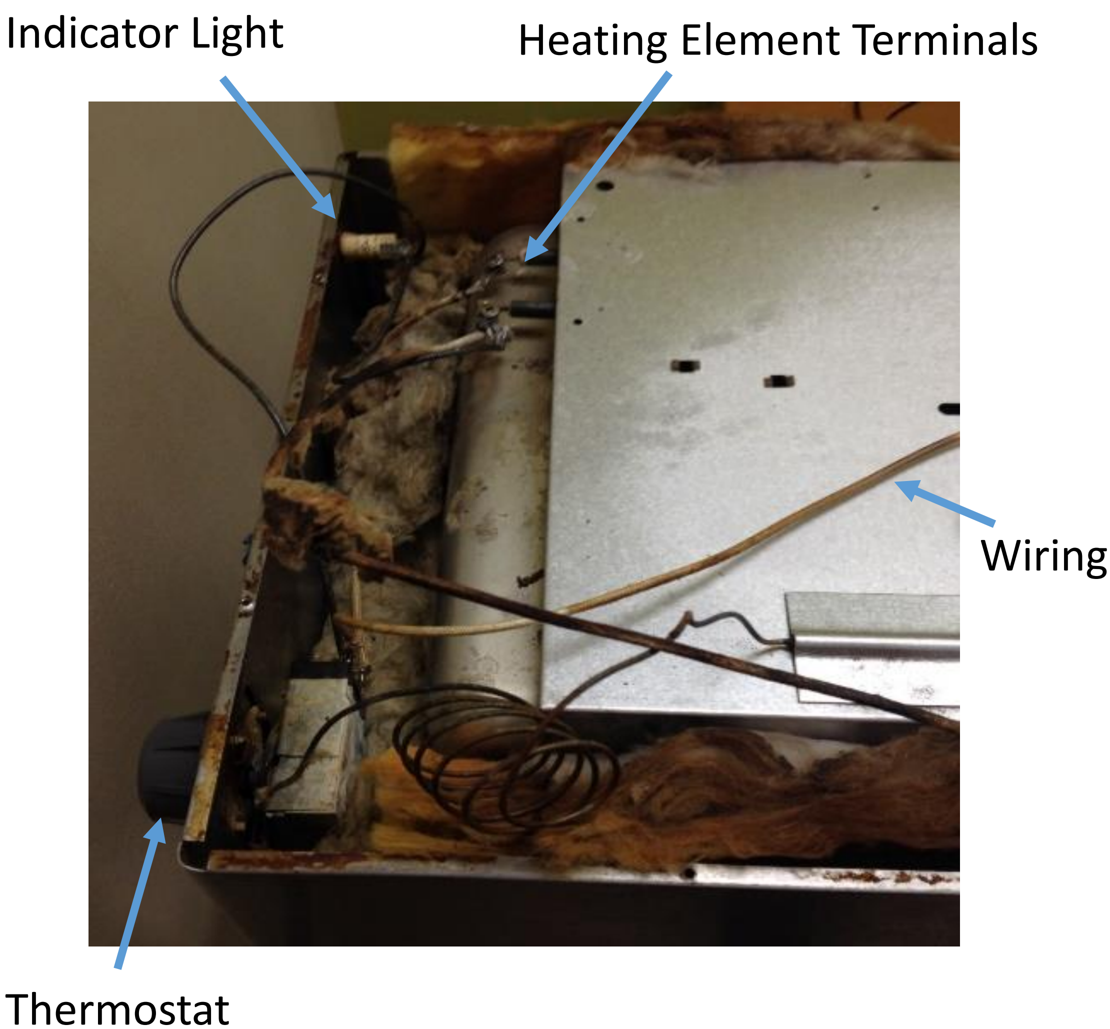
Keep your stainless steel warmers clean and free from calcium buildup.
Use alkaline, alkaline chlorinated or non-chloride cleanser.
Use citric acid-based cleaners to remove calcium deposits.
Wells Delime Cleaner is recommended.

For additional information, please read the NAFEM Stainless Steel Equipment and Cleaning Guide. Contact NAFEM at :

North American Association of Food Equipment Manufacturers
401 N. Michigan Avenue
Chicago, Illinois 60611-4267
(312) 644-6610

Steam Well Components

Wells SMPT countertop warmer. Bottom of unit removed.



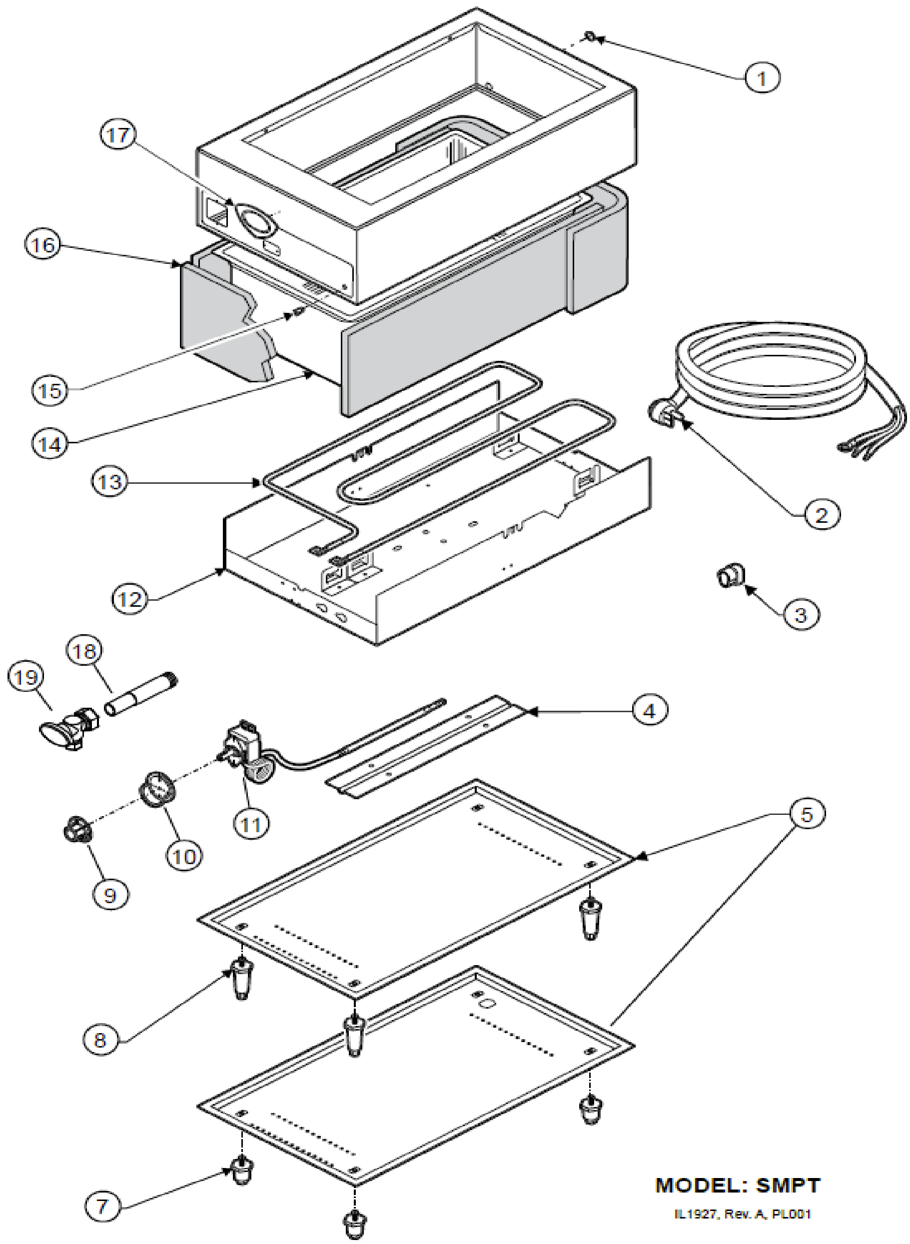
Unit 12:
Countertop Warmers

Fundamentals of Steam

Wells Countertop Warmer Manual Overview – Parts Breakdown Exploded View

EXPLODED VIEW: SMPT

MODEL SMPT



001 p/n 2M-303305 Owners Manual CT Warmers / Thermostat Control

12

Unit 12:
Countertop Warmers

Wells Countertop Warmer Manual Overview – Parts List

PARTS LIST: SMPT

MODEL: SMPT FABRICATED WARMER			
Item No	Part No	Description	Application
1	2P-38628	PLUG HOLE 5/8 DIA	
2	D8-WL0339	ASSY, CORDSET 120V, 15A 14G	
	D8-WL0340	ASSY, CORDSET 6-15P 16/3W 4FT	
	D8-WL0342	ASM-CORD SET CEE7/VII	230V
3	2K-31217	STRAIN RELIEF 90DEG	
4	D8-303352	BRKT THERMO BULB	
5	D8-WL0051	BASE, STD REAR WIRED CORD	
	D8-307895	BAE BTM WIRED CORD	
	D8-Z15106	BOTTOM SMPTD (DRAIN)	SMPTD
7	2A-33572	FEET ADJ 2IN	
8	2R-Y5092	BLK PLASTIC LEG, 4 INCH	
	2A-41946	LEG ADJUST 1"	120C
9	2R-40498	KNOB ASSY	
10	D8-30256	TRIM RING ASSY	
11	2T-38968	THERMO K TYPE	
12	WS-503370	PAN ELEMENT MODS	
13	2N-46681UL	ELEM 120V 1650W SMPT	120V
	2N-Z20147	ELEM 120V 1400W SMPT	120C
	2N-303375UL	ELEM HEATING 240V 1650W	240V
14	WS-55741	PAN W/O DRAIN	SMPT
	D8-WL0255	PAN ASSY W/DRAIN S/TMPTD	SMPTD
15	2J-30516	LIGHT SIGNAL AMBER M3938P	
16	2H-307893	INSULATION FRONT	
16	2H-46073	INSUL SIDE	
17	2M-300534	TRADEMARK DOMED LABEL	
18	2A-Z13799	DRAIN TUBE	SMPTD
19	2K-Z13805	DRAIN VALVE	SMPTD

Hands On Exercise:

Find and document the correct part number for the equipment you are using.

- ❑ Cordset Part Number - ______________________________
- ❑ Heating Element Part Number - _______________________
- ❑ Thermostat Part Number - ___________________________
- ❑ Light Signal Amber Part Number - _____________________

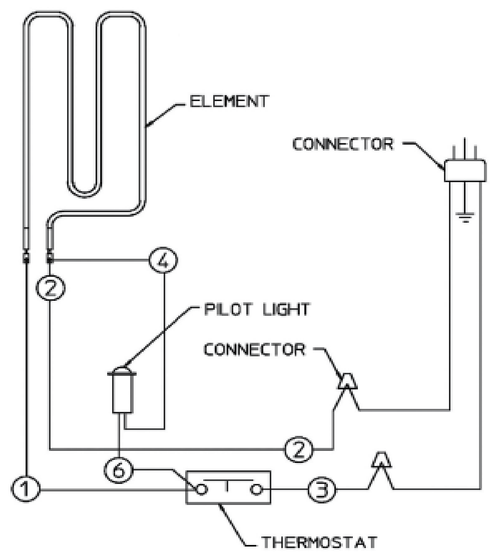
Unit 12:
Countertop Warmers

Fundamentals of Steam

Wells Countertop Warmer Manual Overview – Wiring Diagram

WIRING DIAGRAM

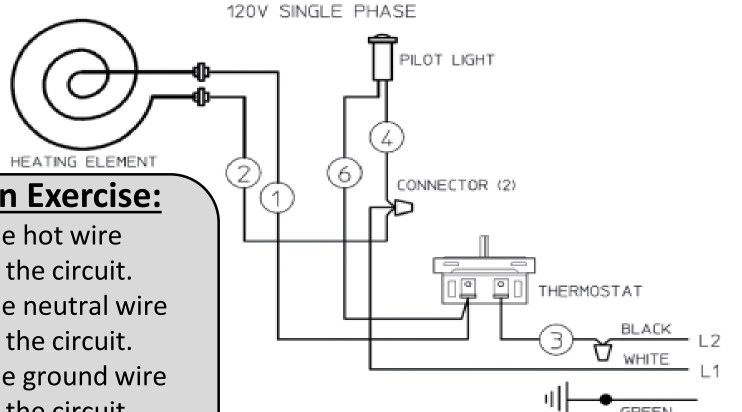
WIRING DIAGRAM FOR SMPT and SMPT-27 WARMER
120V OR 208/240V SINGLE PHASE



WATTS	VOLTS	NOMINAL AMPS 1 PHASE
1650	120	13.8
1650	240	6.9
1240	208	6.0

40570 (D)

WIRING DIAGRAM FOR SW-10T
120V SINGLE PHASE



REV. C PN 40312

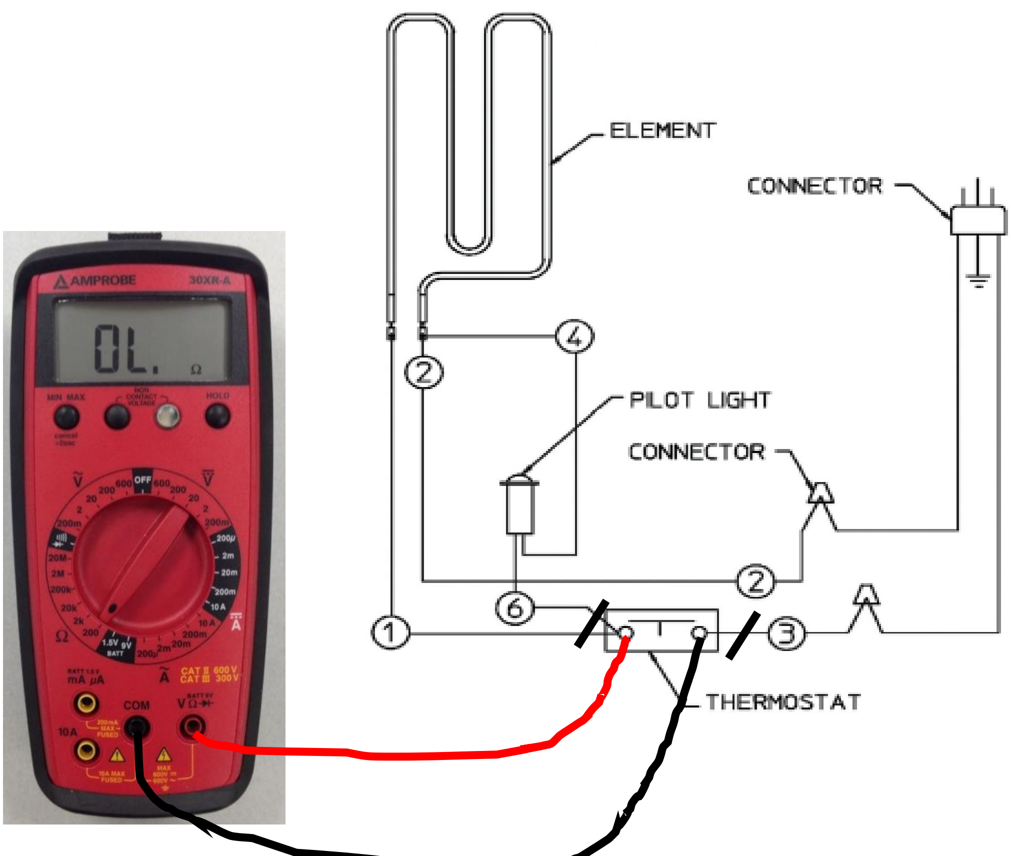
001 p/n 2M-303305 Owners Manual CT Warmers / Thermostat Control

Hands On Exercise:
- ❑ Trace the hot wire through the circuit.
- ❑ Trace the neutral wire through the circuit.
- ❑ Trace the ground wire through the circuit.

Wells Countertop Warmer Manual Overview – Resistance Check

Follow this procedure to check resistance on components such as heating elements, thermostats, lights, or wires.

1. Set multimeter to ohms.
2. Isolate the component you wish to check from the circuit (disconnect the wires from it). If you do not isolate the component you may get a false reading.
3. Put one meter lead on one terminal and the other meter lead on the other terminal.
4. A resistance reading of "O.L" or "I" indicates an open circuit that electricity cannot flow through. A resistance reading of 000 or higher indicates a closed circuit that electricity can flow through.



Wells Countertop Warmer Manual Overview – Manufacturer Information

PARTS & SERVICE (continued)

DESCRIPTION	PART NO.
ACCESSORIES	
8 oz. SOUP LADLE	2L-47567
*LEGS, 1" Plastic, set of 4	WS-21109
*LEGS, 2" Plastic, set of 4	WS-20605
LEGS, 4" Plastic Adjustable	2R-Y5092
LEGS, 4" Metal, Adjustable	2A-Z0314

* Not for use on all appliances. Clearance restrictions may apply. Consult factory.

IMPORTANT: Use only factory authorized service parts and replacement filters.

For factory authorized service, or to order factory authorized replacement parts, contact your Wells authorized service agency, or call:

Wells Manufacturing
10 Sunnen Dr.,
St. Louis MO 63143 USA

Service Dept.
phone: (314) 678-6314
fax: (314) 781-2714

Service Parts Department can supply you with the name and telephone number of the WELLS AUTHORIZED SERVICE AGENCY nearest you.

Hands On Exercise:

- ❑ Fill out the customer service data
- ❑ What is the service department phone number: ___________________________
- ❑ Start-up a countertop warmer
- ❑ Shut-down a countertop warmer

CUSTOMER SERVICE DATA

please have this information available if calling for service

RESTAURANT ________________________________ LOCATION ______________
INSTALLATION DATE __________________________ TECHNICIAN ____________
SERVICE COMPANY ____
ADDRESS ______________________________ STATE ______ ZIP__________
TELEPHONE NUMBER (_____)_____-__________
EQUIPMENT MODEL NO. ________________
EQUIPMENT SERIAL NO. ________________
VOLTAGE: (check one) ❑ 120 ❑ 208 ❑ 240

Unit 13:
Combi Oven

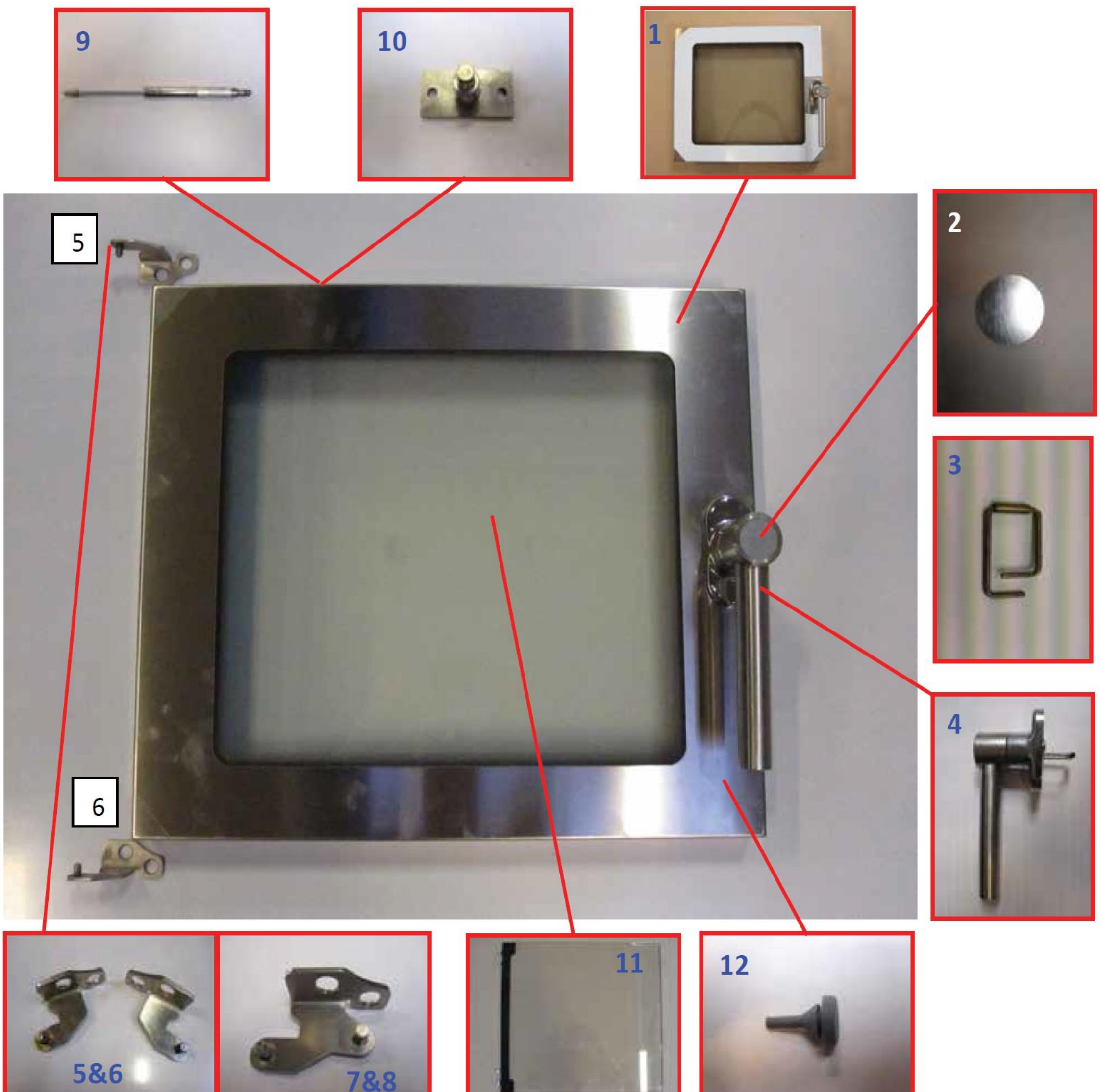
Fundamentals of Steam

Hands On Exercise: Parts identification on a Blodgett BLCT23E Combi Oven

Find the parts manual for the Blodgett BLCT23E Combi Oven on the internet and write the part name and number the picture of the part.

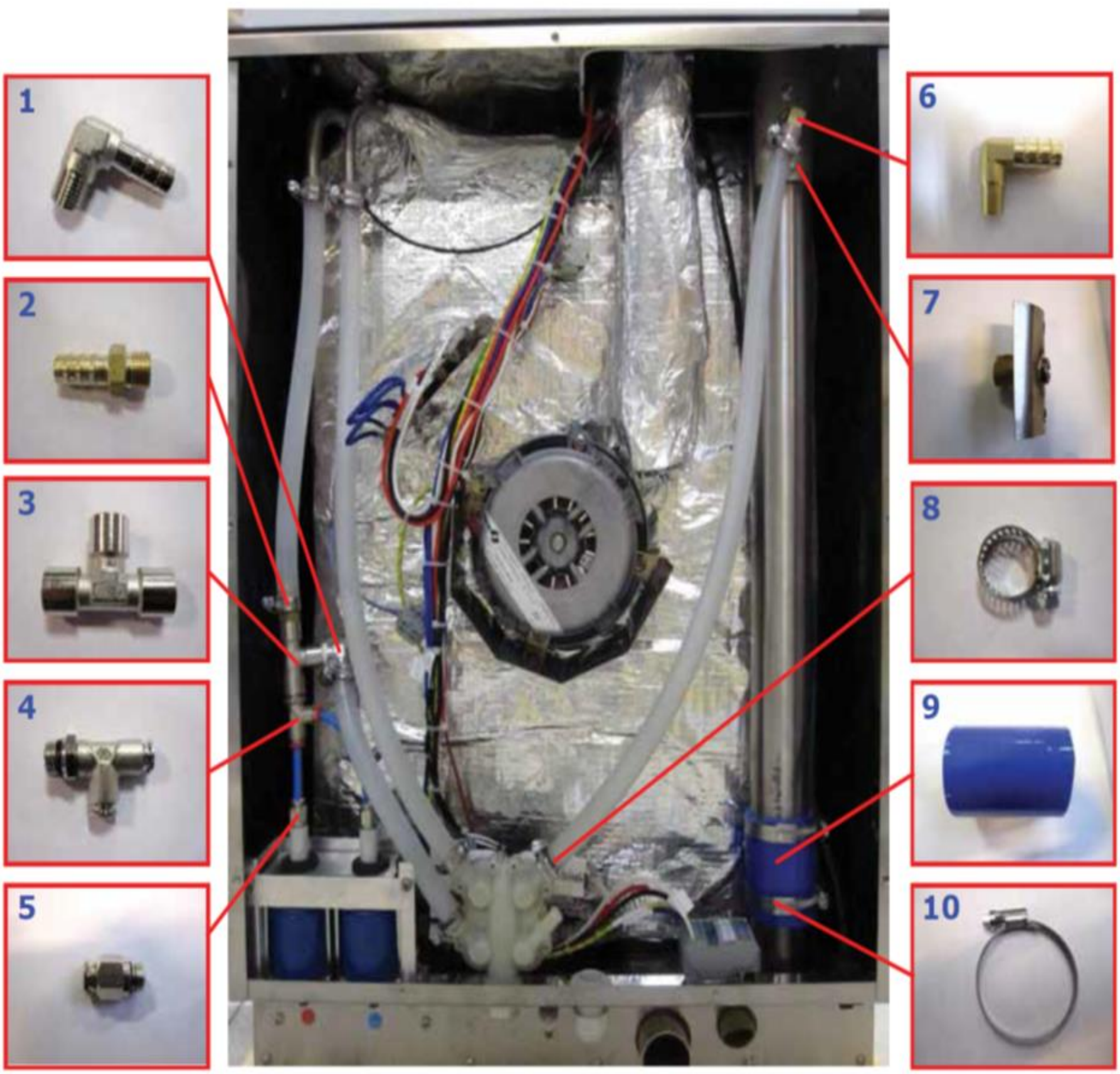
This exercise is designed to familiarize the student with the process of finding parts manuals on the internet as well as looking up the parts they need in a manual.

OVEN DOOR



Hands On Exercise: Parts identification on a Blodgett BLCT23E Combi Oven

REAR VIEW

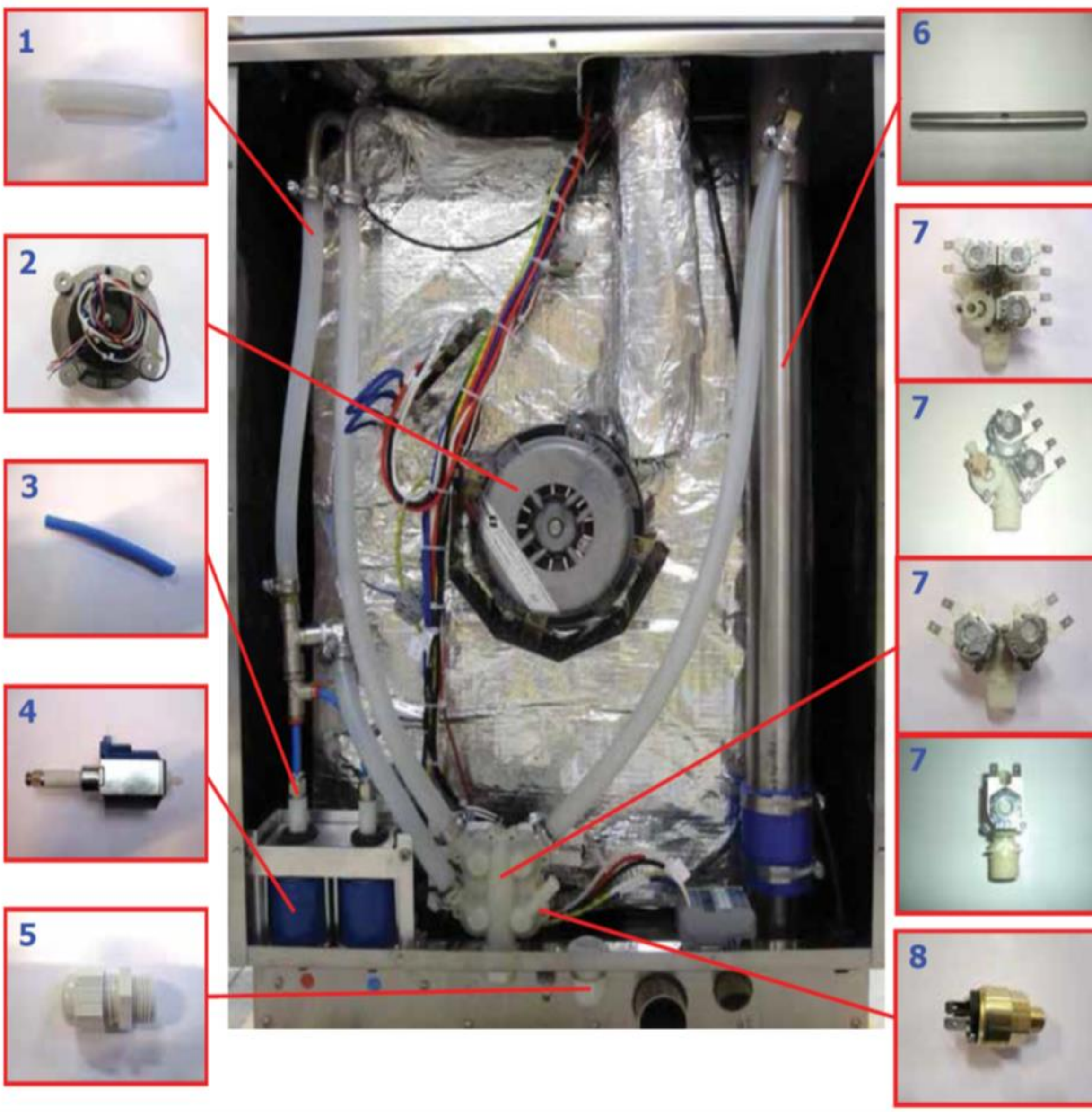


Unit 13:
Combi Oven

Fundamentals of Steam

Hands On Exercise: Parts identification on a Blodgett BLCT23E Combi Oven

REAR VIEW



Unit 13:
Combi Oven

Fundamentals of Steam

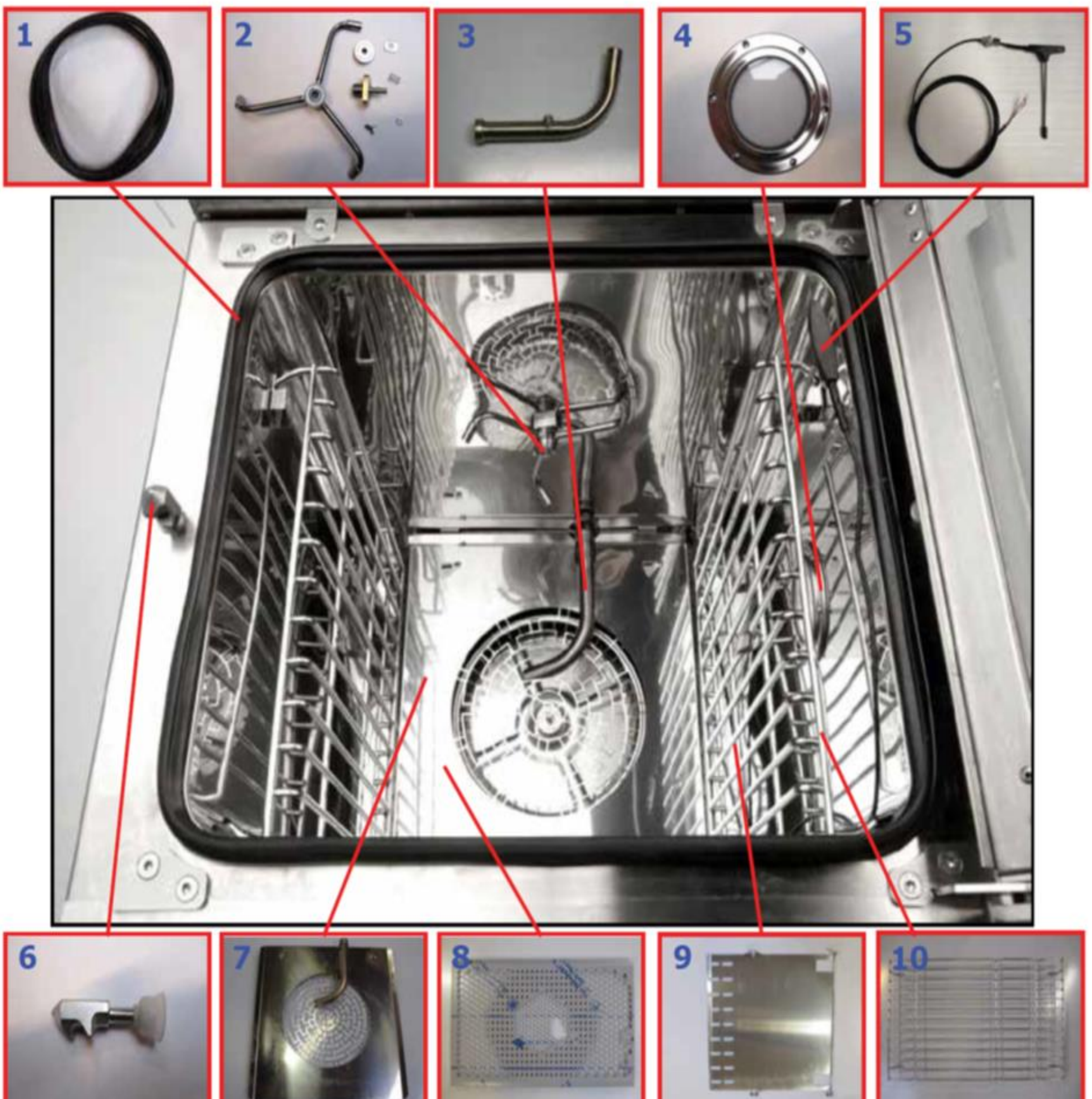
Hands On Exercise: Parts identification on a Blodgett BLCT23E Combi Oven

Unit 13:
Combi Oven

Fundamentals of Steam

Hands On Exercise: Parts identification on a Blodgett BLCT23E Combi Oven

FRONT VIEW AND INTERIOR



Unit 14:
Extras

Helpful Resources

www.armstronginternational.com
www.wisc-online.com
www.clevelandrange.com
www.vulcanfeg.com
www.tlv.com
www.wellsbloomfield.com
www.whatispiping.com

Commercial Food Equipment Service Technician

Fundamentals of Refrigeration

Introduction to Refrigeration Principles, Equipment, Operation, and Repair

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Unit 1:
Intro to Refrigeration Systems

Fundamentals of Refrigeration

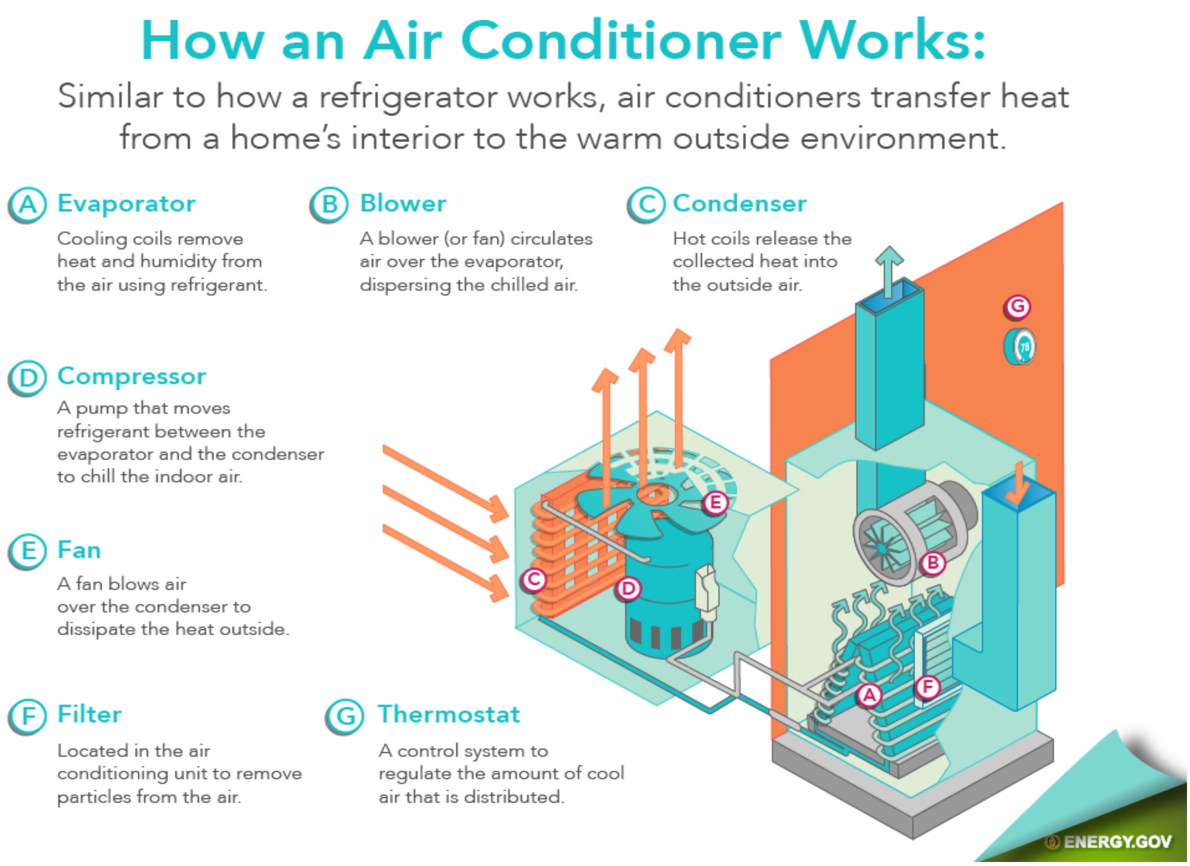
What is Refrigeration?

What is Refrigeration?

Refrigeration is the process of removing heat from a place where it is not wanted to a place that will not have a negative affect. The refrigeration process removes heat. It does not add cold to a space. When you remove heat from a space, the result is a lower temperature which feels cold. Below is an example of how an air conditioner works.

Main Components of a Refrigeration System

Although there are many components to a refrigeration system, there are only four components that a system must have in order to be considered a refrigeration system. The four main components to any refrigeration system are: Compressor, Condenser, Metering Device, and Evaporator.



Unit 1:
Intro to Refrigeration Systems

Fundamentals of Refrigeration

Refrigeration Safety

Safety is of utmost importance when working with refrigeration equipment. When working with refrigeration equipment there is dangerous hazards involved including:

High Voltage
Refrigeration equipment contains components that require voltages ranging from 120 Volts AC to 240 Volts AC. Always unplug equipment before servicing or removing covers and guards. Perform Lockout-Tagout procedures where necessary. Use insulated electrical tools. Always check for the presence of voltage using a voltmeter before beginning work.

High Pressure
Pressurized refrigeration systems operate under a pressurized condition. Pressure release in these systems can be extremely dangerous. Pressurized refrigerants can burn you, penetrate your skin, or blow particles at you. To protect yourself from pressure, wear safety goggles and gloves. Avoid disconnecting any pressurized lines.

High Temperatures
Some components in the refrigeration system operate at high temperatures. These temperatures can scald the skin. Follow gas Lockout-Tagout procedures before servicing gas equipment. Exposed surfaces may be hot to the touch. Wear safety glasses and gloves whenever necessary.

Toxic Chemicals
Chemicals harmful to humans are used to refrigeration equipment. Some of these chemicals are poisonous and caustic. It is important to protect yourself from these chemicals by wearing rubber gloves that protect you from these chemicals if they spill or get sprayed on you. You should also wear safety glasses or a face shield to protect your face and eyes from chemical splashes.

Heavy Equipment
Refrigeration equipment is very heavy in many cases. Some equipment weighs several hundred pounds. When moving heavy equipment or parts, have someone help you, use a dolly, forklift, or pallet jack whenever possible. Don't risk it. Back injuries are the number one injury in the commercial equipment industry. **A back injury can end your career**.

Equipment Types

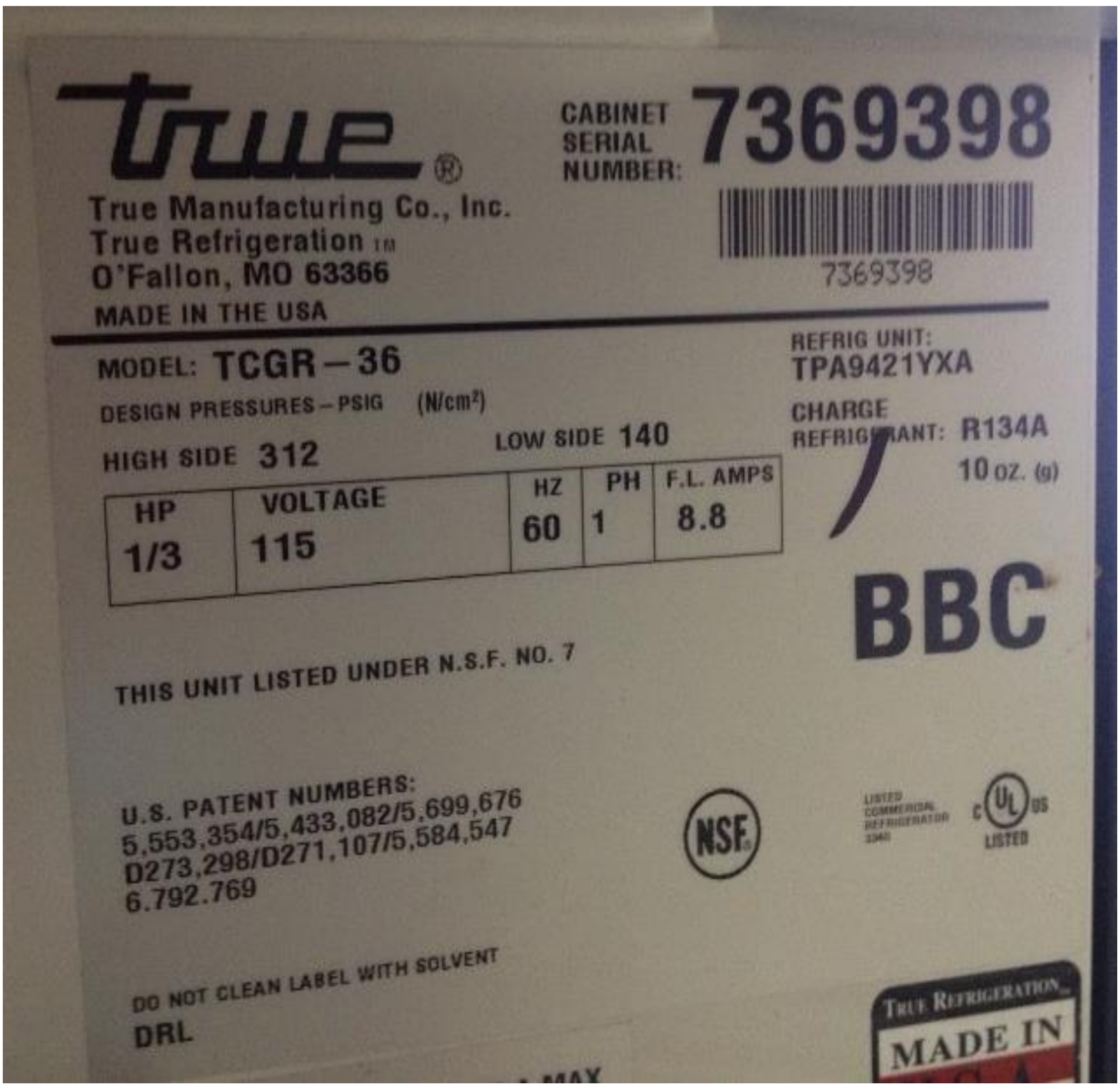
There are many types of equipment refrigeration technicians have to work on. Below are a few types you can expect to see.

Unit 1:
Intro to Refrigeration Systems

Fundamentals of Refrigeration

Data Plates

Refrigeration equipment data plates contain valuable information for the service technician such as serial number, model number, voltage requirements, amperage draw, compressor type, type of refrigerant and test pressures. When calling the manufacturer for parts or troubleshooting help, be sure to have the model and serial number handy to give to the technician on the phone.



Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Four Basic Laws

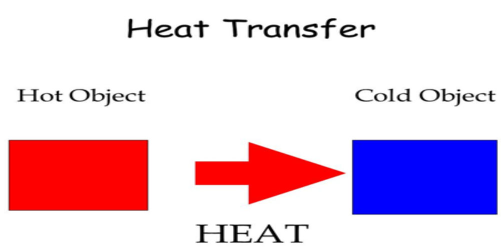
Why learn the basic refrigeration cycle

A good understanding of the basic operation of the refrigeration system is essential for the service technician. Without this understanding, accurate troubleshooting of refrigeration system problems will be more difficult and time consuming, if not (in some cases) entirely impossible.

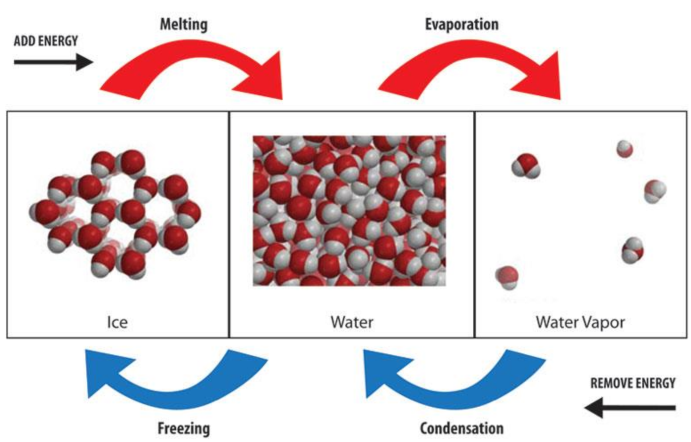
The Four Basic Laws

The refrigeration system uses four basic principles (laws) in its operation they are as follows:

1. "Heat always flows from a warmer body to a cooler body.“



2. "Heat must be added to or removed from a substance before a change in state can occur“



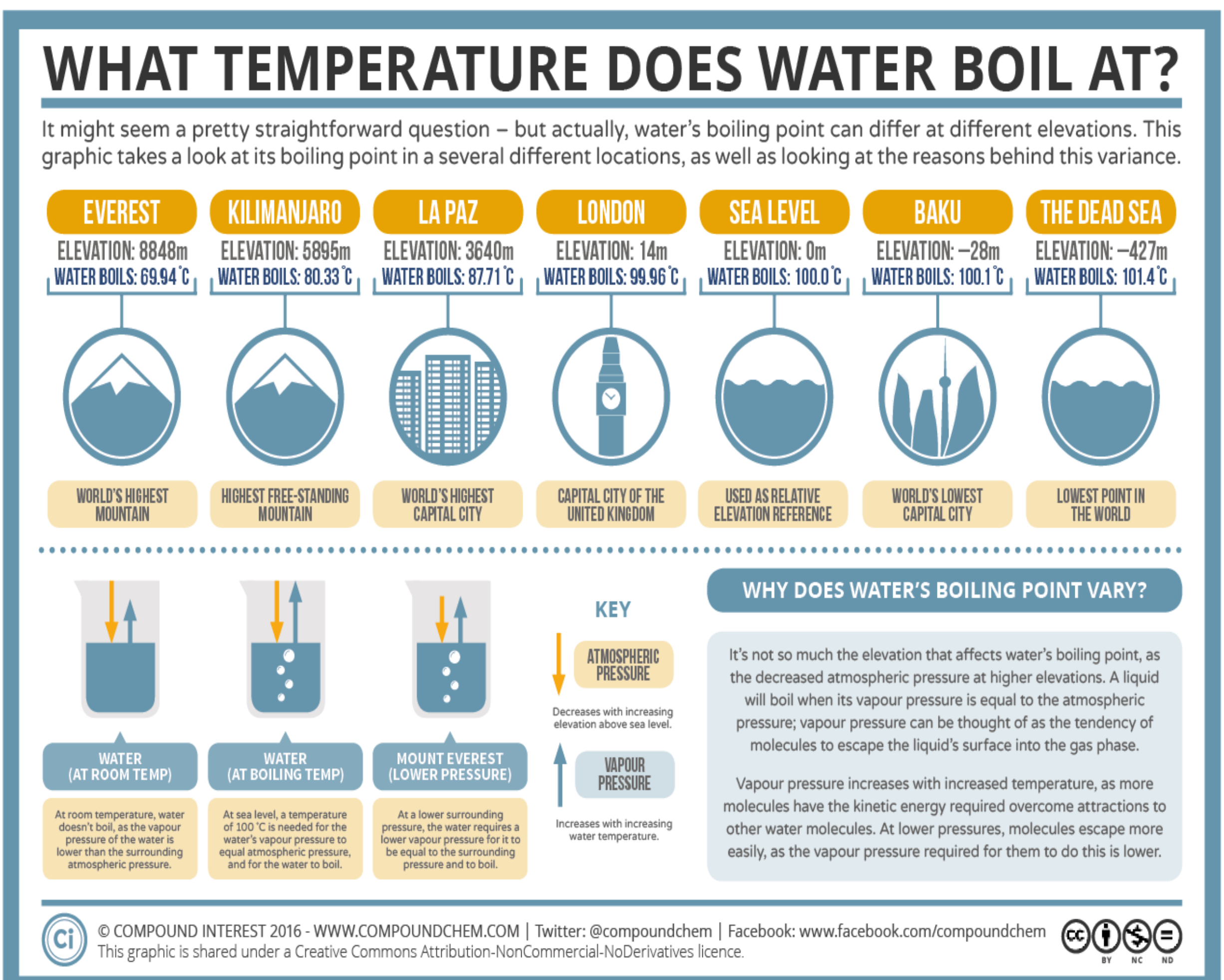
©Middleschoolchemistry.com

Unit 2:
Refrigeration Science

Four Basic Laws

3. "Flow is always from a higher pressure area to a lower pressure area.“

4. "The temperature at which a liquid or gas changes state is dependent upon the pressure."



Basic Refrigeration Cycle

What happens in the compressor

The refrigeration cycle begins at the compressor. Starting the compressor creates a low pressure in the suction line which draws refrigerant gas (vapor) into the compressor.
The compressor then "compresses" this refrigerant, raising its pressure and its (heat intensity) temperature. The refrigerant leaves the compressor through the discharge line as a hot High pressure gas (vapor).

© Sporlanl.en.ec21.com

What happens in the condenser

The refrigerant enters the condenser coil where it gives up some of its heat. The condenser fan moving air across the coil's finned surface facilitates the transfer of heat from the refrigerant to the relatively cooler outdoor air. When a sufficient quantity of heat has been removed from the refrigerant gas (vapor), the refrigerant will "condense" (i.e. change to a liquid). Once the refrigerant has been condensed (changed) to a liquid it is cooled even further by the air that continues to flow across the condenser coil. The design determines at exactly what point (in the condenser) the change of state (i.e. gas to a liquid) takes place. In all cases, however, the refrigerant must be totally condensed (changed) to a liquid before leaving the condenser coil. The refrigerant leaves the condenser coil through the liquid line as a warm high pressure liquid.

© alibaba.com

What happens in the Filter/Drier

It next will pass through the refrigerant drier (if so equipped). It is the function of the drier to trap any moisture present in the system, contaminants, and large particulate matter.

© Comfortup.com

What happens in the metering device

The liquid refrigerant next enters the metering device. The metering device is a capillary tube. The purpose of the metering device is to "meter" (i.e. control or measure) the quantity of refrigerant entering the evaporator coil. In the case of the capillary tube this is accomplished (by design) through size (and length) of device, and the pressure difference present across the device.

© Shineyear.com.tv

Basic Refrigeration Cycle

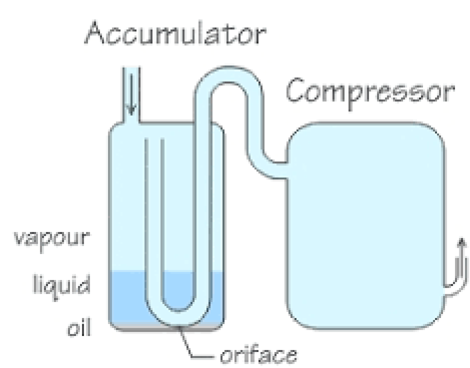
What happens in the evaporator

Since the evaporator coil is under a lower pressure (due to the suction created by the compressor) than the liquid line, the liquid refrigerant leaves the metering device entering the evaporator coil.
As it enters the evaporator coil at the bottom, the larger area and lower pressure allows the refrigerant to expand and lower its temperature (heat intensity). This expansion is often referred to as "boiling". Since the unit's blower is moving indoor air across the finned surface of the evaporator coil, the expanding refrigerant absorbs some of that heat. This results in a lowering of the indoor air temperature, hence the "cooling" effect. The expansion and absorbing of heat cause the liquid refrigerant to evaporate (i.e. change to a gas).
Once the refrigerant has been evaporated (changed to a gas), it is heated even further by the air that continues to flow across the evaporator coil. In all cases, however, the refrigerant must be totally evaporated (changed) to a gas before leaving the evaporator coil. The low pressure (suction) created by the compressor causes the refrigerant to leave the evaporator through the suction line as a cool low pressure vapor.

Walk-in Cooler Evaporator

What happens in the accumulator

The accumulator is a device that accumulates any liquid refrigerant that has not turned into a gas. The liquid refrigerant stays in the accumulator until it boils into a gas. Then the refrigerant gas is siphoned out of the accumulator by the vacuum action of the compressor.



