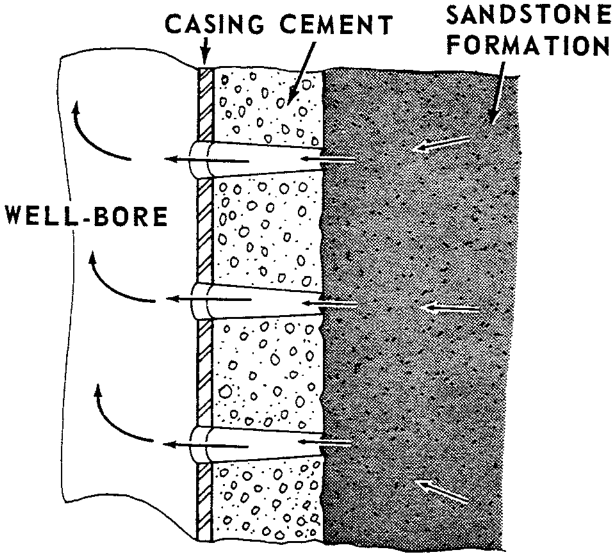
UNIT 2

PATTERNS OF NATURAL FLOW

CONTINUOUS FLOW

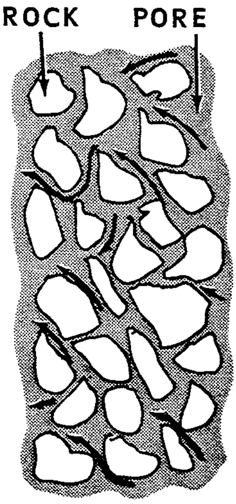
Flow through the Reservoir

1. The fluids in the reservoir are trapped in the pores of the formation rock.

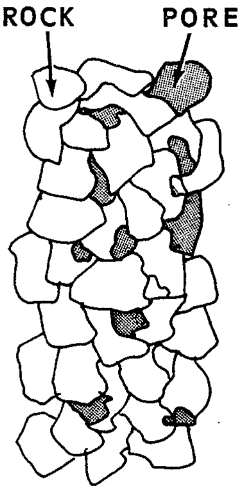


In this reservoir, the fluids are trapped in a porous layer of ____________.

2. Flow in the reservoir depends partly on the nature of the pores in the formation rock.



RESERVOIR A



RESERVOIR B

The pores in the rocks are larger and better connected in reservoir (A/B).

3. So, fluid flows more easily through reservoir ________.

4. If the pores in the formation rock are small and not interconnected, the fluid may not be able to ________ through the reservoir.

5. Even in a high-pressure reservoir, the flow rate may be low if the ________ in the reservoir rock are not large and well-connected.

6. Before the well is drilled, little or no flow may be occurring in the reservoir even though the fluids are under high pressure.

   If all the fluid in the reservoir is at the *same* pressure, the fluid in the reservoir (will/will not) flow back and forth.

7. In the same reservoir, the fluid in different parts of the reservoir may be under different pressures.

   If a high-pressure fluid in one part of a reservoir touches fluid at a slightly lower pressure in another part of the reservoir, fluid will flow (into/out of) the high-pressure area.

8. Fluid flows between areas of (equal/unequal) pressure in the reservoir.

9. In the reservoir, the pressures tend to equalize as fluid flows from the area of ________ pressure to the area of ________ pressure.

10. If the pressures equalize, the flow within the reservoir gradually slows down and finally ________.

11. When a well-bore is completed and opened for flow, it creates a low pressure area in the reservoir.

    If there is no difference between the surface pressure and the reservoir pressure, the well (will/will not) flow.

12. If there is no difference between the reservoir pressure and bottom-hole pressure, the well (will/will not) flow.

13. For a well to flow, there must be a pressure difference or pressure drop (at some point/at all points) in the reservoir and well-bore.