The refrigerant then returns to the compressor, where the cycle is repeated

Basic Refrigeration Cycle

What happens in the evaporator

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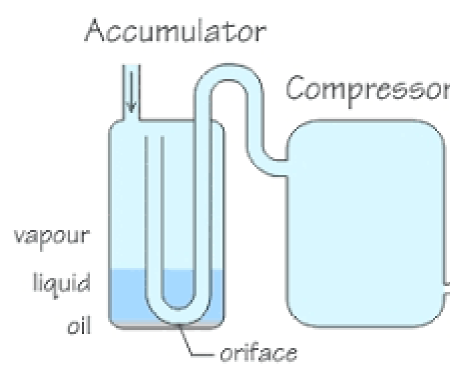
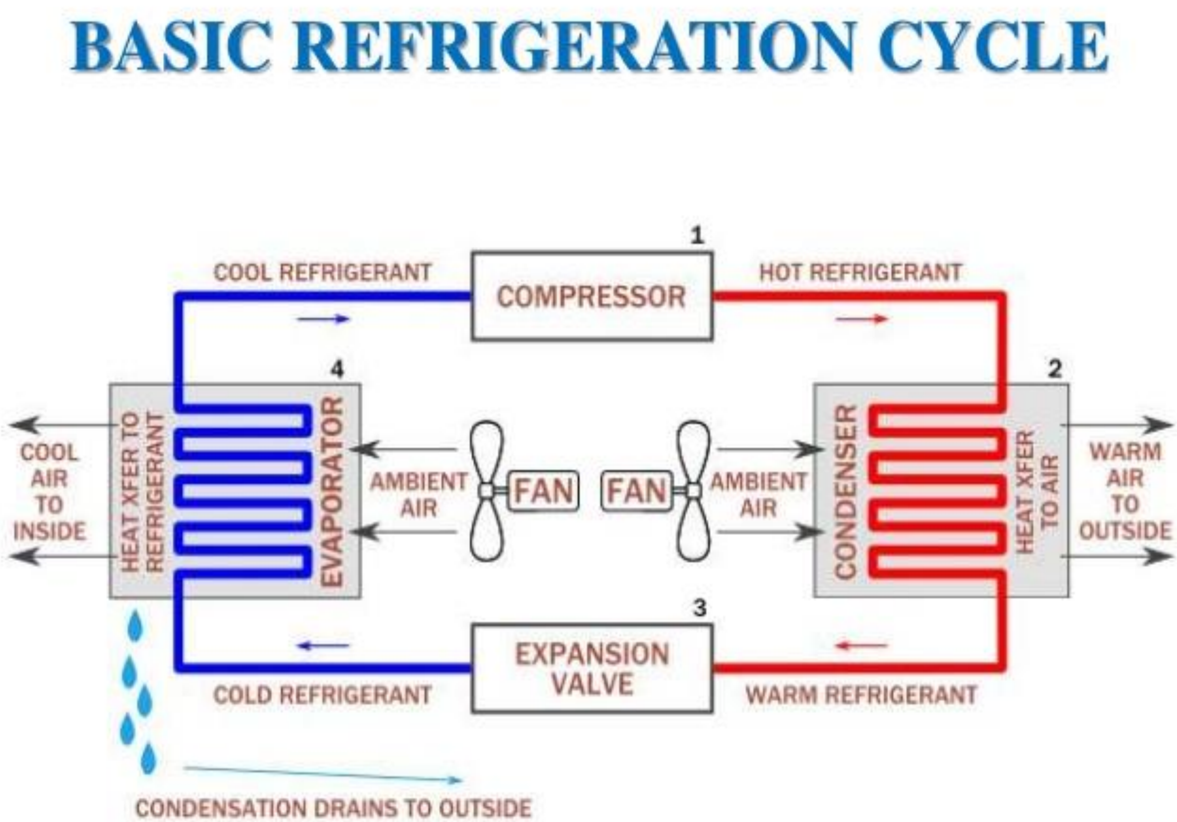


The refrigerant then returns to the compressor, where the cycle is repeated

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Basic Refrigeration Cycle



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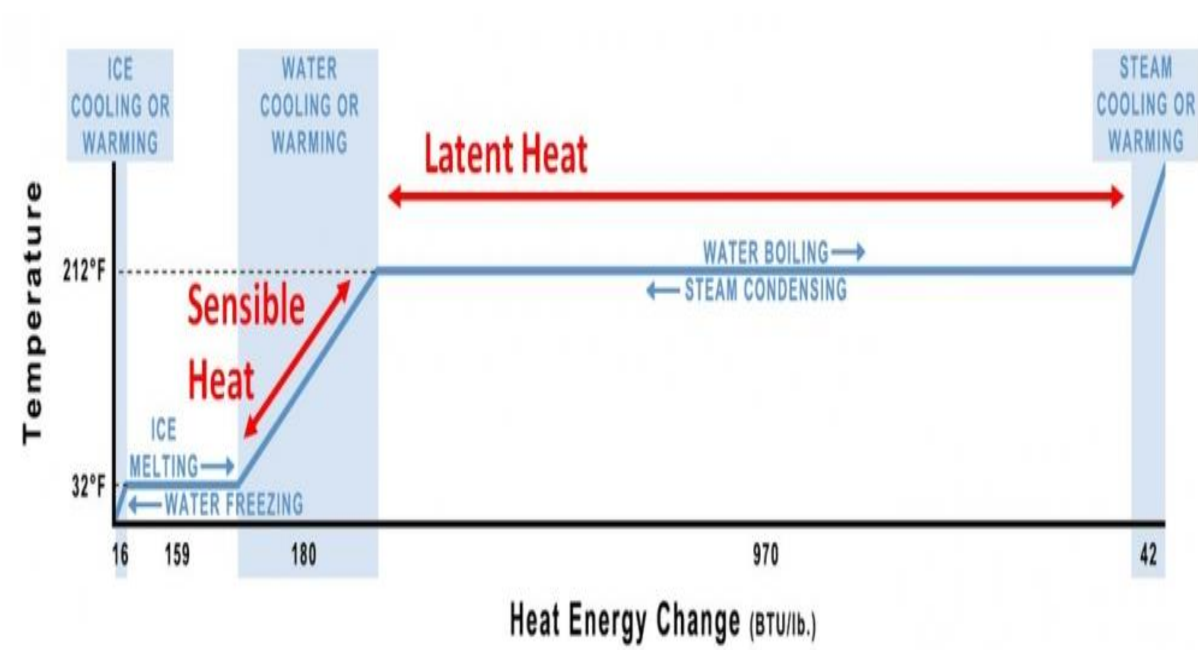
Sensible vs Latent Heat

•Sensible heat
When an object is heated, its temperature rises as heat is added. The increase in heat is called sensible heat. Similarly, when heat is removed from an object and its temperature falls, the heat removed is also called sensible heat. Heat that causes a change in temperature in an object is called sensible heat.

•Latent heat
All pure substances in nature are able to change their state. Solids can become liquids (ice to water) and liquids can become gases (water to vapor) but changes such as these require the addition or removal of heat. The heat that causes these changes is called latent heat. Latent heat however, does not affect the temperature of a substance - for example, water remains at 100°C while boiling. The heat added to keep the water boiling is latent heat. Heat that causes a change of state with no change in temperature is called latent heat.



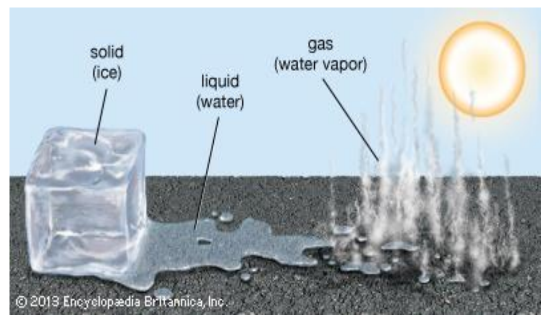
Phase Changes

What is Phase Change?

All substances can exist in three different phases: solid, liquid, and vapor. Water is the most natural example of a substance that we use almost everyday in all three phases.

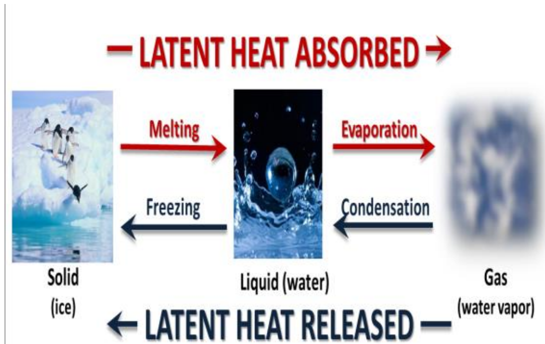
Phase Change Example

For water the three phases have received different names - making it a bit confusing when using it as a model substance. The solid form we call ice, the liquid form we just call water, and the vapor form we call steam. What is common to these three phases is that the water molecules remain unchanged, meaning that ice, water, and steam all have the same chemical formula: H2O.



Phase Change Process

When taking a substance in the solid to the liquid phase the transition process is called melting and when taking it further to the vapor phase the transition process is called boiling (evaporation). When going in the opposite direction change taking a substance from the vapor to the liquid phase the transition process is called condensing and when taking it further to the solid phase the transition process is called freezing (solidification). Latent (hidden) heat transfer has to take place in order for phase change to take place.



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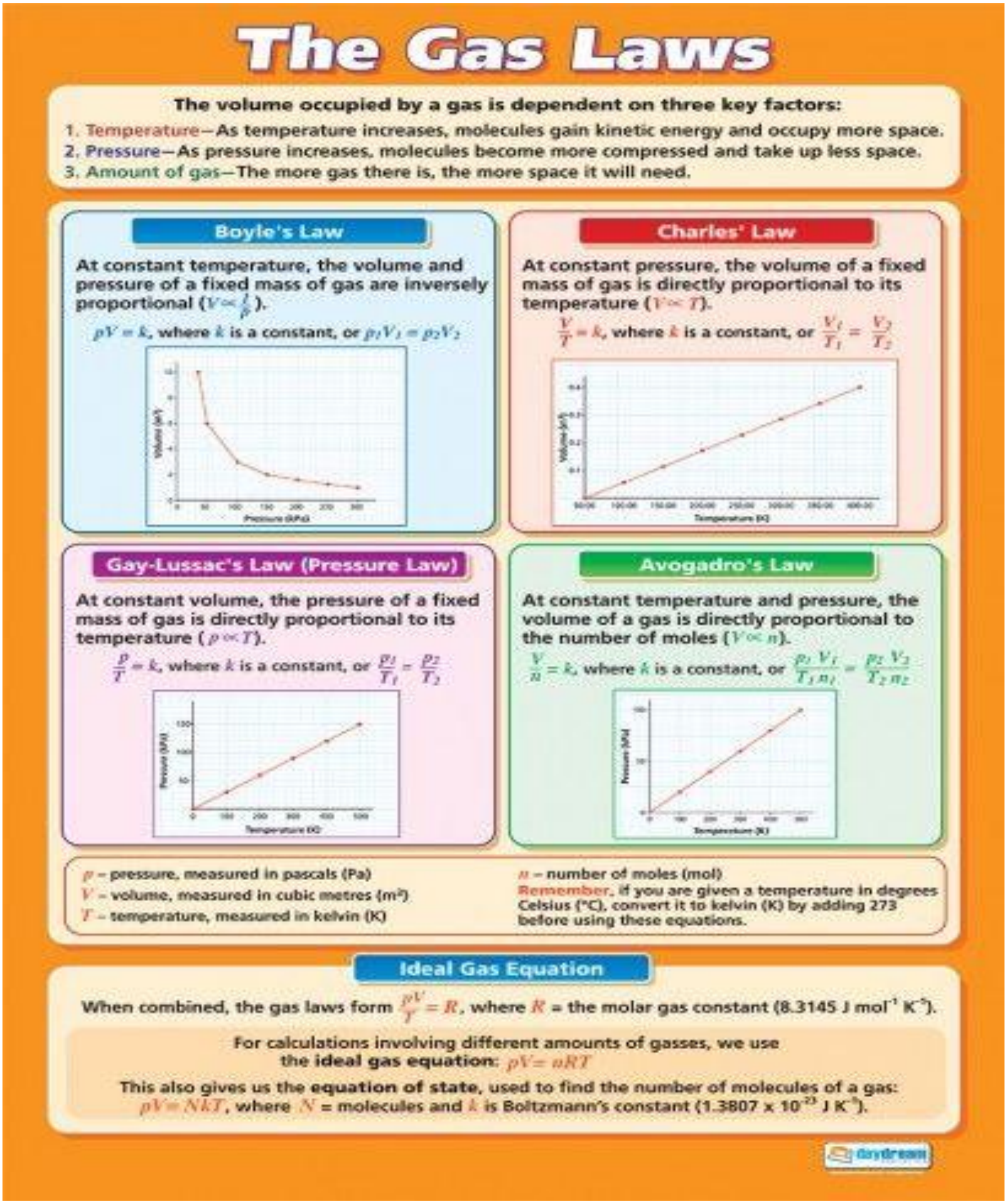
Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Gas Laws



Gas Laws

Boyle's Law	Charles' Law	Guy-Lassac's Law	Combined Gas Law
For a given mass of gas at constant temperature, the volume of a gas varies inversely with pressure	The volume of a fixed mass of gas is directly proportional to its Kelvin temperature if the pressure is kept constant.	The pressure of a gas is directly proportional to the Kelvin temperature if the volume is kept constant.	Combines Boyle's, Charles', and the Temperature-Pressure relationship into one equation. Each of these laws can be derived from this law.
$PV = k$ $P_1V_1 = P_2V_2$	$\frac{V}{T} = k$ $V_1T_2 = V_2T_1$ $\frac{V_1}{T_1} = \frac{V_2}{T_2}$	$\frac{P}{T} = k$ $P_1T_2 = P_2T_1$ $\frac{P_1}{T_1} = \frac{P_2}{T_2}$	$\frac{PV}{T} = k$ $V_1P_1T_2 = V_2P_2T_1$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

Dalton's Law	Ideal Gas Law	Graham's Law
At constant volume and temperature, the total pressure exerted by a mixture of gases is equal to the sum of the pressures exerted by each gas,	The Ideal Gas Law relates the pressure, temperature, volume, and mass of a gas through the gas constant "R".	The rate of effusion/diffusion of two gases (A and B) are inversely proportional to the square roots of their formula masses. [*It can be a ratio of molecular speeds, effusion /diffusion times, distance traveled by molecules, or amount of gas effused*]
$P_{total} = P_1 + P_2 + P_3 + \ldots P_n$	$PV = nRT$	$\frac{Rate_A}{Rate_B} = \frac{\sqrt{molar\ mass_B}}{\sqrt{molar\ mass_A}}$

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Gas Laws

Abbreviations	Standard Conditions
atm = atmosphere mm Hg = millimeters of mercury torr = another name for mm Hg Pa = Pascal kPa = kilopascal K = Kelvin °C = degrees Celsius	0°C = 273 K 1.00 atm = 760.0 mm Hg = 76 cm Hg =101.325 kPa = 101, 325 Pa = 29.9 in Hg
Conversions	**Gas Law's Equation Symbols**
K = °C + 273 $F^{\circ} = 1.8C^{\circ} + 32$ $C^{\circ} = \frac{F^{\circ} - 32}{1.8}$ 1 cm^3 (cubic centimeter) = 1 mL (milliliter) 1 dm^3 (cubic decimeter) = 1 L (liter) = 1000 mL	Subscript (1) = old condition or initial condition Subscript (2) = new condition or final condition Temperature must be in Kelvins n = number of moles = grams/Molar mass R = 8.31 L-kPa/ mol-K = 0.0821 L-atm/mol-K = 62.4 L-Torr/mol-K You must have a common set of units in the problem

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Gas Law Worksheets

1. Convert the following temperatures to K. a) 104 C b) -3 C	
2. Convert the following temperatures to C. a) 67 K b) 1671 K	
3. A sample of nitrogen gas has a volume of 478 cm^3 and a pressure of 104.1 kPa. What volume would the gas occupy at 88.2 kPa if the temperature remains constant?	
4. 8.98 dm^3 of hydrogen gas is collected at 38.8 °C. Find the volume the gas will occup at -39.9 °C if the pressure remains constant.	
5. A sample of gas has a volume of 215 cm^3 at 23.5 °C and 84.6 kPa. What volume will the gas occupy at STP?	

Gas Law Worksheets

6. At a certain temperature, molecules of methane gas, CH_4 have an average velocity of 0.098 m/s. What is the average velocity of carbon dioxide molecules at this same temperature?	
7. Find the relative rate of diffusion for the gases chlorine, Cl_2 and ethane, C_2H_6.	
8. 495 cm^3 of oxygen gas and 877 cm^3 of nitrogen gas, both at 25.0 °C and 114.7 kPa, are injected into an evacuated 536 cm^3 flask. Find the total pressure in the flask, assuming the temperature remains constant.	
9. A sample of gas is transferred from a 75 mL vessel to a 500.0 mL vessel. If the initial pressure of the gas is 145 atm and if the temperature is held constant, what is the pressure of the gas sample in the 500.0 mL vessel?	
10. A sample of gas occupies a volume of 450.0 mL at 740 mm Hg and 16°C. Determine the volume of this sample at 760 mm Hg and 37°C.	

Gas Law Worksheets

11. One mole of H_2S gas escapes from a container by effusion in 77 seconds. How long would it take one mole of NH_3 gas to escape from the same container?	
12. Convert a pressure of 0.0248 mm Hg to the equivalent pressure in pascals (Pa).	
13. Air in a closed cylinder is heated from 25°C to 36°C. If the initial pressure is 3.80 atm, what is the final pressure?	
14. A bubble of helium gas has a volume of 0.650 mL near the bottom of a large aquarium where the pressure is 1.54 atm and the temperature is 12°C. Determine the bubble's volume upon rising near the top where the pressure is 1.01 atm and 16°C.	
15. At what temperature Celsius will 19.4 g of molecular oxygen, O_2, exert a pressure of 1820 mm Hg in a 5.12 L cylinder?	

16. A sample of nitrogen gas, N_2, is collected in a100 mL container at a pressure of 688 mm Hg and a temperature of 565 °C. How many grams of nitrogen gas are present in this sample?	
17. What is the pressure in mm of Hg , of a gas mixture that contains 1g of H_2, and 8.0 g of Ar in a 3.0 L container at 27°C.	
18. To what temperature must 32.0 ft^3 of a gas at 2°C be heated for it to occupy 1.00×10^2 ft^3 at the same pressure?	
19. What is the pressure in atm exerted by 2.48 moles of a gas in a 250.0 mL container at 58°C?	
20. Determine the molar mass of a gas that has a density of 2.18 g/L at 66°C and 720 mm Hg. *(Hint: the number of moles of a substance is its mass/molecular mass and density is mass/volume.)*	

Gas Law Worksheets

Key

1 a) 377 K
b) 270 K

2 a) -206 C
b) 1398 C

3. 564 cm^3

4. 6.71 dm^3

5. 165 cm^3

6. 0.059 m/s

7. rate $Cl_2 : C_2H_6 = 0.650$

8. 294 kPa

9. 21.8 atm

10.. 470 mL

11. 54 sec

12. 3.31 Pa

13. 3.94 atm

14. 1.00 mL

15. - 27°C

16. 0.0368 g

17. 4332 mm Hg

18. 586°C

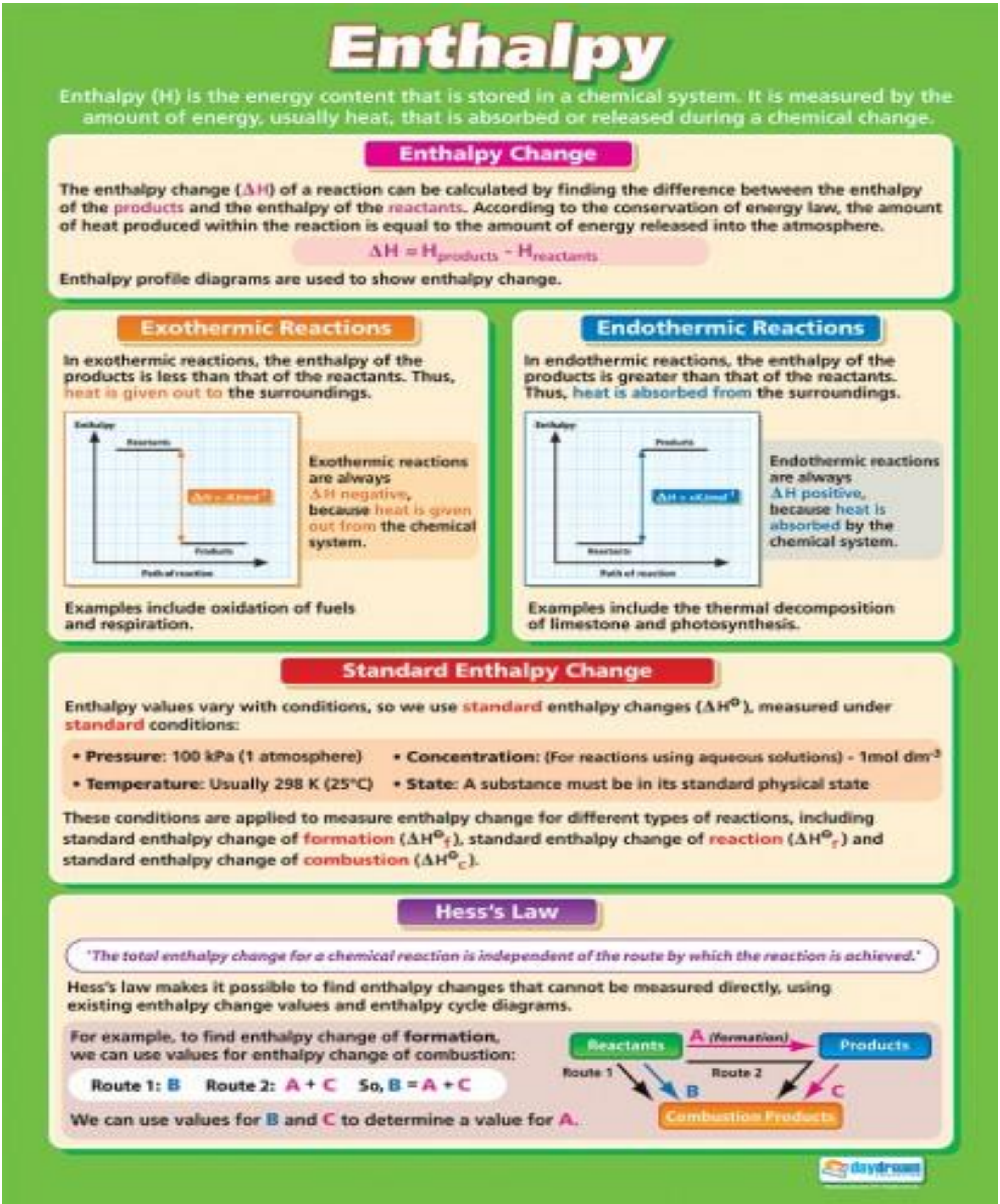
19. 270 atm

20. 64 g/mole

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Enthalpy



Units of Measurement

There are two types of units of measurement. One type is the SI-unit. SI stands for System de International and is typically used in other parts of the world than the US. The other type is the English or alternative system which is typically used in the United States.

Quantity	SI-unit	Alternative units
Time	s (second)	h (hour)
Length	m (meter)	in (inch) ft (foot)
Mass	kg (kilogram)	lb (pound)
Temperature	K (Kelvin)	°C (Celsius) °F (Fahrenheit)
Force	N (Newton)	kp (kilopond)
Pressure	Pa (Pascal) = N/m^2	bar atm (atmosphere) mm Hg (millimeter mercu-ry column) psi (pound per square inch)
Energy	J (Joule) = Nm	kWh (kilowatt hour) cal (calorie) Btu (British thermal unit)
Power	W (Watt) = J/s	calorie/h, Btu/h

Unit Prefixes

The practical use of the SI-units is strongly associated with the use of prefixes to avoid writing either very small or large numbers. A part of the prefixes used can be seen in the table below.

Name	pico	nano	micro	mili	kilo	Mega	Giga	Tera	Peta
Prefix	p	n	µ	m	k	M	G	T	P
Factor	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{3}	10^{6}	10^{9}	10^{12}	10^{15}

Useful Formulas

FORMULA: CONVERTING CELSIUS TO FAHRENHEIT

$$T_F = \left(\frac{9}{5} \times T_C\right) + 32$$

Where:

T_F = *Temperature in degrees Fahrenheit*
T_C = *Temperature in degrees Celsius*

FORMULA: CONVERTING FAHRENHEIT TO CELSIUS

$$T_C = \frac{5}{9} \times (T_F - 32)$$

Where:

T_C = *Temperature in degrees Celsius*
T_F = *Temperature in degrees Fahrenheit*

FORMULA: CONVERTING FAHRENHEIT TO RANKINE

$$T_R = T_F + 459.67$$

Where:

T_R = *Temperature in degrees Rankine*
T_F = *Temperature in degrees Fahrenheit*

FORMULA: CONVERTING RANKINE TO FAHRENHEIT

$$T_F = T_R - 459.67$$

Where:

T_F = *Temperature in degrees Fahrenheit*
T_R = *Temperature in degrees Rankine*

FORMULA: CONVERTING CELSIUS TO KELVIN

$$T_K = T_C + 273.15$$

Where:

T_K = *Temperature in kelvins*
T_C = *Temperature in degrees Celsius*

FORMULA: CONVERTING KELVIN TO CELSIUS

$$T_C = T_K - 273.15$$

Where:

T_C = *Temperature in degrees Celsius*
T_K = *Temperature in kelvins*

FORMULA: PRESSURE

$$P = \left(\frac{F}{A}\right)$$

Where: P = *Pressure in psi or Pa*
F = *Force in pounds or Newtons*
A = *Area in square inches or square meters*

FORMULA: ABSOLUTE PRESSURE

$$P_{abs} = P_{gauge} + P_{atm}$$

Where:

P_{abs} = *Absolute pressure (psia or kPa abs)*
P_{gauge} = *Gauge pressure (psig or kPa)*
P_{atm} = *Atmospheric pressure (14.7 psi or 101.3 kPa)*

FORMULA: CONVERT KPA TO PSI

$$P_{psi} = \frac{P_{kPa}}{6.8948}$$

Where:

P_{psi} = *pressure in pounds-per-square inch*
P_{kPa} = *pressure in kilo Pascals*

FORMULA: CONVERT PSI TO KPA

$$P_{kPa} = P_{psi} \times 6.8948$$

Where:

P_{kPa} = *pressure in kilo Pascals*
P_{psi} = *pressure in pounds-per-square inch*

SPECIFIC INTERNAL ENERGY

$$u = \frac{U}{m}$$

where: u = *specific internal energy (BTU/lb or kJ/kg)*
U = *internal energy (BTU or kJ)*
m = *unit mass (lb or kg)*

FORMULA: CONVERTING BETWEEN BTU AND JOULE

$$1\ BTU = 1.055\ kJ$$

$$1\ kJ = 0.948\ BTU$$

$$1\ BTU/lb = 2.326\ kJ/kg$$

$$1\ kJ/kg = 0.4299\ BTU/lb$$

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Useful Formulas

FORMULA: HEAT TO REMOVE

$$Q = w \times c \times \Delta T$$

where:
- Q = *amount of heat transfer in BTU*
- w = *weight of substance in lbs.*
- c = *specific heat capacity in BTU/lb-°F*
- ΔT = *change in temperature in °F*

FORMULA: CONVERTING FAHRENHEIT TO CELSIUS

$$T_C = \frac{5}{9} \times (T_F - 32)$$

Where:
- T_C = *Temperature in degrees Celsius*
- T_F = *Temperature in degrees Fahrenheit*

FORMULA: CHANGE IN SPECIFIC INTERNAL ENERGY (INCOMPRESSIBLE SUBSTANCES)

$$\Delta u = c\,(T_2 - T_1)$$

where :
- Δu = *change in specific internal energy (Btu/lb or kJ/kg)*
- c = *specific heat capacity (Btu/lb-F or kJ/kg-K)*
- T_2 = *final temperature (°R, °F, °C, K)*
- T_1 = *initial temperature (°R, °F, °C, K)*

FORMULA: CHANGE IN SPECIFIC ENERGY (COMPRESSIBLE SUBSTANCES)

$$\Delta u = c_v\,(T_2 - T_1)$$

where :
- Δu = *change in specific internal energy (Btu/lb or kJ/kg)*
- c_v = *specific heat capacity at constant volume (Btu/lb-R or kJ/kg-K)*
- T_2 = *final temperature (°R, °F, °C, K)*
- T_1 = *initial temperature (°R, °F, °C, K)*

FORMULA: ENTHALPY

$$H = U + PV$$

where:
- H = *Enthalpy (BTU or kJ)*
- U = *Internal Energy (BTU or kJ)*
- P = *Pressure (psi or kPa)*
- V = *Total volume (ft³ or m³)*

FORMULA: SPECIFIC ENTHALPY

$$h = u + Pv$$

where:
- h = *Specific Enthalpy (BTU/lb or kJ/kg)*
- u = *Specific Internal Energy (BTU/lb or kJ/kg)*
- P = *Pressure (psi or kPa)*
- v = *Specific Volume (ft³/lb or m³/kg)*

FORMULA: COMBINED GAS LAW

$$\frac{P_1 \times V_1}{T_1} = \frac{P_2 \times V_2}{T_2}$$

where
- P_1 = *original absolute pressure*
- V_1 = *original volume*
- T_1 = *original temperature (°R, K)*
- P_2 = *new absolute pressure*
- V_2 = *new volume*
- T_2 = *new temperature (°R, K)*

FORMULA: RATE OF CONDUCTIVE HEAT TRANSFER

$$Q = k\left(\frac{T_h - T_c}{L}\right)$$

where:
- Q = *rate of heat transfer (BTU/ft²-hour or *W/m²)*
- k = *thermal conductivity (Btu/ft-h-°R or W/m-K)*
- T_h = *the high temperature side of the object (°F, °C, °R, K)*
- T_c = *the low or cooler side of the object (°F, °C, °R, K)*
- L = *the length or thickness of the object (ft or m)*

**The W in thermal conductivity stands for watts. A watt is equal to 3.412 BTU/h.*

FORMULA: CONDUCTION THROUGH A THIN-WALLED TUBE

$$Q = \frac{2\pi k L (T_i - T_o)}{r_o - r_i}$$

Where:
- Q = *heat flow per unit area of surface*
- k = *thermal conductivity (Btu/ft-h-°R or W/m-K)*
- L = *tube length (ft)*
- T_i = *Temperature at tube's inner radius (°F, °C, °R, K)*
- T_o = *Temperature at tube's outer radius (°F, °C, °R, K)*
- r_o = *Tube's outer radius (ft)*
- r_i = *Tube's inner radius (ft)*

FORMULA: QUALITY

$$X = \frac{m_{vapor}}{m_{vapor} + m_{liquid}}$$

Where:
- X = *quality of the mixture, a number between 0 and 1 (no units)*
- m_{vapor} = *the mass of substance vapor in the system (lb or kg)*
- m_{liquid} = *the mass of liquid substance in the system (lb or kg)*

Useful Formulas

FORMULA: SUBCOOLING

$$SC = T_L - T_C$$

where:
- SC = Subcooling in °F or °C
- T_L = Actual Liquid Line Temperature in °F or °C
- T_C = Temperature from T&P Chart in °F or °C

FORMULA: SUCTION LINE SUPERHEAT

$$SLSH = T_S - T_C$$

where:
- $SLSH$ = Suction Line Superheat in °F or °C
- T_S = Actual Suction Line Temperature in °F or °C
- T_C = Temperature from P/T Chart in °F or °C

FORMULA: DISCHARGE SUPERHEAT

$$DSH = T_D - T_C$$

where:
- DSH = Discharge Superheat in °F or °C
- T_D = Actual Discharge Line Temperature in °F or °C
- T_C = Temperature from T&P chart in °F or °C

FORMULA: HEAT DUTY FOR HEAT EXCHANGE

$$\dot{Q} = \dot{m}(h_o - h_i)$$

where:
- $\dot{Q}$ = heat duty (Btu/h or kJ/h)
- $\dot{m}$ = mass flow rate (lbm/h or kg/s)
- h_o = Enthalpy of the refrigerant flowing out of the heat exchanger (Btu/lbm or kJ/kg)
- h_i = Enthalpy of the refrigerant flowing into the heat exchanger (Btu/lbm or kJ/kg)

FORMULA: THEORETICAL MAXIMUM COEFFICIENT OF PERFORMANCE

$$COP = \frac{Q}{W}$$

where:
- COP = Coefficient of Performance
- Q = Amount of heat transferred (BTU or kJ)
- W = Work performed by the compressor (BTU or kJ)

FORMULA: THEORETICAL MAXIMUM COEFFICIENT OF PERFORMANCE - COOLING

$$COP_{cooling} = \frac{T_{cold}}{(T_{hot} - T_{cold})}$$

where:
- $COP_{cooling}$ = Coefficient of Performance in Cooling mode
- T_{cold} = Temperature of area being cooled (°R/K)
- T_{hot} = Temperature of area where internal energy is being rejected (°R/K)

FORMULA: MASS FLOW RATE

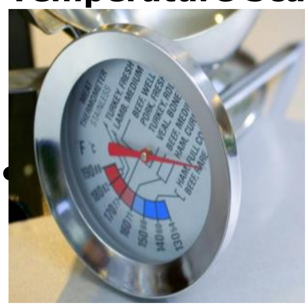
Flowing Liquids: $\dot{m} = \rho \times Q$

Flowing Gases: $\dot{m} = Q / v$

where:
- $\dot{m}$ = mass flow rate (lbm/h or kg/s)
- ρ = density of liquid (lbm/ft³ or kg/m³)
- Q = Volumetric flow of liquid (ft³/h or m³/s)
- v = specific volume of the gas (ft³/lbm or m³/kg)

Temperature Scales

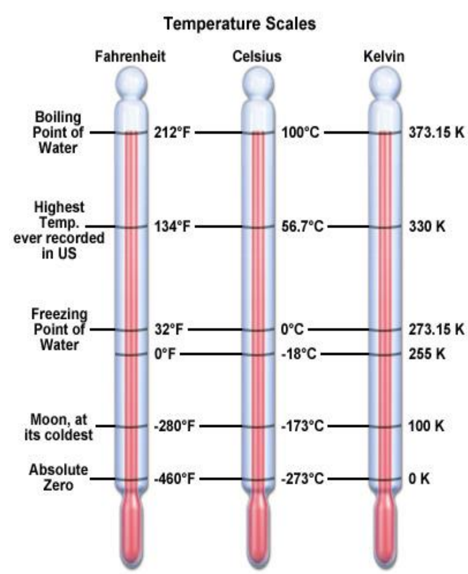
Temperature Scales



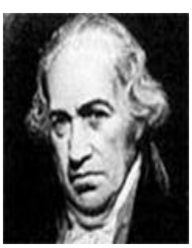
Humans are sensitive to a fairly small range of temperatures. We get uncomfortable if the temperature of our surrounding gets to extreme. We don't like to be too cold or too hot. Even though we can sense the temperature that makes us uncomfortable, we are not able to accurately quantify the exact temperature with our senses. This causes us to rely on temperature scales and measuring devices so our observations will match up with others. A temperature scale is divided into increments known as degrees. Temperature gauges allow us to read these increments.

Two Relative Temperature Scales

The most common type of temperature scale is the relative temperature scale. The two most used relative temperature scales used today are Fahrenheit and Celsius. They are named after Daniel Fahrenheit and Anders Celsius.



Daniel Gabriel Fahrenheit (May 24, 1686 - Sept. 16, 1736) was a German physicist and maker of scientific instruments. He is best known for inventing the alcohol thermometer (1709) and mercury thermometer (1714) and for developing the Fahrenheit temperature scale; this scale is still commonly used in the United States.



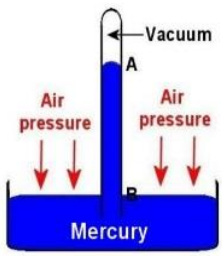
Fahrenheit spent most of his life in the Netherlands, where he devoted himself to the study of physics and the manufacture of precision meteorological instruments. He discovered, among other things, that water can remain liquid below its freezing point and that the boiling point of liquids varies with **atmospheric pressure**. The Fahrenheit scale is based on 32° for the freezing point of water and 212° for the boiling point of water. The Fahrenheit scale is in general use wherever the English system of units has been adopted.

Unit 2: Refrigeration Science

Fundamentals of Refrigeration

Temperature Scales

Definition - Atmospheric Pressure



Atmospheric pressure is defined as the force per unit area exerted by an atmospheric column (that is, the entire body of air above the specified area). Also called barometric pressure, Atmospheric pressure can be measured with a mercury barometer (hence the commonly used synonym barometric pressure), which indicates the height of a column of mercury that exactly balances the weight of the column of atmosphere over the barometer. Atmospheric pressure at sea level is 14.696 PSIA.

Anders Celsius (1701-1744) was a Swedish astronomer who invented the Celsius temperature scale (often called the centigrade scale).

Celsius Scale
The Celsius scale is based on 0° for the freezing point of water and 100° for the boiling point of water. Invented in 1742 by the Swedish astronomer Anders Celsius, it is sometimes called the centigrade scale because of the 100-degree interval between the defined points. The Celsius scale is in general use wherever the metric system of units has been adopted, and it is used in scientific work everywhere.

1. Atmospheric pressure is _______________ P.S.I.A.
2. Water freezes at _______ degrees Celsius.
3. Water freezes at _______ degrees Fahrenheit.
4. Water boils at _________ degrees Celsius.
5. Water boils at _________ degrees Fahrenheit.
6. Air pressure all around us is called
   ____________________ _____________________.

Temperature Scales

Temperature Measurement Instruments
The most common temperature measurement instrument is a thermometer. There are a variety of styles of thermometers available to the technician. Lets look at a few here.

Liquid-in-glass thermometers

- The liquid-in-glass thermometer is a well-known temperature-measuring instrument that is used in a wide range of applications. The fluid used is usually either mercury or colored alcohol, and this is contained within a bulb and capillary tube.
- As the temperature rises, the fluid expands along the capillary tube and the meniscus level is read against a calibrated scale etched on the tube. The process of estimating the position of the curved meniscus of the fluid against the scale introduces some error into the measurement process and a measurement inaccuracy less than ±1% of full-scale reading is hard to achieve.
- Industrial versions of the liquid-in-glass thermometer are normally used to measure temperature in the range between -200°C up to 1500°C.

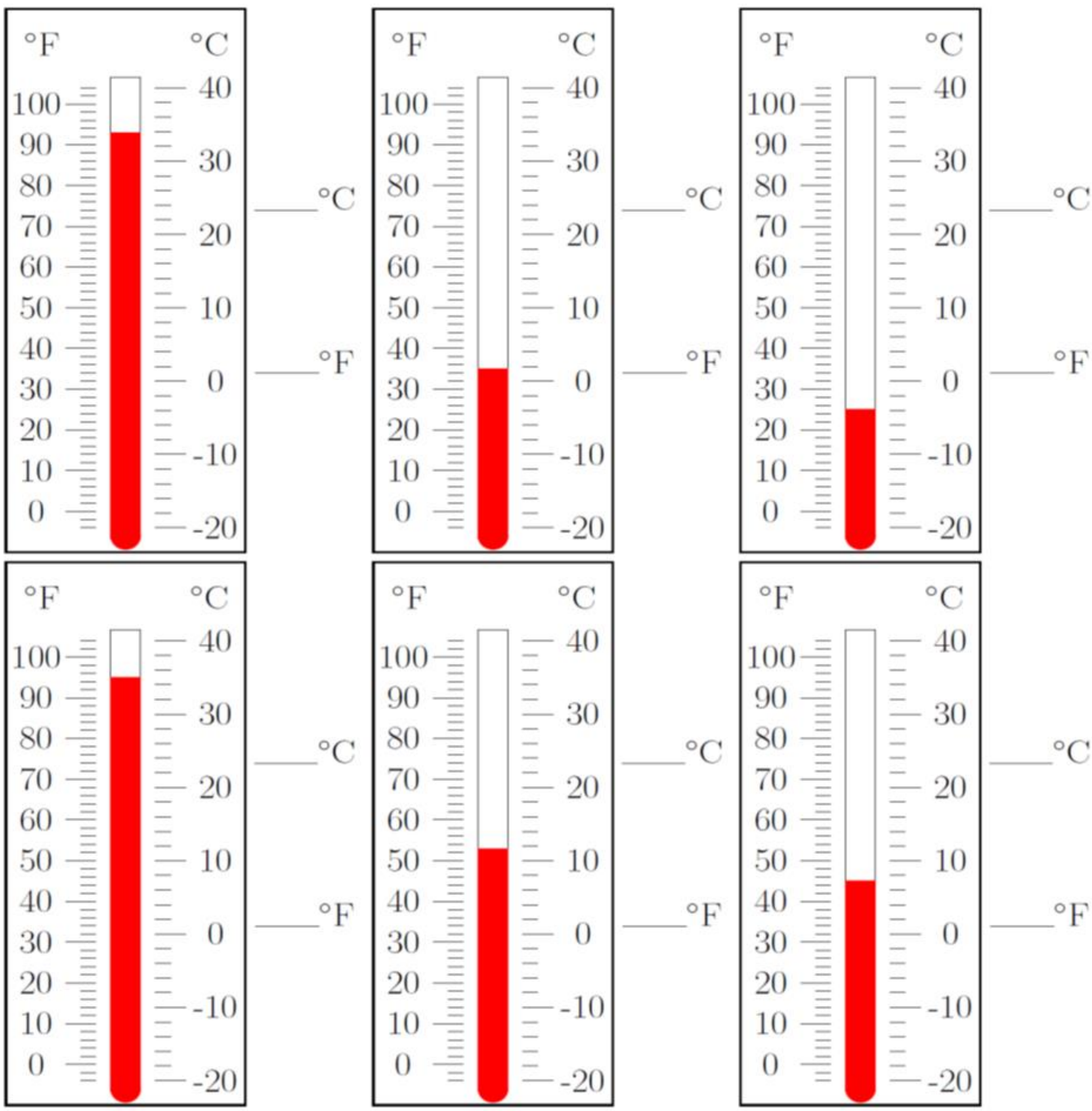
Digital Probe Thermometer

Infrared Digital Thermometer

Hands On Exercise: Reading Temperatures

Reading Temperature (A)

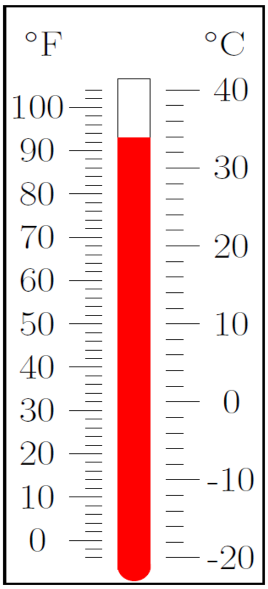
Read and record the temperatures in degrees Celsius and degrees Fahrenheit.



Hands On Exercise: Reading Temperatures

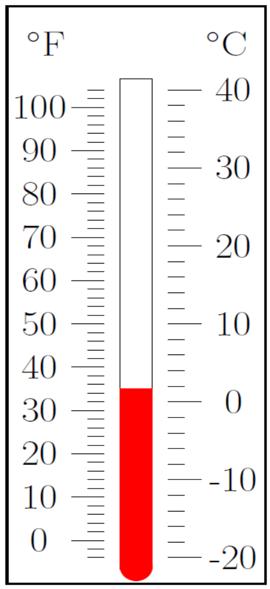
Reading Temperature (A) Answers

Read and record the temperatures in degrees Celsius and degrees Fahrenheit.



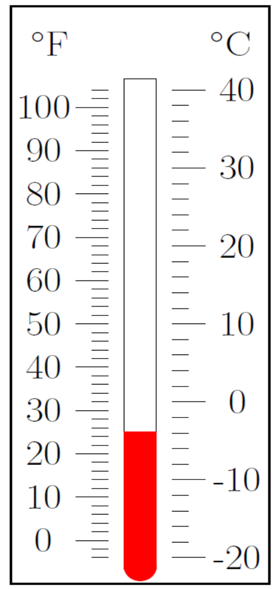
34 °C

93 °F



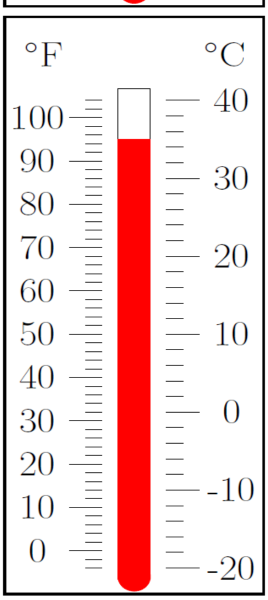
2 °C

35 °F



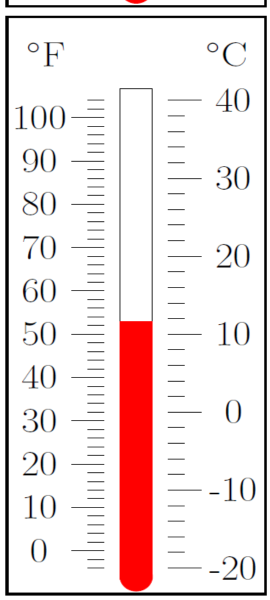
−4 °C

25 °F



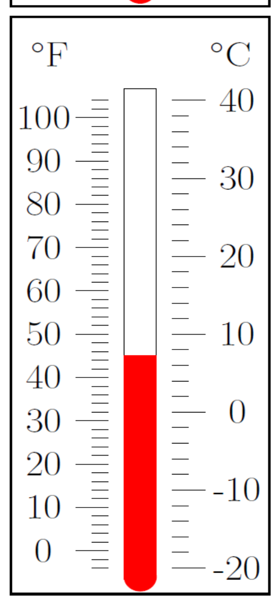
35 °C

95 °F



12 °C

53 °F



7 °C

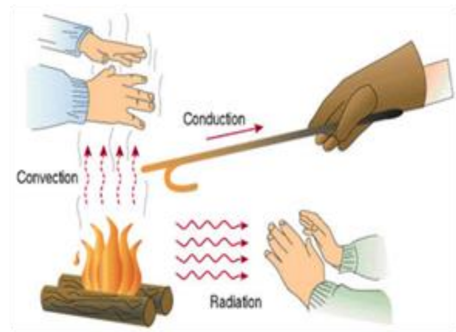
45 °F

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

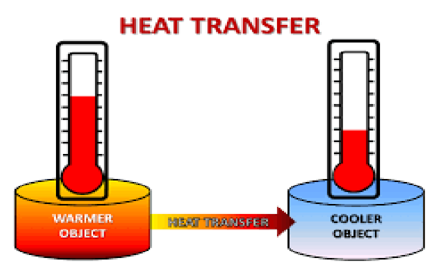
Heat Transfer

Thermal Systems
Thermal systems maintain a desired temperature in a confined space. An refrigerator is a thermal system. The confined space of the system is called the thermal storage area.



Heat Flow
Heat always flows from a warmer object to a cooler object. This heat flow will occur until the warmer object and the cooler object are the same temperature.

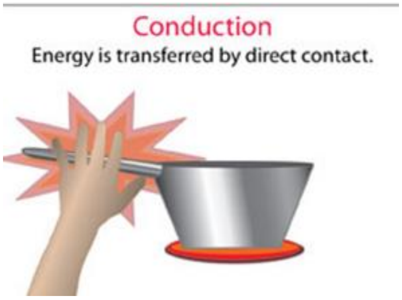
Heat Transfer
There are three methods of heat transfer: conduction, convection, and radiation.



Notes:____

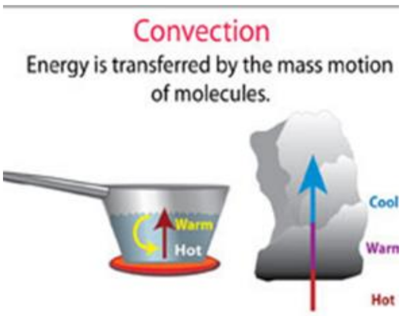
Heat Transfer

Conduction



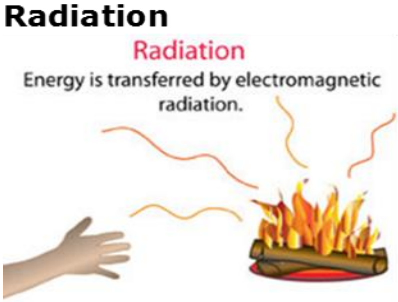
Energy is transferred by the direct contact of molecules, not by the movement of the material. Example: putting your hand on a stove burner. The amount of energy transferred depends on how conductive the material is. Metals are good conductors, so they are used to transfer energy from the stove to the food in pots and pans. Air is the best insulator, so good insulating products try to trap air and not allow it to move.

Convection



Energy is transferred by the mass motion of groups of molecules resulting in transport and mixing of properties. Example: holding your hand over a stove burner. In meteorology, we speak of convection predominantly as that caused by rising currents of warm air. We refer to all other mass motions of air as advection. In cooking equipment, convection ovens have a fan in the oven cavity that moves the air around to distribute the heat over the food.

Radiation



Energy is transferred by electromagnetic radiation
Example: heat felt when standing away from a large fire on a calm night.
Everything that has a temperature above absolute zero radiates energy.
Radiation is not "felt" until it is absorbed by a substance.
It does not require a medium to transfer energy through as do conduction and convection.

Unit 2:
Refrigeration Science

Fundamentals of Refrigeration

Hands On Exercises

- Operate a refrigeration system
- Convert between temperature units Celsius and Fahrenheit
- Convert between pressure units
- Identify heat transfer types

Unit 3:
Temperature / Pressure Measurement

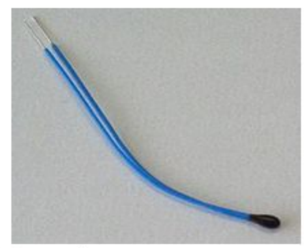
Fundamentals of Refrigeration

Thermistors

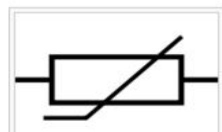
As a protection device, thermistors regulate the flow of current by changing its resistance based on heat. In some cases, a thermistor may cause the current flow to be reduced to a safe value.

- A thermistor is a resistor whose value varies with temperature. the thermistor is also a resistive device that changes its resistance predictably with temperature. Its benefit is a very large change in resistance per degree change in temperature, allowing very sensitive measurements over narrow spans. Due to its very large resistance, lead wire errors are not significant. However, there are several disadvantages to the thermistor:

1. It is a very nonlinear device and reasonable accuracy is obtained only over narrow spans (see Figure).
2. It is quite small and will exhibit errors due to self heating.
3. Exposure to high temperature will cause a dramatic and permanent shift in its output characteristics.



- Most applications of the thermistor are in commercial and laboratory applications. Few are used in industrial process control.



Thermistor symbol

THERMISTORS

- A thermistor is a type of resistor with resistance varying according to its temperature.
- The resistance is measured by passing a small, measured direct current through it and measuring the voltage drop produced.
- There are basically two broad types
  1. *NTC-Negative Temperature Coefficient:* used mostly in temperature sensing
  2. *PTC-Positive Temperature Coefficient:* used mostly in electric current control.

ADVANTAGES AND DISADVANTAGES OF THERMISTORS

- Thermistors, since they can be very small, are used inside many other devices as temperature sensing and correction devices
- Thermistors typically work over a relatively small temperature range, compared to other temperature sensors, and can be very accurate and precise within that range

Hands On Exercise: Use a thermistor to measure temperature

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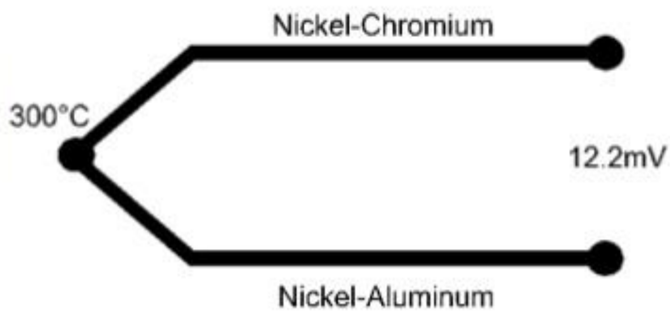
Thermocouples

Thermocouples

A **thermocouple** is a temperature-measuring device consisting of two dissimilar conductors that contact each other at one or more spots. It produces a voltage when the temperature of one of the spots differs from the reference temperature at other parts of the circuit.



Refrigeration techs use thermocouples to measure the temperature of the copper lines that connect the components of a refrigeration system. The thermocouples connect to a digital multimeter capable of reading temperature.

Notes:

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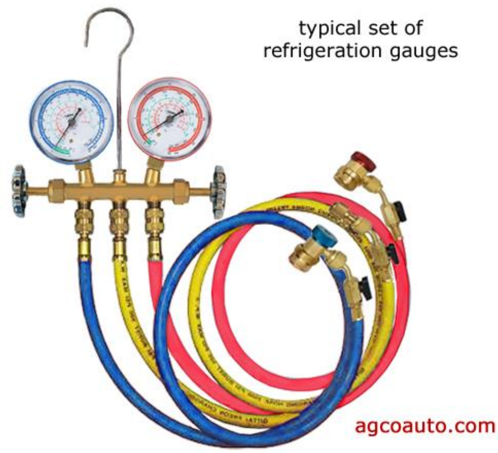
Unit 3:
Temperature / Pressure Measurement

Pressure Gauges

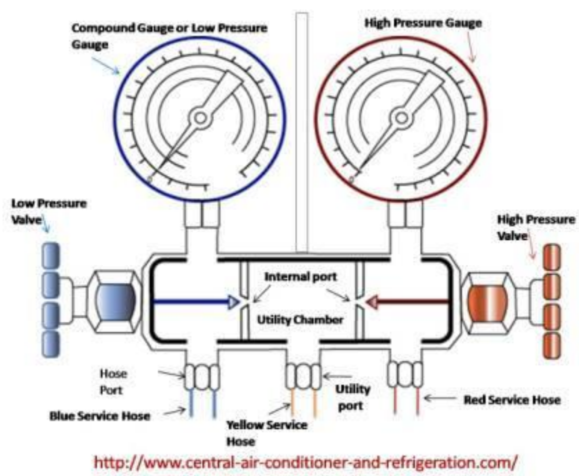
Refrigeration Gauges

When you are working as a heating, ventilation, air conditioning and refrigeration service technician, also known as an HVAC/R technician, your set of gauges is one of your biggest assets. Gauges are used to read the pressure of various liquids and gases in a cooling system, as well as vacuum pressure when you are pressure testing or charging the device. There are a number of different ports on the HVAC gauge set, also known as a manifold, and the main difference in the types of manifolds is the number of ports that you have available to attach accessories to, as well as the pressure that the gauge set can withstand, which is important when working with different refrigerants. This equipment is also used to perform some HVAC service and replacement.



Gauge Manifolds

Gauge manifolds are the most basic of all refrigeration system tools. The gauge manifold is used as both a diagnosis and a service tool. Manifold gauges are used to remove or add refrigerant from the air conditioning system. All gauge manifolds have the same basic parts, although there are some variations among manufacturers. The major parts of a common gauge manifold are shown in picture below.



Hands On Exercise: Use a gauge manifold to measure pressures on a unit

megadepot.com

Gauge Manifold Components

Manifold Body and Hand Valves

The manifold body is made of brass or aluminum. Passages are drilled in the body to connect the other manifold parts. Some manifold bodies have a sight glass to observe the flow of a refrigerant. Hand valves are used to control the flow of refrigerant through the passages of the manifold body. Note the internal passages are arranged so the gauges can read refrigeration system pressures when the valves are closed. The hand valves used on R-12 and R-134a gauge manifolds are usually arranged in the same way, or on a slant or in front of the manifold. These different arrangements make manifold identification easier. Valve wheels for the high and low sides are identified by color. The low side hand wheel is made of blue plastic or has a blue decal in its center. The high side hand wheel is made of red plastic or has a red decal.

Gauges

The gauges used with a refrigeration gauge manifold are either analog (indicator needle), which resemble other pressure gauges, or digital. In an analog gauge, the position of the needle in relation to the numbers on the gauge face indicates the pressure or vacuum in the refrigeration system. Digital gauges provide a numerical reading indicating system pressure or vacuum. All gauge manifolds have high and low pressure gauges. A few older gauge manifolds have three gauges. The third gauge was used to measure compressor output. Older high side gauges are calibrated from 0-500 psi (3445 kPa). Newer high side gauges may be calibrated from 0-250 psi (1723 kPa). Low side gauges are calibrated from 0 to 100-250 psi (689-1723 kPa). In addition to the pressure scale, low side gauges have a provision for measuring 0-29.9” of vacuum (approximately 50 microns).

Gauge Manifold Connection

Procedure Instructions – Quick Reference

1. Connect the high pressure side of the cooling line to the red port on the gauge. The red port and red gauge are always the high pressure gauges. You will want to attach a code-approved red hose, which is made to withstand high pressure, using the flare fittings that are included with it, to the high pressure port on the cooling unit. The high pressure port is typically of a different size and thread pitch than the low pressure side in order to avoid the potential for accidental incorrect hookups.

2. Connect the low pressure side to the blue port on the gauge. The low pressure side will be connected with a blue low pressure hose to the blue pressure gauge and the low pressure side of the cooling unit. This will allow for the proper flow of vacuum pressure or a micron meter in order to determine the vacuum pressure in the system already.

3. Attach a waste hose or vent hose to the center of the manifold set up. If you are going to discharge a unit, or if you are going to vent Freon by attaching the unit, you will need to attach the larger black low pressure hose to the center port of the manifold. By doing so, you will be able to attach a refrigerant recovery bottle to the manifold set to avoid violating federal law regarding the release of refrigerant into the atmosphere.

4. Attach micron meters or other gauges to the additional ports. The additional ports on the manifold can be used to attach micron (vacuum pressure) gauges, or even a vacuum pump, in order to perform the proper services to the cooling system as required for the repair that you are making.

Notes:

Gauge Manifold Connection

Tools Needed

Gauge Manifold

Reversible Ratcheting Refrigeration Wrench

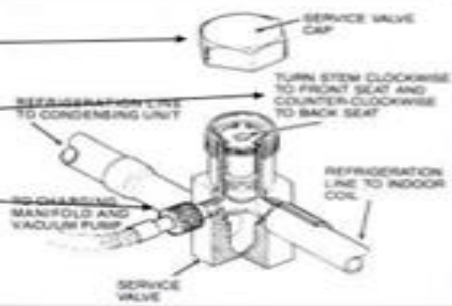
Step #1 Preparing Gauge Manifold for Installation

- Disconnect hoses from blank ports of gauge manifold. They are located on back side of the gauges.
- Inspect gauges to ensure calibration and calibrate if needed.

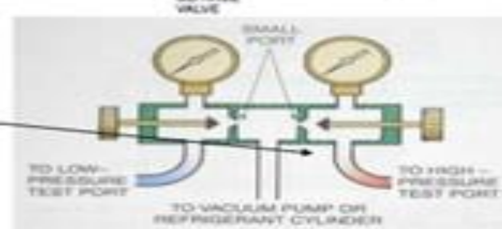
Gauge Manifold Connection

Step #2 Preparing High side of Gauge manifold

- Remove service valve cap from liquid line service valve
- By using ratchet wrench make sure valve is back seated
- Remove service port cap from liquid line service valve
- Once service port cap is removed place on blank port of gauge manifold

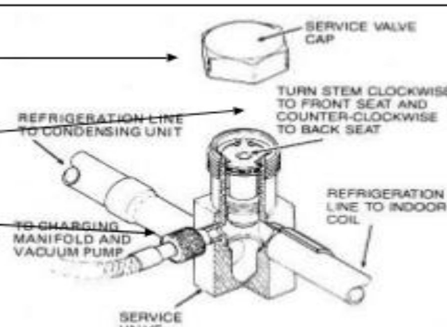


- Connect high side hose from gauge manifold to the service port on the liquid line service valve

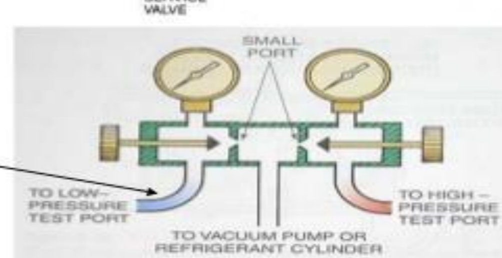


Step #3 Preparing Low side of Gauge Manifold

- Remove service valve cap from suction line service valve
- By using ratchet wrench make sure valve is back seated
- Remove service port cap from suction line service valve
- Once service port cap is removed place on blank port of gauge manifold



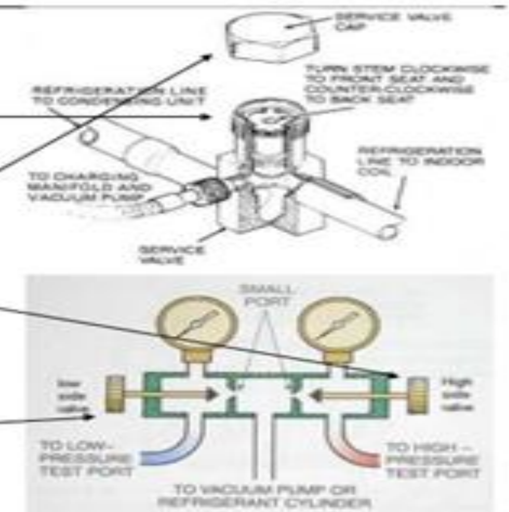
- Connect low side hose from gauge manifold to the service port on the suction line service valve



Gauge Manifold Connection

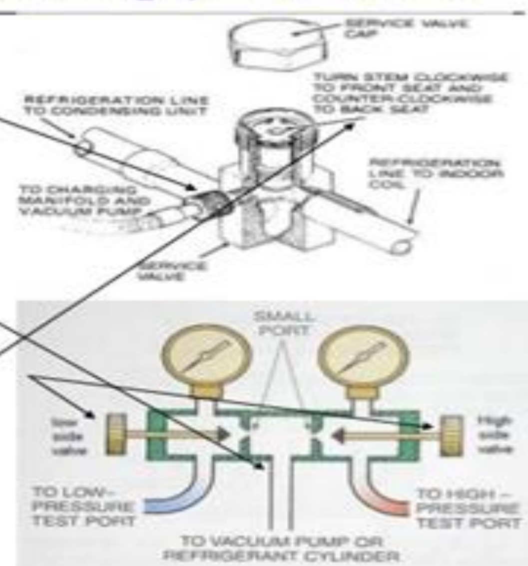
Step # 4 Releasing high side pressure

- Crack the liquid line service valve off the backseat
- Replace the service valve cap on the liquid line service valve
- Open the high side valve on the gauge manifold
- Open the low side valve on the gauge manifold



Step # 5 Purging air from hoses and combining pressures

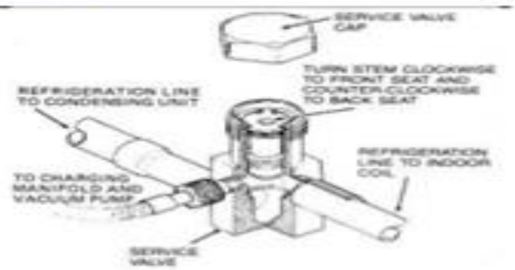
- Loosen the hose connection on the suction service valve (1-2 seconds) to purge air from hoses and manifold then tighten the hose connection back
- Loosen the center hose connection on the blank port of the manifold to purge air
- Close the high side and low side valves on the gauge manifold
- Crack the suction service valve off the back seat
- Replace service valve cap on the suction service valve

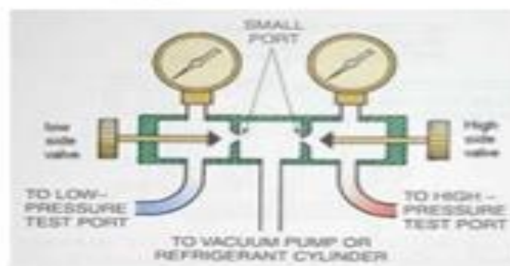


Gauge Manifold Connection

Step # 6 Uninstalling the Gauge Manifold

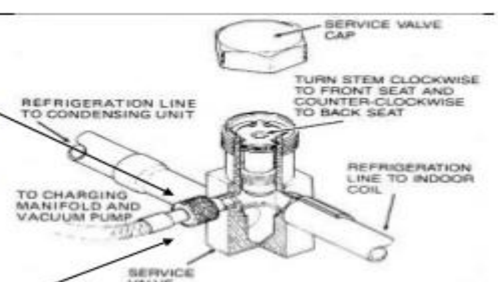
- Remove service valve cap from liquid line service valve
- Backseat the liquid line service valve
- Open high and low side valves on the gauge manifold. Allow pressures to equalize.
- Close the high and low side valves on gauge manifold.
- Remove service valve cap from suction line service valve.
- Backseat the suction line service valve

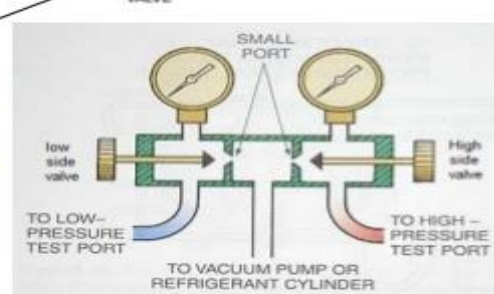




Step # 7 Removing hoses from system

- Remove high side hose from the liquid line service valve
  Remove the service port cap from the high side blank port of the gauge manifold and place it on the liquid line service valve
- Connect the high side hose to blank port of gauge manifold
- Remove the low side hose from the suction line service valve
- Remove the service port cap from the low side blank port of the gauge manifold and place it on the suction line service valve
- Connect the low side hose to blank port of gauge manifold

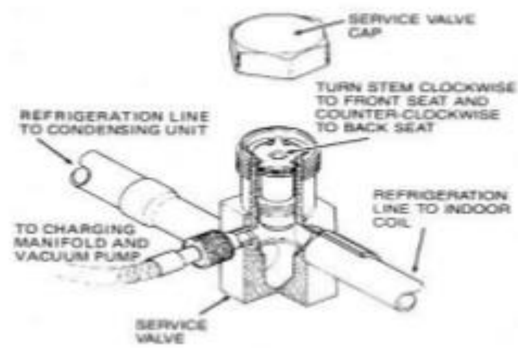




Gauge Manifold Connection

Step # 7 Continued

- Replace the service valve cap on the liquid line service valve
- Replace the service valve cap on the suction line service valve



Refrigeration Line Tap Options

3/4" Suction Line Service Valve (Sweat) YORK[Web Drawing]. Retrieved from http://www.bestbuyheatingandairconditioning.com/Merchant2 Whitman, B., Johnson, B., Tomczyk, J., & Silberstein, E.(2012). Refrigeration and air conditioning technology. (7thed.). New York: Cengage Learning

Pressure/Temperature (P/T) Chart

Using a Pressure/Temperature Chart

When you are charging or just checking a refrigeration unit, you use a set of gauges. The blue hose connects to a port on the low side of the system and your red hose will connect to the high side of the system.

To properly know what your pressures and temperatures should be, you will need to know what refrigerant you are working with and a Pressure/Temperature Chart (P/T chart).

With a P/T chart, if you know a temperature or a pressure of the ambient air or the refrigerant in your system, you can use a P/T chart to convert it to the equal pressure or temperature.

For example using the chart, at 100F, R-22 refrigerant pressure would be 198.4. R-502 at 100F would be 218.6 and R-12 at 100F would be 119.4 PSIG.

If you just know a pressure, cross the pressure on the chart to the corresponding temperature.

TEMPERATURE °F.	REFRIGERANT — CODE				
	22-V	502-R	12-F	134a-J	717-A
85	158.1	176.4	94.1	97.6	153.8
90	170.8	189.8	102.1	106.7	167.9
95	184.3	203.8	110.5	116.3	183.0
100	198.4	218.6	119.4	126.5	199.1
105	213.2	234.1	128.8	137.3	216.3

Unit 3:
Temperature / Pressure Measurement

Fundamentals of Refrigeration

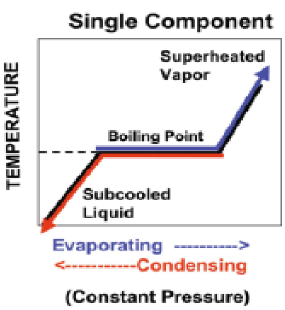
Pressure / Temperature Chart

How to Use a Two-Column Pressure-Temperature Chart

Because the properties of the new zeotropic refrigerant blends are different than traditional refrigerants, it is useful to know how to read a two-column PT chart.

By Jim Lavelle

The pressure-temperature (PT) chart is a valuable tool that service technicians use to check proper system operation. PT charts are most often used for three purposes: to set a coil pressure so that the refrigerant produces the desired temperature; to check the amount of superheat above the saturated vapor condition at the outlet of the evaporator and to check the amount of subcooling below the saturated liquid condition at the end of the condenser.

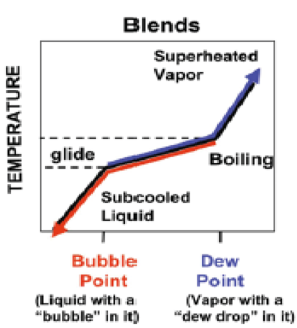


Pressure-Temp. Chart (psig)		
T	R-22	R-134a
-10	16.5	1.9
-5	20.1	4.0
0	24.0	6.5
5	28.2	9.1
10	32.8	11.9
15	37.7	15.0
20	43.0	18.4
25	48.8	22.1
30	54.9	26.1
35	61.5	30.4

Figure 1

Traditional PT charts list the saturated refrigerant pressure, in psig, with a column for temperature down the left side. Single-component refrigerants and azeotropes boil and condense at one temperature for a given pressure. Therefore, only one column is needed to show to show the pressure-temperature relationship for any phase-change process in a system. (**see Fig. 1**)

The properties of the new zeotropic blends are somewhat different than the traditional refrigerants. Zeotropic blends shift in composition during the boiling or condensing process (**see Fig. 2**) As the blend changes phase, more of one component will transfer to the other phase faster than the rest.



Pressure-Temp. Chart (psig)			
T	R-22	R-407C	
		Vapor	Liquid
-10	16.5	12.5	21.3
-5	20.1	15.9	25.4
0	24.0	19.6	29.9
5	28.2	23.6	34.7
10	32.8	28.0	39.9
15	37.7	32.8	45.6
20	43.0	38.0	51.6
25	48.8	43.6	58.2
30	54.9	49.6	65.2
35	61.5	56.1	72.6

Figure 2

This property is called fractionation. The changing composition of the liquid causes the boiling point temperature to shift as well. The overall shift of temperature from one side of the heat exchanger to the other is called the temperature glide.

Zeotropic blends cannot be defined by a single pressure-temperature relationship. The temperature glide will cause different values for temperature at a given pressure, depending on how much refrigerant is liquid and how much is vapor. The most important values for checking superheat and subcool are the end points of the glide or the pressure-temperature relationship for saturated liquid and saturated vapor.

The saturated liquid condition is often referred to as the bubble point. Image a pot of liquid sitting on a stove; as it begins to boil it forms bubbles i the liquid. The saturated vapor condition is referred to as the dew point. Imagine a room full of vapor and dew drops forming on the furniture. PT charts for the zeotropic blends list two columns next to each temperature: one for the saturated liquid (bubble point) and the other for the saturated vapor (dew point).

Some of the zeotropic blends have very low glide (from 1˚F to 2.5˚F). For these blends, the vapor and liquid pressures are only separated by 1 or 2 psi. Because the difference is quite small between the two values some manufacturers' PT charts will only list one column for these blends. Blends with higher glide (greater than 5˚F will generally have both columns listed.

Pressure / Temperature Chart

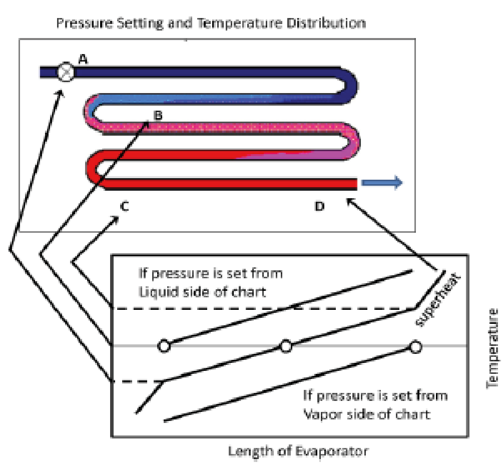
Using a Two-Column PT Chart

When checking a superheat or subcool temperature the procedure is the same as for a single-component refrigerant. Superheat is checked by measuring the temperature of the vapor line, measuring the pressure, then subtracting the saturated temperature from the measured temperature. In the case of a blend, you simply read the saturated temperature next to the pressure in the vapor (dew point) column of the chart.

When checking the subcool condition, the technician will measure the temperature of the liquid line, the pressure at that point and subtract the measured temperature from the saturated temperature at the end of the condenser. With the blend you read the saturated temperature next to the pressure in the liquid (bubble point) column of the chart.

For a single-component or azeotropic refrigerant, the operating pressure for the low side of a system can be found by cross referencing the desired coil temperature on the PT chart. For high-glide blends, however, the desired coil temperature is the average (or midpoint) temperature of the coil.

The problem with two-column PT charts is that the conditions at the endpoints of the temperature glide are listed, not the midpoint. In this case, you must add half of the temperature glide to the desired midpoint temperature, then read the saturated vapor column to determine the operating pressure (**see Fig 3**)



If the vapor column is read directly at the desired temperature, then the end of the evaporator will be the correct temperature, but the rest of the coil will be too cold. If the liquid column is used directly, then the beginning of the coil will be the correct temperature, but the rest of the coil will be too warm.

Two-column PT charts are every bit as useful as the traditional ones. The charging and service procedures are very similar for both single-component refrigerants and zeotropic blends, and the specialized liquid and vapor data correct for the effects of the blends' temperature glide.

Just remember to keep track of the phase of the blend at the point you are interested: saturated vapor uses the vapor (dew point) column and saturated liquid uses the liquid (bubble point) column.

For more information, call 800-262-0012 or e-mail *info@refrigerants.com*

Pressure / Temperature Chart

Refrigerant Pressure-Temperature Chart						
Temperature (F)	**R22**	**R134a**	**R404A**	**R408A**	**R409A**	**R410A**
-50	6.2	18.7	0.6	1.6	17.2	5.3
-45	2.7	16.9	2.7	1.1	15.2	8
-40	0.5	14.8	5	3.3	13.1	11
-35	2.6	12.5	7.6	5.6	10.7	14.2
-30	4.9	9.8	10.4	8.2	8.1	17.8
-25	7.4	6.9	13.4	11	5.1	21.8
-20	10.1	3.7	16.8	14.1	1.9	26.1
-15	13.2	0.1	20.5	17.5	0.8	30.8
-10	16.5	1.9	24.5	21.2	2.8	35.9
-5	20	4.1	28.8	25.2	4.9	41.5
0	23.9	6.5	33.5	29.5	7.2	47.5
5	28.2	9.1	38.6	34.2	9.7	54.1
10	32.8	11.9	44	39.3	12.5	61.2
15	37.7	15	49.9	44.8	15.4	68.8
20	43	18.4	56.2	50.7	18.7	77.1
25	48.7	22.1	63	57	22.2	86
30	54.9	26	70.3	63.7	26	95.5
35	61.5	30.3	78.1	71	30.1	105.7
40	68.5	35	86.4	78.7	34.5	116.6
45	76	40	95.2	87	39.2	128.3
50	84	45.4	104.7	95.8	44.3	140.8
55	92.5	51.1	114.7	105.1	67.6	154.1
60	101.6	57.3	125.3	115.1	74.5	168.2
65	111.2	63.9	136.6	125.6	81.8	183.2
70	121.4	71.1	148.6	136.8	89.5	199.3
75	131.2	78.6	161.2	148.7	97.7	216.1
80	143.6	86.6	174.6	161.2	106.4	234
85	155.7	95.1	188.8	174.4	115.5	253
90	168.4	104.2	203.7	188.4	125.2	273
95	181.8	113.8	219.4	203.1	135.3	294.1
100	195.9	124.1	235.9	218.7	146	316.1
105	210.7	134.9	253.4	235	157.2	339.9
110	226.3	146.3	271.7	252.1	169	364.6
115	242.7	158.4	290.9	270.2	181.4	390.5
120	259.9	171.1	311.1	289.1	194.4	417.7
125	277.9	184.5	332.3	308.9	208	446.3
130	296.8	198.7	354.5	329.7	222.3	476.3
135	316.5	213.6	377.8	351.5	137.2	507.6
140	337.2	229.3	402.2	374.3	252.9	540.5
145	358.8	245.7	427.7	398.1	269.3	574.8
150	381.5	263	454.4	423	286.4	610.6

P/T Chart Worksheet

1. What pressure is R22 at 0F? ______________
2. What pressure is R134a at 0F? ____________
3. What pressure is 404A at 0F? _____________
4. What pressure is 410A at 0F? _____________
5. What pressure is R22 at 50F? ______________
6. What pressure is R134a at 50F? ____________
7. What pressure is 404A at 50F? _____________
8. What pressure is 410A at 50F? _____________
9. What pressure is R22 at 80F? ______________
10. What pressure is R134a at 80F? ____________
11. What pressure is 404A at 80F? _____________
12. What pressure is 410A at 80F? _____________
13. What pressure is R22 at 100F? ______________
14. What pressure is R134a at 100F? ____________
15. What pressure is 404A at 100F? _____________
16. What pressure is 410A at 100F? _____________

PRESSURE UNIT CONVERSIONS WORKSHEET

1 atm = 760 mm Hg = 101325 Pa = 14.7 lb/in^2 = 1.013 bar

1. The air pressure for a certain tire is 109 kPa. What is this pressure in atmospheres? **(Answer: 1.08 atm).**

2. The air pressure inside a submarine is 0.62 atm. What would be the height of a column of mercury balanced by this pressure? **(Answer: 470 mm Hg).**

3. The weather news gives the atmospheric pressure as 1.07 atm. What is this atmospheric pressure in mm Hg? **(Answer: 813 mm Hg).**

4. An experiment at Sandia National Labs in New Mexico is performed at 758.7 mm Hg. What is this pressure in atm? **(Answer: 0.998 atm).**

5. A bag of potato chips is sealed in a factory near sea level. The atmospheric pressure at the factory is 761.3 mm Hg. The pressure inside the bag is the same. What is the pressure inside the bag of potato chips in Pa? **(Answer: 1.01×10^5 Pa).**

6. The same bag of potato chips from problem 5 is shipped to Denver, Colorado, where the atmospheric pressure is 99.82 kPa. What is the difference (in Pa) between the pressure in the bag and the atmospheric pressure? **(Answer: 1200 Pa).**

Hands On Exercises

- ❑Use a thermometer
- ❑Identify and explain refrigeration gauges
- ❑Connect refrigeration gauges to a machine
- ❑Document pressure readings
- ❑Document temperature readings
- ❑Convert Celsius to Fahrenheit
- ❑Convert PSI to kPa
- ❑Read a pressure gauge

Air Flow and Filters

Since a refrigeration system is basically a heat exchange system, it is critical that air flow across the evaporator and condenser is sufficient for the systems needs. Make sure that units are not pushed directly up against walls which will restrict airflow around the back of the machine. Also make sure that nothing is put in front of equipment that will block airflow. Filters should be changed regularly according the manufacturer recommendations. When installing equipment, make sure there is enough room around the equipment for a service technician to be able to work and remove covers to access the system.

©Elementshvac.com

Clean Air Filter

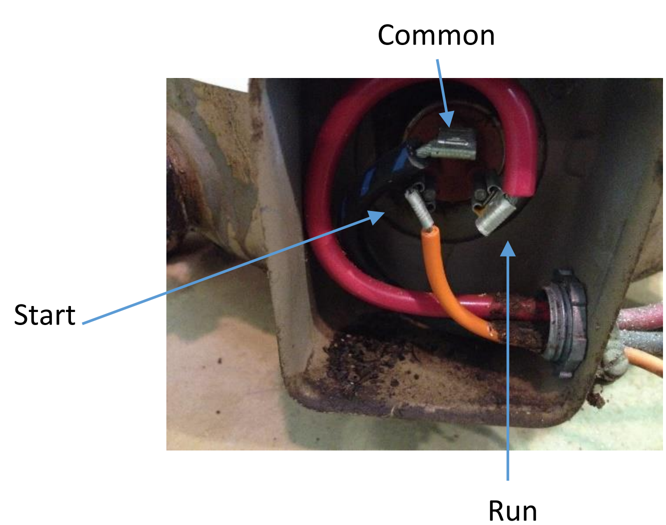
Dirty Air Filter

Compressors

The Compressor

- The compressor is the heart of the system. The compressor does just what it's name is. It compresses the low pressure refrigerant vapor from the evaporator and compresses it into a high pressure vapor.
- The inlet to the compressor is called the "Suction Line". It brings the low pressure vapor into the compressor.
- After the compressor compresses the refrigerant into a high pressure Vapor, it removes it to the outlet called the "Discharge Line".

There are three terminals on compressors that the power source connects to. These terminals are called Common, Start, and Run. Think, CSR, as in Customer Service Representative.



Hermetic Compressors

Hermetic compressors

- A hermetic or sealed compressor is one in which both compressor and motor are confined in a single outer welded steel shell.
- The motor and compressor are directly coupled on the same shaft, with the motor inside the refrigeration circuit. Thus the need for a shaft seal with the consequent refrigerant leakage problem was eliminated.
- Hermetic compressors are ideal for small refrigeration systems, where continuous maintenance (replenishing refrigerant and oil charge etc) cannot be ensured. Hence they are widely used in domestic refrigerators, room air conditioners etc.

Unit 4:
Components

Reciprocating Piston Compressors

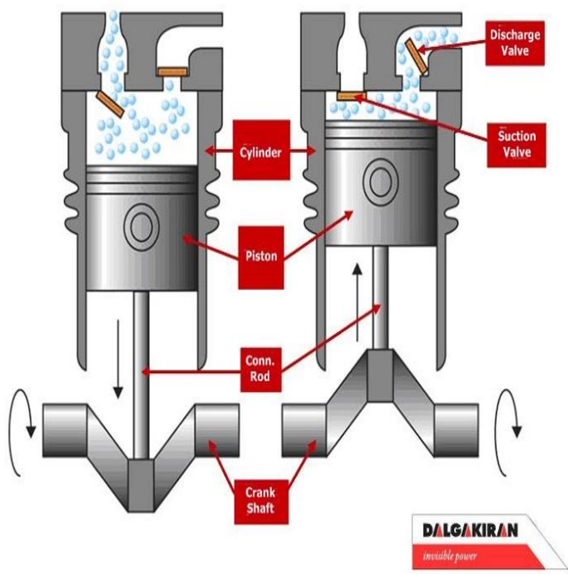
Reciprocating Compressor

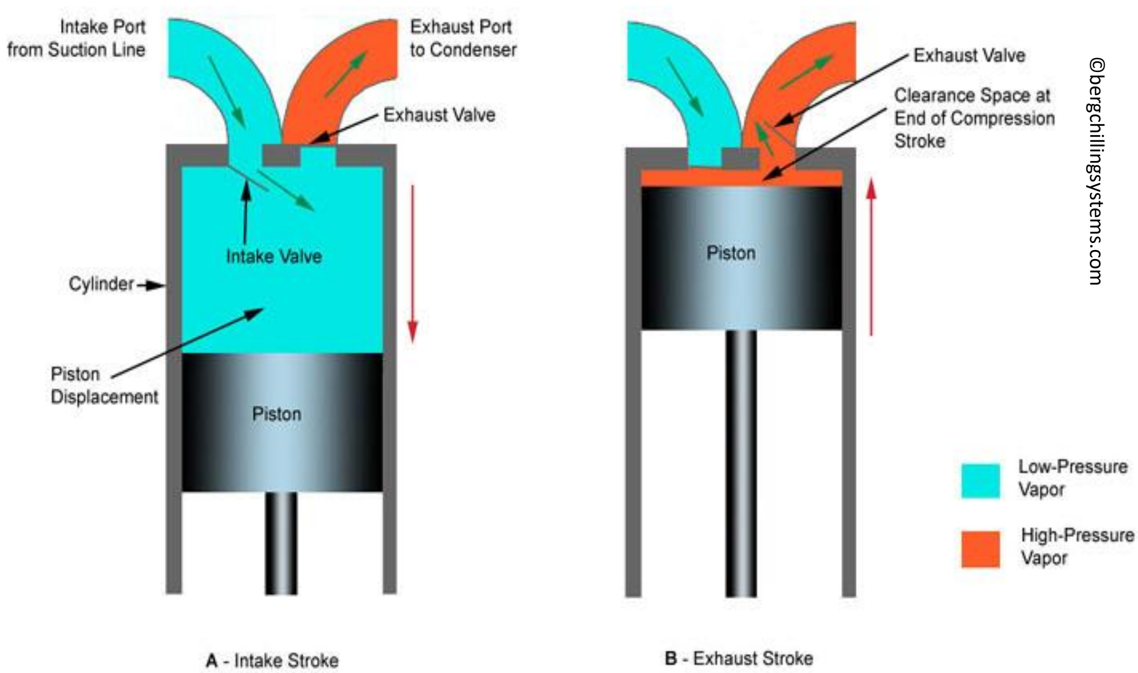
INTRODUCTION

Compressors are work absorbing devices which are used for increasing pressure of fluid at the expense or work done on fluid.

The device/ machine used for compressing air are called air compressors. Compressors are invariably used for all applications requiring high pressure air.

Some of popular applications of compressor are, for driving pneumatic tools and air operated equipments, spray painting, compressed air engine, supercharging surface cleaning, refrigeration and air conditioning, chemical industry etc. compressors are supplied with low pressure air (or any fluid) at inlet which comes out as high pressure air (or any fluid) at outlet.





Unit 4:
Components

Fundamentals of Refrigeration

Scroll Compressors

What is a Scroll Compressor

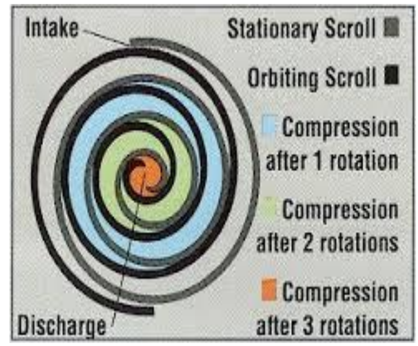
It is challenging to try and detail how this compressor works through words, but here it goes. You need to fit two Archimedean spirals together, one is stationary and the other will orbit inside the other (not rotate). This produces pockets of air or fluid that travel inwards toward a smaller area, ultimately being compressed.

Benefits of a Scroll Compressor

- The system is more efficient than traditional methods of compression increasing and A/C seer rating.
- These types of compressors are far more quiet than past designs.
- The scroll compressor is very stable and produces little vibration.
- 70 percent fewer moving parts than alternative compressors.
- Very small size allows smaller air conditioners.

Vulnerabilities of Scroll Compressors

- Tight tolerances make these systems vulnerable to introduced debris (your air conditioner is a sealed system so the chance is close to zero).
- Scroll compressor can only rotate in one direction.



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Scroll Compressor Operation

- The scroll compressor operates by rotating one scroll within a stationary scroll.
- The ends of the rotating scroll scoop up the refrigerant vapor at the suction port of the compressor.
- As the scroll continues to rotate, the inlet passage is sealed off and the volume of the passage becomes smaller, increasing the pressure of the refrigerant vapor.

DELMAR CENGAGE Learning

Crankcase Heaters

Compressors are often located outside and become cold in winter weather. During the off cycle, the vapor inside the compressor may condense into a liquid. This liquid refrigerant destroys the compressor at the next start-up.

Crankcase heaters serve to keep the crankcase oil warm and thus prevent condensation inside the compressor during the off cycle. The crankcase heater is not needed during the run cycle or when ambient temperatures are above 50 degrees F.

Hands On Exercise: Measure compressor inlet and outlet temperatures and pressure

Slideshare.com

Compressor Nomenclature Example

Copeland® Disc Type Compressor Part Number Nomenclature

3 D S 3 R 17 M E - T F C - 800

Compressor Motor Types

Phase	Description	Code
1	Capacitor Run – Capacitor Start	C
1	Induction Run – Capacitor Start	I
3	WYE (Star) Delta	E
3	6 lead part winding or across the line, except 575 Volt	F
3	Misc, 3 Phase Single Voltage 3 lead Dual Voltage 9 lead 575V 60 HZ/500V 50 HZ Under 20 HP 3 lead 20 HP & up 6 lead part winding	T

Electrical Codes

60 HZ	50 HZ	Code
115-1	—	A
230-1	—	B
208/230-3	200/220-3	C
460-3	380/420-3	D
575-3	550-3	E
208-1	—	H
208/230/460-3	200/280/400-3	K
N/A	210/240/380-3	L
N/A	380/420-3	M
230/460-3	200/400-3	N
N/A	200/240	R
200-3	—	U
208/230-1	200/220-1	V
N/A	220/240-1	Z

Compressor Family Series
Either a number or letter established for each model

Primary Application Range
R = High Temp
S = Medium Temp
F = Low Temp

Oil Type
E = Polyolester Oil
A = Alkyl Benzene Oil
O = Mineral Oil
L = No Oil

Bill of Material
Product variations

Compressor Model Type

Air Cooled

Code	Description
A =	Standard – air cooled

Refrigerant Cooled

Code	Description
R =	Standard – refrigerant cooled
T =	Two-Stage

Water Cooled

Code	Description
W =	Standard water cooled

Disc Type

Code	Description
D =	Disc type – refrigerant cooled

Displacement and Valve Plate
A letter only, randomly assigned for each different displacement valve plate combination within any one family series.

Model Variation
A number or letter assigned to indicate major variations within any one family series.

Nominal Capacity
at Rating Condition
(2 numeric characters)

Capacity Multiplier
K = 1,000
M = 10,000

Compressor Motor Protection

Type Protection	Code
External Inherent Protection – One Protector, (Line Break) Use with Contactor	A
Internal Inherent Protection – One Protector, (Line Break) Use with Contactor	F
Internal Thermostat(s) and External Supplementary Protector(s) mounted on compressor. (Two for 3 Phase, one for 1 Phase) Use with Contactor	H
Internal Thermostat(s) and Three External Supplementary Protector(s) mounted on compressor. Use with Contactor	L
Internal Thermal Protection – Electronic Sensors and Control Module External Use with Contactor	S

Start Capacitors

Capacitors are electrical devices used in split phase electric motors to assist in starting and running.

The start capacitor

The start capacitor is a component used on single phase motors to assist the motor start. It is used when there may be a considerable resistance to initial rotation. This could heavy components that are attached to the motor or a compressor that must start with a difference in pressures. This difference, in refrigeration systems, would be a higher pressure in the discharge of the compressor compared to a lower pressure in the suction side.

In refrigeration systems, many compressors use a PSC motor that can be converted to a start capacitor motor.

The start capacitor is much higher strength than a run capacitor.

The physical size of the start cap is not usually larger than a run cap but, unlike a run capacitor, it is not designed to stay in the circuit. If it is left in the circuit, it will overheat and fail with a minute or two. The start capacitor cannot be kept in the circuit longer than a few seconds. One of the most common types of devices to remove the start capacitor from the circuit after the motor has started is the potential relay.

This relay uses an interesting electrical potential.

When a motor is started and comes up to speed, the motor windings induce power in those same windings. This power travels in the opposite direction and stacks on top of the incoming power. As the motor speed increases, this power increases. This is called back EMF.

Back EMF exists in both windings, but the potential relay is energized by the back EMF between start and common.

As the speed increases to 75% of the rated motor speed, the back EMF rises high enough to energize the potential relay coil and opens the normally closed contacts, that deenergizes the circuit containing the start capacitor.

Start Capacitor

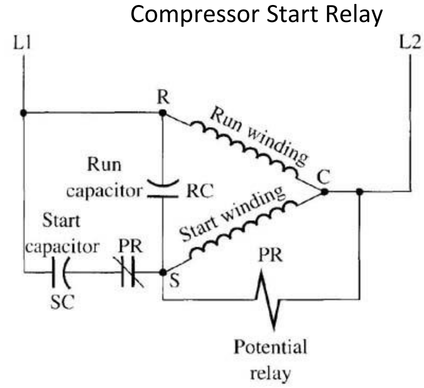
©en.wikipedia.com

Potential Relay

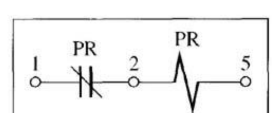
©Hvacpartsshop.com

Compressor Start Relay

©hvactutorial.wordpress.com



(a) Diagram of potential relay connected to a capacitor start, capacitor run motor



(b) Diagram of potential relay

©industrial-electronics.com

Fundamentals of Refrigeration

Unit 4:
Components

Run Capacitors

Run Capacitors

The run capacitor is designed to be used continuously in the motor circuit.
They are similar to a rechargeable battery that can be discharged and charged very quickly.

The run cap is used to provide moderate starting torque for PSC (permanent split capacitor) fan motors.

They also increase efficiency of the motor when running. They are wired into the circuit permanently.

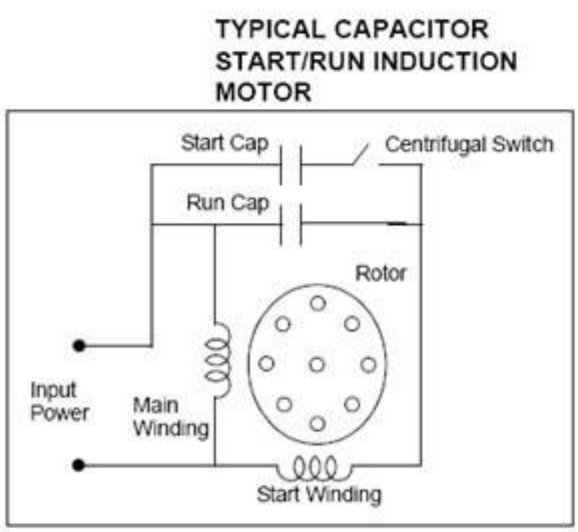
These capacitors are usually encased in metal. The reason for the metal case is to help transfer heat out of the capacitor.

Inside the case there is a type of oil that can easily transfer heat.

©jaycar.com

Run Capacitor

©tempcoindustrial.com



©quora.com

Unit 4:
Components

Fundamentals of Refrigeration

Condenser

What is a condenser?

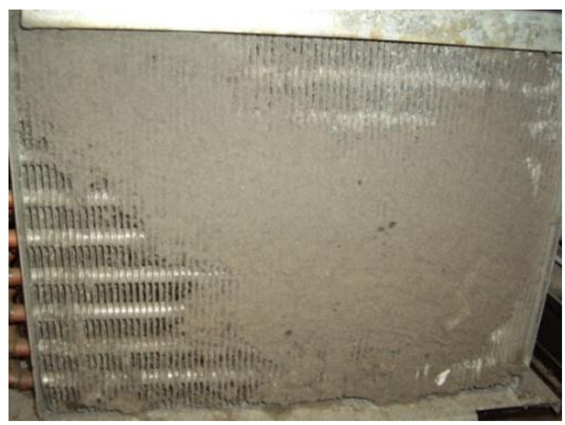
The condenser is a heat exchanger. High pressure, high temperature gas enters the top portion of the condenser. Air movement created by a fan removes heat from the refrigerant as it flows through the condenser. As heat is removed from the refrigerant, it condenses into a liquid. The refrigerant should be a liquid by the time it leaves the bottom of the condenser.

Condenser Cleanliness

If the fins and tubing of the condenser is dirty, air flow is blocked which reduces the amount of heat that is removed from the refrigerant This causes some of the refrigerant not to condense into a liquid. It is critical for proper operation of a refrigeration system that the condenser is clean and has a properly operating fan.


©madseninc.com

Central AC Condensing Unit


©www.commercial-freezers-coolers-depot.com

Dirty, lint covered condenser on a cooler

©Removeandreplace.com

Cleaning a refrigerator condenser

Notes:

Unit 4:
Components

Fundamentals of Refrigeration

Condensing Units

Condensing Unit

This is a condensing unit. Condensing units are separated from the space that is to be cooled.

What does the condensing unit consist of?

The condensing unit consists of the compressor, condenser, condenser fan, and filter/drier. In the photo, the capillary tube (metering device) comes out of the filter/drier and is routed to the evaporator.

Location and Power Source

On a central air conditioning system, the condensing unit is located outside next to the building or on the roof of some commercial buildings. On a cooler or refrigerator, the condensing unit is found at the bottom of the machine. Electrical power must be supplied to the condensing unit. In some coolers, the condensing unit plugs in to an electrical outlet on the machine. The power to the electrical outlet on the machine is controlled by the thermostat. So, when the thermostat calls for cooling, it is actually supplying voltage to the outlet on the machine and because the condensing unit is plugged in to that outlet, the condensing unit comes on. Central AC units get their power from an electrical disconnect located close by the unit. When the thermostat in a the space to be cooled calls for cooling, an electrical supply is sent to a contactor and the condensing unit. When the contactor coil is energized, it engages the switch contacts on the contactor and sends power to the compressor and condenser fan motor.

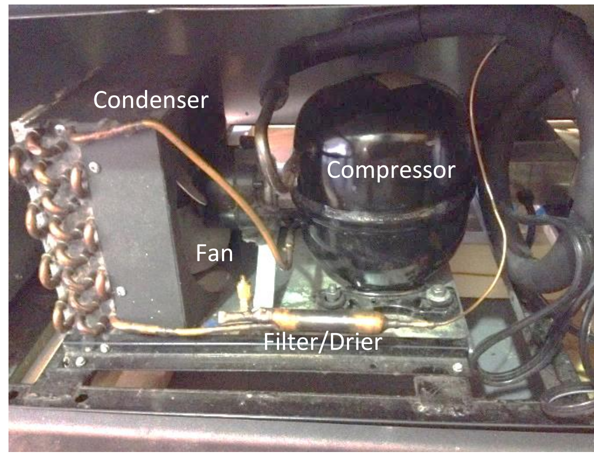


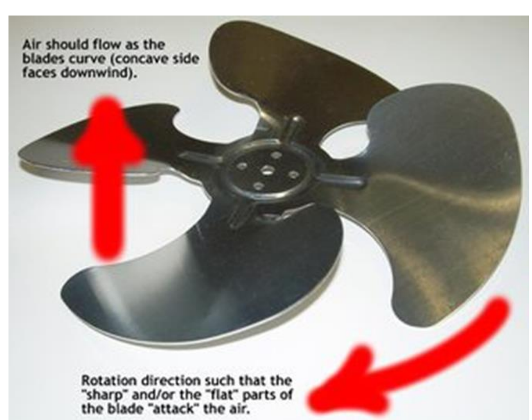
Photo by Kelly Wells

Cooler Condensing Unit

©madseninc.com

Central AC Condensing Unit

Simsheatingandcooling.com



Metering Devices

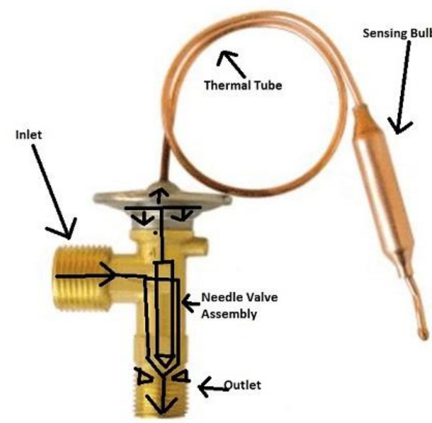
Metering Devices

Metering devices regulate how much liquid refrigerant enters the evaporator. Commonly used metering devices are small thin copper tubes called Capillary Tubes (Cap Tubes) and thermally controlled diaphragm valves called Thermostatic Expansion Valves (TXV's).

©Amazon.com

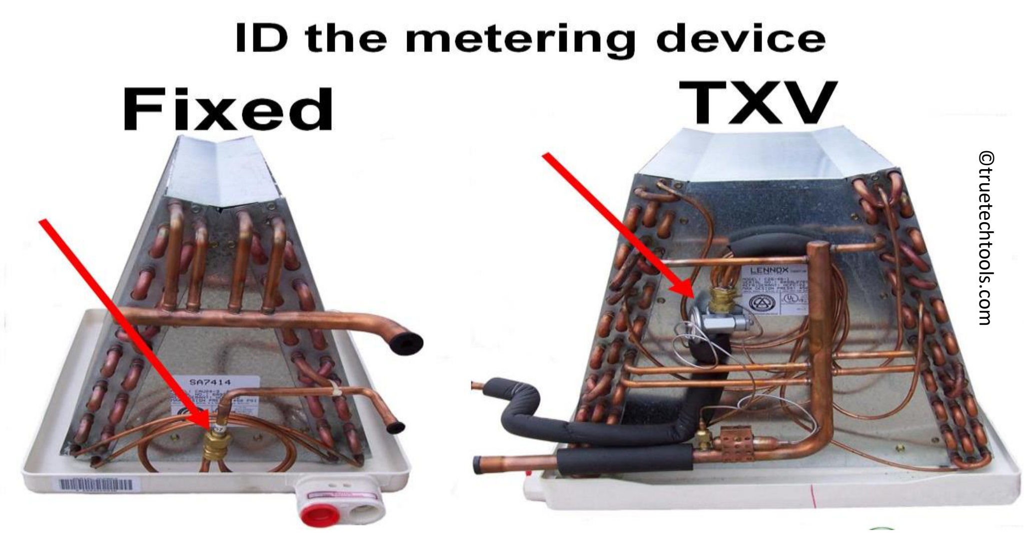
The metering device tries to maintain a preset temperature difference or "Superheat", between the inlet and outlet openings of the evaporator.

As the metering device regulates the amount of refrigerant going into the evaporator, the device lets small amounts of refrigerant out into the line and loses the high pressure it has behind it. This instant pressure change causes and instant temperature change.



©Honda-tech.com

Now we have a low pressure, cooler liquid refrigerant entering the evaporator coil. The pressure went down so the temperature went down.



©truetechtools.com

Capillary Tubes

The capillary tube is one of the most commonly used throttling devices in the refrigeration and the air conditioning systems. The capillary tube is a copper tube of very small internal diameter. It is of very long length and it is coiled to several turns so that it would occupy less space. The internal diameter of the capillary tube used for the refrigeration and air conditioning applications varies from 0.5 to 2.28 mm (0.020 to 0.09 inches). Capillary tube used as the throttling device in the domestic refrigerators, deep freezers, water coolers and air conditioners. When the refrigerant leaves the condenser and enters the capillary tube its pressure drops down suddenly due to very small diameter of the capillary. In capillary tubes the fall in pressure of the refrigerant takes place not due to the orifice but due to the small opening of the capillary.

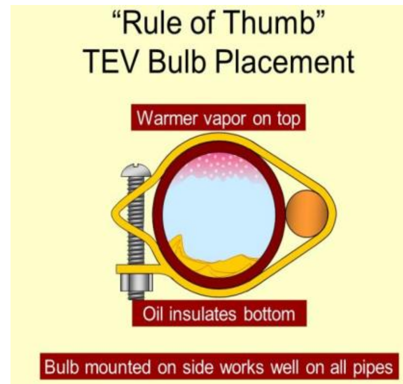
The decrease in pressure of the refrigerant through the capillary depends on the diameter of the capillary and the length of the capillary. The smaller the diameter and longer the length of the capillary is, the more the drop in pressure of the refrigerant is as it passes through it.

In the normal working conditions of the refrigeration unit there is drop in pressure of the refrigerant across the capillary but when the unit stops, the refrigerant pressure across the two sides of the capillary equalize. Due to this reason when the compressor restarts there won't be much load on it.

Cap Tube Cutter

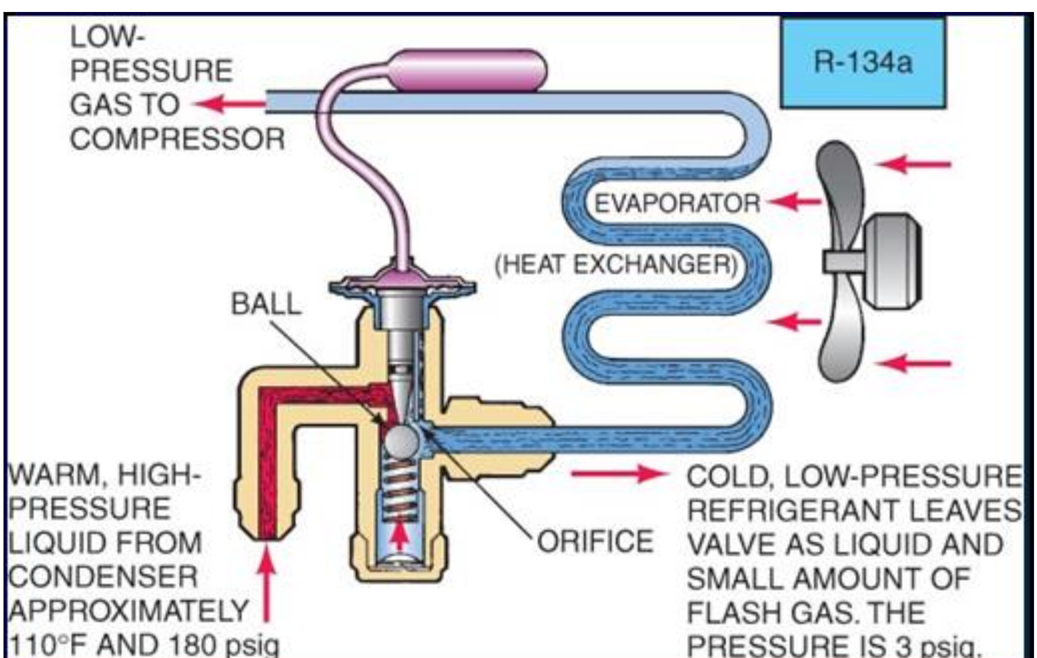
Thermostatic Expansion Valves

A very common type of metering device is called a thermostatic expansion valve or TXV. This valve has the capability of controlling the refrigerant flow. If the load on the evaporator changes the TXV increases or decreases the refrigerant flow accordingly.



The TXV has a sensing bulb attached to the outlet of the evaporator. This bulb senses the suction line temperature and sends a signal to the TXV allowing it to adjust the flow rate. This is important because, if not all, the refrigerant in the evaporator changes state into a gas, there could be liquid refrigerant content returning to the compressor. This can be fatal to the compressor. Liquid can not be compressed and when a compressor tries to compress a liquid, mechanical damage can happen. The compressor can suffer mechanical damage in the valves and bearings. This is called "slugging".

Normally TXV's are set to maintain 10 degrees of superheat. That means that the gas returning to the compressor is at least 10 degrees away from the risk of having any liquid.



Unit 4:
Components

Fundamentals of Refrigeration

Evaporators

What is an evaporator?

The evaporator is where the heat is removed from your house, business, or refrigerator box.

Low pressure liquid leaves the metering device (either cap tube or TXV) and enters the evaporator.

Usually a fan will move warm air from the conditioned space across the finned evaporator coils.

The cooler refrigerant in the evaporator tubes, absorb the warm room air. The change of temperature causes the refrigerant to “flash” or “boil” and it changes from a low pressure liquid to a low pressure cold vapor or gas.

The low pressure vapor is pulled into the compressor and the cycle starts over.

The amount of heat added to the liquid to make it saturated and change states is called “Superheat”.

One way to charge a system with refrigerant is by superheat.

A completely froze over evaporator indicates a bad evaporator fan motor or incorrect cycle times.

A partially froze over evaporator may indicate low refrigerant charge.

Photo by: Kelly Wells

Photo by: Kelly Wells

Unit 4:
Components

Fundamentals of Refrigeration

Other Components

Overview of Refrigeration Components

There are other components of the refrigeration outside of the four major components. A brief description of these components follows.

Receiver

On some systems, the refrigerant leaves the condenser and goes into a receiver. A receiver stores liquid refrigerant and is large enough to isolate the refrigerant completely in the receiver by blocking off the inlet and outlet ports with valves. This allows all the refrigerant to be isolated in the receiver while the technician performs service on the system. Most small appliances do not have receivers.

© directindustry.com

Sight Glass

A sight glass can sometimes be found in a system and will be located in between the filter/drier and the expansion valve. It has a clear glass lens that the refrigerant can be observed through. A sight glass also has a moisture indicator that will turn colors (by a chemical salt) if moisture is present in the system. In a properly operating system, you will be able to see liquid refrigerant flowing in the sight glass.

© traderscity.com

Notes:____

Thermostats

Thermostats

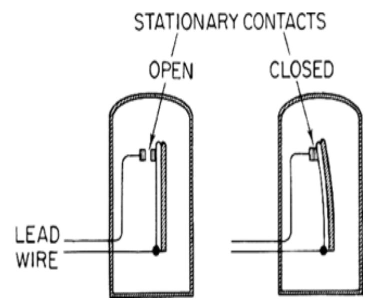
The temperature in any structure, regardless of its age, location or design can be maintained at comfortable levels with a thermostat. Thermostats are designed and built in many different forms and sizes to meet the applications required in the industry.

Cooler Thermostat

Photo by Kelly Wells

Applications

The basic function of a thermostat is to respond to a temperature change by opening and closing a set of electric contacts. Many different types of thermostats are used in the industry to perform a variety of switching actions. A cooling thermostat closes on a increase in temperature and opens on an decrease in temperature.



Bimetallic Element Operation

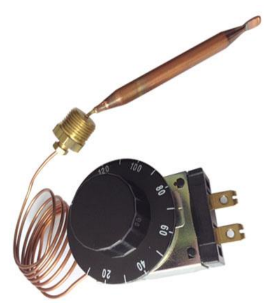
©encylcopedia2.thefreedictiona.com.

Controlling Elements and Types of Thermostats

Two types of thermostat controlling elements are commonly used. The controlling element of a thermostat is the part that moves when a change in temperature is sensed. The bimetal thermostat is commonly used to control the temperature of air in an air-conditioning or heating application.

Remote Bulb Thermostat

The power element, which is the bulb, and the diaphragm are connected with a section of small tubing. The bulb is filled with liquid and gas and then is sealed. The pressure exerted by the diaphragm on the mechanical linkage will open and close a set of contacts. As the bulb temperature changes, so will the pressure exerted on the diaphragm. If the temperature of the bulb increases, so will the pressure.


Remote Bulb Thermostat

©Athiele.com.br

Bimetal Thermostat

The heart of most types of thermostats is a bimetal element. The element get its name from the fact that it uses a bimetal to cause the movement that open and closes a set of contacts. A bimetal is a combination of two pieces of metal. The metals are welded together. Each metal has a different coefficient of expansion. If the temperature of these two metals is increased, one will become longer than the other because of the different expansion qualities.


Bimetal Thermostat

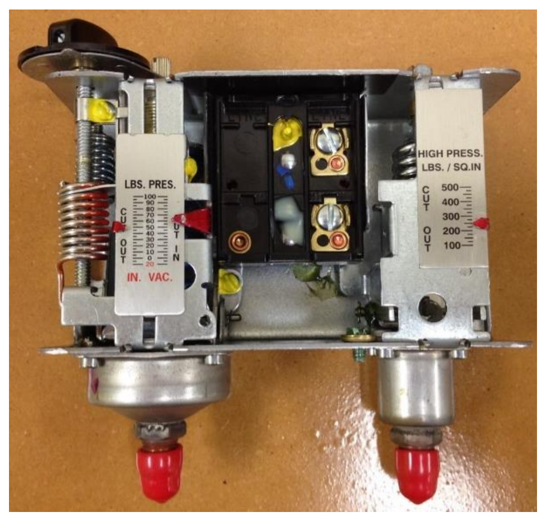
©Thermal-sensors.com

Dual-Pressure Control Device

The temperature of a refrigerated box can be controlled by a low-pressure control (LPC), instead of a thermostat, because of the pressure/temperature relationship in the refrigeration system. By cycling the compressor in response to the suction (low side) pressure, box temperature can be controlled. This type of control is most popular in small-refrigerated boxes such as beer coolers.

To control box temperature with a low-pressure control, the system must use a thermostatic expansion valve, non-bleed type. The condensing unit must be located in an ambient, which is warmer than the box's highest operating temperature. As box temperature decreases, the evaporator temperature decreases, and a lower suction pressure results. When the suction pressure reaches the low-pressure control's cut-out setting, the LPC's contacts open and stop the compressor. As the box temperature rises, the evaporator's temperature also rises, the evaporator pressure increases, and when the cut-in setting of the LPC is reached, its contacts close and the compressor is started. There are some advantages to this type of system. The low-pressure control will act as a "loss of charge" control. Short cycling, due to door openings, etc., is prevented. The same is not true for a standard temperature control. Wiring is simplified and installed cost is reduced.

Dual-Pressure Control



Dual-Pressure Control without Cover

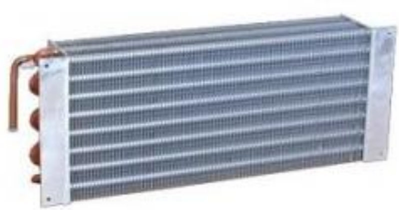
Top of Dual-Pressure Control

Unit 4:
Components

Fundamentals of Refrigeration

Hands On Exercise: Identify refrigeration components

- Identify the following refrigeration related components, then locate the components on a refrigeration unit.