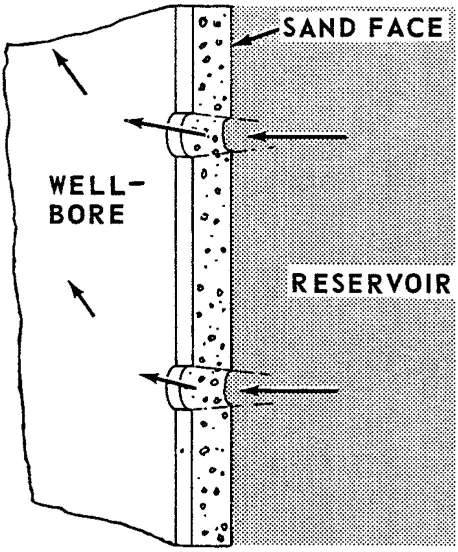
14. A larger pressure drop causes a (higher/lower) flow rate than a smaller pressure drop.

15. As the well produces, fluid leaves the reservoir and enters the well-bore.

Pressure in the reservoir around the well-bore gradually (increases/decreases).

16. This low-pressure area near the well-bore draws more fluids from the higher pressure areas back in the ____________.

17. The part of the reservoir that touches the well-bore is called the sand face.



Fluid flows across the sand face from the ____________ into the ____________-____________.

18. Fluid flows into the well-bore as long as there is a pressure drop across the ____________ ____________.

19. The larger the difference in pressure, the (higher/lower) the rate of flow.

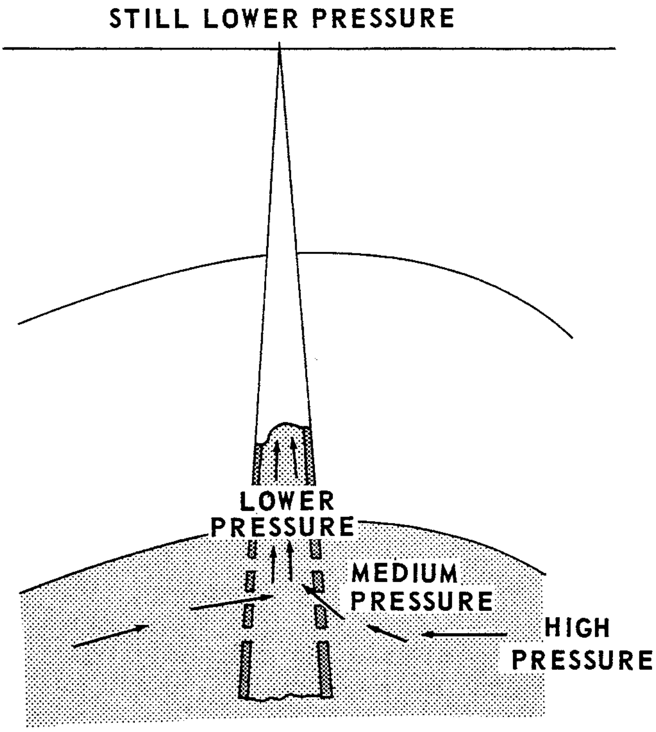
20. When a well is shut in so that flow stops at the surface, pressure *equalizes* at the sand face.

Reservoir pressure and bottom-hole pressure gradually become (the same/different) after the well is shut in.

21. When reservoir pressures begin to equalize, flow through the reservoir (slows down/speeds up).

22. If the bottom-hole pressure equals the pressure in the reservoir near the sand face, flow into the well-bore ____________.

23. Let's review by looking at the pressure drops from the reservoir to the surface.



Fluid flows:

from a high-pressure area back in the reservoir toward a ____________-pressure area at the sand face;