Schematics

Electrical Symbols for HVACR Diagrams							
Component	**Symbol**	**Component**	**Symbol**	**Component**	**Symbol**	**Component**	**Symbol**
Capacitor	*Identifying terminal (nearest ground)	Thermocouple		**Switches**		General selector switch	Any number of transmission paths may be shown
Circuit breakers	Thermal Magnetic	Transformer		Single throw		Segment contact	or
Relay, timer, solenoid, etc.	*Designate device	Thermal overload coil		Double throw		Thermal relay	
Contacts	Normally open (NO) Normally closed (NC) Timed closed (TC) Timed open (TO)	Terminal		Double pole double throw		**Motors**	
Conductors	Crossing Junction	Thermistor		Push button (NO)	Circuit closing (make)	General	
Fuse		**Connectors**		Push button (NC)	Circuit opening (break)	Windings	Main Aux.
Fusible link		Male		Push button (Two circuit)	No spring return	**Conductors**	
Ground connection		Female		Pressure activated	(NO) (NC)	Power (factory wired)	
Light		Engaged		Temperature activated (NO)	Close on rising	Control (factory wired)	
Meter	*Denote usage	4 Conductor		Temperature activated (NC)	Open on rising	Power (field installed)	
Diode		**Alarms**		Flow activated (NO)	Close on increase	Control (field installed)	
Resistor		Bell		Flow activated (NC)	Open on increase	**Transistors**	
Shielded cable		Horn		Liquid level (NO)	Close on rising	PNP type	
Multiple conductor cable		Buzzer		Liquid level (NC)	Open on rising	NPN type	

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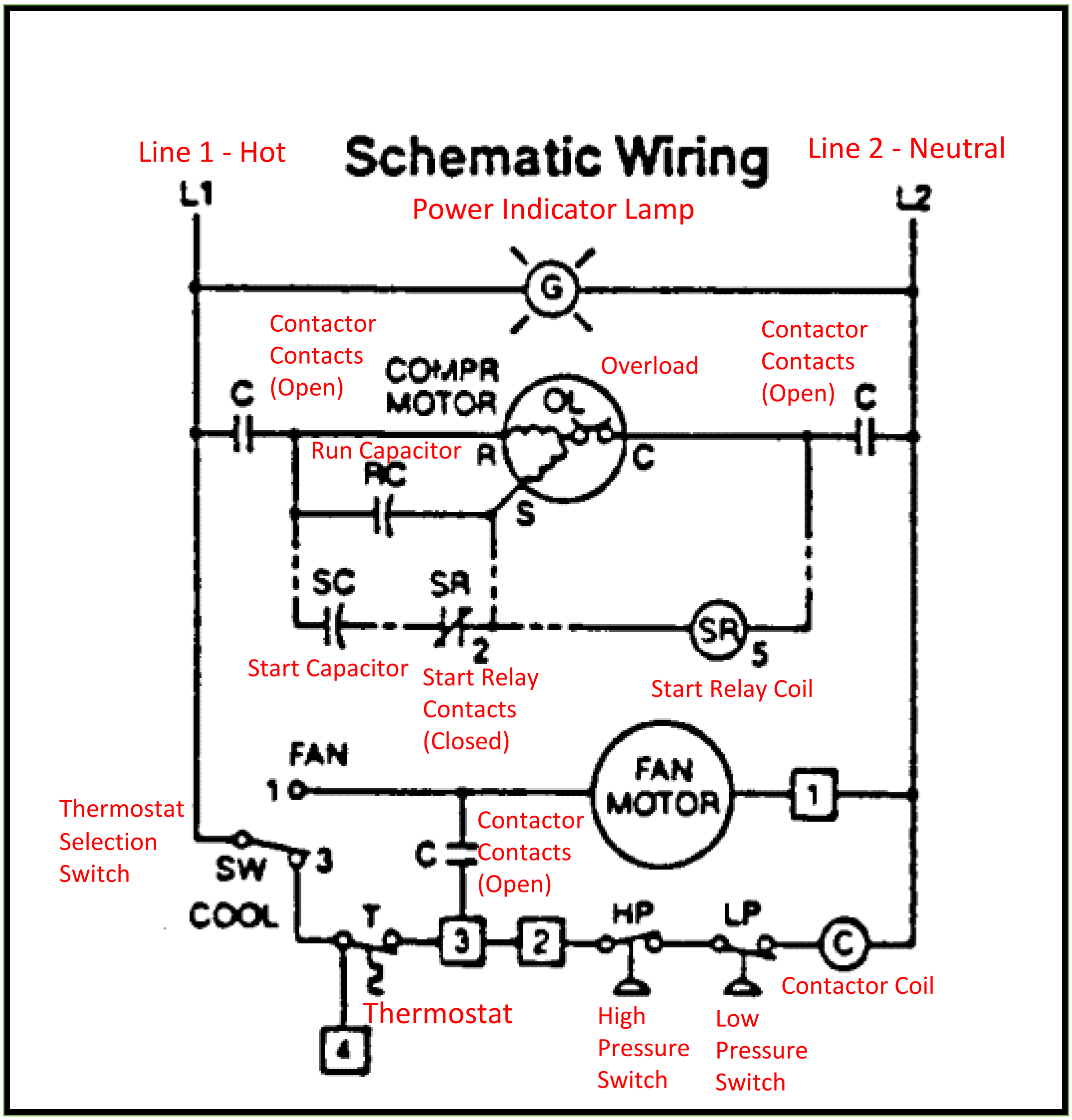
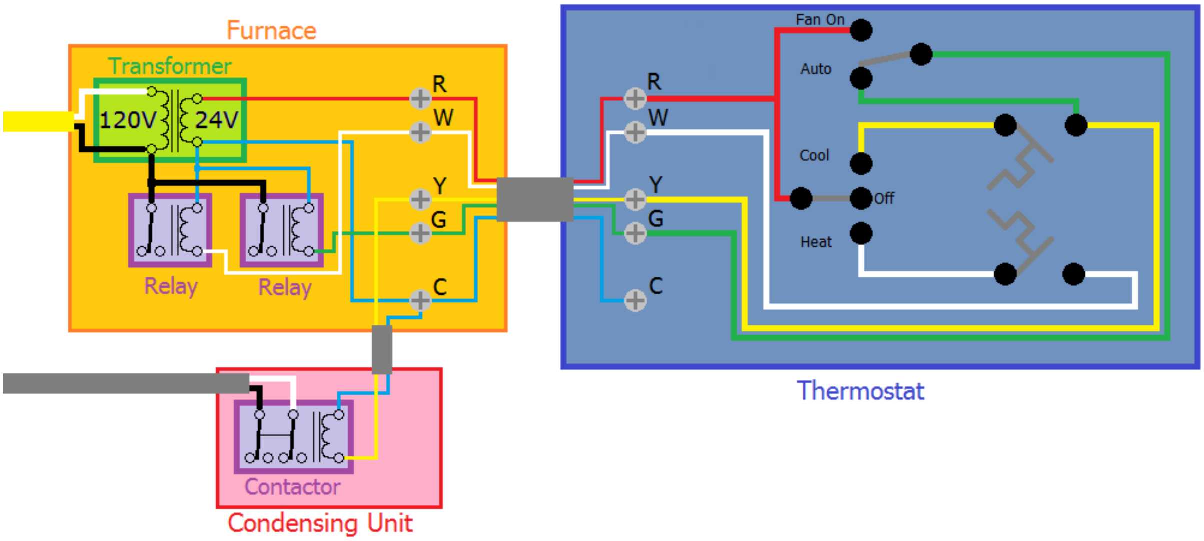
Schematic Wiring Example

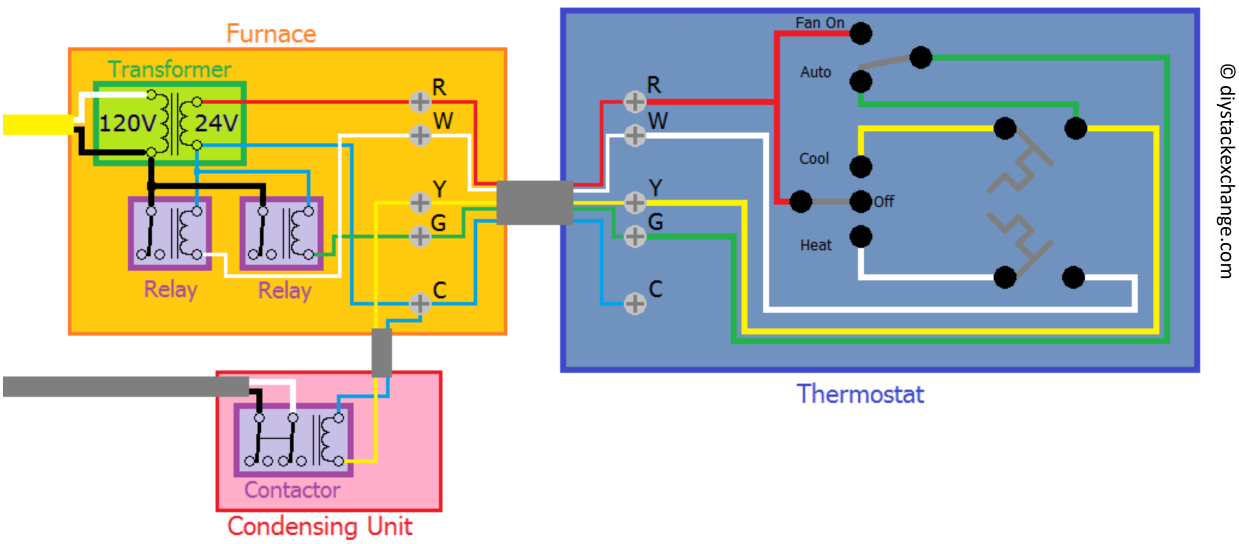


Refrigeration Circuits



1. What would the blue wire be? ________________________________(hot or neutral)
2. What would the red wire be? _________________________________(hot or neutral)
3. What would the thermostat white wire be? __ __________________(hot or neutral)
4. What would the green wire be? _______________________________(hot or neutral)
5. What would the black wire be? _______________________________(hot or neutral)
6. What would the yellow wire be? ______________________________(hot or neutral)

Central Heat and Air Schematic



Lets take a look at what is going on in this schematic.

1. On the furnace unit, there is a transformer. This transformer takes 120 volts AC and transforms it to 24 volts AC. The black wire coming into the transformer is the hot (live) wire and the white wire is the neutral (dead) return wire. The black wire supplies power to the circuit and the white wire closes the circuit by returning back to the power source. The black wire is also supplying 120 volts to the switch contacts of the two relays. The left relay is the heater relay and the right relay is the blower fan relay.

2. The red wire (R) coming off the 24 volt transformer provides supply voltage to the thermostat. It lands at the FAN ON and the COOL/HEAT mode switch.

3. When COOL is selected on the thermostat, power from the red wire is sent to the temperature sensing switch in the thermostat through the yellow COOL wire. When this switch closes because the temperature is higher than the set point of the thermostat, power flows through the yellow wire (Y) to the contactor coil and energizes the contactor. When the contactor coil becomes energized, the switch contacts with 120 VAC setting at them are connected to the contacts that supply power to the condensing unit allowing the compressor and condenser to run. It also flows through the green wire to the AUTO switch. Since AUTO is a closed switch position, power flows to the coil of the fan relay allowing the fan to run. Once the thermostat is satisfied with the temperature in the room, the thermostat temperature switch opens up and kills power to the contactor coil which causes the 120 VAC contacts to open and the condensing unit shuts off. The blue wire coming off the 24 volt side of the transformer is the neutral for the two relay coils, the contactor coil and a neutral for the thermostat.

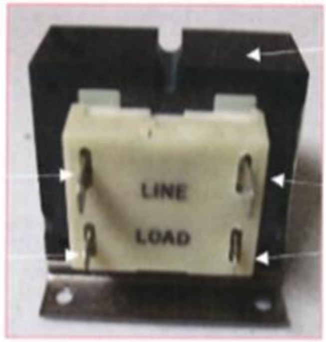
4. If FAN ON is selected, power flows from the red wire to the green wire which sends power to the coil on the fan relay. When this coil is energized, the 120VAC sitting at the fan relay switch contacts is allowed to flow to the fan motor turning on the fan.

5. If HEAT is selected, power flows through the white HEAT wire to the temperature switch in the thermostat. When the thermostat calls for heat, the switch contacts are closed and power flows through the white wire to the (W) thermostat contact and then to the heater relay coil. When the heater relay coil is energized, the 120VAC sitting at the relay switch contacts is allowed to flow to the heating element or ignition system.

How to Test a Transformer

Primary 120 VAC - Line — A

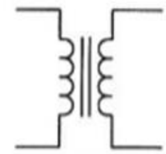
Secondary 24 VAC - Load — C



E 

B

D



Schematic Symbol

How to Check Voltage on a 120 Volt to 24 Volt Transformer.

1. Make sure power (120VAC) is connected to the line terminals.
2. Set meter to the AC voltage at the 200 volt setting.
3. Put one lead on terminal **A** and the other lead on terminal **B** and you should get a reading of 120 Volts. If not, check the power supply to the transformer.
4. Put one lead on terminal **C** and the other lead on terminal **D** and you should get a reading of 24 Volts AC. If not, the secondary winding is open. Replace the transformer.

How to Check Continuity on a Transformer.

1. Make sure <u>**no power**</u> is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).

Primary Winding Check

3. Put one lead on terminal **A** and the other lead on terminal **B**. You should read “000”.

Secondary Winding Check

4. Put one lead on terminal **C** and the other lead on terminal **D**. You should read “000”.

Check for Primary and Secondary Windings Shorted Together

5. Put one lead on terminal **A** and the other lead on terminal **C**. You should read “I” or “O.L”.
6. Put one lead on terminal **B** and the other lead on terminal **D**. You should read “I” or “O.L”.

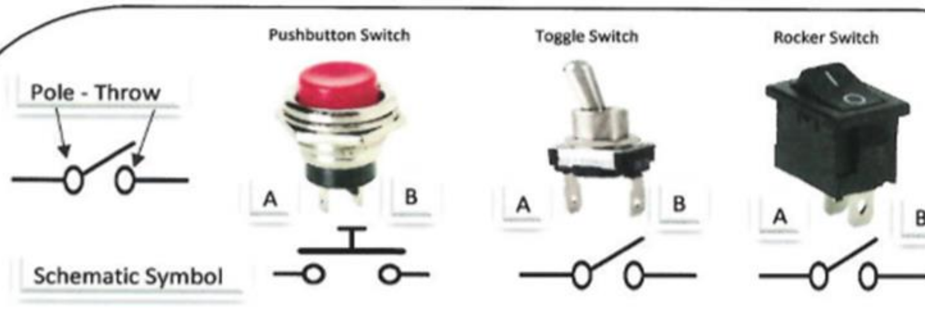
Check for Primary Windings Shorted to Core

7. Put one lead on terminal **A** and the other lead on terminal **E**. You should read “I” or “O.L”.

Check for Secondary Windings Shorted to Core

8. Put one lead on terminal **C** and the other lead on terminal **E**. You should read “I” or “O.L”.

How to Test a Switch

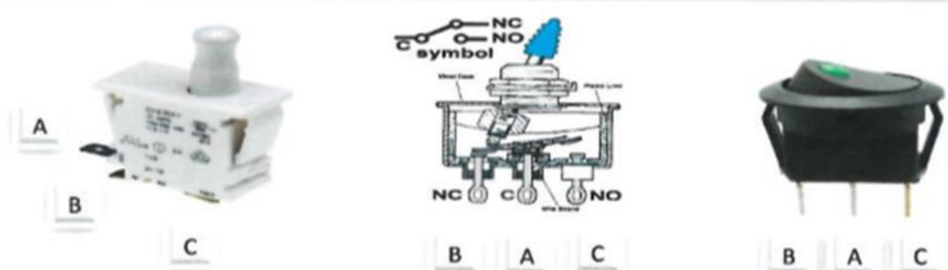


Switch Legend

Com = Common (Power In)
NC = Normally Closed (Connected to common when switch is not activated)
NO = Normally Open (Connects to common when switch is activated)

How to Test Continuity on a Single Pole Single Throw Switch

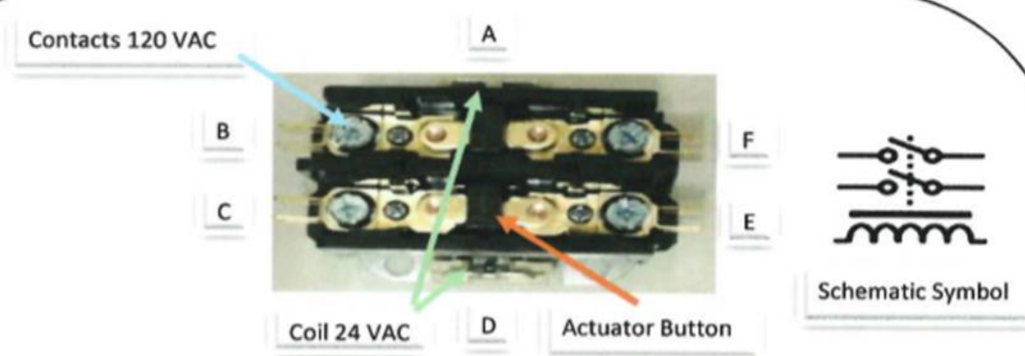
1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (e.g. - 200Ω).
3. Put one lead on terminal **A** (Com) and the other lead on terminal **B** (NO).
4. When the switch is open (off) you should read "**I**" or "**O.L**".
5. When the switch is closed (on) you should read "**000**" or higher indicating a small amount of resistance.



How to Test Continuity on a Single Pole Double Throw Switch

1. Make sure no power is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).
3. Set switch operator in the off position.
4. Put one lead on terminal A (Com) and the other lead on terminal B (NC). You should read "000". The circuit is closed.
5. Put one lead on terminal A (Com) and the other lead on terminal C (NO). You should read "I" or "O.L". The circuit is open.
6. Put one lead on terminal B and the other lead on terminal C. You should read "I" or "O.L".
7. Put one lead on terminal E and the other lead on terminal F. You should read "I" or "O.L".

How to Test a Contactor



How to Check Voltage on a 240 Volt to Contactor with a 24 Volt Coil Installed on a Machine

1. Set meter to **AC** Voltage in the proper range.
2. Trace wires to see where the line voltage is coming in. It will be connected to the line terminals either **B** & **C** or **F** & **E**.
3. Example: If line voltage is at **B** & **C**, put one lead on terminal **B** and the other lead on terminal **C** and you should get a reading of 240 Volts. If not, check the voltage source.
4. When you manually activate the contactor by pushing the center button to make contact across one side to the other, you should get 240 volts at **F** & **E** as well.
5. To check for voltage across the coil, put one lead on terminal **A** and the other lead on terminal **D**. You should read 24 Volts when the controller (e.g. – Thermostat) sends power to the contactor.

How to Check Continuity on a Contactor

1. Make sure <u>**no power**</u> is going to component and the component is isolated from the circuit.
2. Set meter to the lowest resistance setting (200Ω).

Coil Check

3. Put one lead on terminal **A** and the other lead on terminal **D**. You should read "**000**" or higher. If it reads "O.L", try a different range setting. If it still reads "O.L", the coil is open and the contactor is bad.

Switch Contacts Check

4. Put one lead on terminal **B** and the other lead on terminal **F**. You should read "**O.L**". When the actuator button is pushed you should read "000". A higher reading could indicate carbon buildup on the contact points.
5. Repeat Step 4 for contacts **C** & **E**

Check for Coil Winding Shorted to Ground ⏚

6. Put one lead on terminal **A** or **D** and the other lead on ground. You should read "I" or "**O.L**".

How to Test a Capacitor

How to measure capacitance

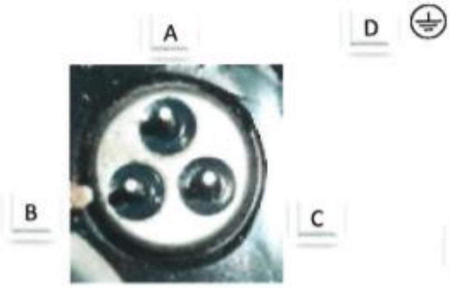
Use your multimeter to confirm the capacitor is fully discharged.

1. Use your digital multimeter (DMM) to ensure all power to the circuit is OFF. If the capacitor is used in an ac circuit, set the multimeter to measure ac voltage. If is used in a dc circuit, set the DMM to measure dc voltage.
2. Visually inspect the capacitor. If leaks, cracks, bulges or other signs of deterioration are evident, replace the capacitor.
3. Turn the dial to the Capacitance Measurement mode (Capacitance symbol). The symbol often shares a spot on the dial with another function. In addition to the dial adjustment, a function button usually needs to be pressed to activate a measurement. Consult your multimeter's user manual for instructions.
4. For a correct measurement, the capacitor will need to be removed from the circuit. Discharge the capacitor as described in the warning above.

Note: Some multimeters offer a Relative (REL) mode. When measuring low capacitance values, the Relative mode can be used to remove the capacitance of the test leads. To place a multimeter in Relative mode for capacitance, leave the test leads open and press the REL button. This removes the residual capacitance value of the test leads.

5. Connect the test leads to the capacitor terminals. Keep test leads connected for a few seconds to allow the multimeter to automatically select the proper range.
6. Read the measurement displayed. If the capacitance value is within the measurement range, the multimeter will display the capacitor's value. It will display OL if a) the capacitance value is higher than the measurement range or b) the capacitor is faulty. 8

How to Test a Compressor



Schematic Symbol

How to Check Continuity on the Electrical Windings in a Compressor

1. Make sure no power is going to component and the component is isolated from the circuit. Remove cap covering winding terminals/start relay.
2. Set meter to the lowest resistance setting (200Ω).
3. Terminal **A** is called "Common", Terminal **B** is called "Start", and Terminal **C** is called "Run".

Open Winding Test

4. Put one lead on terminal **A** and the other lead on terminal **B**, you should read "**000**" or higher.
5. Put one lead on terminal **A** and the other lead on terminal **C**, you should read "**000**" or higher.
6. Put one lead on terminal **B** and the other lead on terminal **C**, you should read "**000**" or higher.

Grounded Winding Test

7. Put one lead on terminal **A** and the other lead on terminal **D**, you should read "O.L" or "I".
8. Put one lead on terminal **B** and the other lead on terminal **D**, you should read "O.L" or "I".
9. Put one lead on terminal **C** and the other lead on terminal **D**, you should read "O.L" or "I".

Analysis

10. If a reading of "O.L" or "I" is found during steps 4 through 6 then there are open windings and the compressor is bad.
11. If a reading of "000" or higher is found during steps 7 through 9 then the compressor is shorted to ground and the compressor is bad.

Subcooling

Subcooled Liquid

A subcooled liquid refrigerant is a refrigerant consisting of 100% saturated liquid that has had additional heat removed.

What is Subcooling?

Subcooling is the amount of heat removed from a refrigerant after it has condensed, measured in degrees.

Application

Technicians calculate Subcooling to determine if systems with thermostatic expansion valves have the correct refrigerant charge.

Measuring Subcooling

Step 1: Measure the pressure of the fluid leaving the condenser.

Step 2: Measure the temperature of the refrigerant line at the condenser outlet.

Step 3: Use a P/T Chart for the system's specific refrigerant to convert the liquid pressure to temperature.

Step 4: Subtract the temperature converted from the liquid pressure from the actual temperature. This is the Subcooling.

FORMULA: SUBCOOLING

$$SC = T_L - T_C$$

where:

SC = *Subcooling in °F or °C*

T_L = *Actual Liquid Line Temperature in °F or °C*

T_C = *Temperature from T&P Chart in °F or °C*

Step 5: Consult manufacturer specification to see if superheat is correct or in range.

Unit 5:
Troubleshooting

Fundamentals of Refrigeration

Superheat

Superheated Vapor (Gas)

A vapor whose temperature has increased above its 100% saturated condition for the pressure that it is under. This is achieved by increasing the temperature of the refrigerant vapor so that it is higher than its boiling point.

What is Superheating?

Superheat is the amount of heat added to a refrigerant after it has evaporated, measured in degrees.

Application

Technicians calculate Superheat to determine if systems with capillary tube metering devices have the correct refrigerant charge.

Measuring Suction Line Superheat

Step 1: Measure the suction line pressure entering the compressor.

Step 2: Measure the temperature of the suction line.

Step 3: Using a P/T Chart, determine the refrigerants theoretical temperature based on its pressure.

Step 4: Using the suction line superheat formula, determine the superheat.

FORMULA: SUCTION LINE SUPERHEAT

$$SLSH = T_S - T_C$$

where:

$SLSH$ = *Suction Line Superheat in °F or °C*
T_S = *Actual Suction Line Temperature in °F or °C*
T_C = *Temperature from P/T Chart in °F or °C*

Step 5: Consult manufacturer specification to see if superheat is correct or in range.

CFC's

CFC's

Chlorofluorocarbons (CFCs) are a family of refrigerants containing the elements chlorine, fluorine, and carbon. CFCs have characteristics that make them more likely to reach the stratosphere than most other compounds containing chlorine. Refrigerants that contain chlorine but not hydrogen are so stable that they do not breakdown in the lower atmosphere after being released. Chlorine or bromine reacts with ozone (O_3), causing it to change back to oxygen (O_2), which destroys the ozone layer.

CFCs have a high ozone depletion potential (ODP). The ODP is a relative measure of the ability of CFCs and HCFCs to destroy ozone. The potential of any substance to destroy the ozone is ranked relative to CFC-11, which is given the ODP value of 1. Hydrofluorocarbons (HFCs) have a zero ODP but do contribute to global warming, another issue that is discussed later.

The following refrigerants contain CFCs:

- R-500
- R-12

HCFC’s

Hydrochlorofluorocarbons (HCFCs) are a family of refrigerants containing hydrogen, chlorine, fluorine, and carbon. Because the hydrogen reduces the stability of the compound, these refrigerants have an increased deterioration potential before reaching the stratosphere, which means HCFCs have a low ODP. HCFCs have been used to replace CFCs because they cause less depletion of the ozone, making them less harmful to stratospheric ozone than CFCs.

In January 1, 2010, a ban was placed on the production, sales, or importation of new systems that use HCFC-22 or HCFC-142b refrigerants or blends containing these refrigerants with the implementation of two rules: the Pre-Charged Appliance Rule and the Allocation Rule. Currently, these refrigerants can only be used in the service and repair of existing equipment.

The Pre-Charged Appliances rule bans the sale or distribution of pre-charged air-conditioning and refrigeration products, and components containing HCFC-22 or HCFC-142b, or blends containing one or both of these substances. The ban applies to appliances and components manufactured on or after January 1, 2010, but not to appliances or components manufactured before that date.

The Allocation Rule, along with existing EPA requirements, prohibits manufacturers from charging newly manufactured appliances with virgin HCFC-22 or HCFC-142b or blends containing these refrigerants. These sales and production restrictions on HCFC-22 and HCFC-142b also affect any refrigerant blend that contains these refrigerants. HCFC-22 is used as a component in other common refrigerant blends including R-401A, R-402A, R-409A, and R-502. These refrigerants have applications in retail food refrigeration, cold storage warehouses, industrial process refrigeration, and transport refrigeration.

On January 1, 2015, the HCFC ban will extend to all HCFCs for use in new systems and will only allow the use of HCFCs for special applications including the service and repair of existing equipment.

On January 1, 2020, the ban on the production or import of any HCFC refrigerant will take effect. Therefore, after January 1, 2020, only reclaimed or recovered HCFCs can be used in existing equipment.

Most small commercial AC systems manufactured before 2010 use HCFC-22. However, due to the ban on HCFC-22 in new equipment, HFC-410A is now the refrigerant commonly used in new residential and small commercial heat pump and air conditioning systems.

The following refrigerants contain an HCFC:

- R-22
- R-123

HFC’s

HFCs

Hydrofluorocarbons (HFCs) are a family of refrigerants containing hydrogen, fluorine, and carbon, but no chlorine. HFC refrigerants will not damage stratospheric ozone.

The following refrigerants are HFCs:

· R-134a

· R-410A

Although HFCs have zero ODP, they do have a high global warming potential (GWP). According to the EPA, CFCs, HCFCs, and HFCs all contribute to global warming. Many European nations are now considering banning refrigerants with a GWP above 150 or even 100.

Refrigerant Blends

What is a refrigerant blend?

Blends are made up of two or more single component refrigerants. One of two situations will occur, depending on how strongly the different molecules are attracted to each other.

Azeotrope

An Azeotrope is a blend that behaves like a single component refrigerant. When a blend forms an azeotrope, it displays unique and unexpected properties. R-500 and R-502 are azeotrope refrigerants.

Zoetrope

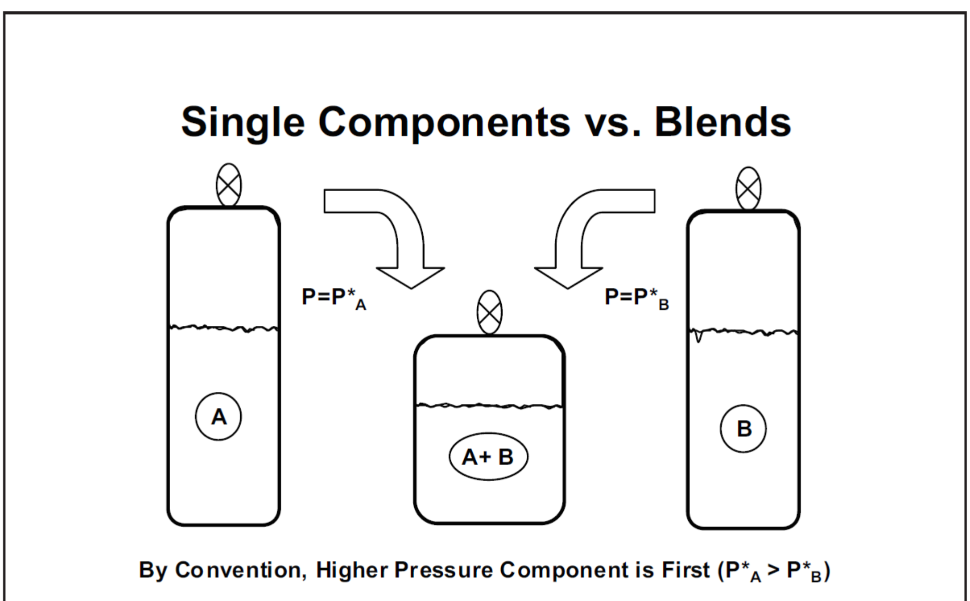
A Zoetrope is a blend that behaves like a mixture of the individual components. Zeotropes have predictable properties based on combinations of the pure components' properties.

Near-azeotropes

In addition, it is sometimes helpful to classify some blends as near-azeotropes. These blends have predictable blend properties; however, the difference between these properties and what is observed for single-component refrigerants is not that significant.

Many of the problems associated with system operation using a blend will not be noticeable with near-azeotropes.

Refrigerant Blends are in the 400 and 500 Series refrigerants.



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Refrigerant Property Summary

Refrigerant Property Summary

	COMPONENTS (Weight %)	TYPE	TEMP. GLIDE (°F)	LUBRICANTS	COMMENTS
R-22	100%	HCFC	0	Mineral Oil or Alkylbenzene	Refrigeration systems, commercial refrigeration, air conditioning, chillers.
R-23	100%	HFC	0	Polyolester	Very low temperature refrigeration. Properties similar to R-13; can also retrofit R-503.
R-123	100%	HCFC	0	Mineral Oil or Alkylbenzene	Low pressure centrifugal chillers. Can retrofit R-11 equipment with modifications.
R-124	100%	HCFC	0	Mineral Oil or Alkylbenzene	High ambient air conditioning. Can retrofit R-114 equipment with modifications.
R-134a	100%	HFC	0	Polyolester	Medium temperature refrigeration, chillers, automotive A/C. Can retrofit R-12 and R-500 equipment.
R-401A	22/152a/124 (53/13/34)	HCFC Blend	8	Alkylbenzene or MO/AB Mix	Low/medium temperature refrigeration. Can retrofit R-12 and R-500 equipment.
R-401B	22/152a/124 (61/11/28)	HCFC Blend	8	Alkylbenzene or MO/AB Mix	Low/medium temperature refrigeration. Can retrofit R-12 and R-500 equipment.
R-402A	125/290/22 (60/2/38)	HCFC Blend	2.5	Alkylbenzene or MO/AB Mix	Low/medium temperature refrigeration. Can retrofit R-502 equipment.
R-402B	125/290/22 (38/2/60)	HCFC Blend	2.5	Alkylbenzene or MO/AB Mix	Ice machines. Can retrofit R-502 equipment.
R-403B	290/22/218 (5/56/39)	HCFC Blend	2	Mineral Oil or Alkylbenzene	Has been used successfully to retrofit R-13B1-type equipment, but has slightly different operating conditions.
R-404A	125/143a/134a (44/52/4)	HFC Blend	1.5	Polyolester	Low/medium temperature refrigeration.
R-407A	32/125/134a (20/40/40)	HFC Blend	10	Polyolester or POE/MO Mix	Low/medium temperature refrigeration. Can retrofit R-22 equipment.
R-407C	32/125/134a (23/25/52)	HFC Blend	10	Polyolester or POE/MO Mix	Low/medium temperature refrigeration, air conditioning. Can retrofit R-22 equipment.
R-408A	125/143a/22 (7/46/47)	HCFC Blend	1	Mineral Oil or Alkylbenzene	Low/medium temperature refrigeration. Can retrofit R-502 equipment.
R-409A	22/124/142b (60/25/15)	HCFC Blend	13	Mineral Oil or Alkylbenzene	Low/medium temperature refrigeration, some A/C. Can retrofit R-12 or R-500 equipment.
R-410A	32/125 (50/50)	HFC Blend	0.2	Polyolester	New residential A/C systems. Not for retrofitting.
R-414B	22/124/600a/142b (50/39/1.5/9.5)	HCFC Blend	13	Mineral Oil or Alkylbenzene	Low/medium temperature refrigeration, some A/C, automotive A/C. Can retrofit R-12 equipment.

Refrigerant Property Summary

National Refrigerants, Inc. Technical Guidelines

Property Summary

	COMPONENTS (Weight %)	TYPE	TEMP. GLIDE (°F)	LUBRICANTS	COMMENTS
R-417C	125 / 134a / 600 (19.5/78.8/1.7)	HFC Blend	6	Mineral Oil, Alkylbenzene, or Polyolester	Low/medium temperature refrigeration, retrofit blend for R-12 applications. Can also replace HCFC-based blends
R-422B	125/134a/600a (55/42/3)	HFC Blend	5	Mineral Oil, Alkylbenzene or Polyolester	Medium temperature refrigeration, air conditioning. Can retrofit R-22 equipment.
R-422C	125/134a/600a (82/15/3)	HFC Blend	5	Mineral Oil, Alkylbenzene or Polyolester	Low/medium temperature refrigeration. Can retrofit R-502 and R-22 equipment, with modifications.
R-422D	125/134a/600a (65.1/13.5/3.4)	HFC Blend	5	Mineral Oil, Alkylbenzene or Polyolester	Low/medium temperature refrigeration. Can retrofit R-22 equipment.
R-507	125/143a (50/50)	HFC Blend	0	Polyolester	Low/medium temperature refrigeration.
R-508B	23/116 (46/54)	HFC Blend	0	Polyolester	Very low temperature refrigeration. Can retrofit R-13 or R-503 equipment.

R – 22 Refrigerant

PRESSURE-TEMPERATURE CHART

TEMP (°F)	R-22 psig
-40	0.5
-35	2.6
-30	4.9
-25	7.4
-20	10.1
-15	13.2
-10	16.5
-5	20.1
0	24.0
5	28.2
10	32.8
15	37.7
20	43.0
25	48.8
30	54.9
35	61.5
40	68.5
45	76.0
50	84.0
55	92.6
60	102
65	111
70	121
75	132
80	144
85	156
90	168
95	182
100	196
105	211
110	226
115	243
120	260
125	278
130	297
135	317
140	337
145	359
150	382

R-22

APPLICATIONS:

- Residential Air Conditioning
- Commercial Air Conditioning

PERFORMANCE:

- For maximum performance from equipment manufactured with R-22 — it's best to service with R-22
- Compatible with Mineral, Alkylbenzene and Pololyester Lubricants

Nonflammable / Non-toxic

Physical Properties of Refrigerants	NATIONAL R-22
Refrigerant Classification	HCFC
Molecular Weight	86.5
Boiling Point (1atm, °F)	-41.5
Critical Pressure (psia)	723.7
Critical Temperature (°F)	205.1
Critical Density (lb./ft^3)	32.7
Liquid Density (70°F, lb./ft^3)	75.3
Vapor Density (bp.lb./ft^3)	0.294
Heat of Vaporization (bp, BTU/lb.)	100.5
Specific Heat Liquid (70 °F, BTU/lb. °F)	0.2967
Specific Heat Vapor (1atm, 70 °F, BTU/lb. °F)	0.1573
Ozone Depletion Potential (CFC 11 = 1.0)	0.05
Global Warming Potential (CO_2 = 1.0)	1810
ASHRAE Standard 34 Safety Rating	A1

AVAILABLE SIZES

Type	Size
Cylinder	30 lb.
	50 lb.
	125 lb.
	1000 lb.
	1750 lb.

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web: www.refrigerants.com
e-mail: info@refrigerants.com

Unit 6:
Refrigerants

R – 22 Refrigerant

NATIONAL™

R-22 Servicing Guidelines

Servicing Considerations:

- Do not top off an existing R-22 charge with any other refrigerant.
- Recovery of R-22 requires a cylinder with a service pressure of 260 psi minimum.
- Follow industry approved best practices for recovery of refrigerant and achieve a full vacuum on the system at the end of the recovery process. Avoid mixing refrigerants during recovery.

THINGS TO REMEMBER:

- R-22 is the **BEST CHOICE** of refrigerant for a system that was designed for R-22
- Servicing of R-22 systems will be allowed for the life of the installed system
- Bank your recovered R-22 to manage your supply for years to come
- R-22 will be available in sufficient quantities to meet servicing demands
- R-22 is the best economic choice in most instances because a R-22 designed system will operate most efficiently and at optimal capacity using R-22
- **ALWAYS** purchase R-22 from reputable wholesalers who will guarantee that their product meets AHRI Standard 700 purity standards.

For information on retrofitting, please refer to NRI's Retrofit Handbook at www.refrigerants.com/pdf/NRI_RetroftHndBk.pdf

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4/2015

Unit 6:
Refrigerants

R-407A Refrigerant

Closest Match in Capacity & Efficiency to R-22

Available in the following sizes:
25R407A — 25 lb. cylinder
100R407A — 100 lb. cylinder*
925R407A — 925 lb. cylinder*
1550R407A — 1,550 lb. cylinder*
*deposit required

NATIONAL R-407A

- *Low and medium temperature refrigeration applications*
- *Excellent performance match to R-22 in low temperature applications compared to other retrofit blends*
- *Slightly lower discharge temperature than R-22; while reducing the need for compressor heat-protection, such as liquid injection,* **National R-407A** *continues to work well with heat reclaim systems*
- *Works with existing capillary tube or TXV (adjustment of TXV may be necessary)*

TEMP (°F)	R-22	National R-407A Liquid (psig)	National R-407A Vapor (psig)
-40	0.6	3.9	1.0
-35	2.6	6.4	1.0
-30	4.9	9.2	3.3
-25	7.4	12.2	5.8
-20	10.2	15.6	8.5
-15	13.2	19.2	11.5
-10	16.5	23.2	14.9
-5	20.1	27.5	18.5
0	24.0	32.2	22.5
5	28.3	37.3	26.9
10	32.8	42.8	31.6
15	37.8	48.7	36.7
20	43.1	55.1	42.3
25	48.8	62.0	48.3
30	55.0	69.3	54.8
35	61.5	77.2	61.8
40	68.6	85.6	69.4
45	76.1	94.6	77.4
50	84.1	104	86.1
55	92.6	114	95.3
60	102	125	105
65	111	137	116
70	121	149	127
75	132	162	139
80	144	175	152
85	156	190	165
90	168	205	179
95	182	221	194
100	196	238	210
105	211	255	227
110	226	274	245
115	243	293	264
120	260	314	284

Values from NIST Refprop 8.0 — Red Figures (IN Hg) Vacuum

Physical Properties of Refrigerants	R-22	National R-407A	National R-407C
Refrigerant Classification	HCFC	HFC	HFC
Molecular Weight	86.5	90.1	86.2
Boiling Point (1atm, °F)	-41.5	-49.9	-43.6
Critical Pressure (psia)	723.7	658.6	672.1
Critical Temperature (°F)	205.1	181	187
Critical Density (lb./ft^3)	32.7	31.4	32
Liquid Density (70°F, lb./ft^3)	75.3	72.6	72.4
Vapor Density (bp.lb./ft^3)	0.294	0.305	0.289
Heat of Vaporization (bp, BTU/lb.)	100.5	100.8	106.7
Specific Heat Liquid (70 °F, BTU/lb. °F)	0.2967	0.3554	0.3597
Specific Heat Vapor (1atm, 70 °F, BTU/lb. °F)	0.1573	0.1967	0.1987
Ozone Depletion Potential (CFC 11 = 1.0)	0.05	0	0
Global Warming Potential (CO2 = 1.0)	1810	2110	1770
ASHRAE Standard 34 Safety Rating	A1	A1	A1
Temperature Glide (°F)	0	8	10

R-407C Refrigerant

Very Similar System Performance!

NATIONAL R-407C

- Air conditioning and Low/Medium/High temperature refrigeration applications
- Identified as the best performing retrofit refrigerant for R-22 for air conditioning in cooperative industry testing (Alternative Refrigerant Evaluation Program, or AREP, 1992-1997)
- Years of commercial success in the European Union where R-22 has been banned from new equipment since 2001
- Works with existing R-22 expansion devices (orifice tube, capillary tube or TXV); some TXV adjustment may be necessary

Available in the following sizes:
25R407C — 25 lb. cylinder
115R407C — 115 lb. cylinder*
925R407C — 925 lb. cylinder*
1550R407C — 1,550 lb. cylinder*
*deposit required

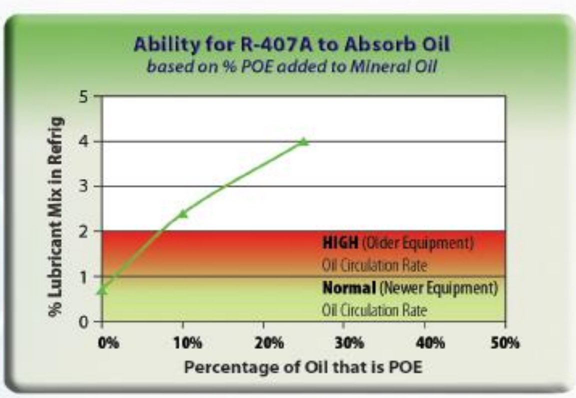
Oil Circulation:
National R-407A and National R-407C

National R-407A and **National R-407C** are HFC-based blends that require POE lubricants in the system to promote oil return.

However, National's laboratory testing* has shown:

- *After a single oil change, the remaining mineral oil mixed well with the added POE, and the combination circulated well with HFC refrigerants.*
- *Partial POE charges will circulate mineral oil better than hydrocarbon additives.*
- *Partial POE oil replacement should simplify the retrofit process for HFC refrigerants.*

Note: Check for any specific equipment or compressor manufacturer's recommendations prior to retrofitting. Field evaluations of this approach to retrofitting are in progress and are showing promising results.
* Data presented at ASHRAE seminars in Chicago (2006), New York (2008), and Salt Lake City (2008).



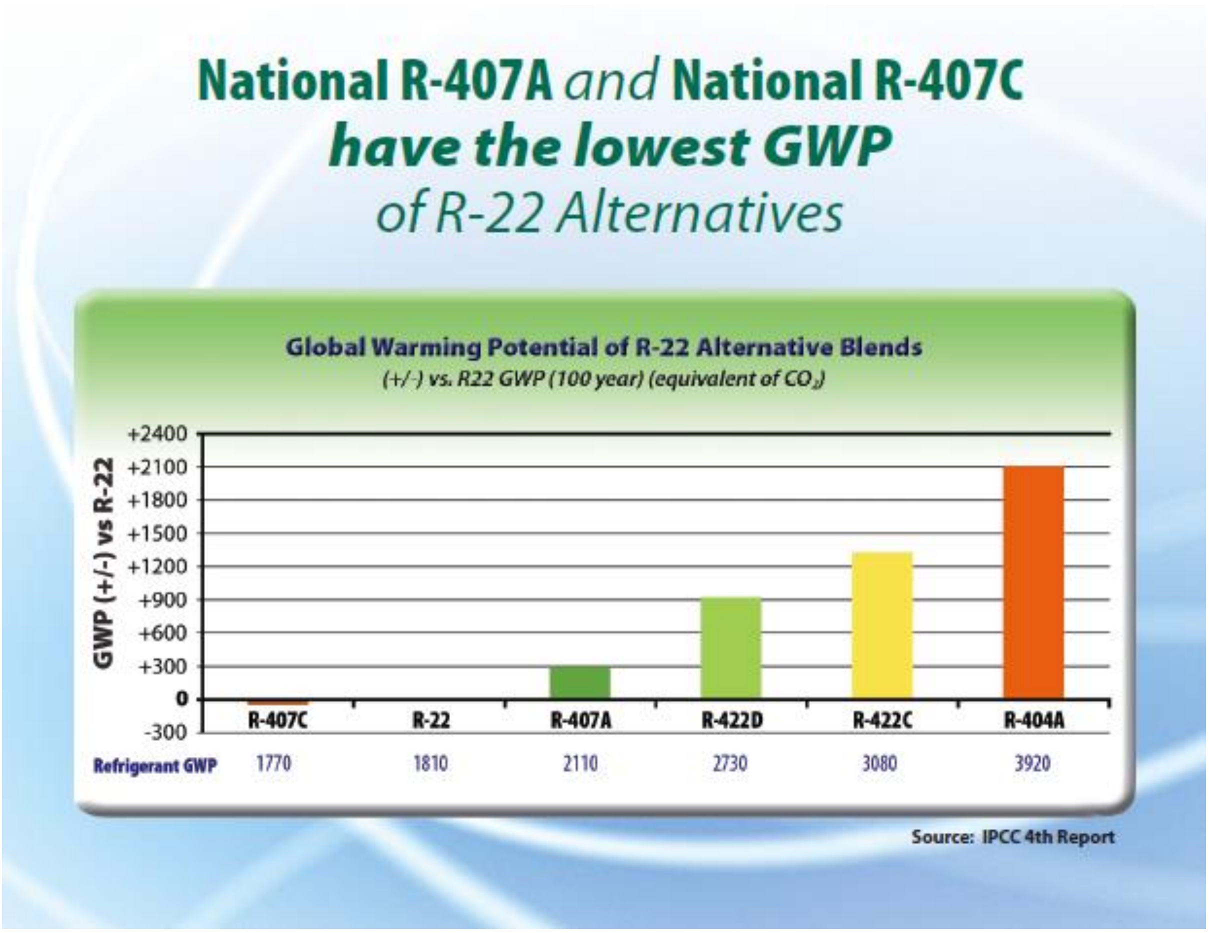
Source: ASHRAE Seminar Presentation. Salt Lake City, June 2008

TEMP (°F)	R-22	National R-407C Liquid (psig)	National R-407C Vapor (psig)
-40	0.6	2.7	2.3
-35	2.6	5.1	0.4
-30	4.9	7.7	1.6
-25	7.4	10.6	3.9
-20	10.2	13.7	6.5
-15	13.2	17.2	9.3
-10	16.5	20.9	12.3
-5	20.1	25.0	15.7
0	24.0	29.5	19.4
5	28.3	34.3	23.5
10	32.8	39.5	27.9
15	37.8	45.2	32.7
20	43.1	51.2	37.9
25	48.8	57.7	43.5
30	55.0	64.7	49.6
35	61.5	72.2	56.1
40	68.6	80.2	63.2
45	76.1	88.8	70.7
50	84.1	97.9	78.8
55	92.6	108	87.5
60	102	118	96.8
65	111	129	107
70	121	141	117
75	132	153	129
80	144	166	141
85	156	180	153
90	168	194	167
95	182	209	181
100	196	225	196
105	211	242	212
110	226	260	229
115	243	279	247
120	260	299	266

Values from NIST Refprop 8.0 — Red Figures (IN Hg) Vacuum

Unit 6:
Refrigerants

GWP of R-22 Alternative Blends



Unit 7:
EPA608 Prep

Fundamentals of Refrigeration

EPA608 Clean Air Act

EPA CERTIFICATION TRAINING

For Air Conditioning & Refrigeration Technicians - Federal Clean Air Act – 608

This presentation is designed to help technicians prepare for the EPA 608 Certification Exam.

This exam is offered regularly at locations throughout the nation and online.
You must pre-register for this exam.
When you pre-register, you will receive a study guide that will help you prepare for the exam.

Section 608 of the Federal Clean Air Act Requires

All persons who maintain, service, repair, or dispose of appliances that contain regulated refrigerants, be certified in proper refrigerant handling techniques.

If EPA regulations change after a technician becomes certified, it is the responsibility of the technician to comply with any future changes.

There are Four (4) Categories of Technician Certification

TYPE I

Persons who maintain, service or repair small appliances must be certified as Type I technicians.

TYPE II

Persons, who maintain, service, repair or dispose of high or very high-pressure appliances, except small appliances and motor vehicle air conditioning systems, must be certified as Type II technicians.

TYPE III

Persons, who maintain, service, repair, or dispose of low-pressure appliances must be certified as Type III technicians.

UNIVERSAL

Persons, who maintain, service or repair both low and high-pressure equipment, as well as small appliances, must be certified as Universal technicians.

TEST FORMAT

The test contains four sections, Core (A), I, II, III.

Each section contains twenty five (25) multiple-choice questions.

A technician MUST achieve a minimum passing score of 70 percent on the CORE and in each group in which they are to be certified. i.e.: 18 out of 25 questions in each section.

If a technician fails one or more of the Sections on the first try, they may retake the failed Section(s) without retaking the Section(s) on which they earned a passing score. In the meantime the technician will be certified in the Type for which they received a passing score.

WHAT IS REFRIGERATION

Heat is a form of energy. Refrigeration is the movement of heat from an area where it is not wanted to an area where it is less objectionable. For example, a refrigerator removes heat from the inside of the cabinet and transfers it to the outside.

PRESSURE / VACUUM

Pressure is defined as the force per unit area, most often described as pounds per square inch (U.S.).

ATMOSPERIC PRESSURE

Our atmosphere extends about 50 miles above the earth and consists of approximately 78% nitrogen, 21% oxygen, the remaining 1% is composed of other gasses. Even though the gas molecules are very small, they have weight. The atmosphere exerts a pressure of 14.7 lbs. per square inch at sea level. At higher altitudes, the atmospheric pressure will be significantly less. The most common method of measuring atmospheric pressure is the mercury barometer. Normal atmospheric pressure at sea level (14.7 psia) will support a column of mercury 29.92 inches high.

GAUGE PRESSURE
The pressure reading we most often use is called gauge pressure. Atmospheric pressure is shown as 0 psi or psig (pound per square inch *gauge*).

VACUUM
Pressures below atmospheric are usually read in inches of mercury (in. Hg) or in millimeters of mercury (mm Hg). A thorough understanding of vacuum principles is an absolute necessity for the air conditioning technician. Since an increase in pressure will increase the boiling point of a liquid, the opposite is also true. Lower pressure will result in a lower boiling point. Any pressure below atmospheric is considered a partial vacuum. A perfect vacuum would be the removal of all atmospheric pressure. For reading deep vacuum, a micron gauge is used. A micron is 1/1000th of a millimeter.

ABSOLUTE PRESSURE

The absolute pressure scale allows measurement of both vacuum and pressure to be made using the same units. Absolute pressure measurements are indicated as psia (pounds per square inch absolute). 0 psia is a pressure that cannot be further reduced. Since atmospheric pressure will measure 14.7 psia at sea level, gauge pressure can be converted to absolute pressure by adding 14.7 to the gauge pressure reading.

CORE
SECTION A
General Knowledge
Passing the CORE is a prerequisite to achieving certification

STRATOSPHERIC OZONE DEPLETION

The stratosphere is the Earth's security blanket. It is located between 10 and 30 miles above sea level and is comprised of, among other things, Ozone. An Ozone molecule consists of three oxygen atoms (0_3).

OZONE PROTECTS US FROM HARMFUL ULTRA- VIOLET RADIATION AND HELPS TO MAINTAIN STABLE EARTH TEMPERATURES

Depletion of Ozone in the Stratosphere Causes . . .
- Crop Loss
- Increase In Eye Diseases
- Skin Cancer
- Reduced Marine Life
- Deforestation
- Increased Ground Level Ozone

CFC’s & HCFC’s in the STRATOSPHERE
CFC's and HCFC's, when released into the atmosphere deplete the Ozone layer.
The chlorine in these compounds is the culprit. When a chlorine atom meets with an Ozone molecule, it takes one Oxygen atom from the Ozone. This forms a compound called Chlorine Monoxide (ClO) and leaves an O_2 molecule.

CHLORINE IS THE CULPRIT
Chlorine Monoxide will collide with another Ozone molecule, release its Oxygen atom, forming two O_2 molecules, and leave the chlorine free to attack another Ozone molecule. A single Chlorine atom can destroy 100,000 Ozone molecules!!!

SOURCE of CHLORINE in the STRATOSPHERE
Some believe that the Chlorine found in the stratosphere comes from natural sources such as volcanic eruptions. However, air samples taken over erupting volcanoes show that volcanoes contribute only a small quantity of Chlorine as compared to CFC's. In addition, the rise in the amount of Chlorine measured in the stratosphere over the past two decades matches the rise in the amount of Fluorine, which has different natural sources than Chlorine, over the same period. Also, the rise in the amount of Chlorine measured in the stratosphere over the past twenty years, matches the rise in CFC emissions over the same period.

Chlorine in CFC’s vs. Naturally Occurring Chlorine
The chlorine in **CFC's** will neither dissolve in water nor break down into compounds that dissolve in water, so they **do not rain out of the atmosphere** and return to earth. Naturally occurring chlorine will dissolve in water (humidity) and rain out of the atmosphere.

OZONE DEPLETION POTENTIAL
Ozone Depletion Potential (ODP) is a measurement of CFC's and HCFC's ability to destroy ozone. **CFC's have the highest ODP**. **HFC's** (R-134A) do not contain chlorine and **have no Ozone Depletion Potential.**

The Three (3) Primary Types of REFRIGERANTS CLEAN AIR ACT
The United States Environmental Protection Agency (EPA) regulates section 608 of the Federal Clean Air Act. Failure to comply could cost you and your company as much as **$37,500.00** per day, per violation and there is a **bounty** of up to **$10,000** to lure your competitors, customers and fellow workers to turn you in. Service technicians who violate Clean Air Act provisions may be fined, lose their certification, and may be required to appear in Federal court.

It is a Violation of Section 608 to:
- Falsify or fail to keep required records;
- Fail to reach required evacuation rates prior to opening or disposing of appliances;
- Knowingly release (vent) CFC's, HCFC's or HFC’s while repairing appliances, with the exception of de-minimus releases;
- Knowingly release (vent) CFC's, HCFC's or HFC’s while repairing appliances, with the exception of de-minimus releases;
- Vent CFC's or HCFC's since July 1, 1992;

It is a Violation of Section 608 to:
- Vent HFC's since November 15, 1995;
- Fail to recover CFC's, HCFC's or HFC’s before opening or disposing of an appliance;
- Fail to have an EPA approved recovery device, equipped with low loss fittings, and register the device with the EPA;
- Add nitrogen to a fully charged system, for the purpose of leak detection, and thereby cause a release of the mixture;
- Dispose of a disposable cylinder without first recovering any remaining refrigerant (to 0 psig.) and then rendering the cylinder useless, then recycling the metal;

STATE & LOCAL REGULATIONS
State & local governments may not pass regulations that are less strict than those contained in Section 608. They may pass regulations that are as strict or stricter than Federal regulations.

THE MONTREAL PROTOCOL
The Montreal Protocol is an international treaty. It regulates the production and use of CFCs, HCFC’s, halons, methyl chloroform and carbon tetrachloride. CFC's were phased out of production on December 31, 1995. HCFC refrigerants are scheduled of phase out in the future.
When virgin supplies of CFC's are depleted, future supplies will come from recovered, recycled, or reclaimed refrigerants.

RECOVERY
To remove refrigerant in any condition from an appliance and store it in an EXTERNAL CONTAINER.

RECOVERY & REUSE
Refrigerant that has been recovered from a unit (if it is not contaminated) may be reused in the unit from which it was removed. It may be reused in another unit so long as the equipment that it was removed from and the unit to which it is being introduced is owned by the same owner. This requirement is designed to prevent excessive cross-contamination.

RECYCLE
To clean refrigerant for reuse by separating the oil from the refrigerant and removing moisture by passing it through one or more filter driers

RECLAIM
To process refrigerant to a level equal to new product standards as determined by chemical analysis. Reclaimed refrigerant must meet standards set forth in ARI 700 before it can be resold.

RECOVERY DEVICES
Refrigerant Recovery and/or Recycling equipment manufactured after November 15, 1993, must be certified and labeled by an EPA approved equipment testing organization to meet EPA standards. There are two basic types of recovery devices.

1) *"System-dependent"* which captures refrigerant with the assistance of components in the appliance from which refrigerant is being recovered.
2) *"Self-contained"* which has its own means to draw the refrigerant out of the appliance (a compressor).

SALES RESTRICTION
As of November 14, 1994, the sale of CFC and HCFC refrigerants was restricted to certified technicians. Only technicians certified under Clean Air Act Section 609 (Motor Vehicle Air Conditioning) are allowed to purchase R-12 in containers smaller than 20 lbs.

SUBSTITUTE REFRIGERANTS & OILS

HFC's are considered Ozone friendly. R-134A is the leading candidate for CFC R-12 retrofit, but it is not a drop-in substitute. Actually, there is not a drop-in alternative, but R-134A can be used in most R-12 systems by following appropriate retrofit procedures.

HFC's will not mix with most refrigerant oils used with CFC's & HCFC's. The oils used in most HFC systems are ESTERS. Esters cannot be mixed with other oils. It is also important to remember that when leak testing an HFC system to use pressurized nitrogen.

REFRIGERANT BLENDS
There are several refrigerant blends commonly in use. Some of the blends are called **Ternary**, which means they are a **three-part blend**. Ternary blends are used with a **synthetic alkylbenzene oil**.

REFRIGERANT BLEND CHARGING
The components of a **blended refrigerant will leak** from a system **at uneven rates due to different vapor pressures.** Therefore, the proper **charging method** for blended refrigerants is to **weigh into the high side of the system as a liquid**.

TEMPERATURE GLIDE
Temperature glide refers to a refrigerant blend that has a **range of boiling points and / or condensing points** throughout the evaporator and condenser respectively.

Unit 7:
EPA608 Prep

Fundamentals of Refrigeration

EPA608 Clean Air Act

AZEOTROPIC REFRIGERANTS
An **azeotropic mixture acts like a single component** refrigerant over its entire temperature / pressure range. An azeotrope does not have a temperature glide.

HYGROSCOPIC OIL
Most refrigerant oils are hygroscopic. A Hygroscopic oil is one that easily absorbs & releases moisture (has a high affinity for **water).** An oil sample should be taken and analyzed if a system has had a major component failure.

RECOVERY and CUSTOMER RELATIONS
Some customers have complained about the increased cost of service. To justify the increase, simply explain that you are duty bound and required by law to recover refrigerants in order to protect the environment and human health.

EPA REQUIREMENT OF EQUIPMENT MANUFACTURERS
EPA regulations require a service aperture or process stub on all appliances that use a Class I or Class II refrigerant in order to make it easier to recover refrigerant.

MIXED REFRIGERANT RECOVERY
Do not mix refrigerants in a recovery cylinder. A refrigerant mix may be impossible to reclaim. If you discover that two or more refrigerants have been mixed in a system, you must recover the mixture into a separate tank. Badly contaminated and mixed refrigerants must be destroyed.

COMPRESSOR BURN-OUT
A strong odor is an excellent indicator of a compressor burn-out. If you suspect a compressor burn-out, flush the system & watch for signs of contamination in the oil. If nitrogen is used to flush debris out of the system, the nitrogen may be vented. A suction line filter drier should be installed to trap any debris that may damage the new compressor.

RECOVERY SPEED
Long hoses will reduce pressure resulting in increased recovery time. Since all refrigerants have a pressure temperature relationship, lower ambient temperatures, result in slower recovery rate.

DEHYRATION
To remove water and water vapor from a refrigeration system. If moisture is allowed to remain in an operating refrigeration system, hydrochloric & hydrofluoric acids may form. Evacuation of a system is the suggested method of dehydration. It is not possible to over evacuate a system.

EVACUATION
Never evacuate a system to the air without first following proper recovery procedures and attaining the mandated vacuum level.

EVACUATION ESSENTIALS for Accurate Readings & Speed
Vacuum lines should be equal to or larger than the pump intake connection. The piping connection to the pump should be as short a length as possible and as large in diameter as possible. The system vacuum gauge should be connected as far as possible from the vacuum pump.

EVACUATION SPEED & EFFICIENCY
FACTORS
- Size of equipment being evacuated
- Ambient temperature
- Amount of moisture in the system
- The size of the vacuum pump and suction line
- Heating the refrigeration system will decrease dehydration time

EVACUATION - Precautions

The use of a large vacuum pump could cause trapped water to freeze. During evacuation of systems with large amounts of water, it may be necessary to increase pressure by introducing nitrogen to counteract freezing.

COMPLETING THE DEHYRATION PROCESS

Measuring a system's vacuum should be done with the system isolated and the vacuum pump turned off. A system that will not hold a vacuum probably has a leak. Dehydration is complete when the vacuum gauge shows that you have reached and held the required finished vacuum.

MEASURING DEHYDRATION EFFECTIVENESS
It is impossible to determine dehydration effectiveness using a compound gauge that reads in inches of Hg *(MERCURY).* The use of a Micron Gauge & achieving 500 microns of vacuum assures proper dehydration.

RECOVERY CYLINDERS

Recovery cylinders are designed to be refilled. Recovery cylinders have 2 ports, one liquid and one vapor. They must not be overfilled or heated. Overfilling or heating can cause an explosion. NEVER heat a refrigerant cylinder with an open flame. The EPA requires that refillable refrigerant cylinders MUST NOT BE FILLED ABOVE 80% of their capacity by weight, and that the safe filling level can be controlled by either mechanical float devices, electronic shut off devices (thermistors), or weight. Refillable cylinders must be hydrostatically tested and date stamped every 5 years. Refillable cylinders used for transporting recovered pressurized refrigerant must be DOT (Department of Transportation) approved. Approved refrigerant recovery cylinders can easily be identified by their colors, YELLOW TOPS and gray bodies. All refrigerant recovery cylinders should be inspected for RUST. If they show signs of rust or appear to not be secure they should be reduced to 0 psig and discarded.

DISPOSABLE CYLINDERS
Disposable cylinders are used with virgin refrigerant and may NEVER be used for recovery.

SCHRADER VALVES
It is necessary to inspect Schrader valve cores for leaks, bends and breakage, & replace damaged valve cores to prevent leakage. Always cap Schrader ports to prevent accidental depression of the valve core.

PERSONAL SAFETY - WEAR
When handling and filling refrigerant cylinders, or operating recovery or recycling equipment, you should wear safety glasses and protective gloves.

NITROGEN PRESSURE–TESTING SAFETY
When pressurizing a system with nitrogen, you should:
Charge through a pressure regulator. Insert a relief valve in the downstream line from the pressure regulator. NEVER install relief valves in series. Replace the relief valve if corrosion is found within the body of a relief valve. To determine the safe pressure for leak testing, check the data plate for the low-side test pressure value.

OXYGEN & COMPRESSED AIR
When leak checking a system, NEVER pressurize the system with oxygen or compressed air. When mixed with refrigerants, oxygen or compressed air can cause an explosion.

SAFETY & LARGE REFRIGERANT LEAKS
If a "large" release of refrigerant in a confined area occurs; Self-Contained Breathing Apparatus (SCBA) is required. If SCBA is not available, IMMEDIATELY VACATE AND VENTILATE the area. In large quantities, refrigerants can cause suffocation because they are heavier than air and displace oxygen. Inhaling refrigerant vapors or mist may cause heart irregularities, unconsciousness, and oxygen deprivation leading to death (asphyxia).

REFRIGERANT SAFETY & OPEN FLAMES
NEVER expose R-12 or R-22 to open flames or glowing hot metal surfaces. At high temperatures, R-12 and R-22 decompose to form Hydrochloric acid, Hydrofluoric acid, and Phosgene gas. Always review the material safety data sheets, when working with any solvents, chemicals, or refrigerants.

SHIPPING & TRANSPORTATION
Before shipping used refrigerant cylinders, complete the shipping paperwork include the number of cylinders of each refrigerant, and properly label each cylinder with the type and amount of refrigerant. Cylinders should be transported in an upright position. Each cylinder must have a DOT classification tag indicating it is a "2.2 non-flammable gas".
Some states may require special shipping procedures to be followed based on their classification of used refrigerants. Check with the DOT in the state of origin.

Persons handling refrigerant during maintenance, service or repair of small appliances must be certified as either a Type I Technician or as a Universal Technician.

RECOVERY EQUIPMENT MANUFACTURED BEFORE NOVEMBER 15, 1993
Must be capable of removing 80% of the refrigerant, whether or not the compressor is operating, or achieve 4 inch vacuum under the conditions of ARI 740.

RECOVERY EQUIPMENT MANUFACTURED AFTER NOVEMBER 15, 1993
Must be certified by an EPA approved testing laboratory, (example, U.L. or E.T.L) as capable of recovering 90% of the refrigerant if the compressor is operating, 80% of the refrigerant if the compressor is not operating, or achieving a 4 inch vacuum under the conditions of ARI 740.

RECOVERY EQUIPMENT
All equipment must be equipped with low loss fittings that can be manually closed, or close automatically, when hoses are disconnected to minimize the refrigerant loss.

LEAK REPAIR REQUIREMENTS
Although leaks should be repaired whenever possible, the EPA does not require leak repair for small appliances.

RECOVERY TECHNIQUES
Self-Contained (Active) Equipment
Active recovery equipment stores refrigerant in a pressurized recovery tank. Before operating a self-contained recovery machine, open the tank inlet valve, and remove excessive non–condensables (air) from the recovery tank. An accurate pressure reading of refrigerant inside a recovery cylinder is required to detect excessive non-condensables. The only way to read refrigerant pressure accurately is at a stable, known temperature. Air in a refrigeration system will cause higher discharge pressures. Follow the operating instructions supplied by the recovery equipment manufacturer regarding purging of non-condensables. All refrigerant recovery equipment should be checked for oil level and refrigerant leaks on a daily basis.

RECOVERY TECHNIQUES
System-Dependent (Passive) Equipment

System-dependent recovery process for small appliances captures refrigerant into a non-pressurized container. These are special charcoal activated plastic “bag” containers. System-dependent equipment captures refrigerant with the assistance of the appliance compressor, an external heat source, or a vacuum pump. A standard vacuum pump can only be used as a recovery device in combination with a non-pressurized container. When using a system dependent recovery process on an appliance with an *operating compressor*, run the compressor and recover from the high side of the system. Usually, one access fitting on the high side will be sufficient to reach the required recovery rate, as the appliance compressor should be capable of pushing the refrigerant to the high side. Appliances with a *non-operating compressor*, access to both the low and high side of the system is necessary. In order to achieve the required recovery efficiency, it will be necessary to take measures to help release trapped refrigerant from the compressor oil, (heat and tap the compressor several times and/or use a vacuum pump). Because appliances with non-operating compressors can not always achieve desired evacuation rates utilizing system-dependent recovery equipment, the EPA requires technicians to have at least one self-contained recovery device available at the shop to recover refrigerant from systems with non-operating compressors. The exception to this rule is technicians working on small appliances only. System dependent devices may only be used on appliances containing 15 lbs. of refrigerant or less.

INSTALLING PIERCING TYPE ACCESS FITTINGS
Fittings should be leak tested before proceeding with recovery. It is generally recommended that solderless piercing type valves only be used on copper or aluminum tubing material. Fittings tend to leak over time and should not be left on an appliance as a permanent service port. After installing a fitting, if you find that the system pressure is 0 psig, do not begin the recovery process.

DEFROST HEATERS
If the appliance is equipped with a defrost heater, such as in a domestic frost-free refrigerator, operating the defrost heater will help to vaporize any trapped liquid refrigerant and will speed the recovery process.

DO NOT RECOVER
Refrigerators built before 1950 may have used Methyl Formate, Methyl Chloride, or Sulfur Dioxide as refrigerant and should not be recovered with current recovery devices. Small appliances used in campers or other recreational vehicles may use refrigerants such as Ammonia, Hydrogen, or Water, and therefore should not be recovered using current recovery equipment.

CHARGING CYLINDERS
When filling a graduated charging cylinder with a regulated refrigerant, the refrigerant vapor that is vented off the top of the cylinder must be recovered.

LEAK DETECTION
After installation of a system, pressurize the unit with nitrogen and leak check. In order to determine the general area of a leak use an electronic or ultrasonic leak detector. To pinpoint the leak use soap bubbles.

Leaking Systems
A refrigeration unit using an open compressor that has not been used in several months is likely to leak from the shaft seal.
During a visual inspection of any type of system, traces of oil are an indicator of a refrigerant leak. Excessive superheat, caused by a low refrigerant charge, is also an indication of a leak in a high-pressure system.

LEAK REPAIR REQUIREMENTS - Comfort Cooling
EPA regulations require that all comfort cooling appliances *(air conditioners)* containing more than 50 lbs. of refrigerant MUST be repaired when the annual leak rate exceeds 15%.

LEAK REPAIR REQUIREMENTS
Commercial & Industrial Process Refrigeration
EPA regulations require that all Commercial and Industrial Process Refrigeration containing more than 50 lbs. of refrigerant MUST be repaired when the annual leak rate exceeds 35%.
Commercial Refrigeration includes appliances used in the retail food and cold storage warehouse sectors, including equipment found in supermarkets, convenience stores, restaurants and other food establishments, and equipment used to store meat, produce, dairy products and other perishable goods. Industrial Process Refrigeration means complex customized appliances used in the chemical, pharmaceutical, petrochemical and manufacturing industries, including industrial ice machines and ice rinks.

EPA608 Clean Air Act

RECOVERY EQUIPMENT
Recovery equipment must be certified by an EPA approved laboratory (UL or ETL) to meet or exceed ARI standards.

RECOVERY REQUIREMENTS
Recovered refrigerants can contain acids, moisture, and oil. Frequently check and change both the oil and filter on a recycling machine. Recycling and recovery equipment using hermetic compressors have the potential to overheat when drawing a deep vacuum because the unit relies on the flow of refrigerant through the compressor for cooling. Before using a recovery unit you should always check the service valve positions, the recovery units oil level, and evacuate and recover any remaining refrigerant from the unit's receiver. When working with multiple refrigerants, before recovering and/or recycling a different refrigerant, purge the recover/recycle equipment by recovering as much of the first refrigerant as possible, change the filter, and evacuate. The only exception to this rule is for technicians working with R-134A who must provide a special set of hoses, gauges, vacuum pump, recovery or recovery/recycling machine, and oil containers to be used with R-134A only. Recovering refrigerant in the vapor phase will minimize the loss of oil, recovering as much as possible in the liquid phase can reduce recovery time. The technician may choose to speed up the recovery process by packing the recovery cylinder in ice and/or applying heat to the appliance. After recovering liquid refrigerant, any remaining vapor is condensed by the recovery system.

RECOVERY NOTES
Refrigerant should be placed in the receiver of units that have a receiver/storage tank. Refrigerant should be removed from the condenser outlet if the condenser is below the receiver. In a building that has an air-cooled condenser on the roof and an evaporator on the first floor, recovery should begin from the liquid line entering the evaporator. Always evacuate an empty recovery cylinder before transferring refrigerant (recovering) to the cylinder. After reaching the desired vacuum, wait a few minutes to see if the system pressure rises, indicating that there is still refrigerant in liquid form or in the oil. Appliances can be evacuated to atmospheric pressure (O psig) if leaks make evacuation to the prescribed level unattainable. The technician must isolate a parallel compressor system in order to recover refrigerant. Failure to isolate a parallel compressor system will cause an open equalization connection that will prevent refrigerant recovery. System-dependent recovery equipment cannot be used on appliances containing more than 15 pounds of refrigerant.

MAJOR REPAIR
Under EPA regulations, a "major repair" means any maintenance, service or repair involving the removal of any or all of the following components: the compressor, the condenser, the evaporator or an auxiliary heat exchanger coil.

REFRIGERANT TYPE
To determine the type of refrigerant used read the nameplate.

FILTER / DRIER
Filter driers will remove moisture from the refrigerant in a system, but there is a limit to their capacity. Some systems are equipped with a moisture indicating sight glass. When the sight glass changes color, the system contains excessive moisture and will need to be evacuated. The filter-drier should be replaced anytime a system is opened for servicing.

CRANKCASE HEATER
A crankcase heater is used to prevent refrigerant from migrating to the oil during periods of low ambient temperature. Refrigerant in the oil will cause oil foaming in the compressor at start-up.

WARNING
A hermetic compressor's motor winding could be damaged if energized when under a deep vacuum. NEVER energize a reciprocating compressor if the discharge service valve is closed.

LIQUID CHARGING
There is a risk of freezing during liquid charging of an R-12 refrigeration system. Begin with vapor from a vacuum level to a pressure of approximately 33 psig. Followed by a liquid charge through the liquid-line service valve. This is also the proper method to charge a system that contains a large quantity of refrigerant.

ASHRAE STANDARD 15
Requires a refrigerant sensor that will sound an alarm and automatically start a ventilation system in occupied equipment rooms where refrigerant from a leak will concentrate.

ASHRAE SAFETY CLASSIFICATION FOR REFRIGERANTS
CFC-11, CFC-12, and HFC-134a are all categorized as A-1.

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Absolute Zero Temperature: Temperature at which all molecular motion ceases. (-459.67 F. and -273.15 C.) Absolute zero, according to current scientific thought, is the lowest temperature that could ever be. In fact, it's so low that we can never quite reach it, although research teams have come within a fraction of a degree.

Absorption Refrigeration: A system in which a secondary fluid absorbs the refrigerant, releasing heat, then releases the refrigerant and reabsorbs the heat. Ammonia or water is used as the vapor in commercial absorption cycle systems, and water or lithium bromide is the absorber.

Accumulator: Storage tank which receives liquid refrigerant from the evaporator and prevents it from flowing into the suction line and entering the compressor.

Across the line Start: Using one contactor to start a three phase motor.

Alternating Current - AC: Electric current in which the direction of the flow is constantly being reversed back and forth. In the USA it changes polarity from positive to negative 60 times per second. In other countries, the rate of alternation is often 50 cycles per second .

Alumina: A substance in a drier used to collect and hold moisture in a refrigeration system.

Ambient Temperature: Temperature of a fluid (usually air) which surrounds an object on all sides.

Ammonia: R-117, Chemical combination of nitrogen and hydrogen

Amperage: The rate of flow of electricity through wire - measured in terms of amperes, very roughly analogous to gallons per minute flowing from a faucet.

Ampere: The unit of current. One ampere is the current flowing through one ohm of resistance at one volt potential. Analogous to gallons of water flow past a given point.

Brazed Plate Heat Exchangers: A hermetically sealed heat exchanger in which the heating surface consists of thin corrugated metal plates stacked on top of each other. Channels are formed between the plates and the corner ports are arranged so that the two media (water and/or refrigerant, or both) flow through alternate channels, always in counter-current flow. The media are kept in the unit by a brazed seal around the edge of the plates. The contact points of the plates are also brazed to withstand the pressure of the media handled. These heat exchangers are up to 60% smaller than traditional shell & tube and coaxial type devices. This means they use less space and weigh less.

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BTU: British Thermal Unit. Quantity of heat required to raise or lower the temperature of one pound of water one degree Fahrenheit. You might be able to imagine it this way. Take one gallon (8.33 pounds) of water and put it on your stove. If the water is 60 degrees F. and you want to bring it to a boil (212 degrees F.) then you will need about 1,200 BTUs to do this.

BTUH: British Thermal Unit per Hour. How many BTU's are used per hour.

Calorie: Quantity of heat required to raise or lower the temperature of 1 gram of water 1 degree Celsius.

Capillary Tubing: A refrigerant metering device consisting of a small diameter tube which controls flow by restriction. They are carefully sized by inside diameter and length for each particular application. This device uses it's internal diameter, length and pressure drop to determine it's capacity and has a fixed regulation. The capillary tubing is best suited in constant ambient conditions.

Capacitor: The simplest way to explain the mechanics of a capacitor would be to compare it to a battery. Both store and release electricity. Capacitors are charged with electricity, then releases its stored energy at a rate of sixty times per second in a 60 cycle alternating current system. The sizing is critical to motor efficiency just as sizing of batteries is critical to a radio. A radio that requires a 9V battery will not work with a 1.5V size battery. Thus, as the battery becomes weaker the radio will not play properly. A motor that requires a 7.5 µF capacitor will not work with a 4.0 µF capacitor. Much the same way, a motor will not run properly with a weak capacitor. This is not to imply bigger is better, because a capacitor that is too large can cause energy consumption to rise. In both instances, be it too large or too small, the life of the motor will be shortened due to overheated motor windings. Motor manufacturers spend many hours testing motor and capacitor combinations to arrive at the most efficient combination. There is a maximum of +10% tolerance in microfarad rating on replacement start capacitors, but exact run capacitors must be replaced. Voltage rating must always be the same or greater than original capacitor whether it is a start or run capacitor. Always consult manufacturers to verify correct capacitor size for the particular application. (source:Louisiana State University)

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Cascade System: Arrangement in which two or more refrigeration systems are used in series. The evaporator of one machine is used to cool the condenser of another. These are used in ultra low temperatures.

Celsius Scale: The Celsius temperature scale (°C) was developed by Anders Celsius in 1742. The zero point of the Celsius scale is set to the temperature at which water freezes. The number 100 is set to the temperature at which water boils. The Celsius scale is the standard scale used around most of the world to measure air temperatures. The United States uses the Fahrenheit scale.

Centigrade Scale: The Celsius temperature scale (°C) was developed by Anders Celsius in 1742. The zero point of the Celsius scale is set to the temperature at which water freezes. The number 100 is set to the temperature at which water boils. The Celsius scale is the standard scale used around most of the world to measure air temperatures. The United States uses the Fahrenheit scale.

CFC: Acronym for Chlorofluorocarbon. Any of various halocarbon compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as aerosol propellants and refrigerants. Chlorofluorocarbons are believed to cause depletion of the atmospheric ozone layer.

CFM: Cubic feet per minute. Volume rate of air flow.

Check Valve: Device which permits fluid flow in only one direction.

Coefficient of Performance - COP: Ratio of work performed or accomplished as compared to the energy used. This ratio is calculated by dividing the total heating capacity provided by the heat pump, including circulating fan heat but excluding supplementary resistance heat (Btu's per hour), by the total electrical input (watts) x 3.412.

Compound Refrigeration: An alternative to a cascade system, a Compound system uses two or more compressors connected in series in the same refrigeration cycle.

Compression Ratio: In refrigeration it is the ratio of the absolute low-side pressure to the absolute high-side pressure. To measure you would add 14.7 psi to the measured suction pressure and the head pressure. Then divide the high-side pressure by the low-side pressure.

Compressor: Pump of a refrigeration system which draws a low pressure on the cooling side of a refrigerant cycle and squeezes or compresses the gas into the high pressure or condensing side of the cycle.

Compressor - Centrifugal: A pump which compresses the refrigerant gas through the centrifugal force created by rotors spinning at high speed. In his effort to improve mechanical air-conditioning systems, Willis Havilland Carrier (1876–1950) introduced the first practical centrifugal refrigeration compressor in 1922.

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Compressor - Hermetic: A compressor which has the driving motor sealed inside the compressor housing. The motor operates in an atmosphere of the refrigerant. This style of compressor cannot be disassembled for maintenance. Common terms of describing a hermetic are; welded, can, pot and tin can.

Compressor - Multi-Stage: A compressor having two or more compressive steps. Discharge from each step is the intake pressure of the next in series.

Compressor - Open Drive: A compressor in which the crankshaft extends through the crankcase and is driven by an outside motor. Also called an external drive compressor.

Compressor - Reciprocating: A pump which uses a piston within a cylinder to provide compression. The principle of reciprocating mechanisms is hundreds of years old and the modern reciprocating compressor was undoubtedly driven from the research and development of the reciprocating steam engine.

Compressor - Rotary: A pump which uses vanes, eccentric mechanisms or other rotating devices to provide a pumping action. The first rotary compressor was introduced in 1957, permitting units to be smaller, quieter, weigh less, and more efficient than the reciprocating type.

Compressor - Screw: A screw compressor is a positive displacement machine that uses a pair of intermeshing rotors instead of a piston to produce compression. The rotors comprise of helical lobes affixed to a shaft. One rotor is called the male rotor and it will typically have four bulbous lobes. The other rotor is the female rotor and this has valleys machined into it that match the curvature of the male lobes. The principle of the screw compressor was first patented by Heinrich Krigar in Germany on March 24th 1878, patent number 4121. He modified and improved his designs later that year and lodged a second patent (number 7116) on August 16th 1878.

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Compressor - Scroll: A scroll compressor is a positive displacement machine that uses the compression action provided by two intermeshing scrolls - one fixed and the other orbiting. The orbiting scroll basically wobbles inside the fixed scroll, it doesn't rotate it just wobbles on a cam on crankshaft. The rotating scrolls intermesh quite closely and some manufacturers mention that efficiency increases as the scrolls bed into each other, indicating an initial wear process. The principle of the scroll compressor was developed during the early 1900's and was patented for the first time in 1905. Although the theory for the scroll compressor indicated a machine potentially capable of reasonably good efficiencies, at that time the technology simply didn't exist to accurately manufacture the scrolls. It was almost 65 years later that the concept was re-invented by a refrigeration industry keen to exploit the potentials of scroll technology.

Compressor - Semi Hermetic: A hermetic compressor that can be disassembled for maintenance. Usually made of cast iron.

Compressor - Tandem: A refrigeration system where two compressors are piped together having a common suction and discharge. In a Copeland semi-hermetic application, the motor end bells are removed and replaced with a connecting chamber with a suction valve mounted. Since each compressor may be operated individually, the tandem provides simple capacity reduction and maximum power savings.

Compressor - Two Speed: A compressor with a two speed motor providing capacity reduction and power savings.

Condense: Action of changing a gas or vapor to a liquid.

Condenser: The part of the refrigeration system which receives hot, high pressure refrigerant gas from the compressor and cools it until it returns to a liquid state.

Condensing Pressure: Pressure inside a condenser at which refrigerant vapor gives up its latent heat of vaporization and becomes a liquid. This varies with temperature.

Condensing Temperature: Temperature inside a condenser at which refrigerant vapor gives up its latent heat of vaporization and becomes a liquid. This varies with the pressure.

Contactor: A type of magnetically-operated device used for repeatedly establishing and interrupting an electrical power circuit. It is usually applied to devices controlling power above 5kW, whereas the term 'relay' is ordinarily employed below 5kW. The terms are often used interchangeably.

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Contactor - Definite Purpose: These contactors have been designed for specific applications where the operating conditions are clearly defined. The definite purpose contactors are usually rated for current alone and have less ability to handle inrush LRA current. They normally have a lower initial cost compared to general purpose contactors.

Contactor - General Purpose: These contactors are built for severe industrial use. They are usually designed for a minimum life of over 1,000,000 electrical cycles on most type of motor loads. General purpose contactors are listed by sizes that are generally related to motor horsepower groupings. They are also rated in current, a more useful rating for compressors. They usually conform to NEMA ratings.

Contactor - Resistive Rating: The resistive rating of a contactor is what the contactor has the capacity to withstand for brief surges of amp draw. Most contactors have a resistive rating as well as a motor rating. The resistive rating is higher in amperage value than the motor rating amperage value. This is because a resistive load is not called on to make and break motor current.

Convection Heat: Transfer of heat by means of movement or flow of a fluid or gas.

Coulomb: The quantity of electricity transferred by an electric current of one ampere in one second.

Crankcase Pressure Regulator - CPR: An outlet pressure regulator which maintains a predetermined maximum outlet pressure. Designed to prevent compressor motor overload. They were commonly used on low temp R-12 systems.

Cryogenics: Refrigeration which deals with producing temperatures of -250 F below zero and lower.

Cupronickel: An alloy of copper, nickel and strengthening impurities, such as iron and manganese. Cupronickel does not corrode in seawater because its electro negativity is adjusted to be neutral with regard to seawater. Because of this it is used for marine components, and sometimes for the propellers, crankshafts and hulls of premium tugboats, fishing boats and other working boats.

Definitions

Current: Transfer of electrical energy in a conductor by means of electrons changing position.

Current Relay: A device which opens or closes a circuit. It is made to act by a change of current flow in that circuit.

Defrost Control: A control which initiates the defrost cycle in the refrigeration cycle.

Defrost Cycle: Part of the refrigeration cycle in which evaporator frost and ice accumulation is melted. The use of electric heat strips or hot gas is the most common form. The defrost cycle also flushes any oil that is trapped in the evaporator back to the compressor. There should be a minimum of four defrost cycles per 24 hours to help with oil return.

Desiccant: A substance used in a drier to collect and hold moisture in a refrigeration system. Common desiccants are activated alumina and silica gel.

Desuperheat: The process of removing heat from superheated refrigerant. This is commonly done with a TXV or liquid line solenoid valve which injects liquid refrigerant into the compressor body for motor cooling.

Dew Point: Temperature at which vapor (at 100 percent humidity) begins to condense and deposit as liquid.

Differential: The temperature or pressure difference between cut-in and cut-out temperature or pressure of a control.

Direct Current - DC: Electric current in which the direction of the flow moves continuously in one direction. In a DC circuit, electrons emerge from the negative, or minus, pole and move towards the positive, or plus, pole. Nevertheless, physicists define DC as traveling from plus to minus.

Discharge Line: The high pressure, hot gas line coming out of the compressor.

Discus Valve: A hockey puck type discharge valve which minimizes refrigerant re-expansion volume common in reed valves. It is typically 10% more energy efficient than reed compressor technology. The geometry of a traditional reed compressor does not allow all the discharge gas to exit when the piston is at top dead center. This leads to re-expansion volume, which is especially prevalent in low temperature applications. The discus compressor valve minimizes the gap between the piston and the discharge valve, making re-expansion virtually zero. This results in the highest possible efficiency.

Definitions

Drier: A component of the refrigeration system with a substance used to remove moisture from the system. The first two numbers of a drier represent the cubic inch and the last number represents 1/8 of an inch. For example, 163-S indicates a 16 cubic inch capacity and 3/8 sweat. Without the "S" would represent a flare drier.

Dry Bulb Temperature: Air temperature as indicated by an ordinary thermometer.

Dry Ice: Refrigeration substance made of solid carbon dioxide which changes directly from a solid to a gas (sublimates). Its subliming temperature is -109 F (-78 C).

Electricity The flow of electrons in a circuit. The speed of electricity is the speed of light (approximately 186,000 miles per second). In a wire, it is slowed due to the resistance in the material. Its pressure, or force, is measured in "volts," and its flow, or current, is measured in "amperes" or simply "amps." The amount of work it produces is measured in "watts" (amps X volts).

Electrolysis: Movement of electricity through a substance which causes a chemical change in the substance or its container.

Electromotive Force - EMF: The term used to describe anything which behaves like an electrical pump. Batteries, generators, thermoelectric devices, solar cells, and piezoelectric crystals all do the same job in an electrical circuit: they pick conduction charges up at points of low potential energy and lift them up to high potential energy. If we imagine that current is positive charge in motion, then an emf pumps the current from low voltage up to high voltage. Unit of measurement is the volt.

Energy Efficiency Ratio - EER: The energy efficiency rating (EER) of an air conditioner is its BTU rating over its wattage. For example, if a 10,000-BTU air conditioner consumes 1,200 watts, its EER is 8.3 (10,000 BTU/1,200 watts). You would like the EER to be as high as possible, but normally a higher EER is accompanied by a higher price.

Enthalpy: Enthalpy is a measure of heat in a substance. Scientists figure out the mass of a substance when it is under a constant pressure. Once they figure out the mass, they measure the internal energy of the system. All together, that energy is the enthalpy. They use the formula "H = U + PV." H is the enthalpy value, U is the amount of internal energy, and P and V are Pressure and Volume of the system.

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Evaporator Pressure Regulator - EPR: An inlet pressure regulator which maintains a predetermined evaporator inlet pressure, regardless of sudden load or suction pressure changes. Commonly used on supermarket racks or multi-evaporator units maintaining different temperatures.

Evacuation: Removal of air and moisture from a refrigeration system. Blowing out lines with refrigerant will not remove trapped air or moisture in the system. Evacuation is the only means to remove contaminants in the system. Evacuating to 500 microns, or to the limits of the vacuum pump, is recommended.

Evaporation: Term applied to the changing of a liquid to a gas. Heat is absorbed in this process.

Evaporative Cooler: Alias, Swamp cooler. Nature's most efficient means of cooling is through the evaporation of water. Evaporative cooling works on the principle of heat absorption by moisture evaporation. The evaporative cooler draws exterior air into special pads soaked with water, where the air is cooled by evaporation, then circulated. Evaporative cooling is especially well suited where the air is hot and humidity is low.

Evaporator: A component of a refrigeration system in which saturated refrigerant absorbs heat and turns into a gas (superheated).

Expansion Valve - Automatic - AEV: The automatic expansion valve maintains a constant pressure in the evaporator by more or less flooding the evaporator surface, depending on the heat load of the cold chamber. The main disadvantage of this expansion valve is its relatively poor efficiency. It has been mainly used in applications where the cooling load is fairly constant and low evaporating pressures must be avoided. However, it is seldom used nowadays.

Expansion Valve - Balanced Port: In regular expansion valves the operating superheat varies due to an unbalance of pressure drop caused by changes of the head pressure and/or suction pressure. This unbalance can result in compressor flooding or evaporator starvation. The "Balanced Port" concept cancels the effect of this pressure unbalance, permitting the expansion valve to operate at a relatively constant superheat over a wide range of operation conditions.

Expansion Valve - Bi-Flow: This type TEV will meter refrigerant in either direction which makes it ideally suited for package heat pump applications. Bi-flow capability means reduced system complexity and resulting cost. (A single bi-flow TEV can replace 2 conventional TEV's and 2 check valves).

Expansion Valve - Electric - EEV: This type of valve is controlled by an electronic circuit which is often designed to allow the valve to control some aspect of system operation in addition to superheat at the outlet of the evaporator. For example, evaporator discharge air temperature or water temperature from a chiller could be monitored by the EEV's controller.

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Expansion Valve - External Equalized: This type TEV senses the suction pressure at the outlet of the evaporator to control the metering of refrigerant. These valves are not affected by pressure drop across the evaporator, including the refrigerant distributors, and may be used for all refrigeration applications. The external equalizer type valve must be used on evaporators which use a refrigerant distributor. It provides no operational disadvantages with the respect to an internally equalized valve other than requiring an external equalizer be connected. An external equalizer does not provide some means of equalizing the high and low side pressures during the off cycle. A separate internal bleed hole is required. The equalizer connection on the valve, usually 1/4", must not be capped!

Expansion Valve - Heat Pump: This type of expansion valve has a special power element charge. This charge assist the outside coil of air-to-air heat pumps using R-22 in providing 0 degree superheat, or "wet gas", back to the windings of hermetic heat pump compressors during very low outdoor temperatures.

Expansion Valve - Internal Equalized: This type TEV senses the suction pressure at the valve outlet to control the metering of refrigerant. Internally equalized valves should be limited to single circuit evaporator coils having a pressure drop no greater than the equivalent of a 2 degree F saturated temperature change.

Expansion Valve - Pressure Limited - MOP: This type TEV has a power element charge that causes the TEV to close above a predetermined evaporator pressure, thereby restricting flow to the evaporator and limiting the maximum evaporator pressure at which the system can operate. It may not be used on conjunction with a crankcase pressure regulator CPR).

Expansion Valve - Thermostatic - TEV: The thermostatic expansion valve regulates refrigerant flow by maintaining a nearly constant superheat at the evaporator outlet. The effect of this type of regulation is, it allows the evaporator to remain as nearly fully active as possible under all load conditions.

Fahrenheit Scale: The Fahrenheit scale (°F) was the first widely used temperature scale. It was developed in the early 1700s by G. Daniel Fahrenheit. The zero point of the Fahrenheit scale is attained by mixing equal parts of water, ice, and salt. Fahrenheit set the number 32 at the freezing point of water. He set the boiling point of water to 212 on his scale.

Fan Cycle Control: A control or device on an air cooled condenser which cycles the condenser fan(s) by means of pressure or temperature to maintain head pressure in low ambient conditions of 50 F or lower. This is required to control liquid refrigerant feed to the evaporator. The flow characteristics of expansion valves and capillary tubing are proportional to the pressure differential across them. Care must be taken when making adjustments to prevent short cycling. Short cycling is most likely to occur at ambient temperatures of 30 to 70 degrees F. Any fan cycle that is less than 5 minutes is considered short cycling. Fans should never cycle more than 10-12 cycles per hour. Short cycling is normally caused by too close a differential in the control setting. It is recommended that the lead fan, on multiple fan units, be wired to run continuously. If more control is required, add a flooded condenser control along with the fan cycling control.

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FLA - Full Load Amps: Changed in 1976 to "RLA - Rated Load Amps".

Flash Gas: Instantaneous evaporation of some liquid refrigerant in the evaporator which cools the remaining liquid refrigerant to desired evaporation temperature.

Flash Point: The lowest temperature at which a liquid gives off enough vapor to ignite when a source of ignition is present.

Flood Back: The results of liquid refrigerant from the evaporator entering the compressor. This situation will damage the compressor if preventive measures are not taken.

Flooded System: Type of refrigeration system in which liquid refrigerant fills most of the evaporator.

Foaming: Formation of a foam in an oil-refrigerant mixture due to rapid evaporation of the refrigerant dissolved in the oil. This is most likely to occur when the compressor starts and the pressure is suddenly reduced in the crankcase. In most circumstances a pump down solenoid valve and a crankcase heater would help prevent this. Compressor wear will be accelerated if nothing is done.

Freezer Burn: Condition applied to food stored in a freezer that has not been properly wrapped and has become hard, dry and discolored.

Freeze Up: Formation of ice in the TXV or any other control device which stops the flow of refrigerant. This happens when there is moisture in the system. Another form of freeze up is when frost forms on the evaporator and stops the airflow. This second condition will cause flood back.

Frost Back: A condition in which liquid refrigerant may be flowing from the evaporator into the suction line. It's usually indicated by sweating or frosting of the suction line.

Fusible Plug: A hollow plug of fitting filled with a metal with a low melting temperature. It is commonly used on a liquid receiver as a safety device to release pressure in case of a fire.

Gas: Vapor phase or stage of a substance.

Gas, Noncondensable: Gas which will not form into a liquid under the operating pressure-temperature conditions.

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Ground Wire: An electrical wire which will safely conduct electricity from a structure into the ground.

Halogens: Substance containing fluorine, chlorine, bromine and iodine.

HCFC: Acronym for Hydrochlorofluorocarbons which are halogenated compounds containing carbon, hydrogen, chlorine and fluorine. They have shorter atmospheric lifetimes than CFCs and deliver less reactive chlorine to the stratosphere where the "ozone layer" is found.

Head Pressure: The gauge pressure taken on a refrigeration system between the compressor discharge line and the metering device. The pressure may differ when measuring the liquid pressure verses the hot gas pressure.

Head Pressure Control: A pressure operated control which opens an electrical circuit if the high side pressure rises above a desired setting.

Heat: Energy transferred from one body to another as the result of a difference in temperature. Heat flows from a hotter body to a colder body when the two bodies are brought together. This transfer of energy usually results in an increase in the temperature of the colder body and a decrease in that of the hotter body. A substance may absorb heat without an increase in temperature as it changes from one phase to another—that is, when it melts or boils. The distinction between heat (a form of energy) and temperature (a measure of the amount of energy) was clarified in the 19th century by such scientists as J.-B. Fourier, Gustav Kirchhoff, and Ludwig Boltzmann.

Heat Exchanger: Any of several devices that transfer heat from a hot to a cold fluid.

Heat of Fusion: Heat released from a substance to change it from a liquid state to a solid state. The heat of fusion of ice is 144 Btu per pound.

Heat of Respiration: Process of taking in air for oxygen and releasing it to dispose of carbon dioxide. Plants and vegetables produce this heat when stored in a cooler and this heat must be calculated in with the total Btu/h load.

Heat Load: Amount of heat, measured in Btu or watts, which is removed during a period of 24 hours.

Heat Pump: A heat pump is a reversible A/C system that does mechanical work to extract heat from a cooler place and deliver heat to a warmer place. The heat delivered to the warmer place is, approximately, the sum of the original heat and the work done. Greater temperature differences between the warm and cold regions require greater amounts of work. In warm weather the heat pump acts like a traditional air conditioner, removing heat from the indoors and delivering heat to the outdoors. In cool weather, it removes heat from the outdoors and delivers heat to the indoors.

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Heat Transfer: Movement of heat from one body or substance to another. Heat may be transferred by radiation, conduction, convection or a combination of these three methods.

Hertz - Hz: Unit of frequency. The number of hertz (abbreviated Hz) equals the number of cycles per second. The frequency of any phenomenon with regular periodic variations can be expressed in hertz, but the term is used most frequently in connection with alternating electric currents. It is named for the German physicist Heinrich Hertz, born Feb. 22, 1857, died Jan. 1, 1894.

HFC: Acronym for Hydrofluorocarbon.

High Pressure Control: A pressure operated control which opens an electrical circuit if high side pressure becomes too high.

High Side: The part of a refrigeration system between the compressor discharge line and the metering device.

Horsepower: Common unit of power, the rate at which work is done. In the English system, one horsepower equals 33,000 foot-pounds of work per minute—that is, the power necessary to lift a total of 33,000 lbs a distance of one foot in one minute. This value was adopted by James Watt in the late 18th century after experiments with strong dray horses and is actually about 50% more than the rate an average horse can sustain for a working day.

Hot Gas Bypass: Basically, this is a regulator in a refrigeration system which bypasses hot gas entering the the condenser into the the suction line or the evaporator inlet, to prevent the compressor suction pressure from falling below a desired setting. This is used when the load varies over a wide range.

Humidity: The concentration of water vapor in the air.

IAQ: Indoor air quality.

Insulation: Any material that is a poor conductor of heat or electricity, and that is used to suppress the flow of heat or electricity.

Definitions

Kelvin Scale: The Kelvin temperature scale (K) was developed by Lord Kelvin in the mid 1800s. The zero point of this scale is equivalent to -273.16 °C on the Celsius scale. This zero point is considered the lowest possible temperature of anything in the universe. Therefore, the Kelvin scale is also known as the "absolute temperature scale". At the freezing point of water, the temperature of the Kelvin scale reads 273 K. At the boiling point of water, it reads 373 K.

Kilowatt: Unit of electrical power equal to 1000 watts.

King valve: Liquid receiver service valve. This valve may be a horizontal or, more commonly, a vertical type.

Latent Heat: The heat given off or absorbed when a material melts or freezes, or boils or condenses. For example, when ice is heated, once the temperature reaches +32 F (0 C), it's temperature won't increase until all the ice is melted. The ice has to absorb heat in order to melt. But even though it's absorbing heat, it's temperature stays the same until all the ice has melted. The heat required to melt the ice is called the latent heat. The water will give off the same amount of latent heat when you freeze it.

Liquid Line: The line containing the high pressure, subcooled liquid refrigerant starting at the outlet of the condenser which continues to the inlet of the metering device.

Low Ambient Control: A control or device on an air cooled condenser which maintains head pressure in low ambient conditions of 50 F or lower, which is required to control liquid refrigerant feed to the evaporator. The flow characteristics of expansion valves and capillary tubing are proportional to the pressure differential across them. Commonly used controls are; fan cycling, flooded condenser valves, fan speed controls, power operated inlet air shutters or a water regulating valve on a water cooled system.

Low Pressure Control: A pressure operated control which opens an electrical circuit if the low side pressure falls below a desired setting.

Low Side: The part of a refrigeration system between the outlet of the metering device and the inlet of the compressor.

LRA - Locked Rotor Amps: It's the current you can expect under starting conditions when you apply full voltage. It occurs instantly during start up.

Maximum Fuse Size: 225% of RLA.

MBH Thousands of British Thermal Units (Btu). 82 MBH = 82,000 Btu.

http://www.hvacrinfo.com/definitions.htm

Unit 8:
Terminology

Definitions

MCC - Maximum Continuous Current: A motor protection value that is 156% of the established rated load current. Used to comply with U.L. and N.E.C. requirements that a motor compressor protection system will not permit a continuous current in excess of 156% of the rated load amps.

Megohm: A unit of resistance equal to one million ohms.

Metering Device: A metering device is installed at the inlet of the evaporator. It creates a pressure drop from the high side liquid refrigerant to the low side evaporator. The metering device can be an expansion valve, capillary tube, piston or even a manual valve.

Microfarad: The microfarad (symbolized µF) is a unit of capacitance, equivalent to 1/1,000,000 farad (0.000001 (10 to the -6th power).

Micron Gauge: Instrument for measuring vacuums very close to a perfect vacuum.

Miscibility: Liquids that are capable of being mixed. In order for oil to return to the compressor properly, the oil and refrigerant must be miscible (dissolve) in each other.

Modulating: Type of device or control which tends to adjust by increments (minute changes) rather than by either "full on" or "full off" operation.

Moisture Indicator: A liquid line sight glass that has a visible indicator which changes color to determine the moisture content of the refrigerant.

Motor, Four Pole: A 1725 RPM motor. A four-pole motor operating on the bench under no-load conditions runs at 1,800 RPM. When the motor is loaded, the spinning magnetic field in the stator does not change speed. Instead, the rotor or moving part of the motor is restrained by the load from “catching up” to the field speed. The difference between the field speed of 1,800 RPM and the rotor speed of approximately 1,725 RPM is called the “slip.”

Motor, PSC: A "psc motor" stands for "permanent split capacitor motor." All single phase motors have a problem starting, unlike three-phase motors. A PSC motor has a run capacitor connected between the run and start windings of the motor. The run capacitor creates a "phase shift" which is all that's needed to achieve a little magnetic field rotation to start the rotor moving.

http://www.hvacrinfo.com/definitions.htm

Definitions

Motor, Shaded Pole: These motors have only one main winding and no start winding. Starting is accomplished through a design that uses a copper ring around a small portion of each motor pole. This "shades" that portion of the pole, causing the magnetic field in the ringed area to lag the field in the non-ringed portion. The reaction of the two fields initiates rotation. Since it lacks a start winding, starting switch, or capacitor, the shaded pole motor is electrically very simple and inexpensive. Speed can be controlled by varying the voltage. These motors offer poor starting torque, typically 25 to 75 percent of rated load, and very low efficiency. These motors typically are up to 1/8 horsepower and have sleeve bearings.

Motor, Six Pole: A 1175 RPM Motor. A six-pole motor operating on the bench under no-load conditions runs at 1,200 RPM. When the motor is loaded, the spinning magnetic field in the stator does not change speed. Instead, the rotor or moving part of the motor is restrained by the load from "catching up" to the field speed. The difference between the field speed of 1,200 RPM and the rotor speed of approximately 1,175 RPM is called the "slip."

Motor, Split Phase: The split phase motor is mostly used for "medium starting" applications. It has start and run windings, both are energized when the motor is started. When the motor reaches about 75% of its rated full load speed, the starting winding is disconnected by an automatic switch.

Motor, Two Pole: A 3450 RPM Motor. A two-pole motor operating on the bench under no-load conditions runs at 3,600 RPM. When the motor is loaded, the spinning magnetic field in the stator does not change speed. Instead, the rotor or moving part of the motor is restrained by the load from "catching up" to the field speed. The difference between the field speed of 3,600 RPM and the rotor speed of approximately 3,450 RPM is called the "slip."

Motor Burnout: Condition in which the insulation on an electric motor has deteriorated due to overheating. If a compressor does burn out, the oil becomes extremely acidic. If all this acid is not removed when the compressor is replaced, the elevated acid levels will attack the new compressor and cause another compressor motor burn-out.

Mullion Evaporator Coil: An evaporator that mounts behind the frame member (mullion) between two doors. This type coil is a space saver and mounts vertically behind the mullion. This allows for more space for the shelves or drawers in an under counter reach in cooler.

Nonferrous: A group of metals and metal alloys which contain no iron.

http://www.hvacrinfo.com/definitions.htm

Definitions

Ohm: A unit of measurement of electrical resistance. One ohm exists when one volt causes a flow on one ampere.

Ohm's Law: The relationship between the volt, the ampere and the ohm discovered by German physicist George Simon Ohm in 1827. It is stated as follows: E = I x R, Where E = volts, I = amps and R = ohms.

Oil Separator: A device used to remove oil from gaseous refrigerant and return it to the compressor.

Overload Protector: A device, usually temperature or current operated, which opens a circuit to stop the operation of unit if dangerous conditions arise.

Ozone: A nearly colorless (but faintly blue) gaseous form of oxygen, with a characteristic odor like chlorine. Ozone is found in trace quantities in the Earth's atmosphere at all times, primarily in the stratosphere between heights of about 7 and 33 miles (the ozonosphere or ozone shield) where its production results from photochemical processes involving ultraviolet radiation. Its maximum concentration occurs between 13 and 17 miles. In the lower atmosphere, ozone is commonly formed as a product of electrical discharges through the air.

Ozone Layer: A region of the upper atmosphere, between about 10 to 20 miles in altitude, containing a relatively high concentration of ozone that absorbs solar ultraviolet radiation in a wavelength range not screened by other atmospheric components. Also called ozonosphere.

Part Wind Start: Using two contactors to start a three phase motor.

Peltier Effect: In 1834 French scientist Jean Peltier noted that when an electrical current is applied across the junction of two dissimilar metals, heat is removed from one of the metals and transferred to the other. This is the basis of thermoelectric refrigeration.

Potential Relay: A device which opens or closes a circuit. It is made to open on high voltage and close on low voltage.

PSI: Acronym for "pounds per square inch".

PSIA: Acronym for "pounds per square inch absolute". Absolute pressure equals gauge pressure plus atmospheric pressure (14.7 psi).

PSIG: Acronym for "pounds per square inch gauge". The "G" indicates that it is gauge pressure and not absolute pressure.

http://www.hvacrinfo.com/definitions.htm

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Definitions

Psychrometer: Also called a hygrometer, an instrument for measuring the relative humidity of air.

Psychometric Chart: Shows the relationship between air volume, temperature, and relative humidity and is used to calculate specific humidity (gpp), dew point (wet bulb temp.), and vapor pressure.

Pump Down: The act closing off the liquid line, with a solenoid valve, when the thermostat is satisfied in a refrigeration system. The compressor then pumps the refrigerant into a receiver tank. It is important that a pump down be installed to prevent liquid refrigerant from trapping in the evaporator which may flood the compressor on start up or migrate to the compressor during the off cycle.

Radiant Heat: Transfer of heat by heat rays.

Receiver: A cylinder (tank) connected to the condenser outlet for storage of liquid refrigerant in the system.

Refrigerant: A refrigerant is a compound used in a heat cycle that undergoes a phase change from a gas to a liquid and back.

Refrigeration: The function of a refrigeration system is to remove heat from a place where it is not wanted (conditioned space) and reject it into another place where the heat is unobjectionable (outside the conditioned space). Refrigeration systems are closed systems; that is, they are sealed from the atmosphere.

Register: Combination grille and damper assembly covering an air opening or the end of an air duct.

Relative Humidity: Humidity is a state of (usually invisible) moisture in the air; relative humidity (RH) is the amount of moisture in a given volume of air as compared to the amount that it is capable of holding, and measured as a percentage; if the RH is 30 percent, that means the air is holding 30 percent of the moisture it is capable of holding; as air temperature increases, so does the air's capacity to hold moisture; if the air temperature rises and its moisture content (humidity) stays the same, then the relative humidity becomes a lower percentage; when the temperature inside a building is raised, as so often is the case in the winter, the RH indoors will drop; the only way to re-establish the proper RH is to add moisture to the air (the function of a humidity).

Relay: A type of electro magnetically operated device used for repeatedly establishing and interrupting an electrical power circuit. It is usually applied to devices controlling power below 5kW, whereas the term 'contactor' is ordinarily employed above 5kW. The terms are often used interchangeably.

Relay, Start: An electrical device which connects and/or disconnects the start windings of an electric motor.

http://www.hvacrinfo.com/definitions.htm

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Definitions

Relief Valve: A safety device on a sealed system. It opens to release pressure when a dangerous pressure is reached.

Resistance: A material's opposition to the flow of electric current; measured in ohms.

Reverse Cycle Defrost: Method of heating the evaporator for defrosting ice buildup. Valves move hot gas from the compressor into the evaporator.

Reversing Valve: A component of a heat pump that reverses the refrigerant's direction of flow, allowing the heat pump to switch from cooling to heating or heating to cooling.

RLA: Acronym for "rated load amps". The maximum current a compressor should draw under any operating conditions. Often mistakenly called running load amps which leads people to believe, incorrectly, that the compressor should always pull these amps. You should never use the listed RLA to determine if the compressor is running properly or to condemn a compressor. The running amps of a compressor are determined by the evaporator temperature, condensing temperature and the line voltage.

Rotor: The rotating or turning part of a motor.

RPM: Acronym for "rounds per minute".

Run Time - Refrigeration Equipment: The amount of time a condensing unit is run per hour or per 24 hours. A cooler is normally sized for 16 hours and a freezer 18 hours.

Run Winding The electrical winding of a motor which has current flowing through it during the normal operation of the motor.

Saturated Refrigerant: The state of refrigerant when it is a combination of gas and liquid (bubbles) It will either condense or evaporate at this condition.

Seasonal Energy Efficiency Ratio - SEER: This is a rating system used to establish the efficiency level of cooling equipment. The higher the SEER rating, the less electricity the equipment uses and the more efficient it is. SEER is determined by dividing the cooling capacity, measured in BTU/h, of a continuously operating air conditioner by the electric power unit, measure in WATTs, of power consumed.

http://www.hvacrinfo.com/definitions.htm

Definitions

Sensible Heat: The heat absorbed or transmitted by a substance during a change of temperature which is not accompanied by a change of state.

Service Valve: A manually operated valve mounted on a refrigeration system, normally the compressor, which is used for checking the pressures.

Service Factor: Service factor is a multiplier that is applied to the motor's normal horsepower rating to indicate an increase in power output (or overload capacity) that the motor is capable of providing under certain conditions. Common values of service factor are 1.0, 1.15, and 1.25.

Shell and Tube Condenser: This type of condenser consists of a shell (a large tube) with a series of small tubes inside it. Water flows through the tubes and refrigerant flows through the shell. Heat is transferred from the refrigerant to the water.

Short Cycling: A compressor that starts and stops more frequently than it should. The results of short cycling is usually a burned overload or defective start components.

Sight Glass: An indicator with a glass window, normally installed in the liquid line, which indicates the presence of gas bubbles. Some styles have a visible indicator which changes color to determine the moisture content of the refrigerant.

Silica Gel: A substance used to collect and hold moisture in a refrigeration system.

Single Phase: Producing, carrying, or powered by a single alternating voltage.

Sling Psychrometer: The simplest hygrometer - a sling psychrometer - consists of two thermometers mounted together with a handle attached on a chain. One thermometer is ordinary. The other has a cloth wick over its bulb and is called a wet-bulb thermometer. When a reading is to be taken, the wick is first dipped in water and then the instrument is whirled around. During the whirling, the water evaporates from the wick, cooling the wet-bulb thermometer. Then the temperatures of both thermometers are read. If the surrounding air is dry, more moisture evaporates from the wick, cooling the wet-bulb thermometer more so there is a greater difference between the temperatures of the two thermometers. If the surrounding air is holding as much moisture as possible - if the relative humidity is 100% - there is no difference between the temperatures. A chart is then used to check the differences for each degree of temperature so that the observer can find relative humidity easily.

http://www.hvacrinfo.com/definitions.htm

Unit 8:
Terminology

Fundamentals of Refrigeration

Definitions

Slugging: Liquid slugging is a condition which occurs when liquid refrigerant is allowed to enter the compressor cylinders. This could be the results of flood back during the run cycle or migration during the off cycle.

Solenoid Valve: An electromechanical valve (for use with liquid or gas) controlled by running (or stopping) an electrical current through a solenoid coil, which either closes or opens the valve. The most common use is when a normally closed valve is used on the liquid line for pump down.

Specific Gravity: The weight of a substance compared with the weight of an equal volume of pure water at 39 degrees Fahrenheit.

Specific Heat: The quantity of heat, expressed in Btu, required to raise the temperature of 1 lb of a substance 1°F.

Split System: A refrigeration or A/C system which places the condensing unit outside or away from the evaporator.

Start Winding: The electrical winding of a motor which has current flowing through it briefly while the motor is starting.

Stator: The stationary part of an electric motor.

Steam: Water in the vapor state, as when you boil water.

Subcooled Refrigerant: Cooling of liquid refrigerant below its condensing temperature.

Sub cooler: A component of a refrigeration system or a section of the condenser in which the temperature of the condensed refrigerant liquid is reduced. This improves the energy efficiency.

Sublimation: The condition where a substance changes from solid to a gas without becoming a liquid, dry ice for example.

Suction Line: The low pressure refrigerant gas line between the outlet of the evaporator and the inlet of the compressor.

http://www.hvacrinfo.com/definitions.htm

Definitions

Superheat: The term used to describe the difference between the vapor point (ie. taking suction pressure and converting it to temperature using a pressure temperature chart) and the actual temperature of the refrigerant exiting the evaporator coil.

Superheated Refrigerant: The temperature of refrigerant vapor above its boiling point as a liquid for that refrigerant. For example; Any increase in temperature of steam above it's boiling point (212 degrees) is called "superheat". Steam at 220 degrees F is superheated by 8 degrees F.

Swamp Cooler: Slang name for an evaporative cooler. Nature's most efficient means of cooling is through the evaporation of water. Evaporative cooling works on the principle of heat absorption by moisture evaporation. The evaporative cooler draws exterior air into special pads soaked with water, where the air is cooled by evaporation, then circulated. Evaporative cooling is especially well suited where the air is hot and humidity is low.

TD: Temperature difference.

Temperature: Temperature is the property that gives physical meaning to the concept of heat. If an object is cold, we say it has a low temperature. If it is hot, we say it has a high temperature. It can also be observed that if a hot poker is plunged into cold water, the poker becomes cooler and the water becomes warmer. This means that the hot body gives up some of its heat to the cold body.

TEV: Acronym for "thermostatic expansion valve" which regulates refrigerant flow by maintaining a nearly constant superheat at the evaporator outlet. The effect of this type of regulation is, it allows the evaporator to remain as nearly fully active as possible under all load conditions.

Thermistor: A resistor whose resistance changes with temperature. Because of the known dependence of resistance on temperature, the resistor can be used as a temperature sensor.

Thermocouple: Two dissimilar metals connected at a point, that produce an electrical current when heated.

Thermodisk: A thermodisk is a temperature sensing device. When heat is applied to the disk, a bi-metal plate will bend. This will either make or break an electrical flow.

http://www.hvacrinfo.com/definitions.htm

Definitions

Thermodynamics: In general, the relationships between heat and other properties such as temperature, pressure, density, etc.

Thermoelectric Refrigeration: In 1834 French scientist Jean Peltier noted that when an electrical current is applied across the junction of two dissimilar metals, heat is removed from one of the metals and transferred to the other. This is the basis of thermoelectric refrigeration. Thermoelectric refrigeration uses a cold junction, a heat sink and a DC power source. The refrigerant in both liquid and vapor form is replaced by two dissimilar conductors. The cold junction (evaporator surface) becomes cold through absorption of energy by the electrons as they pass from one semiconductor to another, instead of energy absorption by the refrigerant as it changes from liquid to vapor. The compressor is replaced by a DC power source which pumps the electrons from one semiconductor to another. A heat sink replaces the conventional condenser fins, discharging the accumulated heat energy from the system. A thermoelectric cooling system refrigerates without use of of mechanical devices, except perhaps in the auxiliary sense, and without refrigerant.

Thermostat: A device used to switch electrical current at a selectable set point temperature.

Three Phase: Producing, carrying, or powered by a three electrical circuits.

Ton of Refrigeration: Refrigeration effect equal to the melting of 1 ton of ice in 24 hours. This may be expressed as 12,000 Btu/24 hour.

Transducer: Any device that converts one form of energy into another form of energy, specifically when one of the quantities is electrical. Thus, a loudspeaker converts electrical impulses into sound (mechanical impulses), a microphone converts sound into electrical impulses, a solar cell converts light into electricity, etc.

Transformer: An electrical device that either raises or lowers the voltage of electricity.

Transformer, Buck and Boost: An electrical device that raises the voltage of electricity.

Transistor: Transistors are tiny electrical devices that can be found in everything from radios to robots. They have two key properties: 1) they can amplify an electrical signal and 2) they can switch on and off, letting current through or blocking it as necessary.

Tube in Tube Condenser: A water cooled condensing unit in which a small tube is placed inside a larger tube. Refrigerant passes through the outer tube and water through the inner tube, usually in a counter flow way which produces a better heat transfer.

TXV: A common slang term, used in the refrigeration industry, for a thermostatic expansion valve.

http://www.hvacrinfo.com/definitions.htm

Definitions

Ultraviolet: The invisible rays of the spectrum of light which are at its violet end. Sometimes abbreviated UV.

Vacuum: Vacuum is a pressure lower than atmospheric, except in outer space. Vacuums occur only in closed systems.

Valve Platea plate containing the suction and discharge valves that is mounted between the head and deck of a semi hermetic compressor.

Vapor: The gaseous form of any substance.

Vapor Barrier: A material with a high resistance to vapor movement, such as foil, plastic film, or specially coated paper, that is used to control condensation or prevent migration of moisture.

Vapor Lock: Rapid formation of vapor in lines, that causes a restriction in flow. Vapor formation begins to occur in lines when the medium reaches a temperature where the vapor pressure of the medium is equal to the pressure in the system.

Velocity: An object's speed and direction of motion.

Voltage: Electrical pressure which causes current to flow.

Volt: Basic unit of electrical potential. One volt is the force required to send one ampere of electrical current through a resistance of one ohm.

http://www.hvacrinfo.com/definitions.htm

Definitions

Water valve: A manual or electrical operated valve which provides a flow of water.

Watt: A watt is a unit of power equal to one joule of energy per second. The watt was named for the Scottish engineer and inventor James Watt (1736-1819).

Wax: An ingredient in some lubricating oils which may separate from the oil if cooled enough.

Wet Bulb: A device used in measuring relative humidity. Evaporation of moisture lowers the temperature of wet bulb compared to dry bulb temperature of the same air sample.

Wet Bulb Temperature: The lowest temperature that can be obtained by evaporating water into the air at constant pressure. Wet bulb temperatures can be used along with the dry bulb temperature to calculate dew point or relative humidity.

Unit 9:
Extras

Fundamentals of Refrigeration

Additional Hands On Exercises

❑Calculate superheat on a unit
❑Calculate Subcooling on a unit
❑Charge a unit with refrigerant
❑Braze a copper line
❑Recover refrigerant using a recovery machine
❑Purge a system with a vacuum pump
❑Use refrigerant scales
❑Change a condenser fan motor
❑Change an evaporator fan motor
❑Straighten a fan blade
❑Check voltage at a wall outlet
❑Check voltage at a circuit breaker
❑Perform lock-out tag-out on a unit
❑Find a service manual for a unit on the internet
❑Look up parts for a unit
❑Check amperage on a unit
❑Identify a recovery cylinder
❑Light a propane torch
❑Operate an oxy-acetylene torch
❑Identify copper fittings
❑Swage copper tubing
❑Flare copper tubing

Helpful Websites

- www.khanacademy.com
- www.danfoss.com
- www.yellowjacket.com
- www.graycoolingman.com
- www.engineeringtoolbox.com
- www.achrnews.com
- www.refrigerants.com
- www.epatest.com
- www.escogroup.org
- www.hvactrainingsolutions.com

CFEST

Commercial Food Equipment Service Technician

Hydraulics & Pneumatics

Fundamentals of Fluid Power

Introduction to Fluid Power in the Food Service Equipment

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Hydraulics & Pneumatics

Fundamentals of Fluid Power

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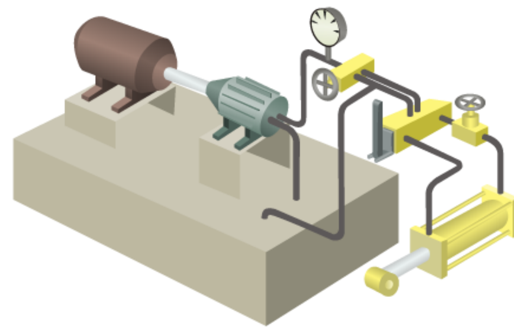
Hydraulics & Pneumatics

Unit 1: Introduction to Fluid Power

Fundamentals of Fluid Power

What is Fluid Power?

What is fluid power?
A fluid power system is any system that uses a liquid or a gas to transmit energy throughout the system.


wisc-online.com

Hydraulics
Hydraulic systems use fluid like oil to transmit energy to accomplish some sort of work.

Pneumatics
Pneumatic systems use air or gas to transmit energy to accomplish some sort of work.

The earliest fluid used was water hence the name hydraulics was applied to systems using liquids. In modern terminology, hydraulics implies a circuit using mineral oil and pneumatics implies a circuit using air.

Typically fluid is thought of as a liquid but gas is also considered to be a fluid so the category of fluid power includes Hydraulics (which uses liquid as its medium) and pneumatics (which uses gas or air as its medium).

Hydraulic Applications


De.Wikipedia.com


Safetymoment.net


Wiki.electrolab.fr


Flickr.com

Some applications of hydraulics:

- Earth moving equipment
- Forklifts
- Vehicle lifts
- Cardboard bailers

Pneumatic Applications


Commons.Wikimedia.org


Dcprops.com


Indiamart.com

Totalapex.com

Some applications of pneumatics:

- Air tools
- Props
- Robotics
- Syrup pumps

Blaise Pascal

Blaise Pascal, Mathematician/Philosopher

- **Born:** 19 June 1623
- **Birthplace:** Clermont-Ferrand, France
- **Died:** 19 August 1662
- **Best Known As:** 17th century mathematical genius

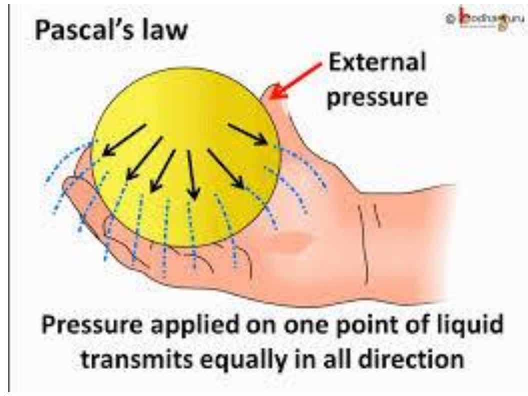
A prodigy in math, Blaise Pascal was a contemporary and rival of René Descartes. In spite of years of ill health and a short life, Pascal accomplished quite a bit: he published a significant work on the geometry of conical sections when he was only sixteen; he invented a calculating machine by the time he was nineteen; he and Pierre de Fermat founded the modern theory of probability; he described the principle that is the basis for the hydraulic press (called Pascal's Law); and he proved that there was a vacuum above the atmosphere. Pascal had a religious conversion in the 1650s and devoted himself to religion instead of science.

Pascal's scientific contributions include the principle of hydrostatics, now known as Pascal's law, which is the basis of the hydraulic press used in hydraulic brakes and other applications.

Source: http://www.answers.com/topic/blaise-pascal

Pascal's Law

Pascal's law is a principle that pertains to hydraulic systems. It applies when a confined fluid is under pressure and when it is in a hydrostatic condition (not moving).



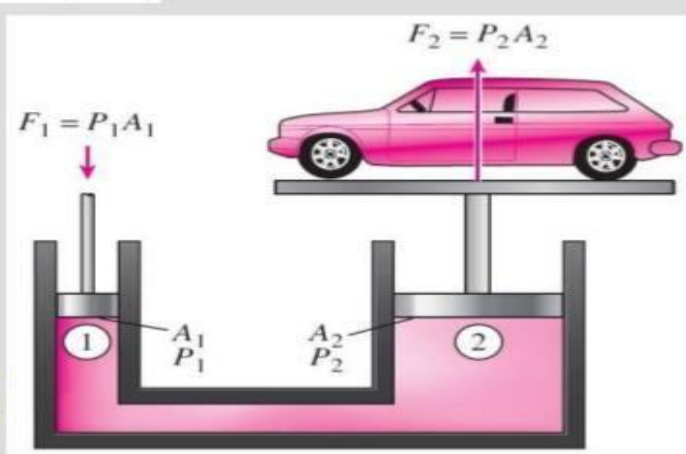
Pascal's law states:
"The pressure exerted in a confined fluid is transmitted undiminished in all directions and acts at right angles to the containing surfaces.

The shape of the container the confined fluid is in does not matter. Liquids will transmit pressure throughout the liquid, regardless of the shape of the container. A force therefore can be applied wherever you want it. The force can be multiplied according the area of the pistons used to push down on the water.

Pascal's law: The pressure applied to a confined fluid increases the pressure throughout by the same amount.

$$P_1 = P_2 \quad \rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \rightarrow \quad \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

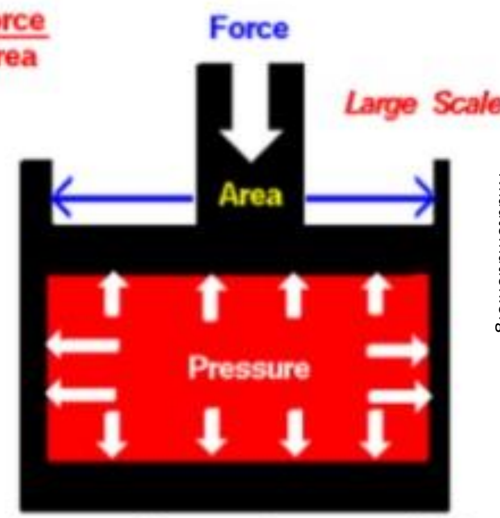
The area ratio A_2/A_1 is called the *ideal mechanical advantage* of the hydraulic lift.



Lifting of a large weight by a small force by the application of Pascal's law.

Pressure and Force

Pressure is $\frac{Force}{Area}$



Pressure force acts perpendicular to enclosing surfaces.

Pressure-temperature law

$$P \propto T$$

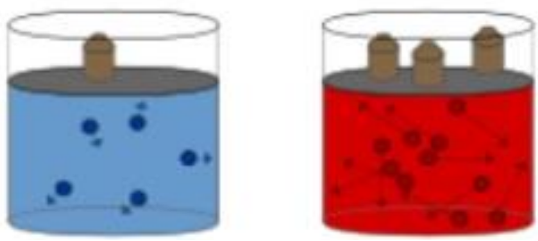
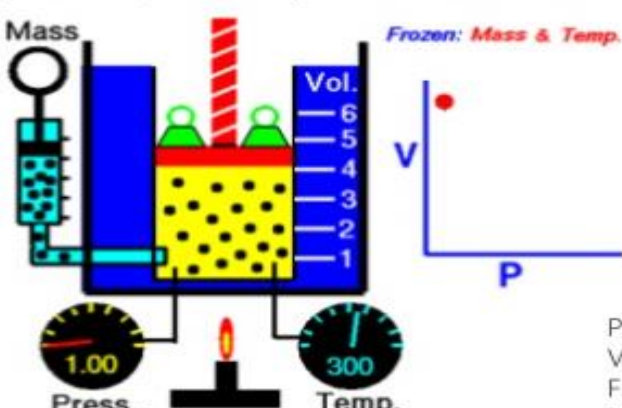


Illustration of pressure varying with temperature.

Pressure is a scalar quantity. (magnitude, no direction)

Boyle's law or Boyle–Mariotte law

the absolute pressure and volume of a given mass of confined gas are inversely proportional, if the temperature remains unchanged within a closed system.



$$pV = k$$

Pressure	= Voltage
Volume	= Capacitance
Flow rate	= Current
Flow Restrictions	= Resistance

Thus, it states that the product of pressure and volume is a constant for a given mass of confined gas as long as the temperature is constant

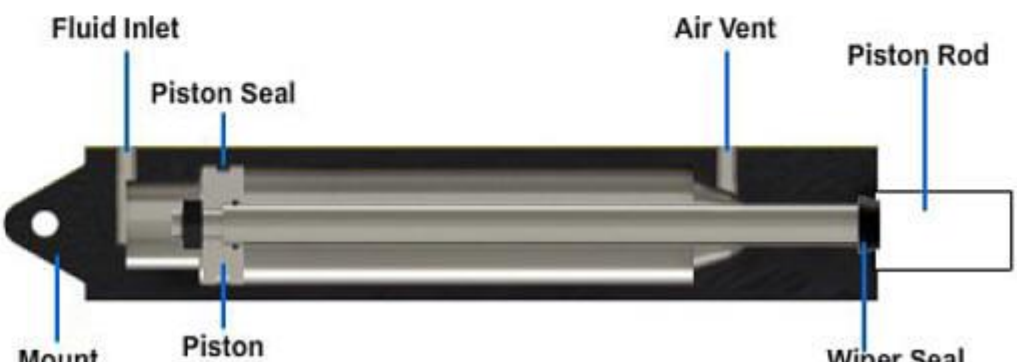
Actuators

In hydraulics and pneumatics, actuators convert the fluid power from the pump or air compressor into mechanical work. In mobile fluid power systems, actuators can be grouped as cylinders and motors. A fluid power cylinder is a linear actuator; a fluid power motor is a rotary actuator.

An actuating cylinder is a device that converts fluid power to linear motion, or straight-line force and motion. Since linear motion is a back-and-forth motion along a straight line, this type of actuator is sometimes referred to as reciprocating. The cylinder consists of a ram or piston operating within a cylindrical bore. Actuating cylinders may be installed so that the cylinder is anchored to a stationary structure and the ram or piston is attached to the mechanism to be operated, or the piston or ram may be anchored to the stationary structure and the cylinder attached to the mechanism to be operated.

Cylinders

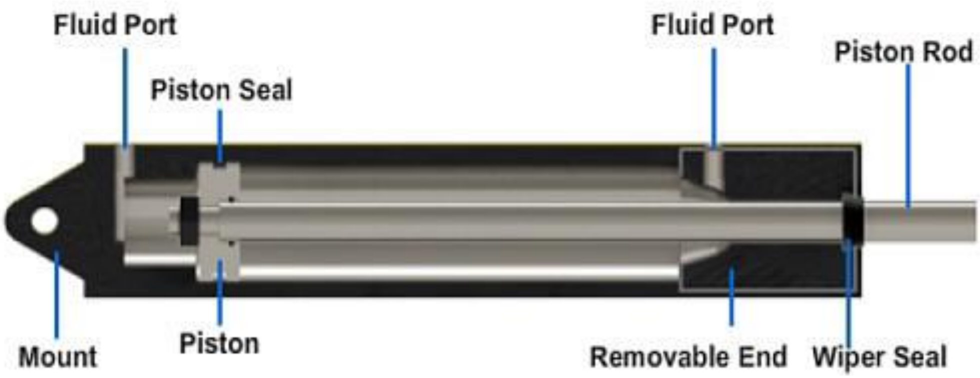
The terms ram and piston are often used interchangeably. However, a ram-type cylinder is usually considered one in which the cross-sectional area of the piston is more than one half of the cross-sectional area of the movable element. In most actuating cylinders of this type, the rod and the movable element have equal areas. This type of movable element is frequently referred to as a plunger. The most common ram-type cylinders are the single- and the double-acting.



Single-acting piston type cylinder.

The ram-type actuator is primarily used to push rather than pull. Some applications require simply a flat surface on the external part of the ram for pushing or lifting the unit to be operated. Other applications require some mechanical means of attachment, such as a clevis or eyebolt. The design of ram-type cylinders varies in many other respects to satisfy the requirements of different applications.

Actuators



Double-acting piston type cylinder.

The piston-type cylinder has an actuating cylinder in which the cross-sectional area of the piston is less than one half of the cross-sectional area of the movable element. This type of cylinder is normally used for applications that require both push and pull functions. The piston-type cylinder is the most common type used in fluid power systems.

The essential parts of a piston-type cylinder are a cylindrical barrel, a piston and rod, end caps, and suitable seals. The end caps are attached to the end of the barrel. These end caps usually contain fluid ports. The end cap on the rod end contains a hole for the piston rod to pass through. Suitable seals are used between the hole and the piston rod to keep fluid from leaking out and to keep dirt and other contaminants from entering the barrel. The opposite end cap of most cylinders is provided with a fitting for securing the actuating cylinder to some structure. This end cap is referred to as the anchor end cap.

The piston rod may extend through either or both ends of the cylinder. The extended end of the rod is normally threaded so that some type of mechanical connector, such as an eyebolt or clevis, and locknut can be attached. This threaded connection provides for adjustment between the rod and the unit to be actuated. After the correct adjustment is made, the locknut is tightened against the connector to prevent the connector from turning. The other end of the connector is attached to, either directly or through additional mechanical linkage, the unit to be actuated.

Fluid Power Summary

Summary of the principles of fluid power

1. Pressure is transmitted throughout a liquid.

2. A force may be applied anywhere to the liquid.

3. All hydraulic systems use a small master piston and a large slave piston.

4. A small force is used to create a very big force.

5. The small master piston is used to apply a force.

6. The slave piston is always bigger than the master piston.

7. The larger slave piston will multiply the original force put on the master piston.

Safety

There are various safety hazards associated with hydraulic systems. It is critical to be aware of these hazard and be trained on how to safely use hydraulic equipment. Some hydraulic safety hazards include:

- Fluid injection injuries
- Burns from hot fluid
- Slips and falls from leaking equipment
- Noise hazards
- Eye hazards
- Skin hazards
- Fire hazards
- Physical crush hazards

Fluid Injection Injuries

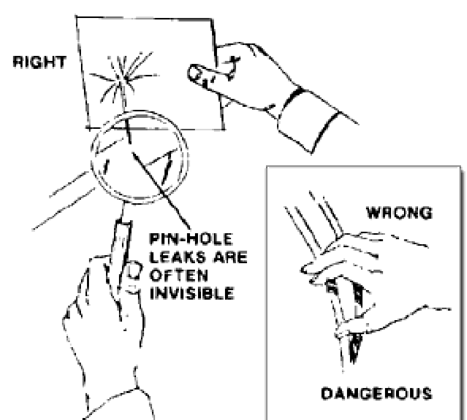
Fluid injection injuries are extremely dangerous because the don't appear to be a problem at first. However is the injury is not treated immediately, the result can be devastating.

Hydraulic Fluid Injection Injury

If toxic hydraulic fluid is accidentally injected into the human body (e.g. technician was feeling a pressurized line to check for a pinhole leak), it will start to poison the person from within.

Hydraulic Fluid Injection Injury

Never check for a leak in a pressurized hose with your hand. Use a piece of wood, cardboard, or metal and run along the line you suspect of leaking.



Detecting pinhole leaks in a hydraulic system

Hydraulics & Pneumatics

Unit 3:
Hydraulic Components

Fundamentals of Fluid Power

Basic Hydraulic Components

There are five basic components to any hydraulic system. These components are:

- **Power Unit** – The power device is the pump that provides fluid flow through the system.

- **Control Device** – Control devices control the fluid direction and flow in various parts of the system.

- **Actuators** – Actuators do the work in the hydraulic system. Actuators types include cylinders and motors.

- **Conductors** – Conductors are the hoses that connect the components.

- **Fluid** – Fluid is the liquid that flows through the conductors of the system.

Photo credit: wisc-online.com

Hydraulic Power Unit

Photo credit: wisc-online.com

Hydraulic Motor

Photo credit: wisc-online.com

Hydraulic Fluid Reservoir

Hydraulic Power Unit

The hydraulic power unit consists of the components needed to pump fluid through the system. It consists of a reservoir to hold the fluid. A pump to pump the fluid out (one side of the pump sucks the fluid to the pump and the other side of the pump pushes the fluid through the system). The suction line has a suction line filter on it to filter the fluid from the reservoir before it goes through the pump. The pump is driven by what is called a Prime Mover. A prime mover can be an electric motor or a gasoline engine.

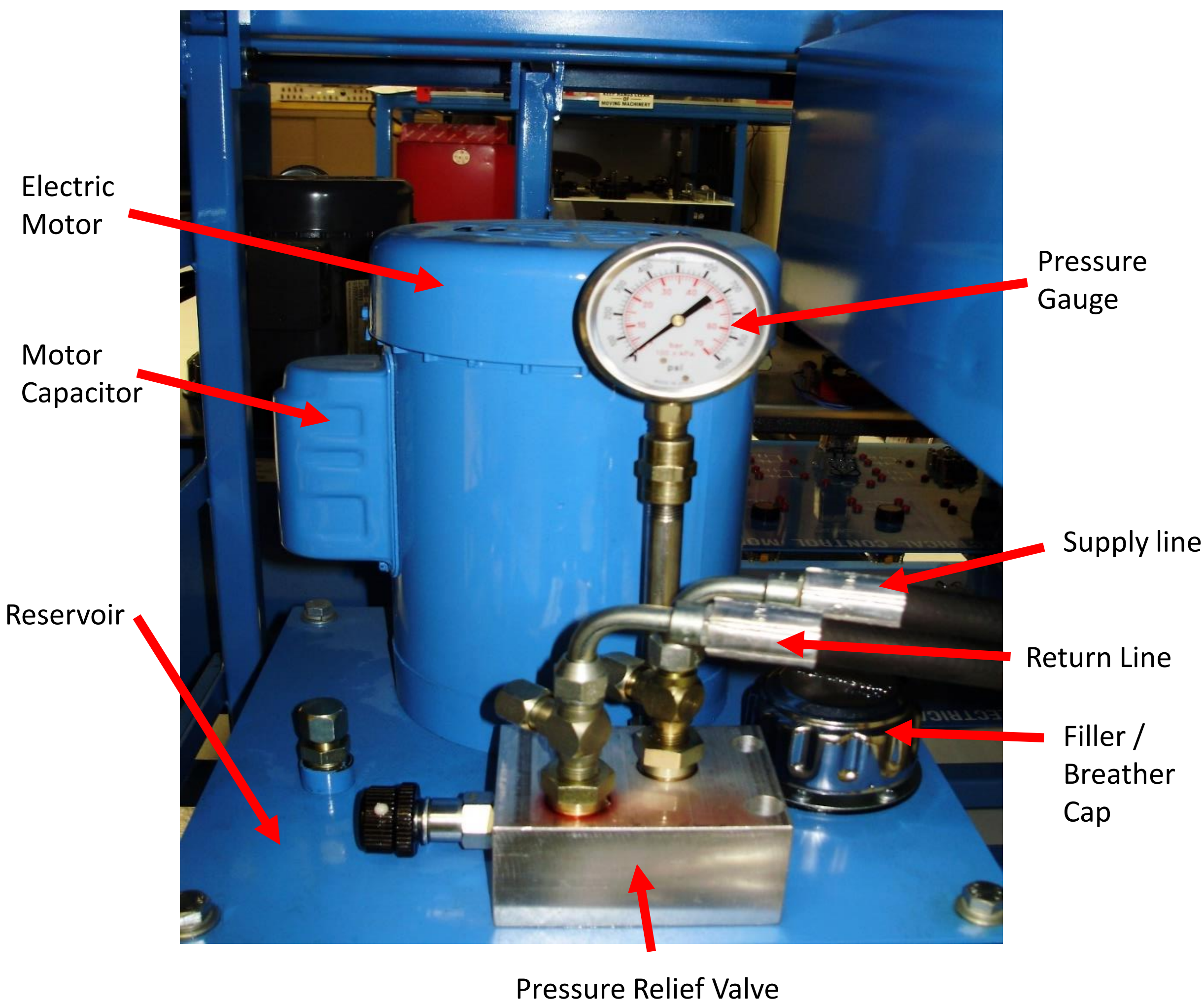


Photo credit: wisc-online.com

Reservoir Tanks

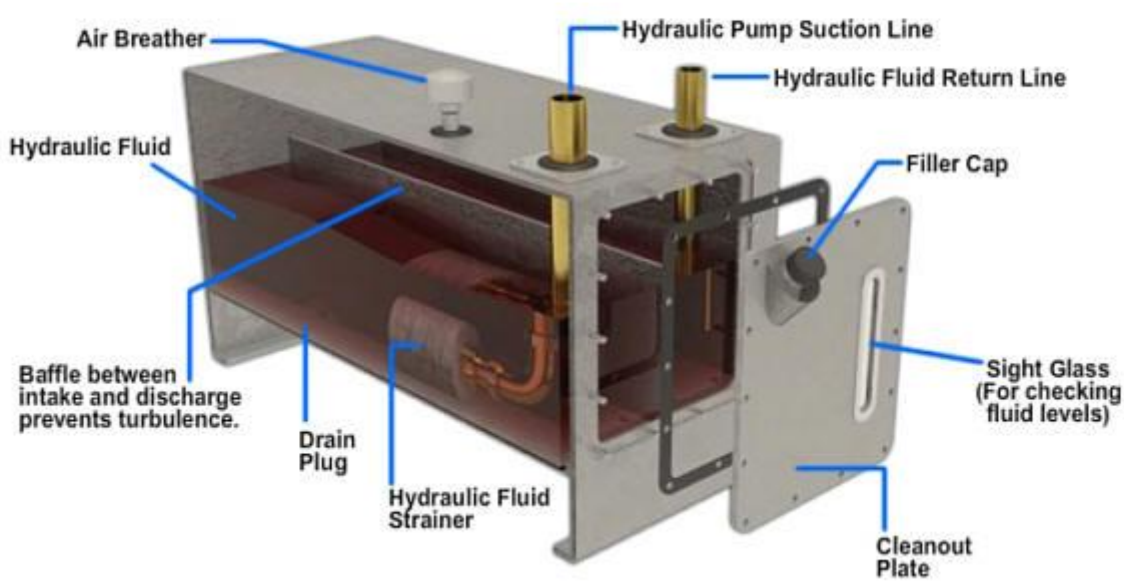
A properly constructed reservoir is more than just a tank to hold oil until the system demands fluid. It should also be capable of the following:

•Dissipating heat from the fluid.
•Separating air from the oil.
•Settling out contamination in the oil.

Ideally, the reservoir should be high and narrow rather than shallow and broad. The oil level should be as high as possible above the opening to the pump suction line. This condition prevents the vacuum at the line opening from causing a vortex or whirlpool effect. Anytime you see a whirlpool at the suction line opening, the system is taking in air.

As a rule of thumb, the reservoir level should be two to three times the pump output per minute. By this rule which works well for stationary machinery, a 20-gallon per minute (gpm) system would require a 40- or 60-gpm reservoir. However, this is not possible for mobile equipment. You are more likely to find a 20- or 30-gallon tank to support a 100-gpm system. This is possible because mobile systems operate intermittently rather than all the time. The largest reservoirs are on mobile equipment. These reservoirs may have a 40- or 50-gallon capacity, capable of handling more than 200-gpm output.

G.P.M = Gallons Per Minute



Reservoir Tanks

The reservoir must be sized to ensure there is a reserve of oil with all the cylinders in the system fully extended. The reserve must be high enough to prevent a whirlpool at the suction line opening. Also, there must be enough space to hold all the oil when the cylinders retract with some space to spare for expansion of hot oil.

An air vent allows the air to be drawn in and pushed out of the reservoir by the ever- changing fluid level. An air filter is attached to the air vent to prevent drawing atmospheric dust into the system by the ever changing fluid level. A firmly secured filling strainer of fine mesh wire is always placed below the filler cap.

The sight gauge is provided so the normal fluid level can always be seen, as it is essential that the fluid in the reservoir be at the correct level. The baffle plate segregates the outlet fluid from the inlet fluid. Although not a total segregation, it does allow time to dissipate the air bubbles, lessen the fluid turbulence (contaminants settle out of non-turbulent fluid), and cool the return fluid somewhat before it is picked up by the pump.

Reservoirs may vary considerably from that shown, however, manufacturers retain many of the noted features as possible depending on design limits and use.


Princessauto.com

Hydraulic Fluid Reservoir


Princessauto.com

Filler / Breather Cap


Northerntool.com

Liquid Level Gauge

Hydraulics & Pneumatics

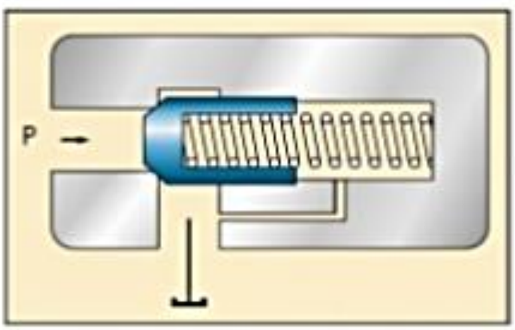
Unit 3: Hydraulic Components

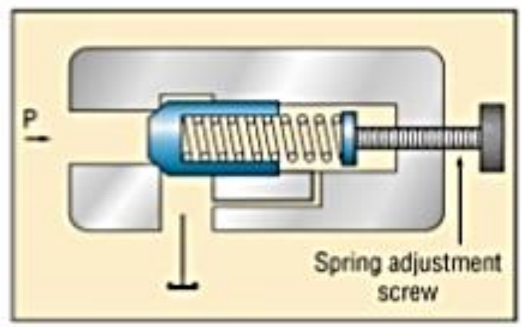
Fundamentals of Fluid Power

Pressure Relief Valves

Hydraulic Actuation System

Pressure Relief Valve





Simple, direct-acting relief valve has no adjusting screw and therefore opens at a fixed, pre-set pressure as controlled by setting the compression spring.

Adjustable, direct-acting relief valve blocks flow through the valve until the force of system pressure on the poppet overcomes the adjustable spring force and downstream pressure.

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Nfiautomation.org

Pressure Gauges

Being able to monitor the pressure at different points in a hydraulic system can be advantageous, especially when it comes to troubleshooting a system. A pressure gauge is a device use to display system pressures in a system.

Photo credit: wisc-online.com

Typical Units of Pressure

V·T·E	pascal	bar	pounds per square inch
	Pa	bar	psi
1 Pa	≡ 1 N/m^2	10^{-5}	1.450377×10^{-4}
1 bar	10^5	≡ 10^6 dyn/cm^2	14.50377
1 at	0.980665×10^5	0.980665	14.22334
1 atm	1.01325×10^5	1.01325	14.69595
1 Torr	133.3224	1.333224×10^{-3}	1.933678×10^{-2}
1 psi	6.8948×10^3	6.8948×10^{-2}	≡ 1 lb_F/in^2

The SI unit for pressure is the Pascal (Pa), equal to one newton per square meter (N/m^2 or kg·m^{-1}·s^{-2}).

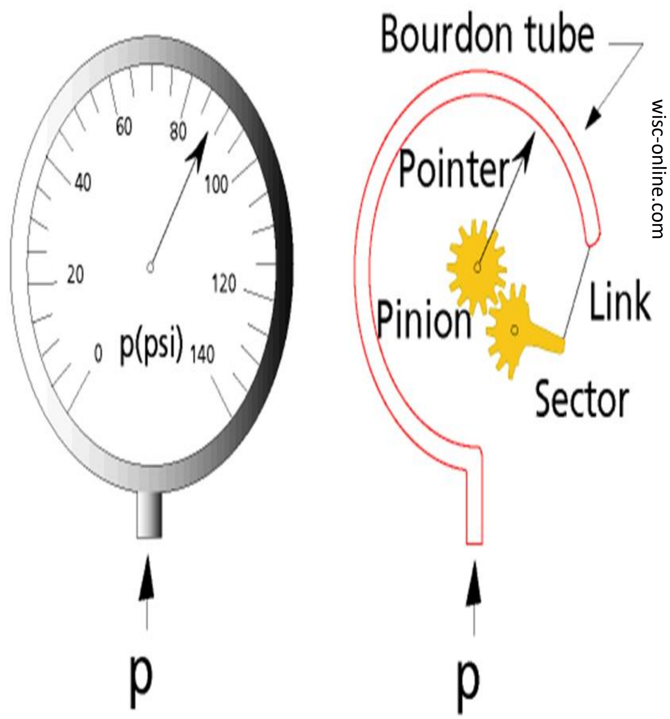
1 Bar = 14.69 psi = 100 kilo pascal

Pressure Gauge

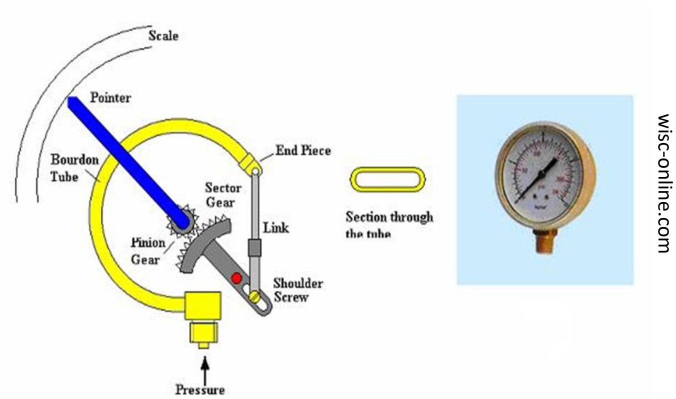
Purpose
Being able to monitor the pressure at different points in a hydraulic system can be advantageous, especially when it comes to troubleshooting a system.

What is a pressure gauge?
A pressure gauge is a device use to display system pressures in a system. Pressure Gauges are used throughout hydraulic systems to indicate system pressures.

Units of measurement
Pressure gauges indicate pressure in units of psi (pounds per square inch), pa (Pascal), and bar.



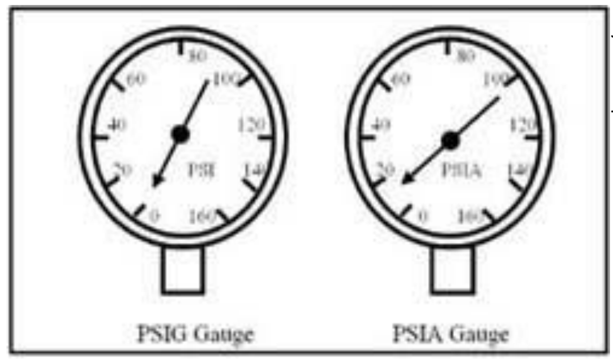
The Bourdon Tube Gauge
The Bourdon tube pressure gauge is one of the most common gauge types.
The components of the Bourdon tube gauge include the gauge body, faceplate, cover, Bourdon tube, pointer (indicator needle), pinion, sector, and link.



Bourdon Tube Gauge Operation
When pressure enters the bottom of the Bourdon tube, the tube tries to straighten out. When this happens, the link attached to the tube moves the sector, which in turn moves the pinion. The pointer is attached to the pinion so when the pinion moves, the pointer moves and indicates the pressure in the system.

Pressure Gauge

Normally, pressure gauges read in psi (with no additional letter). Commonly called gauge pressure, psi disregards the earth's atmospheric pressure of 14.7 psia, because it has no effect either negative or positive on a fluid power circuit. The a on the end of psia stands for absolute, and would be shown on a gauge with a pointer that never goes to zero unless it is measuring vacuum. Another type of gauge that shows both negative and positive pressures would have a pointer with an inches-of-mercury (in. Hg) scale below zero and a psig scale above zero. Both of these gauges could read pressure or vacuum.



Hydraulicspneumatics.com

A typical psig gauge and one type of psia gauge.

Notes:____

Hydraulic Fluid

The main purpose of the fluid in any system is to **transmit energy**. It also lubricates the stem, provides a seal between moving parts, and transfers heat from the system.

Electric, internal combustion, steam powered, or other prime movers drive a pump that sends oil through lines to valves that control actuators.

The fluid in these lines must transmit the prime movers energy to the actuator so it can perform work.

The fluid must flow easily to reduce power losses and make the circuit respond quickly. A hydraulic system circulates the same fluid repeatedly from a fixed reservoir that is part of the prime mover.

The fluid is an almost non-compressible liquid, so the actuators it drives can be controlled to very accurate positions, speeds, or forces.

Most hydraulic systems use mineral oil for the operating media but other fluids such as water, ethylene glycol, or synthetic types are not uncommon.

New-line.com

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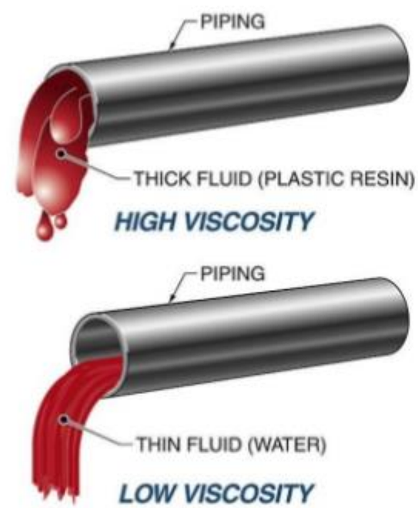
Viscosity

Types of Flow
Viscosity is a measure of a fluids thickness or ability to flow.

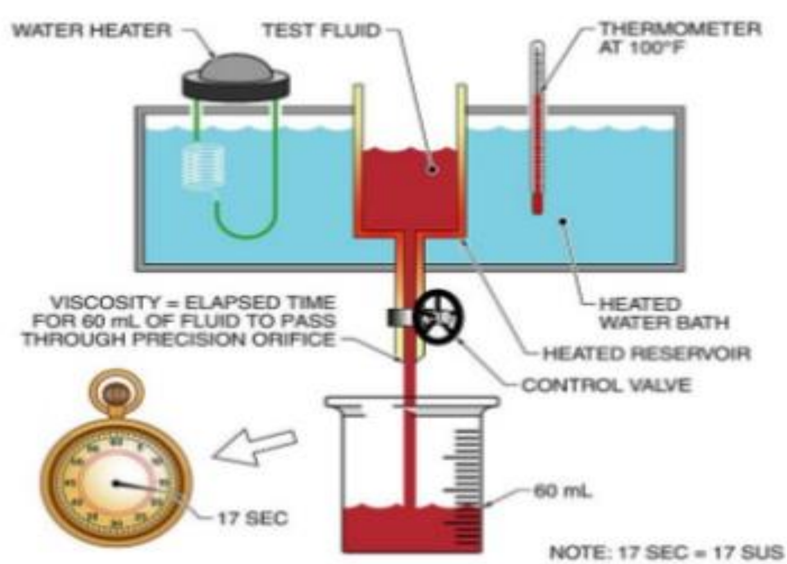


High Viscosity
Fluids that are thick and flow with difficulty have high viscosity. Sometimes high viscosity is caused by the fluid being cold. This causes the fluid to thicken up and slows down the flow.

Low Viscosity
Fluid that are thin and flow easily have low viscosity. Sometimes low viscosity is caused by the fluid being too hot. This causes the fluid to become thinner allowing it to flow better. If fluid is too thin, it may seep past seals and O-rings and cause leaking issues.

Viscosity of Fluid

A Saybolt viscometer is a test instrument used to measure fluid viscosity.



Hydraulic Pump

Hydraulic pumps are used in hydraulic drive systems and can be hydrostatic or hydrodynamic. A hydraulic pump is a mechanical source of power that converts mechanical power into hydraulic energy (hydrostatic energy i.e. flow, pressure). It generates flow with enough power to overcome pressure induced by the load at the pump outlet. When a hydraulic pump operates, it creates a vacuum at the pump inlet, which forces liquid from the reservoir into the inlet line to the pump and by mechanical action delivers this liquid to the pump outlet and forces it into the hydraulic system. Hydrostatic pumps are positive displacement pumps while hydrodynamic pumps can be fixed displacement pumps, in which the displacement (flow through the pump per rotation of the pump) cannot be adjusted, or variable displacement pumps, which have a more complicated construction that allows the displacement to be adjusted. Although, hydrodynamic pumps are more frequent in day-to-day life. Hydrostatics pump which are of various types works on the principle of Pascal's law. It states that the increase in pressure at one point of the enclosed liquid in equilibrium of rest is transmitted equally to all other points of the liquid, unless the effect of gravity is neglected.(in case of statics)

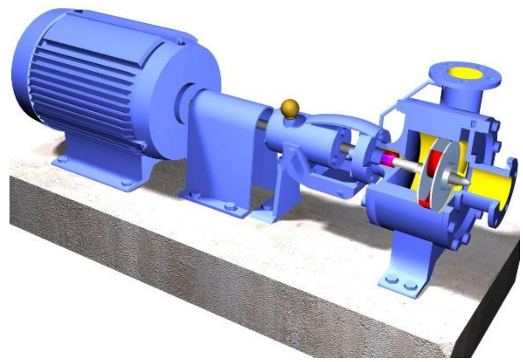
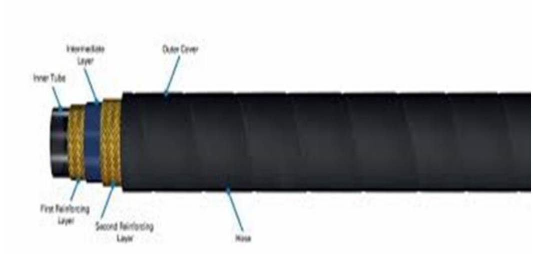


Photo credit: Wikimedia.org

Notes:________________

Hydraulic Hose

There are places on many machines where rigid pipe or tubing cannot be used because of their inflexibility.
Rigid lines can cause problems at cylinders with pivot mountings, pumps on noise-isolation mounts, or connections between separate units.
Hose avoids these problems. However, wholesale use of hose in place of rigid lines it is not generally recommended.
Hose is expensive, must be replaced on a regular basis, and flexes and stretches under pressure surges.
This flexing produces extra volume and adds to cycle time.



Safety Rules When Working with Hydraulic Hoses
First: never go under the manufacturers recommendation for minimum bend radius.
Second: don't use hose above its rated working pressure.
Third: avoid operating at temperatures above the rating of the hose.
Fourth: don't install hose where it must twist during each cycle or make it operate in a twist because of poor tightening procedures.

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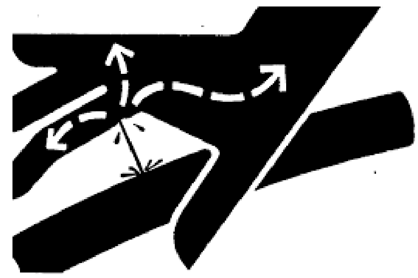
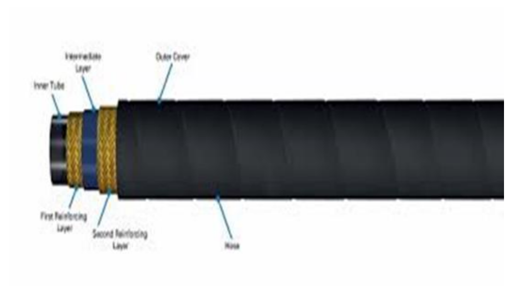
Hydraulic Hose Safety

While most common injuries may be just a result of slip and fall, three more serious dangers exist:

- burns from hot hydraulic fluid spray,
- injuries sustained from falling or whipping hydraulic lines
- injection of hydraulic fluid into the skin.



Manuals.deere.com



A pinhole leak in your hydraulic hose can release hydraulic fluid with enough pressure to penetrate both clothing and skin?

Employees can become complacent around hydraulic systems and that is when mistakes are made, maintenance is neglected and injuries occur.

Fittings

Quick Connect Fittings
Quick connect fittings are fittings used in a hydraulic system that allow quick connecting and disconnecting of hydraulic hoses. Quick connect fittings have check valves in them that prevent the fluid from escaping the hose when the hose is disconnected.


Hydraulic Quick Coupler

Globalindustrial.com

Tee Fittings
Tee fittings are used when the supply line needs to branch off in two different directions.

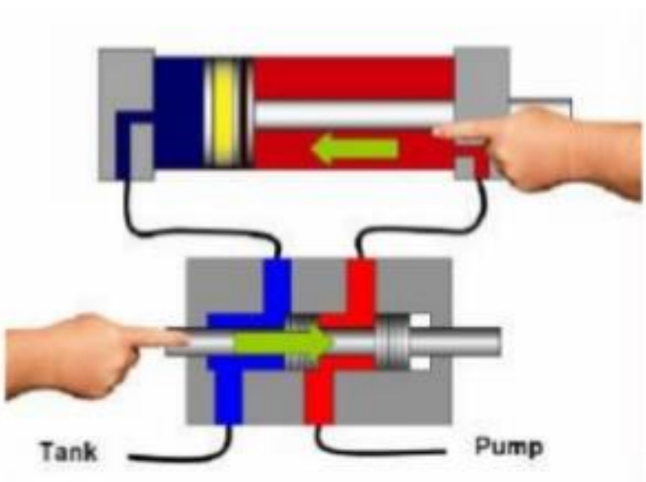
Cross Fittings
Cross fittings are used when the supply line needs to branch off in three different directions.

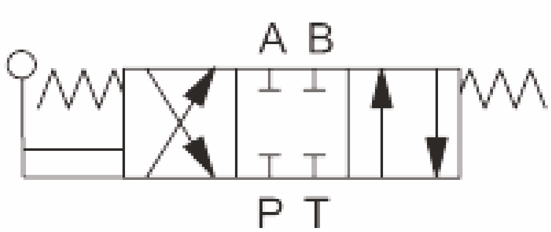
jasmineengineers.com

Directional Control Valves

Valves – Directional Control Valves (DCV)

1. Allowing the passage of fluid and directing it to particular lines
2. Canceling fluid as required by blocking their passage and / or
3. Relieving the fluid back to reservoir





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Flow Control Valves

Flow control valves, sometimes called "needle" valves are used to control the speed of actuators by creating a restriction in the line. They have an adjustment screw that can be screwed in or out to adjust the opening that the fluid is flow through. The basic concept is, you can control the speed of the cylinder or motor by controlling the flow of fluid into the cylinder or motor.

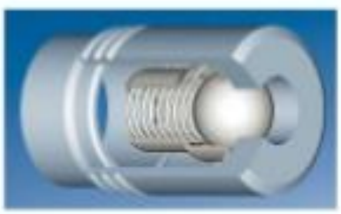
wisc-online.com

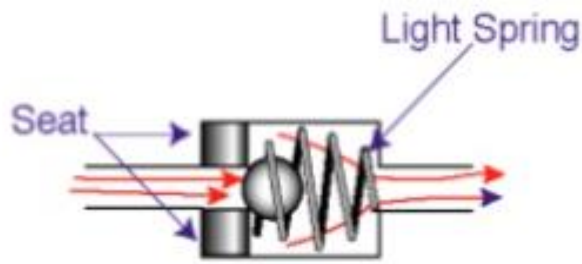
Flow Control Valve

Check Valves

Flow Control Valves: Check Valve

The check valve allows oil flow in one direction and blocks it in the opposite direction.





Check Valve | Spring Loaded Check Valve | Pilot to Open Check Valve | Pilot to Close Check Valve

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Hydraulic Cylinders

Hydraulic cylinders use fluid pressure to produce a linear mechanical motion. Inside the cylinder is a piston with a rod attached to it. The side of the cylinder with the rod extending out of it is called the rod end. The other side of the cylinder is called the cap end. Cylinders have two ports on them that fluid can enter the cylinder through. One port is on the rod end and the other is on the cap end. When fluid enters the rod end, it pushes on the piston and causes the rod to retract. As the rod is retracting, the fluid on the cap end leaves the cylinder and is returned back to the tank. When fluid enters the cap end port, it pushes on the cylinder and the rod extend. As the rod is extending the fluid that was on the rod end exits the rod end port and is returned to the tank.


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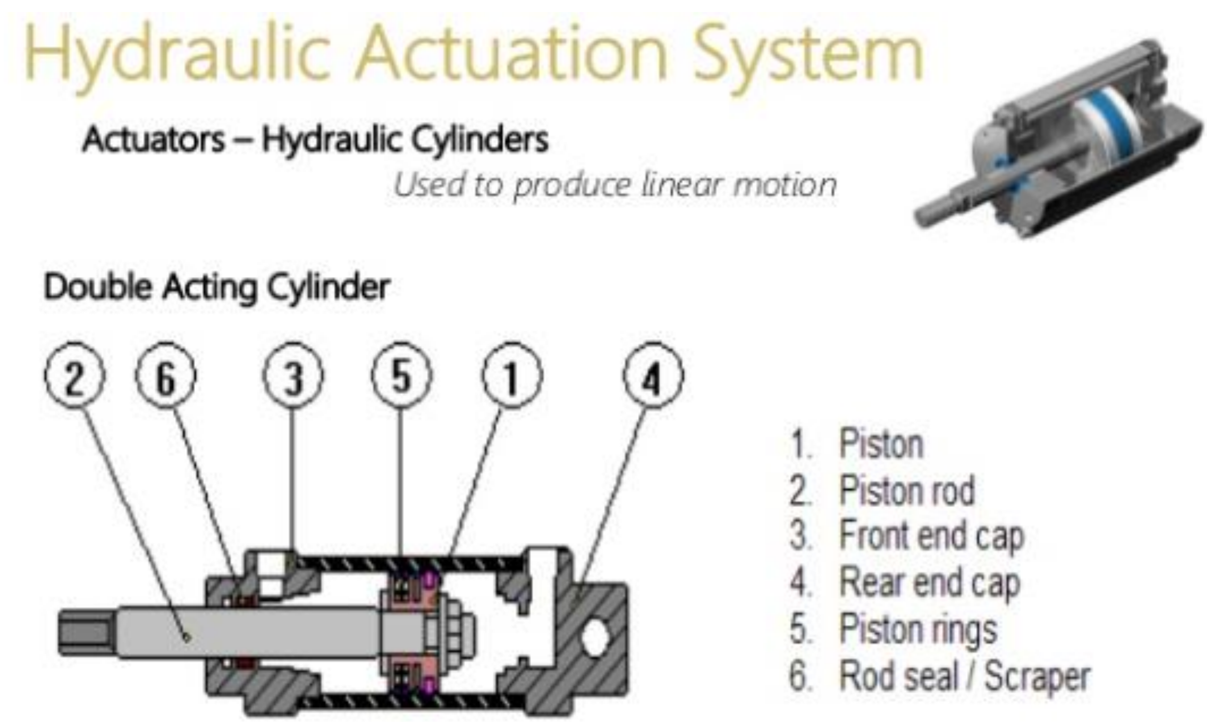
Hydraulic Cylinder



Motors

Motors

A hydraulic motor is a device that converts fluid power energy to rotary motion and force. The function of a motor is opposite that of a pump; oil under pressure is forced in and spilled out, converting fluid force into mechanical force. However, the design and operation of motors are very similar to pumps.

Hydraulic Motor

Motors have many uses in fluid power systems. In hydraulic power drives, pumps and motors are combined with suitable lines and valves to form hydraulic transmissions.
Fluid motors may either be fixed or variable displacement. Fixed-displacement motors provide constant torque and variable speed. Controlling the amount of input flow varies the speed. Variable displacement motors are constructed so that the working relationship of the internal parts can be varied to change displacement. The majority of the motors used in fluid power systems are the fixed-displacement type.

Pneumatic Motor

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Hands On Exercise: Component Identification

Locate and identify the following components on a hydraulic system:

- ❑ Reservoir
- ❑ Liquid Level Gauge
- ❑ Filler / Breather Cap
- ❑ Start / Stop Switch
- ❑ Motor
- ❑ Directional Control Valve
- ❑ Relief Valve
- ❑ Actuator(s)
- ❑ Supply Line
- ❑ Return Line

Hydraulic System Maintenance

Maintenance of a hydraulic system that is properly operated and cared for is a routine task. Maintenance usually consists of changing or cleaning filters and strainers, and occasionally adding or changing the fluid in the system. However, overheating, excessive pressure, and contamination can damage an improperly operated system.

Proper maintenance reduces your hydraulic troubles. By caring for the system using a regular maintenance program, you can eliminate common problems and anticipate special ones. These problems can be corrected before a breakdown occurs.
When you work on a hydraulic system, make cleanliness a priority. Dirt and metal particles can score valves, seize pumps, and clog orifices, resulting in major repair work
.

How large is a micron?

159 µm = 100 mesh screen
100 µm = Table salt
90 µm = Smog particle
70 µm = Thickness of a human hair
60 µm = Pollen
50 µm = Fog particle
40 µm = Visible threshold
24 µm = White blood cell
7 µm = Red blood cell
2 µm = Bacteria
1 µm = 0.00003937 in.

Oil and Filter Changes
Despite all the precautions you take when working on the hydraulic system, some contaminates will get into the system anyway. Good hydraulic oils will hold contaminates in suspension, and the filters will collect them as oil passes through. Good hydraulic oil contains additives that work to keep contaminants from damaging or plugging the system. However, these additives lose their effectiveness after an extended period of time; therefore, oil changes at the recommended intervals can ensure that contamination is held to a minimum. Changing the oil at its recommended interval ensures that the additives will do their job.
Regular filter changes ensure solid particles are removed from the system. Change the filters more often under adverse operating conditions. When changing them, thoroughly clean the filter housing before installing a new filter. Remember to add enough fluid to compensate for any fluid lost in filter replacement.

Jandmparts.com

Hydraulic Fluid Filters

Hydraulic System Maintenance

Cleaning and Flushing the System and Reservoir
Cleaning and flushing the system should be performed based on the manufacturer's recommendation or when the system is known to be contaminated. The nature and amount of deposits in a particular system may vary widely. Inspection of the system may show any condition between a sticky, oily film and a hard, solid deposit (gum or lacquer formation) which completely chokes off the system. If you drain the system periodically according to the manufacturer's recommendations, the formation of gum and lacquer will be greatly reduced.

Speedraulic.com

If you have not seen the inside of your reservoir this is what it will look like.

Pretty new and clean that is what hydraulics crave!

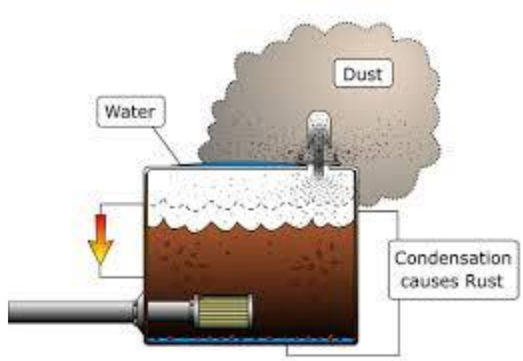
If there is no gum or lacquer formation suspected, clean the system as follows:
•Drain the system completely.
•After draining, clean any sediment from the reservoir, and replace the filter elements.
If flushing is required because the oil is badly contaminated, clean and flush the system as follows:
•Drain the system completely.
•Refill the system with the recommended hydraulic oil for the system involved.
•Operate the equipment to cycle the flushing oil through the system.

Ensure that all valves are operated so that the new oil goes through the lines.
The time necessary to clean the system will vary, depending on the condition of the equipment, 4 to 48 hours usually being sufficient for most systems.(Drain out the flushing oil, replace the filters, and refill the system with clean hydraulic oil of the recommended type.) If gums or lacquer has formed on working parts and the parts are sticking, remove the affected parts and clean them thoroughly. Consult the manufacturer's manual for proper procedures before removing and cleaning any parts.

Moisture Contamination

Aside from particle contamination, water is the second most insidious contaminant found in hydraulics. Present in most fluids even in the most pristine environments, water can increase failure rates 10-20 fold depending on circumstance. Water causes problems in a number of ways: first, any iron or steel surface in contact with water will start to rust. This can induce premature failure due to corrosion, as well as introduce rust particles into the fluid. Second, water is very different to most hydraulic fluids in that changes in pressure and temperature can readily induce a phase change. While water may be a liquid under atmospheric pressure inside the reservoir, on the suction side of a hydraulic pump the lower pressure can cause water to vaporize even at relatively low temperatures. These vapor-filled bubbles will continue to grow until they reach an area of high pressure (e.g. on the discharge side of the pump) when the bubble suddenly and violently collapses. The intense pressures generated by such microscopic implosion events can cause damage to pumps and valves—an effect referred to as "vaporous cavitation."2 Water also helps pull oil degradation byproducts out of solution, which can cause sticky-resinous deposits to form. When these deposits accumulate in the clearances of valves, they can cause small particles to become trapped, further increasing the system's sensitivity to particle contamination.

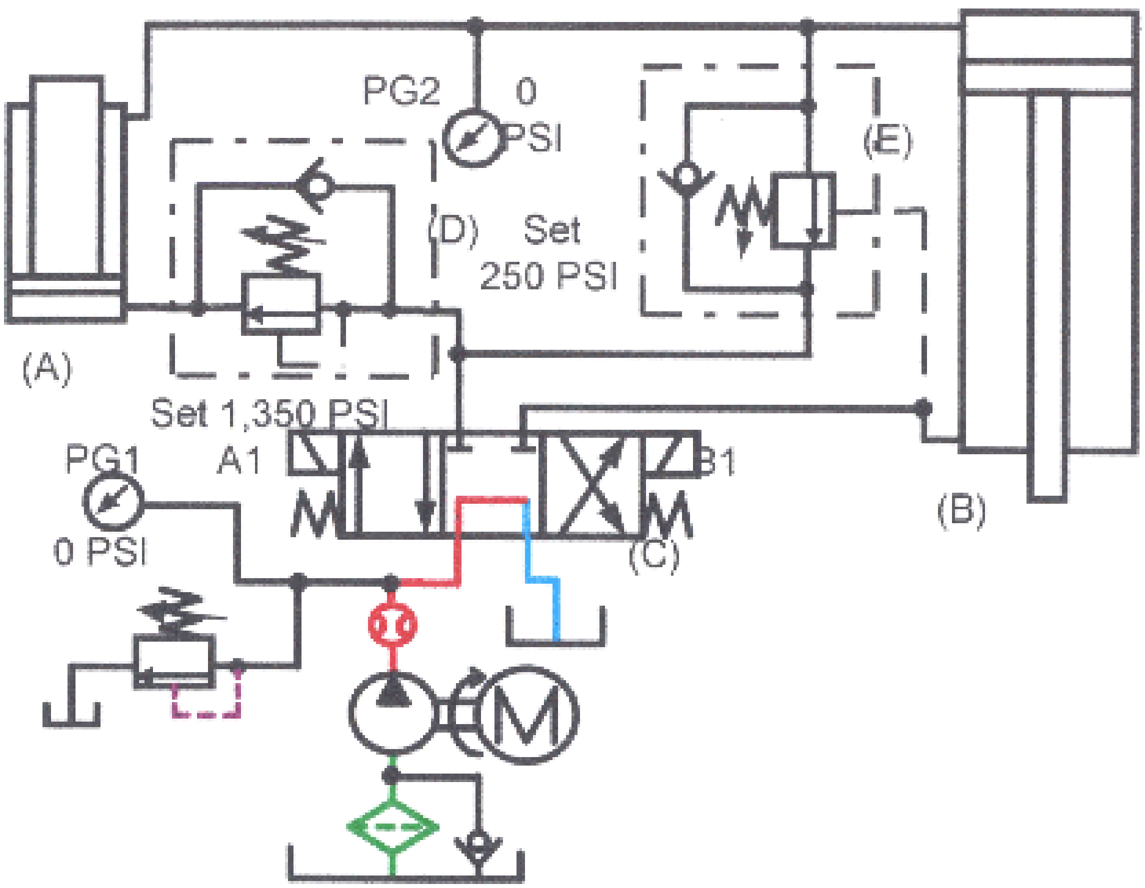
So how much water is too much? To a large extent the answer depends on the type, the age of the fluid, and the operating temperature. The reason for this lies in the form that water takes in lubricants and hydraulic fluids. Most fluids will hold a certain amount of water in the dissolved phase. For the most part, as long as the water remains dissolved, cavitation and corrosion will not occur. However, as soon the water comes out of solution and becomes free or emulsified, water becomes a very real concern. While highly temperature dependent, the saturation point of most conventional hydraulic fluids—the point at which water starts to come out of solution—is in the 100-200 ppm range (0.01-0.02%). Below these levels, most hydraulic systems should be relatively free of water-induced failures.



Mobilehydraulictips.com

Hydraulic Schematics

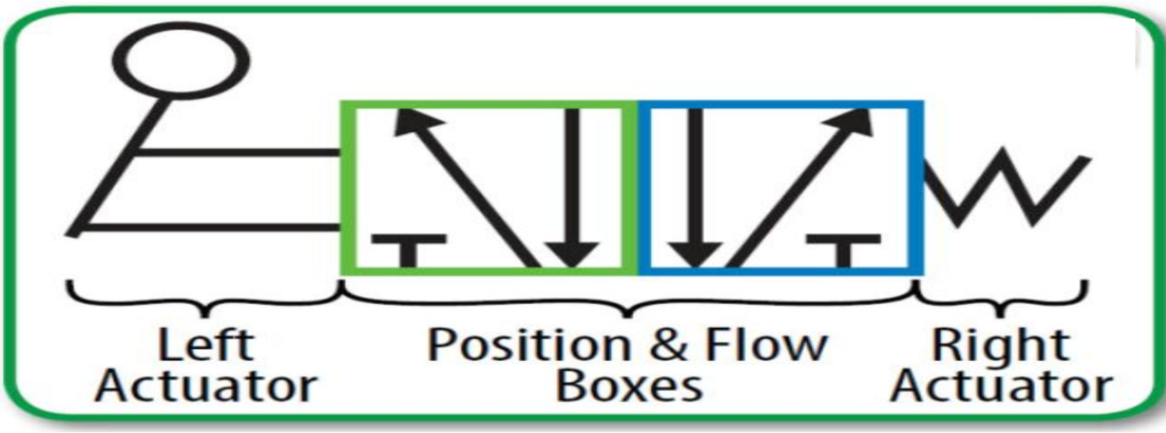
A hydraulic schematic is a diagram that is used to identify the components of a hydraulic system and identify how the system is designed.



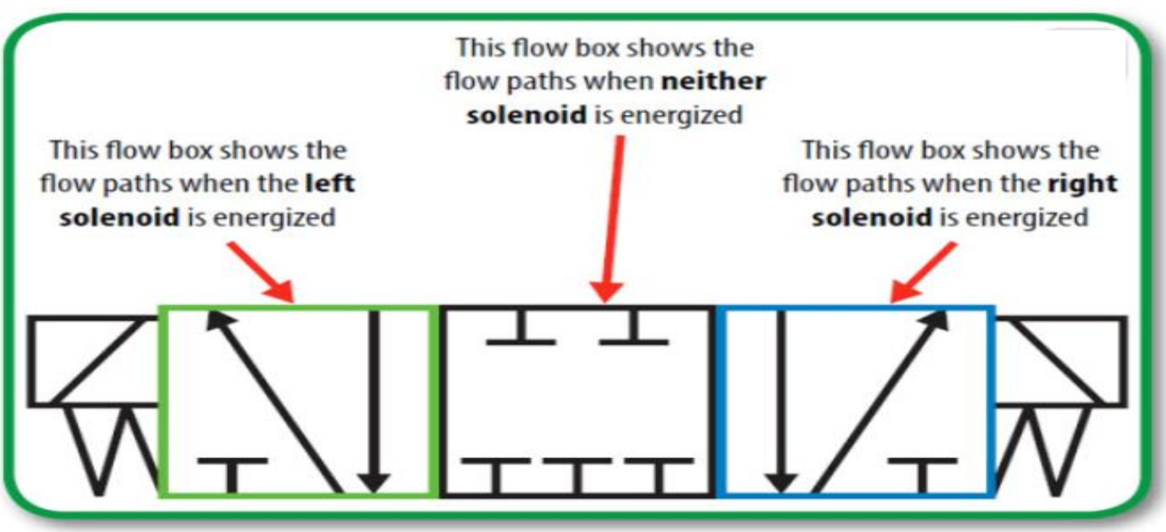
Boulderarts.net

Hydraulic Schematics

DCV symbols have boxes with arrows in them called envelopes. Each envelope represents what happens when the operator is put in the position the envelope represents.



Manufacturingstories.com



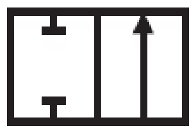
Manufacturingstories.com

3 position, double solenoid actuated, spring return valve

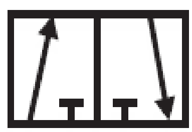
Schematic Symbols

Valve Symbols, Flow Paths and Ports

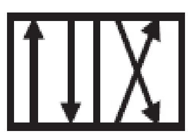
2 position, 2 way, 2 ported



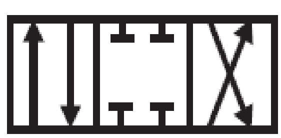
2 position, 3 way, 3 ported



2 position, 4 way, 4 ported

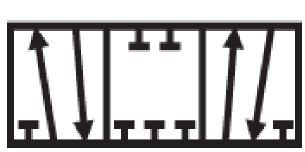


3 position, 4 way, 4 ported, Center Closed



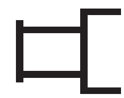
2 position, 4 way, 5 ported

3 position, 4 way, 5 ported

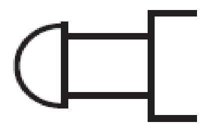


Actuator Symbols

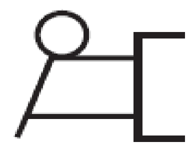
Manual



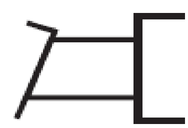
Push Button



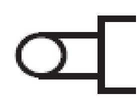
Lever



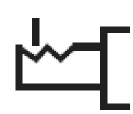
Foot Operated



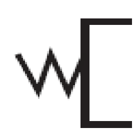
Mechanical



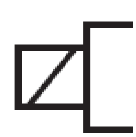
Detent



Spring



Solenoid

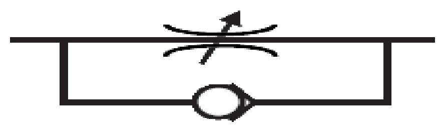


Schematic Symbols

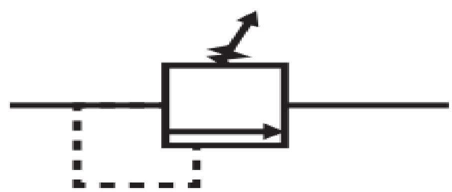
Simple Pneumatic Valves

Check Valve

Flow Control, 1 direction



Relief Valve



Lines

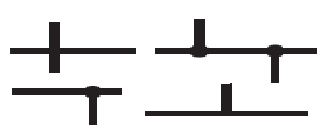
Main Line

Pilot Line

Exhaust Line or Control Line

Lines Crossing

Lines Connecting

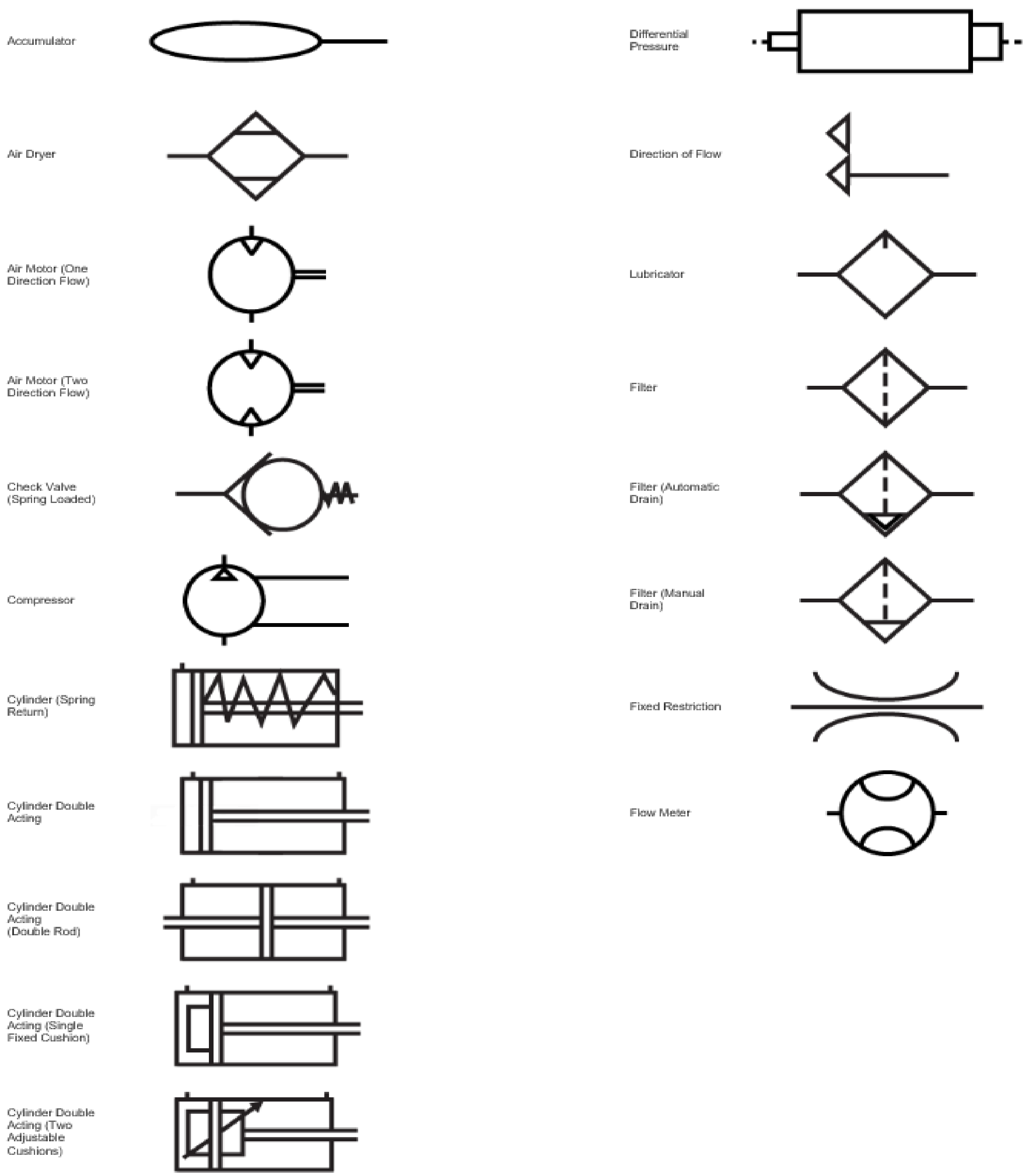


Unit 5: Schematics

Fundamentals of Fluid Power

Schematic Symbols

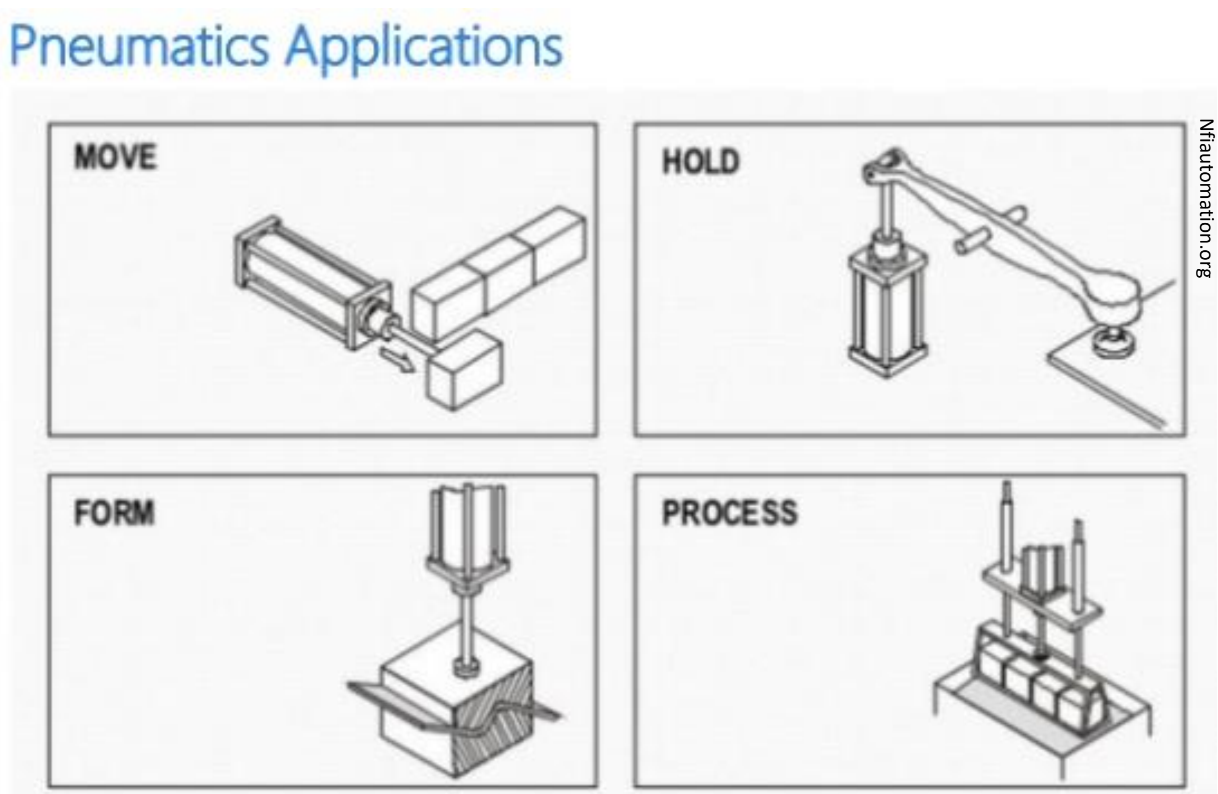
Miscellaneous



Pneumatic Applications

Some common applications for pneumatic equipment include:

- Moving objects
- Holding objects
- Forming objects
- Manufacturing processes

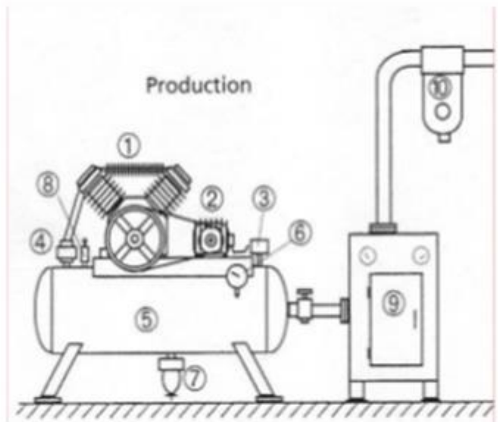


Hydraulics & Pneumatics

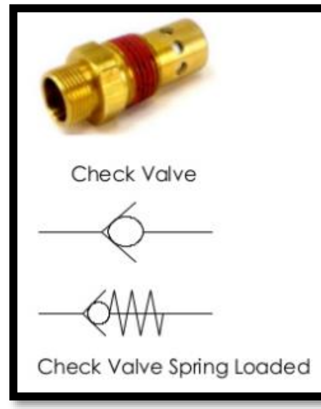
Unit 6:
Pneumatics

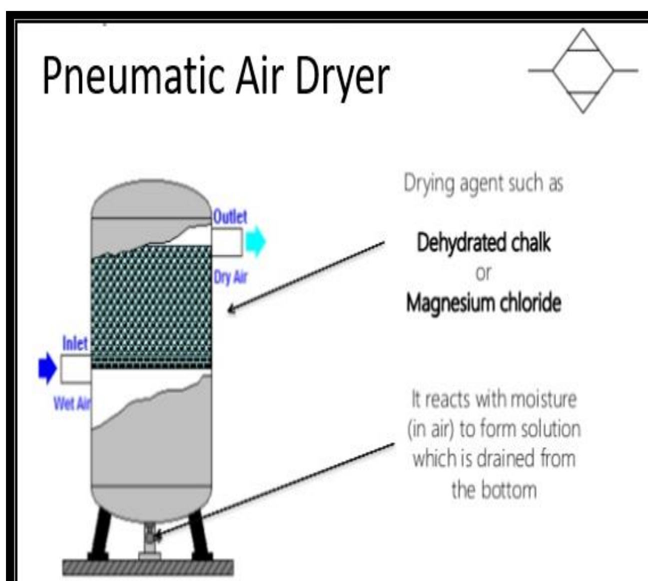
Air Production Components

Components of Air Production System



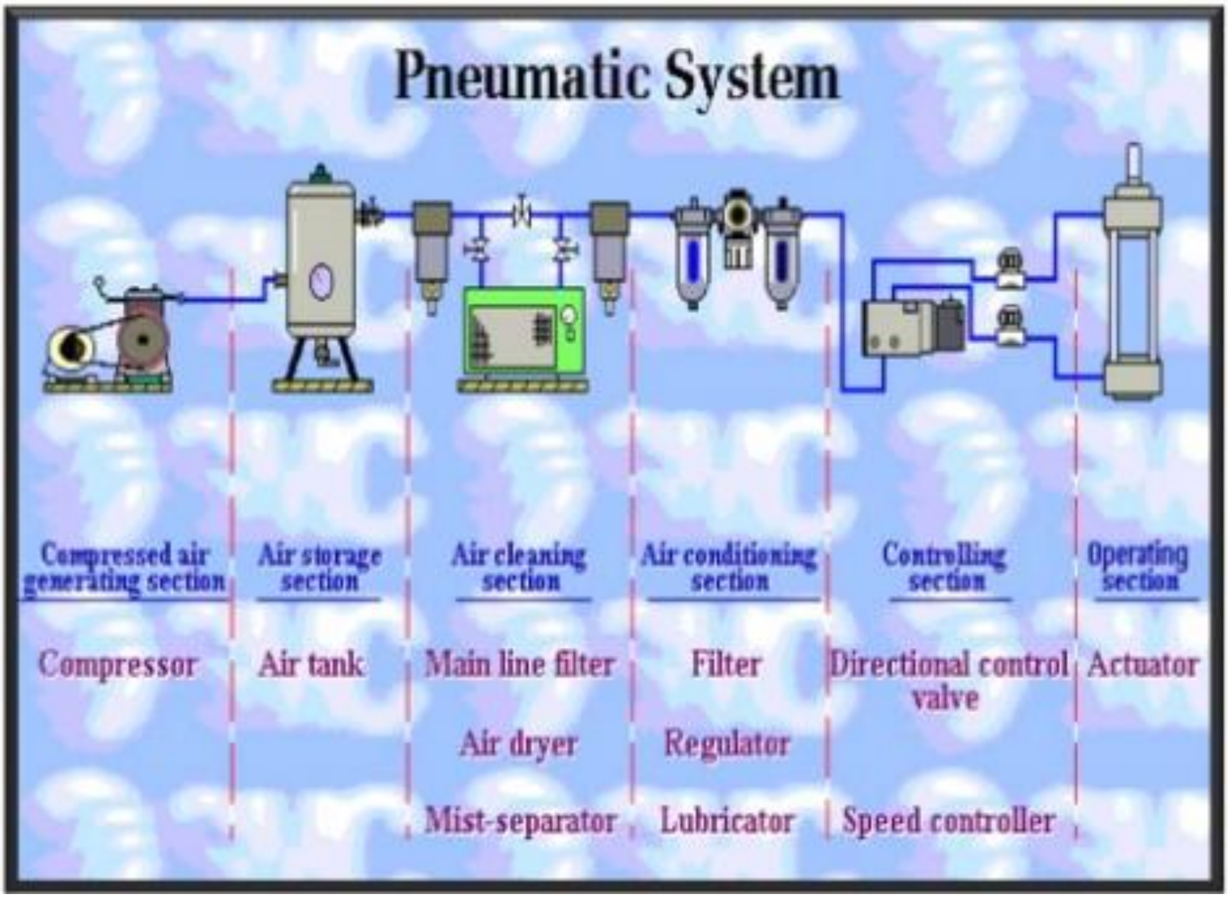
1. Compressor
2. Electric Motor
3. Pressure Switch
4. Check Valve
5. Tank
6. Pressure gauge
7. Auto Drain
8. Safety Valve
9. Air Dryer
10. Line Filter





Nfiautomation.org

Basic Pneumatic Components



Notes:____

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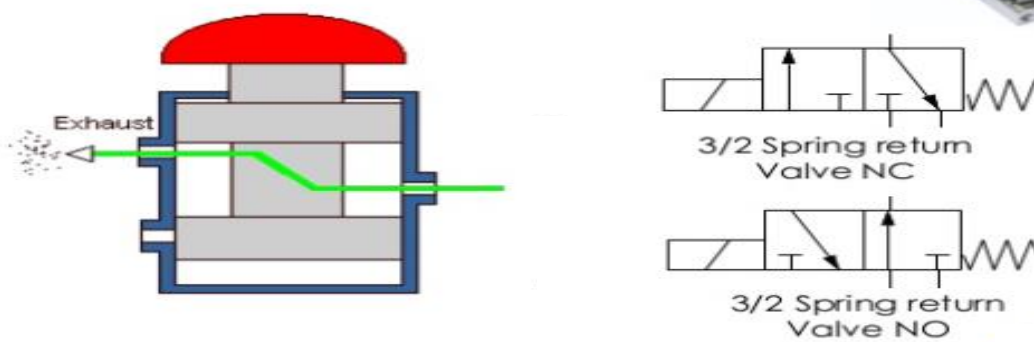
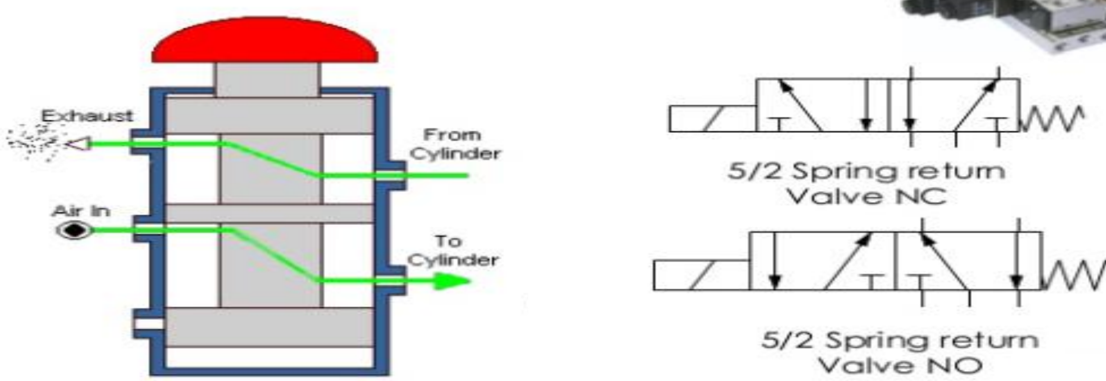
DCV Types

3/2– Directional Control Valves (DCV)



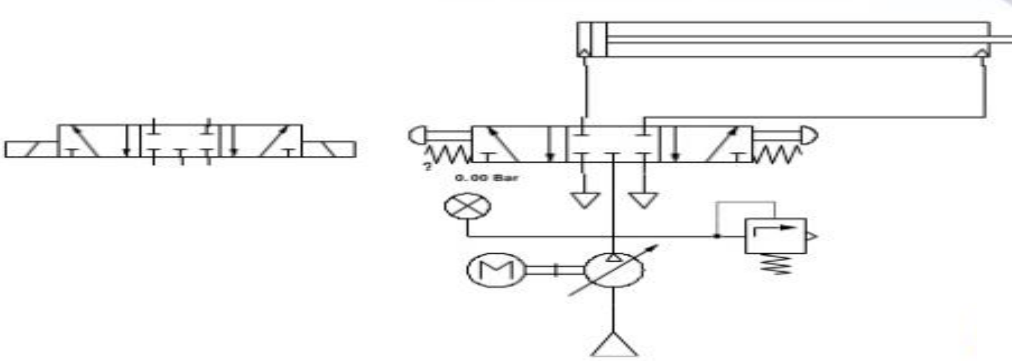
5/2– Directional Control Valves (DCV)



5/3– Directional Control Valves (DCV)

To stop the cylinder in between

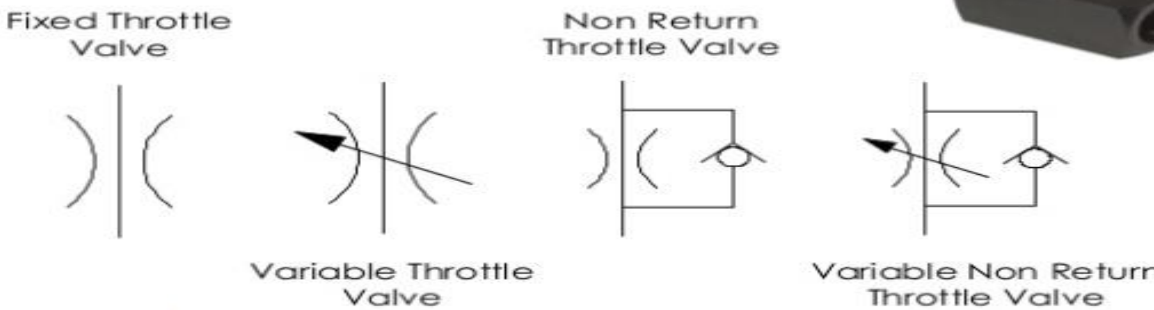
5/3 Double Button Spring Return Valve



Pneumatic Valves

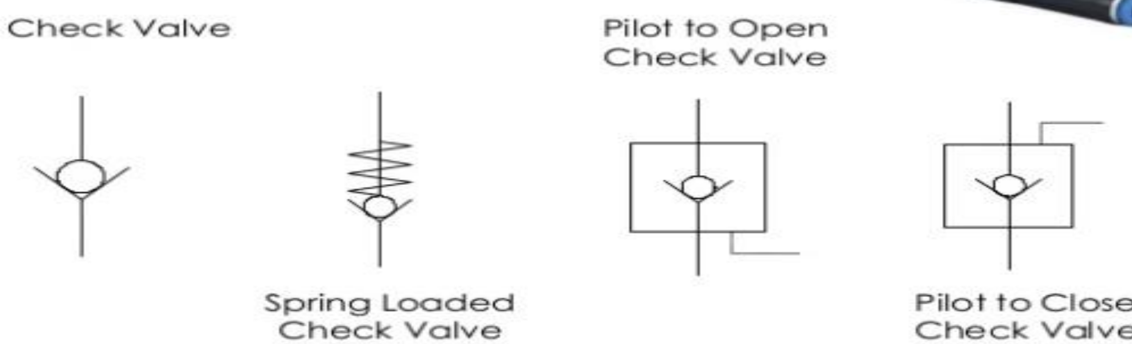
Flow Control Valves: Throttle Valve

To control the flow



Flow Control Valves: Check Valve

The check valve allows oil flow in one direction and blocks it in the opposite direction.



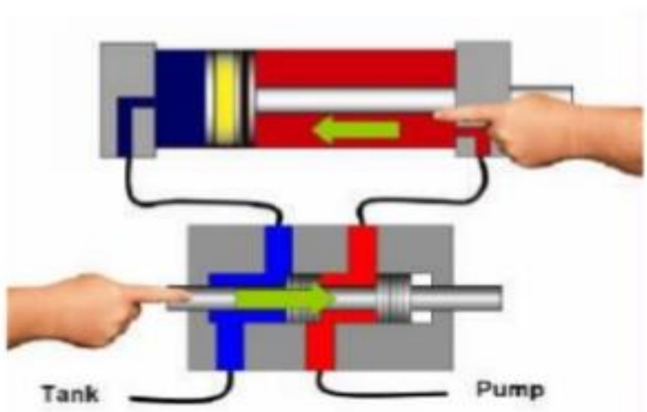
Shut off Valves

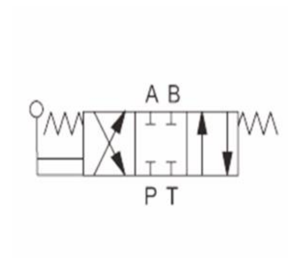
The shut-off valve can isolate 2 distinct lines in an hydraulic circuit

Directional Control Valves

Valves – Directional Control Valves (DCV)

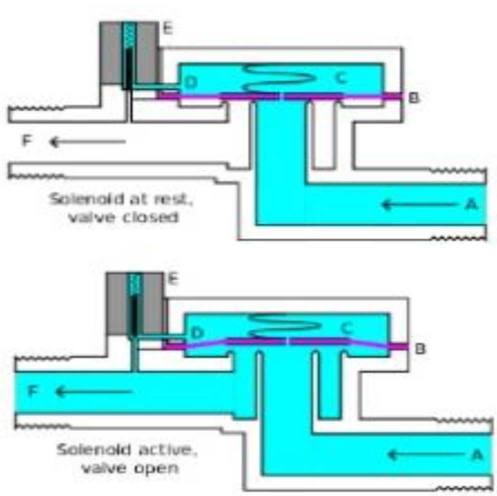
1. Allowing the passage of air and directing it to particular air lines
2. Canceling air signals as required by blocking their passage and / or
3. Relieving the air to atmosphere.

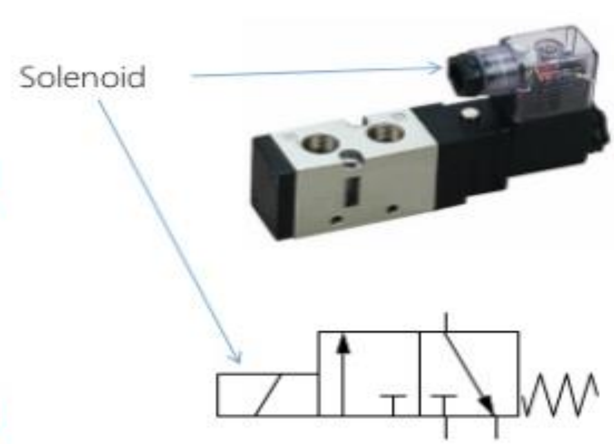




Electro- Pneumatics

Including Electronics/Electrical Circuits in Pneumatics Circuit to control automatically – typically referred to DCV





Solenoid Ratings: 24 VDC, 220 VAC

Single Acting Cylinders

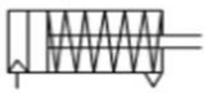
Air Consuming Section

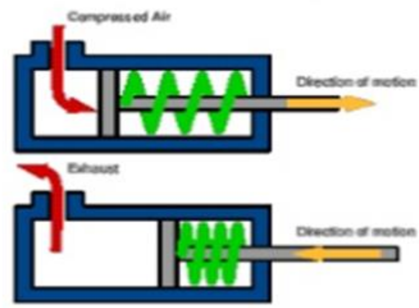
Actuators – Pneumatic Cylinders

Used to produce linear motion

Single Acting Cylinder

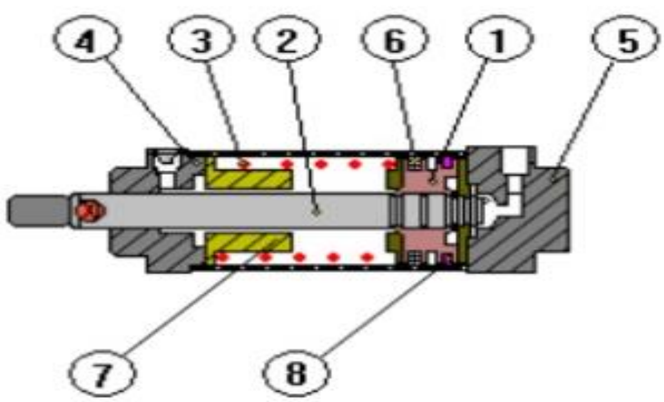
Single-Acting Cylinder With Spring Return





Single-Acting Cylinder With Spring Extend

Single Acting Cylinder



1. Piston
2. Piston rod
3. Compression spring
4. Front end cap
5. Rear end cap
6. Piston rings
7. Stop
8. Barrel

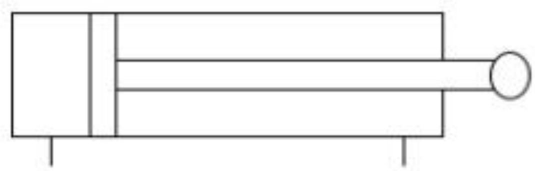
Double Acting Cylinders

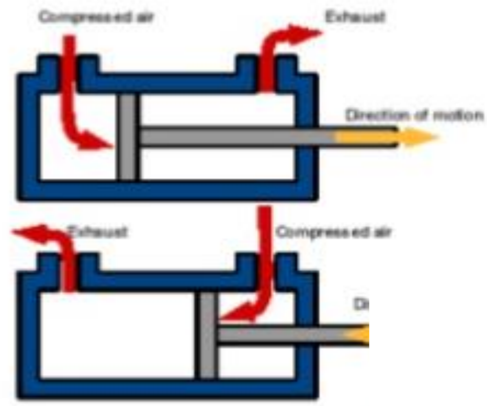
Air Consuming Section

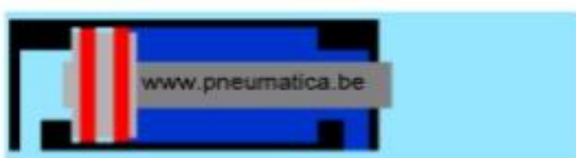
Actuators – Pneumatic Cylinders

Used to produce linear motion

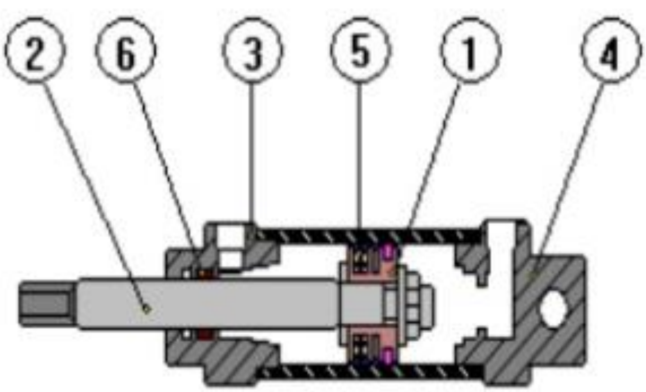
Double Acting Cylinder







Double Acting Cylinder



1. Piston
2. Piston rod
3. Front end cap
4. Rear end cap
5. Piston rings
6. Rod seal / Scraper

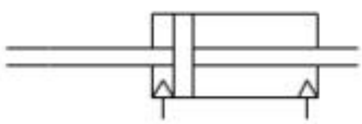
Double Acting Cylinders

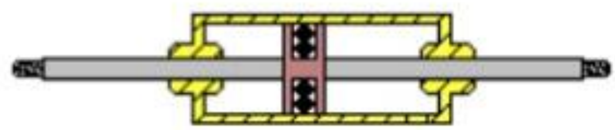
Air Consuming Section

Actuators – Pneumatic Cylinders

Used to produce linear motion

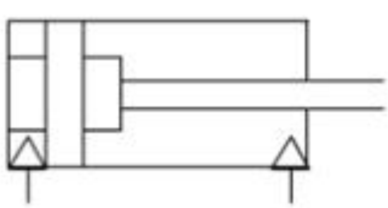
Double Acting Double Rod Cylinder

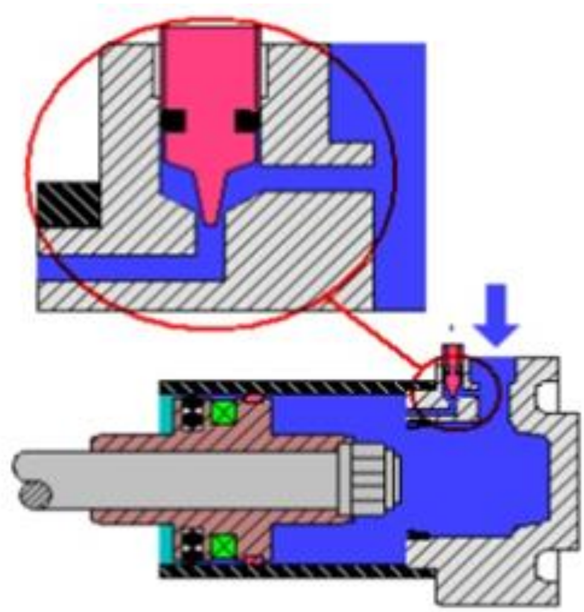




A double ended piston rod makes a cylinder stronger against side load, as it has two bearings at the widest distance possible. This type of cylinder is often mounted with rods fixed and the cylinder itself moving to displace a part.

Double Acting Cylinder with Cushion





On large cylinders, the shock forces can be absorbed by an air cushion that decelerates the piston over the last portion of the stroke

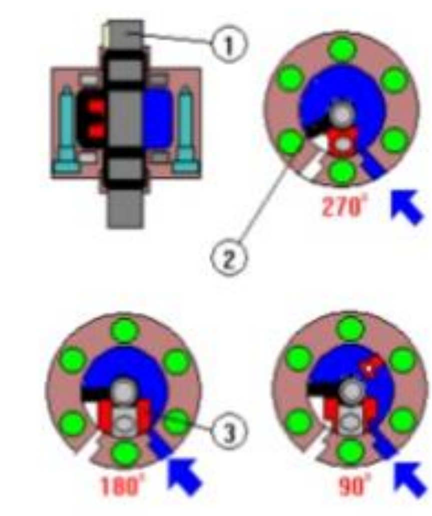
Rotary Actuators

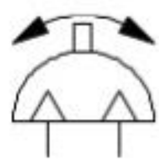
Air Consuming Section

Actuators – Other types of Cylinders

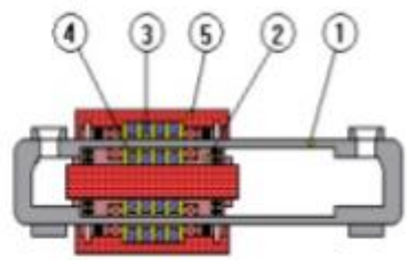
Used to produce rotary/linear motion

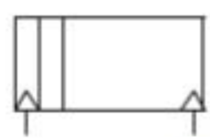
Rotary Actuator- Vane Type





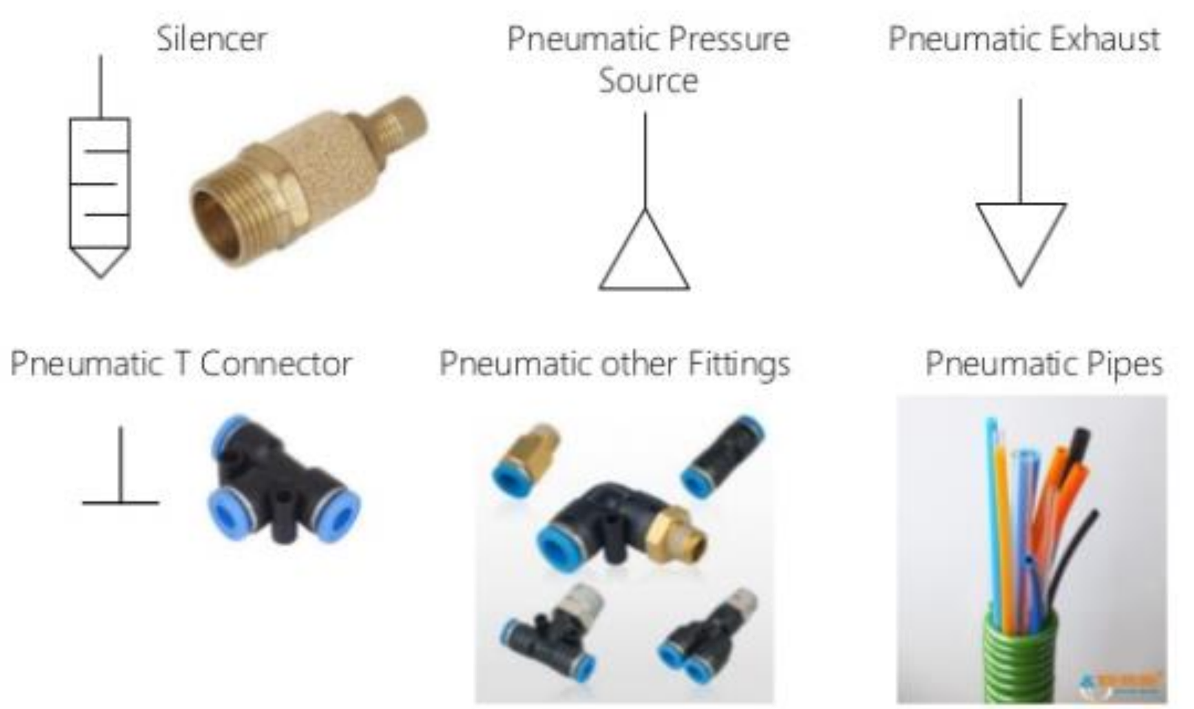
Rodless Cylinder





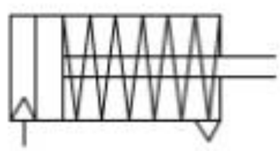
Lines and Connections

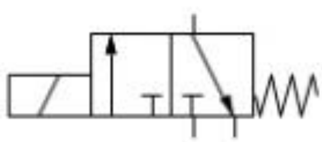
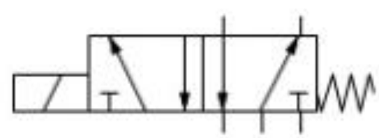
Pneumatics Flow Lines & Connections



Pneumatics Exercises

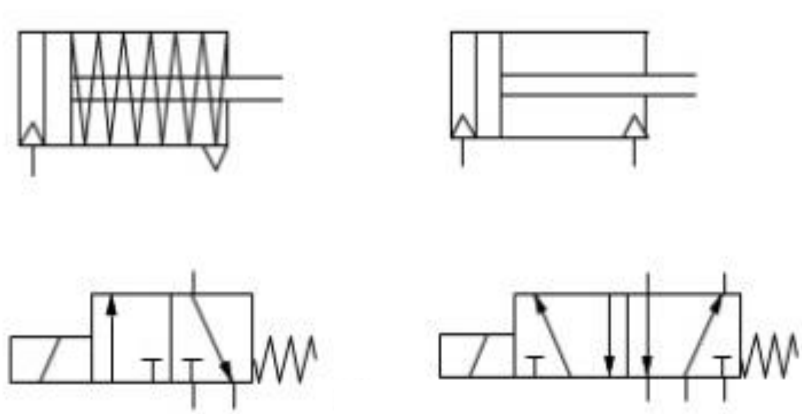
1) Draw a pneumatic circuit to actuate two Single Acting Spring Return cylinder with one 3/2 Valve
2) Draw a pneumatic circuit to actuate Double acting Cylinder with 5/2 Valve



Pneumatics Exercises

1) Draw an Electro- pneumatic circuit to actuate Single acting cylinder with 3/2 solenoid valve actuated by Toggle switch
2) Draw a pneumatic circuit to actuate & latch Double acting Cylinder with 5/3 Spring return Solenoid Valve



Hydraulics & Pneumatics

Unit 7: Cooking Equipment Applications

Fundamentals of Fluid Power

AELLC Arch Fry Dispenser

One application of pneumatics in commercial cooking equipment is in the Arch Fry Dispenser. The Arch Fry Dispenser is a compact automated system that replaces manual basketing of Fries and the equipment that goes with it. The Arch Fry Dispenser automatically weighs 1 pound or 1.5 pound, loads of frozen French Fries and dispenses them into the Fry Baskets. The Arch Fry Dispenser's Hopper 42 lbs. of frozen fries prior to Basket Loading. A rotating Dispenser Drum inside the Hopper transfers the frozen fries onto the Accumulator Doors where an electronic Load Cell accurately weighs the French Fries. Empty Fry Baskets are placed on the Upper Guide. The Fry Baskets slide under the Accumulator Doors where French Fries are dispensed into them. The Basket Lift then lowers the filled Fry Baskets onto the Lower Guide where the Fry Baskets wait to be picked up by a crew person. The Arch Fry Dispenser is usually positioned to the right of an existing fry station and requires 36 linear inches of floor space. NOTE: This piece of equipment is made in America and has American sizes of hardware. All hardware metric conversions are approximate and can vary in size.

AUTOMATED EQUIPMENT LLC

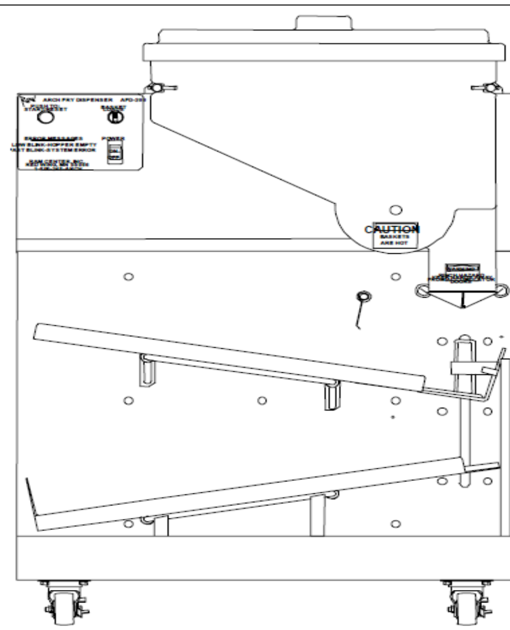
MODEL AFD-200
Arch Fry Dispenser
EQUIPMENT MANUAL
p/n 202089

MANUFACTURED EXCLUSIVELY FOR McDONALD'S BY

Automated Equipment LLC
5128 Moundview Drive
Red Wing, Mn 55066
Phone: 1 (612) 385-2273
Fax: 1 (612) 385-2166
http://www.autoequipllc.com

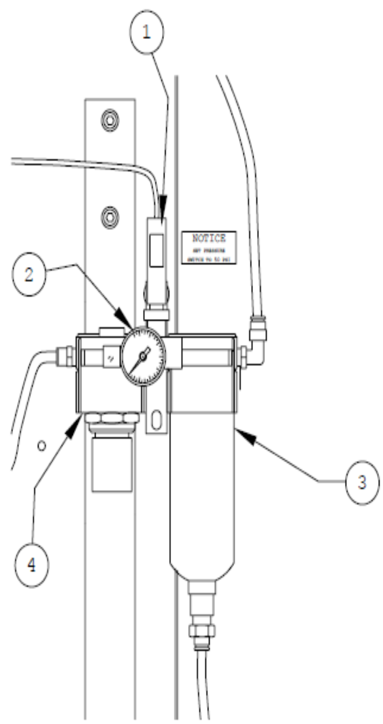
For Service Call
1 (800) 248-2724

After hours, your call will be handled by a pager service. A Technical Support Representative will return your call.



AELLC Arch Fry Dispenser

The picture below shows the air filter/regulator assembly. This equipment requires knowledge of pressure switches, pressure gauges, and regulators. Read the functions of each below.

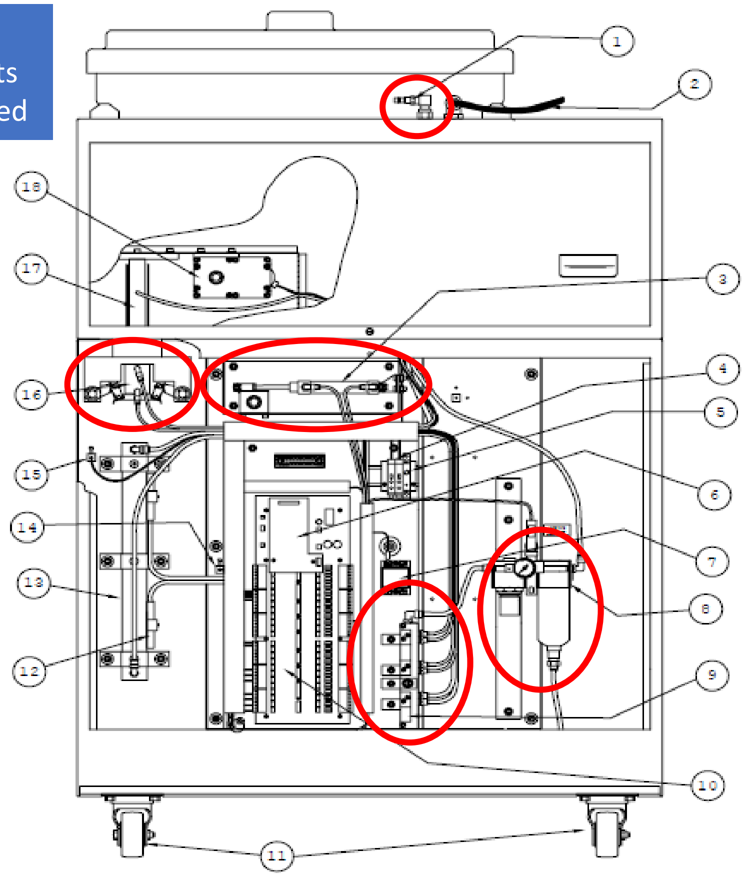


AIR FILTER/REGULATOR (Part Number 202250)

Item	Part Number	Description	Qty	Function
1	included	Pressure Switch	1	Monitors the air pressure, and detects a loss of pressure.
2	202606	Pressure Gauge	1	Displays the current system pressure. Assists in adjusting the regulator.
3	202245	Mist Separator with Auto Drain – Watts (Black)	1	Automatically drains water and debris from the Air Line that may cause damage to the Arch Fry Dispenser.
3	290095	Mist Separator with Auto Drain – SMC (Gray)	1	Automatically drains water and debris from the Air Line that may cause damage to the Arch Fry Dispenser.
4	included	Pressure Regulator	1	Regulates 80 PSI (5.4 bar) pressure from the 90-120 PSI (6 - 8 bar) Compressor.

AELLC Arch Fry Dispenser

Pneumatic Components Circled in Red



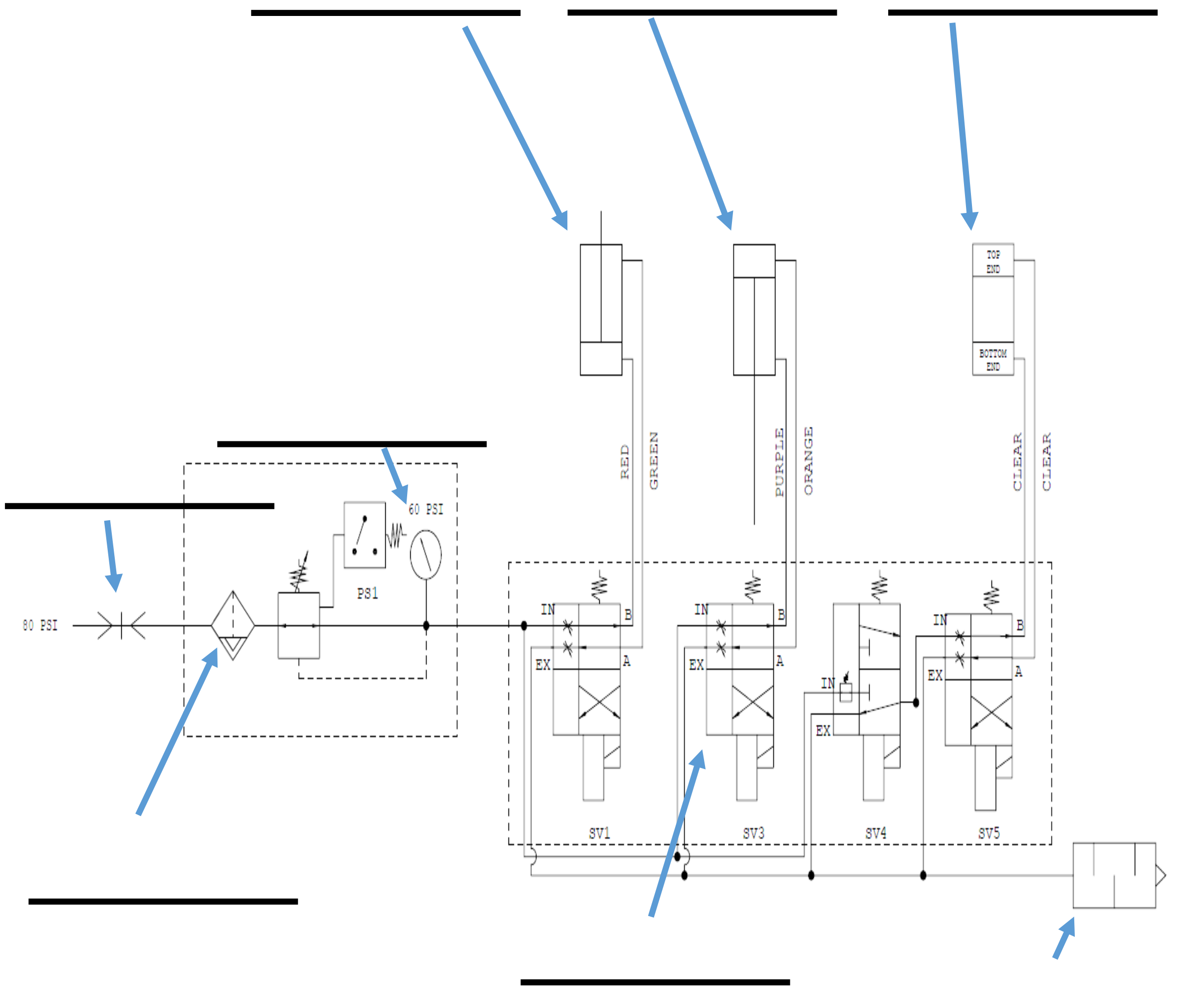
Arch Fry Dispenser (REAR VIEW)

Item	Part Number	Description	Qty	Function
1	213609 213610 213478	Quick Coupler Nipple Quick Disconnect Quick Disconnect Fitting	1 1 1	Connection point for the air line from the compressor. Disconnects airline from the dispenser. Adapts airline to quick disconnect.
2	202172	Power Cord	1	Supplies the Arch Fry Dispenser with power from the wall
3	216089	Stop Gate Cylinder	1	Air-operated cylinder that activates the stop gate.
4	213365	Fiber Optic Amplifiers #1-#2	2	Generates a red light for sensors #1-#2, and controls the sensitivity of the sensors, and inputs Fry Basket present to control card.
5	216485	1.5 AMP Circuit Breaker	1	Protects the fry Drum Motor from electrical overload.
6	213367	Load Cell Board	1	Translates information from the Load Cell into data that the Arch Fry Dispenser I/O Board computer can understand.
7	213924	Solid State Relay	1	Provides high current drive to the drum motor.
8	202250	Filter/Regulator Assembly	1	Controls and monitors the pressure of the air supplied to the Arch Fry Dispenser.
9	203985	4-Stack Air Valve Manifold	1	Air valves that control cylinders in the Arch Fry Dispenser.

7

AELLC Arch Fry Dispenser

The picture below shows different pneumatic components on the Arch Fry Dispenser. See if you can identify the components by their schematic symbol.



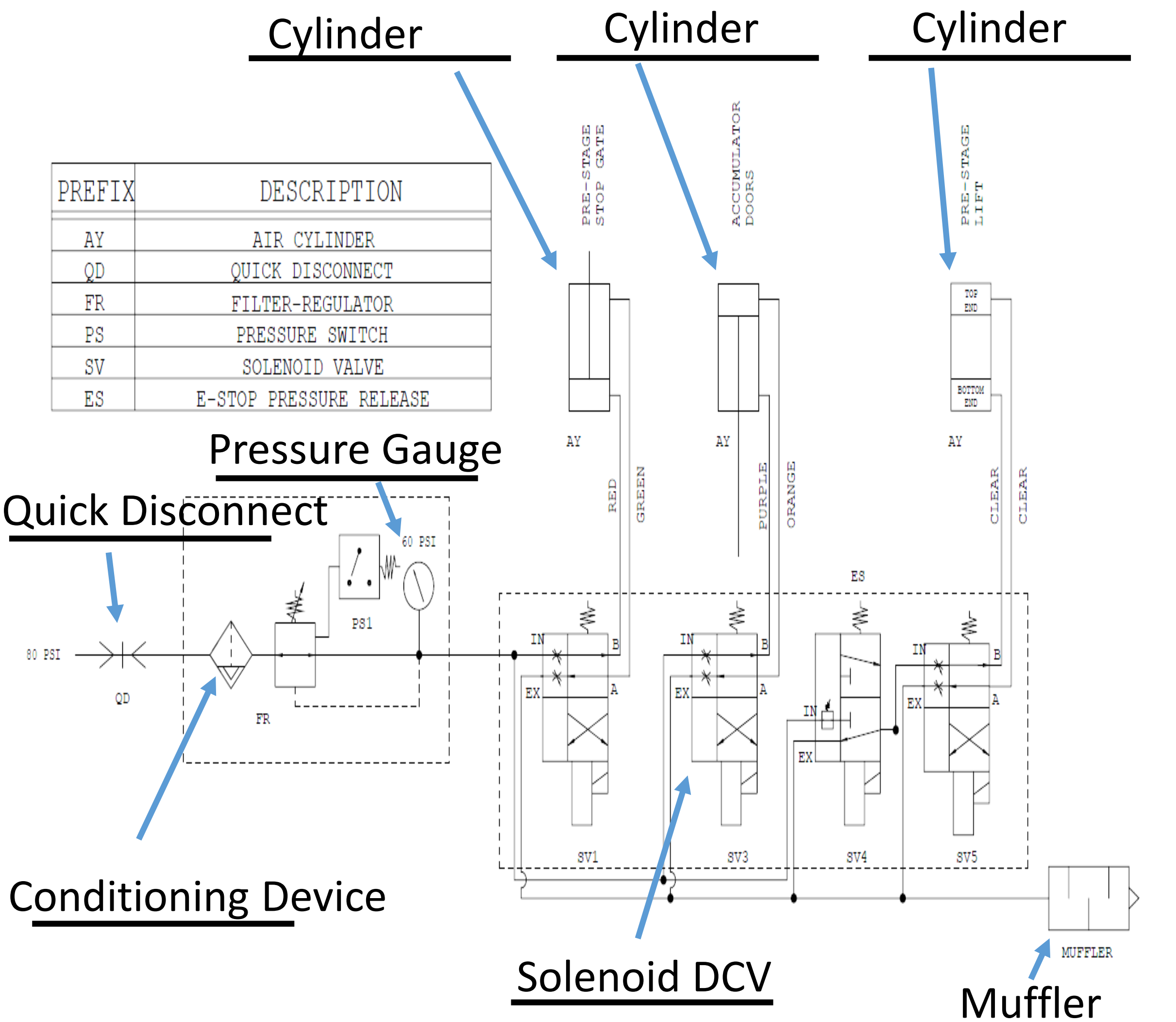
Solenoids Illustrated in the De-energized Condition

Unit 7: Cooking Equipment Applications

Fundamentals of Fluid Power

AELLC Arch Fry Dispenser

The picture below shows different pneumatic components on the Arch Fry Dispenser. Answer Sheet.



PREFIX	DESCRIPTION
AY	AIR CYLINDER
QD	QUICK DISCONNECT
FR	FILTER-REGULATOR
PS	PRESSURE SWITCH
SV	SOLENOID VALVE
ES	E-STOP PRESSURE RELEASE

Solenoids Illustrated in the De-energized Condition

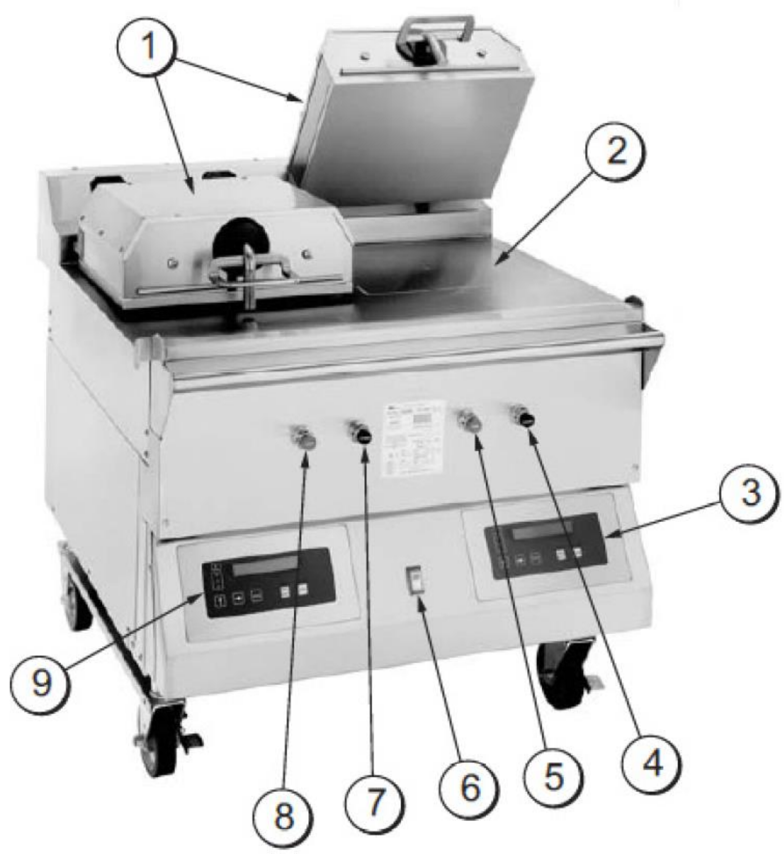
Taylor Auto Lift Grills

An application of pneumatics in the foodservice equipment industry is the Auto Lift Grill manufactured by Taylor.

Taylor Company Clamshell Grill

Models 11, 12, 13, 14, 15, 15E, 16, 22E, 32, 34, 35, 36, 38, C842, and C844

1. Upper Platens
2. Lower Cook Surface
3. Grill Control
4. Standby Button
5. Raise Button
6. Fan Interlock Switch
7. Standby Button
8. Raise Button
9. Grill Control



Fluid Power Glossary

Absorption - The physical mechanism by which one substance attracts and takes up another substance (liquid, gas, or vapor) into its interior.
Accumulator - A container in which fluid is stored under pressure as a source of fluid power.
Accumulator, hydropneumatic bladder - A hydropneumatic accumulator in which the liquid and gas are separated by an elastic bag or bladder.
Actuator, pneumatic/hydraulic - A device in which power is transferred from one pressurized medium (pneumatic) to another (hydraulic) without intensification.
Additive - A chemical added to a fluid to impart new properties or enhance those that already exist.
Adsorption - The physical mechanism by which one substance attracts another substance (either solid, liquid, gas, or vapor) to its surface and causes the second substance to adhere to its surface.
Aftercooler - A device which cools a gas after it has been compressed.
Afterfilter - A filter which follows the compressed air dryer and usually for the protection of downstream equipment from desiccant dust.
Air - A gas mixture consisting of nitrogen, oxygen, argon, carbon dioxide, hydrogen, small quantities of neon, helium and other gases.
Air bleeder - A device for removal of air.
Air breather - A device permitting air movement between atmosphere and the component in which it is installed.
Air motor - A device which converts pneumatic fluid power into mechanical torque and motion. It usually provides rotary mechanical motion.
Air, compressed (pressurized) - Air at any pressure greater than atmospheric pressure.
Air, dried - Air with moisture content lower than the maximum allowable for a given application.
Air, free - Air at ambient temperature, pressure, relative humidity, and density.
Air, saturated - Air at 100% relative humidity, with a dew point equal to temperature.
Air, standard - Air at a temperature of 68.8° F, a pressure of 14.70 pounds per square inch absolute, and a relative humidity of 36% (0.0750 pounds per cubic foot). In gas industries the temperature of "standard air" is usually given as 60.8° F.
Amplification, power - The ratio between the output signal variations and the corresponding input (control) power variation (for analog devices only).
Amplification, pressure - Ratio between outlet pressure and inlet (control) pressure.
Amplification - The ratio between the output signal variations and the control signal variations (for analog devices only).
Analog - Of or pertaining to the general class of fluidic devices or circuits whose output varies as a continuous function of its input.

Fluid Power Glossary

AND device - A control device which has its output in the logical 1 state if and only if all the control signals assume the logical 1 state.
Aniline point - The lowest temperature at which a liquid is completely miscible with an equal volume of freshly distilled aniline (ASTM Designation D611-07).
Aniline point - The lowest temperature at which equals volumes of pure, fresh aniline and an oil will completely dissolve in one another is the aniline point of the oil.
Bernoulli's Law - If no work is done on or by a flowing frictionless liquid, its energy due to pressure and velocity remains constant at all points along the streamline.
Bleeding - Migration to the surface of plasticizers, waxes, or similar materials to form a film or beads.
Boyle's Law - The absolute pressure of a fixed mass of gas varies inversely as the volume, provided the temperature remains constant.
Breakout Force - That force necessary to initiate sliding by overcoming static coefficient of friction. An excessive breakout force indicates the development of adhesion.
Breathing capacity - A measure of flow rate through an air breather.
Bulk modulus - The measure of a fluid's resistance to compressibility. It is the reciprocal of compressibility.
Cavitation - A localized gaseous condition within a liquid stream which occurs where the pressure is reduced to the liquid's vapor pressure, often as a result of a solid body, such as a rapidly moving piston moving through the liquid. Also, the pitting or wearing away of a solid surface as a result of low fluid levels that draw air into the system, producing tiny bubbles that expand explosively at the pump outlet, causing metal erosion and eventual pump destruction.
Charles' Law - The volume of a fixed mass of gas varies directly with absolute temperature, provided the pressure remains constant.
Circuit - An arrangement of interconnected components and parts.
Cold Flexibility - Flexibility following exposure to a predetermined time.
Cold Flow - Continued deformation under stress.
Compatibility, Seal - Ability of an elastomer to resist the action of a fluid on its dimensional and mechanical properties.
Compressibility - The change in volume of a unit volume of a fluid when subjected to a unit change in pressure.
Compression Modulus - The ratio of the compressive stress to the resulting compressive strain (the latter expressed as a fraction of the original height or thickness in the direction of the force). Compression modulus may be either static or dynamic.

Compression Set - The amount by which a rubber specimen fails to return to original shape after release of the compressive load.
Compressor - A device which converts mechanical force and motion into pneumatic fluid power.
Condensation - The process of changing a vapor into a liquid condensate by the extraction of heat.
F-R-L Unit - An assembly comprising an air **filter**, pressure **regulator**, and a **lubricator**.
Conductor - A component whose primary function is to contain and direct fluid.
Contaminant - Any material or substance which is unwanted or adversely affects the fluid power system or components, or both.
Control - A device used to regulate the function of a component or system.
Controller - A device which senses a change of fluid state and automatically makes adjustments to maintain the state of the fluid between predetermined limits, e.g., pressures, temperatures, etc.
Copolymer - A polymer consisting of two different monomers chemically combined.
Creep - The progressive relaxation of a given rubber material while it is under stress. This relaxation eventually results in permanent deformation or "set."
Cushion - A device which provides controlled resistance to motion.
Cylinder - A device which converts fluid power into linear mechanical force and motion. It usually consists of a movable elements such as a piston and piston rod, plunger or ram, operating within a cylindrical bore.
Cylinder cap - A cylinder end closure which completely covers the bore area.
Cylinder capacity, extending - Volume required for one full extension of a cylinder.
Cylinder capacity, retracting - Volume (annular) absorbed by one full retraction of the cylinder.
Cylinder capacity - The volume of a theoretically incompressible fluid that would be displaced by the piston during a complete stroke. (For double acting cylinders it must be given for both directions of stroke.)
Cylinder force, theoretical - The pressure multiplied by the effective piston area, ignoring friction. For double acting cylinders, the value must be given for both directions of stroke.
Cylinder, adjustable stroke - A cylinder equipped with adjustable stops at one or both ends to limit piston travel.
Cylinder area, piston rod - Cross-sectional area of the piston rod.
Cylinder area, piston, effective - Area upon which fluid pressure acts to provide a mechanical force.
Cylinder bore - The internal diameter of the cylinder body.

Fluid Power Glossary

Cylinder, cushioned - A cylinder with a piston-assembly deceleration device at one or both ends of the stroke.
Cylinder, differential - A double acting cylinder in which the ratio of the area of the bore to the annular area between the bore and the piston rod is significant in circuit function.
Cylinder, double acting - A cylinder in which fluid force can be applied to the moveable element in either direction.
Cylinder, double rod - A cylinder with a single piston and a piston rod extending from each end.
Cylinder, dual stroke - A cylinder combination which provides two working strokes.
Cylinder, duplex - A unit comprised of two cylinders with independent control, mechanically connected on a common axis to provide three or four positions depending on the method of application.
Cylinder, piston type - A cylinder in which the piston has a greater cross-sectional area than the piston rod.
Cylinder, plunger (ram) - A cylinder in which the piston has the same cross-sectional area as the piston rod.
Cylinder, rotary actuator - A cylinder which translates piston reciprocation into oscillation of an output shaft.
Cylinder, rotating - A cylinder in which the piston and piston rod, plunger or ram, is permitted to rotate with reference to the cylinder housing.
Cylinder, single acting - A cylinder in which the fluid force can be applied to the movable element in only one direction.
Cylinder, tandem - Arrangement of at least two pistons on the same rod moving in separate chambers on the same cylinder body allowing the compounding of force on the piston rod.
Cylinder, telescoping - Cylinder with two or more stages or extensions, achieved by hollow piston rods sliding one within the other (may be single or double acting).
Cylinder, tie rod - A cylinder with head and cap end closures that are secured by tie rods.
Darcy's Formula - A formula used to determine the pressure drop due to flow friction through a conduit.
Deliquescent - Moisture is separated by using the absorptive properties of special hygroscopic compounds.
Desiccant - Material that tends to remove moisture from compressed air.
Dew point - The temperature at which vapors in a gas condense. For practical purposes, it must be referred to a stated pressure.
Digital - Of or pertaining to the general class of fluidic devices or circuits whose output varies in discrete steps (i.e., pulses or "on-off" characteristics).

Fluid Power Glossary

Displacement, volumetric - Volume absorbed or displaced per stroke of a cylinder or per cycle of a pump or motor.
Dissolved air - Air which is dispersed at a molecular level in hydraulic fluid to form a single phase.
Dissolved water - Water which is dispersed at a molecular level in hydraulic fluid to form a single phase.
Dither - A low amplitude, relatively high frequency periodic electrical signal, sometimes superimposed on the servo valve input to improve system resolution. Dither is expressed by the dither frequency (Hz) and the peak-to-peak dither current amplitude.
Droop - The deviation between no flow secondary pressure and secondary pressure at a given flow.
Dryer, compressed air - A device for reducing the moisture content of the working compressed air.
Durometer - 1. An instrument for measuring the hardness of rubber. Measures the resistance to the penetration of an indenter point into the surface of rubber. 2. Numerical scale of rubber hardness.
Efficiency - Ratio of output to the corresponding input.
Elasticity - The property of a material which tends to return to its original shape after deformation.
Elastomer - Any synthetic or natural material with resilience or memory sufficient to return to its original shape after distortion.
Elongation - Generally means "ultimate elongation" or percent increase in original length of a specimen when it breaks.
Emulsion, oil in water - A dispersion of oil in a continuous phase of water.
Emulsion, water in oil - A dispersion of water in a continuous phase of oil.
Emulsifier - additive that promotes formation of a stable mixture, or emulsion, of oil and water.
Emulsion - A homogeneous dispersion of two immiscible liquids, generally of a milky or cloudy appearance.
Entrained air - A mechanical mixture of air bubbles having a tendency to separate from the liquid phase.
Expectancy, life - The predicted working period during which a component or system will maintain a specified level of performance under specified conditions. Sometimes expressed in statistical terms as a probability.

Fluid Power Glossary

Filter - 1. A device whose primary function is the removal by porous media of insoluble contaminants from a liquid or a gas. 2. Chemically inert, finely divided material added to the elastomer to aid in processing and improve physical properties.
Filter, strainer - A coarse hydraulic filter usually of woven wire construction. This may be in the form of a complete filter or just an element.
Filter, by-pass (reserve) A filter which provides an alternate unfiltered flow path around the filter element when a preset differential pressure is reached.
Filter, spin-on - A filter with spin-on element sealed in its own pressure housing for independent mounting to the filter.
Filtration ratio (βm) - The ratio of the number of particles greater than a given size (β) in the influent fluid to the number of particles greater than the same size (m) in the effluent fluid.
Fitting - A connector or closure for fluid power lines and passages.
Fitting, compression - A fitting which seals and grips by manual adjustable deformation.
Fitting, flange - A fitting which utilizes a radially extending collar for sealing and connection.
Fitting, flared - A fitting which seals and grips by a pre-formed flare at the end of the tube.
Fitting, flareless - A fitting which seals and grips by means other than a flare.
Flash point - The temperature to which a liquid must be heated under specified conditions of the test method to give off sufficient vapor to form a mixture with air that can be ignited momentarily by a flame.
Flip flop - A digital component or circuit with two stable states and sufficient hysteresis so that it has "memory." Its state is changed with a control pulse; a continuous control signal is not necessary for it to remain in a given state.
Flow characteristic curve - The change in regulated (secondary) pressure occurring as a result of a change in the rate of air flow over the operating range of the regulator.
Flow rate - The volume, mass or weight of a fluid passing through any conductor per unit of time.
Flow, laminar (streamline) - A flow situation in which fluid moves in parallel lamina or layers.
Flow, output - Flow rate discharged at the outlet port.
Flow, turbulent - A flow situation in which the fluid particles move in a random fluctuating manner.
Flow - Movement of fluid generated by pressure differences.
Fluid capacity - The liquid volume coincident with the "high" mark of the level indicator.
Fluid friction - Friction due to the viscosity of fluids.
Fluid logic - A branch of fluid power associated with digital signal sensing and information processing, using components with or without moving parts.

Fluid Power Glossary

Fluid miscibility - Capacity of fluids to be mixed in any ratio without separation into phases.
Fluid power system - A system that transmits and controls power through use of a pressurized fluid within an enclosed circuit.
Fluid power - Energy transmitted and controlled through use of a pressurized fluid.
Fluid stability - Resistance of a fluid to permanent changes in properties.
Fluid stability, oxidation - Resistance of a fluid to permanent changes caused by chemical reaction with oxygen.
Fluid, anti-corrosive - A fluid containing metal corrosion inhibitors.
Fluid, aqueous - A fluid which contains water as a major constituent besides the organic material. The fire resistance properties are derived from the water content.
Fluid, fire resistant - A fluid difficult to ignite which shows little tendency to propagate flame.
Fluid, hydraulic - A fluid suitable for use in a hydraulic system.
Fluid, Newtonian - Fluid having a viscosity that is always independent of the rate of shear.
Fluid, pneumatic - A fluid suitable for use in a pneumatic system, usually air.
Fluid, rust protection - Capacity of a fluid to prevent the formation of rust under specified conditions.
Fluid - A liquid, gas or combination thereof.
Force motor - A type of electromechanical transducer having linear motion used in the input stages of servo valves.
Free air - Any compressible gas, air or vapor trapped within a hydraulic system that does not condense or dissolve to form a part of the system fluid.
Free water - Water droplets or globules in the system fluid that tend to accumulate at the bottom or top of the system fluid depending on the fluid's specific gravity.
Frequency response - The changes, under steady-state conditions, in the output variable which are caused by a sinusoidal input variable.
Gauge damper (snubber) - A device employing a fixed or variable restrictor inserted in the pipeline to a pressure gage, to prevent damage to the gage mechanism caused by rapid fluctuations of fluid pressure.
Gauge protector - A device inserted in the pipeline to a pressure gage and arranged to isolate the pressure gage from the fluid pressure if this exceeds a predetermined limit. The device can usually be adjusted to suit the range of the pressure gage.
Gauge, bourdon tube - A pressure gage in which the sensing element is a curved tube that tends to straighten out when subjected to internal fluid pressure.
Gauge, diaphragm - A gage in which the sensing element is relatively thin and its inner portion is free to deflect with respect to its periphery.
Gauge, instrument - An instrument or device for measuring, indicating, or comparing a physical characteristic.

Fluid Power Glossary

Gauge, pressure - A gage which indicates the pressure in the system to which it is connected.
Head - The height of a column or body of fluid above a given point expressed in linear units. Head is often used to indicate gage pressure. Pressure is equal to the height times the density of the fluid.
Head, cylinder - The cylinder end closure which covers the differential area between the bore area and the piston rod area.
Head, friction - The pressure required to overcome the friction at the interior surface of a conductor and between fluid particles in motion. It varies with flow, size, type and condition of conductors and fittings, and the fluid characteristics.
Head, pressure - The pressure due to the height of a column or body of fluid.
Head, static - The height of a column or body of fluid above a given point.
Heat exchanger - A device which transfers heat through a conducting wall from one fluid to another. (Typically to cool a system.)
Heater - A device which transfers heat through a conducting wall from one fluid to another. (Typically to warm up a system.)
Hose, wire braided - Hose consisting of a flexible material reinforced with woven wire braid.
Hose - A flexible line or conductor whose nominal size is its inside diameter.
Hydraulic amplifier - A fluid device which enables one or more inputs to control a source of fluid power and thus is capable of delivering at its output an enlarged reproduction of the essential characteristics of the input. Hydraulic amplifiers may utilize sliding spools, nozzle-flappers, jet pipes, etc.
Hydraulic motor - A device which converts hydraulic fluid power into mechanical force and motion. It usually provides rotary mechanical motion.
Hydraulic motor efficiency, hydromechanical - Ratio of the effective torque to the derived torque.
Hydraulic motor efficiency, overall - Ratio of the output power to the effective hydraulic power.
Hydraulic motor efficiency, volumetric - Ratio of the derived output flow to the effective input flow.
Hydraulic motor, fixed displacement - A hydraulic motor in which the displacement per unit of output motion cannot be varied.
Hydraulic motor, flow, input - Flow rate crossing the transverse plane of the inlet port.
Hydraulic motor, gear, external - A motor having two or more external gears.
Hydraulic motor, gear, internal - A motor with an internal gear in engagement with one or more external gears.

Fluid Power Glossary

Hydraulic motor, gear - A motor in which two or more gears act in arrangement as working members.
Hydraulic motor, vane - A motor in which the fluid under pressure acting on a set of radial vanes causes rotation of an internal member.
Hydraulic stepping motor - A hydraulic motor which follows the commands of a stepped input signal to achieve positional accuracy.
Hydraulics - Engineering science pertaining to liquid pressure and flow.
Hydrodynamics - The engineering science which governs the movement of liquids and the forces opposing that movement.
Hydrokinetics - Engineering science pertaining to the energy of liquid flow and pressure.
Hydro-pneumatics - Pertaining to the combination of hydraulic and pneumatic fluid power.
Hydrostatic transmission - Combination of one or more hydraulic pumps and motors forming a unit.
Hydrostatics - Engineering science pertaining to the energy of liquids at rest.
Indicator, differential pressure - An indicator which signals a difference in pressure between two points in a fluid power system.
Inhibitor - Any substance which, when present in very small proportions, slows, prevents or modifies chemical reactions such as corrosion or oxidation.
Intensification, ratio of - The ratio of the secondary pressure to the primary pressure or of the primary flow rate to the secondary flow rate.
Intensifier, double acting - A unit which magnifies the secondary fluid pressure regardless of the direction of flow of the primary fluid.
Intensifier, single acting - A unit which only magnifies the fluid pressure in one direction of flow of the primary fluid.
Intensifier, single shot - An intensifier in which the continuous application of primary fluid at the inlet port can only give a limited volume of secondary fluid.
Intensifier - A device which converts low pressure fluid power into higher pressure fluid power.
Joint - A line positioning connector.
Joint, rotary - A joint connecting lines which have relative operational rotation.
Leakage rate - The rate at which a gas or liquid passes through a barrier. Total leakage rate includes the amounts that diffuse or permeate through the material of the barrier as well as the amount that escapes around it.
Line, return - A pipe (conductor) to return the working fluid to the reservoir.
Line, working - A line which conducts fluid power.
Line - A tube, pipe, or hose for conducting fluid.
Lubricator - A device which adds controlled or metered amounts of lubricants into a fluid power system.

Fluid Power Glossary

Magnetic plug - A plug which attracts and holds ferromagnetic particles.
Manifold - A conductor which provides multiple connection ports.
Maximum inlet pressure - The maximum rated gage pressure applied to the inlet port of the regulator.
Memory - Tendency of a material to return to original shape after deformation.
Meter-in Circuit - A speed control circuit in which the control is achieved by regulating the supply flow to the actuator.
Meter-out Circuit - A speed control circuit in which the control is achieved by regulating the exhaust flow from the actuator.
Modulus of elasticity - One of the several measurements of stiffness or resistance to deformation, but often incorrectly used to indicate specifically static tension modulus.
Modulus - Tensile stress at a specified elongation. (Usually 100% elongation for elastomers.)
Moving parts logic - The technology of achieving logic control by means of fluid devices having moving parts.
Muffler - A device for reducing gas flow noise. Noise is decreased by back pressure control of gas expansion.
Newt - A unit of kinematic viscosity in the English system. It is expressed in square inches per second (see Stokes).
NOR device - A control devices which has its output in the logical 1 state if and only if all the control signals assume the logical 0 state.
NOT device - A control device which has its output in the logical 1 state if and only if the control signal assumes the logical 0 state. The NOT device is a single input NOR device.
Oil swell - The change in volume of a rubber article due to absorption of oil or other fluid.
Open Circuit - A circuit in which return fluid is directed to a reservoir before being recirculated.
OR device - A control device which has its output in the logical 0 state if and only if all the control signals assume the logical 0 state.
Outgassing - A vacuum phenomenon wherein a substance spontaneously releases volatile constituents in the form of vapors or gases. In rubber compounds, these constituents may include water vapor, plasticizers, air, inhibitors, etc.
Output stage - The final stage of hydraulic amplifications used in a servovalve.
Ozone resistance - Ability to withstand the deteriorating effect of ozone (which generally causes cracking).

Fluid Power Glossary

Packing - A sealing device consisting of bulk deformable material of one or more mating deformable elements, reshaped by manually adjustable compression to obtain and maintain effectiveness. It usually uses axial compression to obtain radial sealing.
Pascal's Law - A pressure applied to a confined fluid at rest is transmitted with equal intensity throughout the fluid.
Permanent set - The deformation remaining after a specimen has been stressed in tension for a definite period and released for a definite period.
Permeability - The rate at which a liquid or gas under pressure passes through a solid material by diffusion and solution. In rubber terminology, it is the rate of gas flow expressed in atmospheric cubic centimeters per second through an elastomeric material one centimeter square and one centimeter thick.
Petroleum fluid - A fluid composed of petroleum oil which may contain additives and/or inhibitors.
Pipe - A conductor whose outside diameter is standardized for threading. Pipe is available in standard, extra strong, or double extra strong wall thickness.
Piston rod - The element transmitting mechanical force and motion from the piston.
Plasticizer - A substance, usually a heavy liquid, added to an elastomer to decrease stiffness, improve low temperature properties, and improve processing.
Pneumatics - Engineering science pertaining to gaseous pressure and flow.
Poise - The standard unit of dynamic viscosity in the cgs (centimeter gram second) system. It is the ratio of the shearing stress to the shear rate of fluid and is expressed in milli-pascal sec. (equals 1 centipoise).
Polymer - A material formed by the joining together of many (poly) individual units (mer) of one or more monomers; synonymous with elastomers.
Port - A terminus of a passage in a component to which conductors can be connected.
Port, differential pressure - A port which provides a passage to the upstream and downstream sides of a component.
Post cure - The second step in the vulcanization process for the more exotic elastomers. Provides stabilization of parts and drives off decomposition products resulting from the vulcanization process.
Pour point - The lowest temperature at which a liquid will flow under specified conditions (ASTM Designation D97).
Power unit - A combination of pump, pump drive, reservoir, controls and conditioning components to supply hydraulic power to a system.
Pressure - Force per unit area, usually expressed in pounds per square inch (bar).
Pressure, absolute - The pressure above zero absolute, i.e., the sum of atmospheric and gage pressure. In vacuum related work it is usually expressed in millimeters of mercury (mm-Hg).

Fluid Power Glossary

Pressure, atmospheric - Pressure exerted by the atmosphere at any specific location. (Sea level pressure is approximately 14.7 pounds per square inch absolute. 1 bar = 14.5 psi).
Pressure, back - The pressure encountered on the return side of a system.
Pressure, break loose (breakout) - The minimum pressure which initiates movement.
Pressure, burst - The pressure which causes failure of and consequential loss of fluid through the product envelope.
Pressure, charge - The pressure at which replenishing fluid is formed into a fluid power system.
Pressure, control range - The permissible limits between which system pressure may be set.
Pressure, cracking - The pressure at which a pressure-operated valve begins to pass fluid.
Pressure, differential (pressure drop) - The difference in pressure between any two points of a system or a component.
Pressure, gage - Pressure differential above or below ambient atmospheric pressure.
Pressure, induced - Pressure generated by an externally applied force.
Pressure, inlet - The pressure at the apparatus inlet port.
Pressure, intensified - In a fluid power cylinder, the outlet pressure required to slow the piston rod extending under regulated pressure introduced at the cap end.
Pressure, maximum inlet - The maximum rated gage pressure applied to the inlet.
Pressure, nominal - A pressure valve assigned to a component or system for the purpose of convenient designation.
Pressure, outlet - Pressure at the apparatus outlet port.
Pressure, override - The difference between the cracking pressure of a valve and the pressure reached when the valve is passing its rated flow.
Pressure, peak - The maximum pressure encountered in the operation of a component.
Pressure, pilot - The pressure in the pilot circuit.
Pressure, precharge - The pressure of compressed gas in an accumulator prior to the admission of a liquid.
Pressure, proof - The non-destructive test pressure, in excess of the maximum rated operating pressure, which causes no permanent deformation, excessive external leakage, or other resulting malfunction.
Pressure, rated - The qualified operating pressure which is recommended for a component or system by the manufacturer.
Pressure, shock - The pressure existing in a wave moving at sonic velocity.

Fluid Power Glossary

Pressure, static - The pressure in a fluid at rest.
Pressure, surge - The pressure resulting from surge conditions.
Pressure, system - The pressure which overcomes the total resistances in a system. It includes all losses as well as useful work.
Pump - A device which converts mechanical torque and motion into hydraulic fluid power.
Pump, fixed displacement - A hydraulic pump in which the volume displaced per cycle cannot be varied.
Pump, gear, external - Pump with two or more external gears.
Pump, gear, internal - Pump with an internal gear in engagement with one or more external gears.
Pump, gear - Pump in which two or more gears act in engagement as pumping members.
Pump, hydraulic - A device which converts mechanical force and motion into hydraulic fluid power.
Pump, multiple stage - Two or more hydraulic pumps in series.
Pump, piston, axial - Pump having several pistons with mutually parallel axes which are arranged around and parallel to a common axis.
Pump, piston, inline - Pump having several pistons with mutually parallel axes arranged on a common plane.
Pump, piston, radial - Pump having several pistons arranged to operate radially.
Pump, piston - Pump in which the fluid volume is displaced by one or more reciprocating pistons.
Pump, screw - A hydraulic pump having one or more screws rotating in a housing.
Pump, vane, balanced - Pump in which the transverse forces on the rotor are balanced.
Pump, vane, unbalanced - Pump in which the transverse forces on the rotor are not balanced.
Pump, vane - A hydraulic pump having multiple radial vanes within a supporting rotor.
Pump, variable displacement - A hydraulic pump in which the volume displaced per cycle can be varied.
Quick -Acting Coupling - A component that can quickly join or separate a fluid line repeatedly by hand without the use of tools.
Refrigerated Dryer - Moisture is separated by lowering the air temperature by means of refrigeration compressor and heat exchanger.
Regenerative Circuit - A circuit in which pressurized fluid discharged from a component is returned to the system to reduce power input requirements.
Regenerative Dryer - The capacity of the dryer to separate moisture can be restored without replacing the drying compound.

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Regulator, Air Pressure - A (usually adjustable) pressure-reducing valve with pressure gauge that transforms a fluctuating air pressure supply to provide a constant, lower pressure output.
Reinforcing Agent - Material dispersed in an elastomer to improve compression, shear, or other stress properties.
Reservoir (tank) - A container for storage of liquid in a fluid power system.
Reservoir, Hydraulic - A reservoir for storing and conditioning a liquid in a hydraulic system.
Reservoir, pressure sealed - A sealed reservoir for storage of fluids under pressure.
Resilient - Capable of returning to original size and shape after deformation.
Reyn - The standard unit of absolute viscosity in the English system. It is expressed in pound-seconds per square inch.
Reynolds Number - A numerical ratio of the dynamic forces of mass flow to the shear stress due to viscosity. Flow usually changes from laminar to turbulent between Reynolds Numbers 2,000 and 4,000.
Ring, O - An elastomeric circular seal that has a round cross section.
Ring, piston - A piston sealing ring. It is usually one of a series and is often split to facilitate expansion or contraction.
Ring, scraper - A ring which removes material by a scraping action.
Rotation - The direction of rotation is always quoted as viewed looking at the shaft end. In dubious cases, provide a sketch.
Seal, cup - A sealing device with a radial base integral with an axial cylindrical projection at its outer diameter.
Seal, dynamic - A sealing device used between parts that have relative motion.
Seal, elastomer - A material having rubber-like properties; i.e., having the capacity for large deformation and rapid and substantially complete recovery on release from the deforming force.
Seal, rod (shaft) - A sealing device which seals the periphery of a piston rod.
Seal, static (gasket) - A sealing device used between parts that have no relative motion.
Sensor - A device which detects and transmits changes in external conditions.
Separator - A device whose primary function is to isolate contaminants by physical properties other than size. (Separators remove gas from liquid medium or remove liquid from gaseous medium).

Fluid Power Glossary

Sequence Circuit - A circuit which established the order in which two or more phases of a circuit occur.
Servo valve - A valve which modulates output as a function of an input command.
Servo valve, electrohydraulic - A servo valve which is capable of continuously controlling hydraulic output as a function of an electrical input.
Servo valve, electrohydraulic, flow control - An electrohydraulic servo valve whose primary function is control of output flow.
Servo valve hysteresis - The difference in the servo valve input currents required to produce the same output during a single cycle of valve input current when cycled at a rate below that at which dynamic effects are important.
Servo valve null leakage - Total internal leakage from the valve in the null position.
Servo valve, pressure control - A hydraulic servo valve whose primary function is the control of output pressure.
Shrinkage - Decreased volume of seal, usually caused by extraction of soluble constituents by fluids followed by air drying.
Silencer - A device for reducing gas flow noise. Noise is decreased by tuned resonant control of gas expansion.
Snubber - see gage damper.
Solenoid, digital - Electrically energized device which generates on-off signals.
Solenoid, proportional - An electrical device that reacts proportionally to strength of electrical signal.
Sorption - The term used to denote the combination of absorption and adsorption processes in the same substance.
Specific gravity, liquid - The ratio of the weight of a given volume of liquid to the weight of an equal volume of water.
Squeeze - Cross section diametric compression of O-ring between surface of the groove bottom and surface of other mating metal part in the gland assembly.
Stage - A hydraulic amplifier used in a servo valve. Servo valves may be single stage, two stage, three stage, etc.
Standard - A document, or an object for physical comparison, for defining product characteristics, products, or processes; prepared by a consensus of a properly constituted group of those substantially affected and having the qualifications to prepare the standard for voluntary use.
Stokes - The standard unit kinematic viscosity in the cgs (centimeter gram second) system. It is expressed in square centimeters per second; 1 centistokes equals 0.01 stokes.
Strainer - see filter, strainer.

Fluid Power Glossary

Surface tension - The surface force of a liquid in contact with a fluid by which it tends to assume a spherical form and to present the least possible surface. It is expressed in pounds per foot or dynes per centimeter.
Surge - A transient rise of pressure or flow.
Swell - Increased volume of specimen caused by immersion in a fluid (usually a liquid).
Switch, float - An electric switch which is responsive to liquid level.
Switch, flow - An electric switch operated by fluid flow.
Switch, pressure differential - An electric switch operated by a difference in pressure.
Switch, pressure - An electric switch operated by fluid pressure.
Synthetic fluid, silicate ester - A fluid compound of organic silicates. It may contain additives.
Synthetic fluid - Fluid other than mineral on which has been artificially compounded for use in a fluid power system.
Temperature, ambient - The temperature of the environment in which an apparatus is working.
Tensile strength - Force in pounds per square inch required to cause the rupture of a specimen of a rubber material.
Terpolymer - A polymer consisting of three different monomers chemically combined.
Tie rod - An axial external cylinder element which traverses the length of the cylinder. It is prestressed at assembly to hold the ends of the cylinder against the tubing. Tie rod extensions can be a mounting device.
Torque motor - A type of electromechanical transducer having rotary motion used in the input stages of servo valves.
Torque - Rotary force transmitted by the driving shaft of the pump.
Torr - A unit of pressure equal to 1/760 of an atmosphere.
Torricelli's Theorem - The liquid velocity at an outlet discharging into the free atmosphere is proportional to the square root of the head.
Transducer, flow - A device which converts fluid flow to an electrical signal.
Transducer, pressure - A device which converts fluid pressure to an electrical signal.
Trunnion - A mounting device consisting of a pair of opposite projecting cylindrical pivots. The cylindrical pivot pins are at right angle or normal to the piston rod centerline to permit the cylinder to swing in a plane.
Tube - A conductor whose size is its outside diameter. Tube is available in varied wall thickness and material.
Vacuum - Pressure less than ambient atmospheric pressure.
Vacuum pump - A device which uses mechanical force and motion to evacuate gas from a connected chamber to create subatmospheric pressure.

Fluid Power Glossary

Valve, cartridge - A valve with working parts contained in a cylindrical body. The cylindrical body must be inserted into a housing for use. Ports through the body cooperate with ports in the containing housing.
Valve, directional control - A valve whose primary function is to direct or prevent flow through selected passages.
Valve, directional control, 3-way - A directional control valve whose primary function is to pressurize and exhaust a port.
Valve, directional control, 4-way - A directional control valve whose primary function is to pressurize and exhaust two ports.
Valve, directional control, check - A directional control valve which permits flow of fluid in only one direction.
Valve, directly operated - A valve in which the controlling forces acting on the element directly influence the movement of the control elements.
Valve, electrohydraulic, proportional - A valve which responds proportionally to input signals.
Valve, flow control (flow metering) - A valve whose primary function is to control flow rate.
Valve, flow control, bypass - A pressure compensated flow control valve which regulates the working flow diverting surplus fluid to reservoir or to a second service.
Valve, flow control, deceleration - A flow control valve which gradually reduces flow rate to provide deceleration.
Valve, flow control, pressure compensated - A flow control valve which controls the rate of flow independent of system pressure.
Valve, flow dividing, pressure compensated - A flow dividing valve which divides the flow at a constant ratio regardless of the difference in the resistances of the branches.
Valve, flow dividing - A valve which divides the flow from a single source into two or more branches.
Valve, hydraulic - A valve for controlling liquid.
Valve, needle - A flow control valve in which the adjustable control element is a tapered needle. Its usual purpose is the accurate control of the rate of volume of flow.
Valve, pilot operated (indirect) - A valve in which a relatively small flow through an integral vent line relief (pilot) controls the movement of the main element.
Valve, pilot - A valve applied to operate another valve or control.
Volume change - A change in the volume of a seal as a result of immersion in a fluid expressed as a percentage of the original volume.
Vulcanization - A thermo-setting reaction involving the use of heat and pressure, resulting in greatly increased strength and elasticity of rubber-like materials.

Fluid Power Formulas

There are many different formulas used in the design of hydraulic systems. Here are a few of them.

Area in in^2. = D^2 x .7854

Area = πr^2

Circle Area = Diameter^2 x .7854 or $\text{Circle Area} = \frac{\pi D^2}{4}$

Force (lbs.) = PSI (psi) x Area (in.^{2})

$$\text{Pressure (psi)} = \frac{\text{Force (lbs.)}}{Area\ (\text{in.}^2)}$$

$$\text{Rod Speed in in./minute} = \frac{GPM\ x\ 231}{Area}$$

$$\text{GPM} = \frac{\text{Rod Speed}\ x\ Area}{231}$$

Work (ft. lbs.) = Distance moved (ft.) x Force Exerted (lbs.)

$$\text{Power} = \frac{Distance\ moved\ (ft.)\ x\ Force\ exerted\ (lbs.)}{\text{Time (seconds)}}$$

Fluid Power Formulas

Cylinder Horsepower Calculation:

Horsepower = GPM x PSI x .000583

Torque Developed by a Hydraulic Motor:

$$\text{Torque (lb. in.)} = \frac{\text{PSI x motor displacement (in.3)}}{2\pi}$$

Motor Horsepower Calculation:

$$\text{Horsepower} = \frac{\text{R}PM\ x\ \text{Torque (lb.in.)}}{63{,}025}$$

GPM (Gallons Per Minute) Determines Output Speed

$$\textbf{Cylinder}\ \text{Rod Speed(in. min.)} = \frac{GPM\ x\ 231}{\text{Piston Area (in.2)}}$$

$$\textbf{Motor}\ \text{Shaft Speed(RPM)} = \frac{GPM\ x\ 231}{\text{Motor Displac}ement\ (in.3\ \ per\ rev.}$$

Practice Problems

Fluid Power Practice Problems

Directions
Answer the following questions. Sketch each, then label all known values. Be sure to include all steps and units throughout each solution.

All problems assume that conditions are ideal. Forces such as friction are not considered.
Problems

1. A pneumatic system is producing 100 lbs./in.2 of gauge pressure. A cylinder is needed to press an adhesive label onto a product. It has been determined that 5 lbs. of force is optimal to complete this task.

- Sketch and label all known and unknown values.
- What is the required area of the pneumatic cylinder?
- What is the required diameter of the pneumatic cylinder?

2. A hydraulic lift system utilizes two 3 in. diameter cylinders. Workers must determine how much the system is capable of lifting before deciding how much weight can be lifted safely. The system runs at a gauge pressure of 2000 lbs./in.2.

- Sketch and label all known and unknown values.
- What is the area of each piston?
- How much is the system capable of lifting?

3. The gauge pressure of a pneumatic cylinder reads 20 lbs./in.2 when the volume is 30 in.3. The cylinder is compressed until the gauge reads 60 lbs./in.2. Assume standard atmospheric pressure (14.7 psi).

- Sketch and label all known and unknown values.
- What is the absolute pressure before and after the cylinder gas is compressed?
- What is the volume in the cylinder after the gas is compressed?

Practice Problems

4. The air temperature in a 28 in.3 container with a free sliding piston is initially measured at 45 °F. The temperature is raised to 200 °F. What is the new volume of the container?

- Sketch and label all known and unknown values.
- What are the absolute temperature readings initially and after the temperature has been raised?
- What is the volume in the cylinder after the temperature has been raised?

5. A 60 ft3 compressor tank container has a gauge pressure of 160 lbs./in.2 and a temperature of 70 °F. The temperature after some time decreases to 40 °F. Find the final pressure in the tank. Assume standard atmospheric pressure.

- Sketch and label all known and unknown values.
- What are the absolute temperature readings initially and after the temperature decreases?
- What is the absolute pressure of the system before the temperature decreases?
- What is the absolute pressure of the system after the temperature decreases?

6. A flow meter is attached in a hydraulic line that measures 12 gal/min. The line has an inside diameter of 1.5 in. Find the flow velocity where the fluid passes the meter.

- Sketch and label all known and unknown values.
- What is the flow rate measured as in.3 /min at the meter?
- What is the area of inside diameter of the line?
- What is the flow velocity where the fluid passes the meter?

7. A hydraulic press must be used to press-fit two components together in an assembly process. The system must generate at least 775 lbs. of force to perform the press fit. The piston at the input cylinder is pushed with a force of 250 lbs. and has an area of 30 in.2. The output can use up to 15 cylinders that are each 30 in.2. How many cylinders are needed?

- Sketch and label all known and unknown values.
- How much mechanical advantage is required to gain the necessary force?
- How many output cylinders must be incorporated into the design?

Additional Hands-On Exercises

- ❑ Identify components on a hydraulic machine
- ❑ Operate a hydraulic machine (forklift, pallet jacket, vehicle lift)
- ❑ Look up the SDS sheet on hydraulic fluid
- ❑ Identify components on a pneumatic machine
- ❑ Operate a pneumatic machine (air tool, air compressor)
- ❑ Read a pressure gauge
- ❑ Adjust a pressure regulator
- ❑ Inspect hydraulic and pneumatic hoses, lines, and fittings
- ❑ Check for a pneumatic air leak with bubble soap
- ❑ Connect quick-disconnect hoses
- ❑ Read an AELLC Fry Dispenser manual
- ❑ Read a Taylor Auto Lift Grill manual
- ❑ Look up parts in a parts manual
- ❑ Draw fluid power schematic symbols
- ❑ Draw a hydraulic schematic
- ❑ Draw a pneumatic schematic
- ❑ Look up a job description that requires fluid power knowledge
- ❑ Speak with someone at a hydraulics supply house about fluid power
- ❑ Explore field that require fluid power knowledge

Helpful Websites

www.hydraulicspneumatics.com
www.wisc-online.com
www.khanacademy.com
www.study.com
www.quizlet.com
www.engineeringtoolbox.com

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