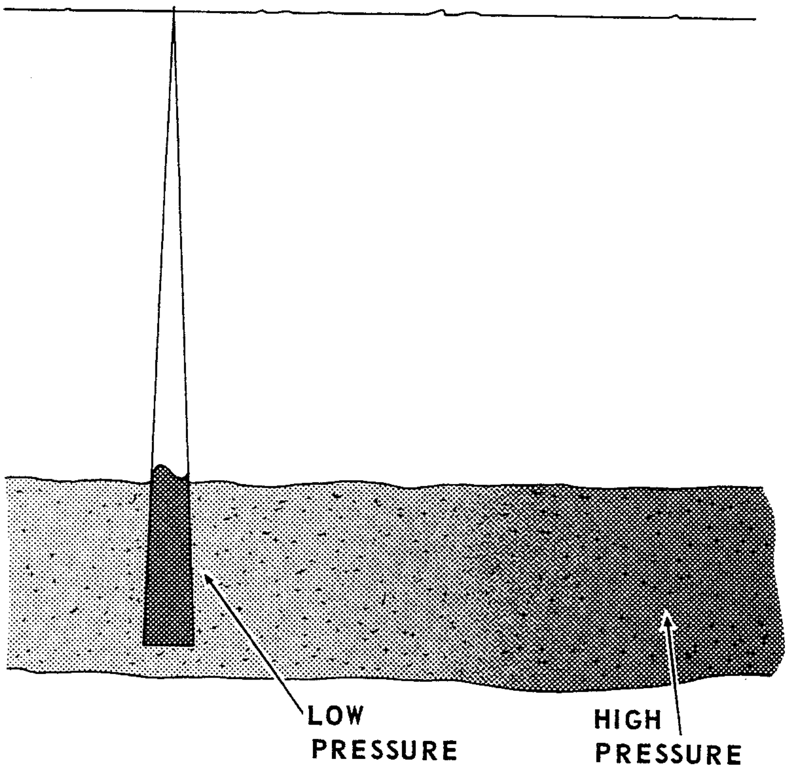
across the sand face to a ____________-pressure area in the well-bore;

from the bottom of the well up into a still ____________-pressure area at the surface.

24. The pressure drop across the sand face of a flowing well affects production.

Steady flow occurs when reservoir pressure near the sand face remains (higher/lower) than flowing BHP.

25. When flow through the reservoir is slow, fluid may leave the sand face faster than it comes from the rest of the reservoir.



Then, the reservoir pressure near the sand face (increases/decreases).

26. And the pressure drop across the sand face (increases/decreases).

27. When the pressure drop decreases, flow across the sand face (increases/decreases).

28. As flow across the sand face decreases, flow through the reservoir may continue.

The reservoir may then begin to build up ____________ at the sand face again.

29. The production from a well is increased when the pressure drop at the sand face is increased.

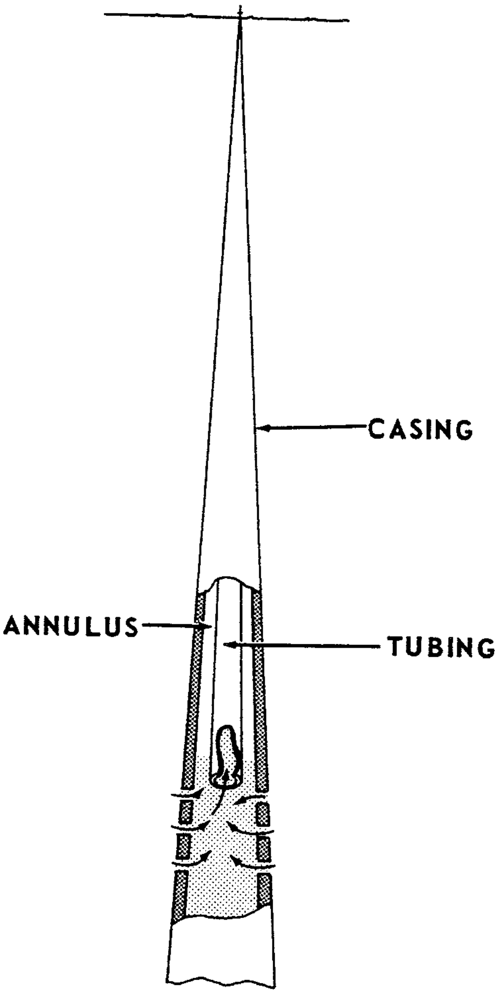
Production decreases when the pressure drop at the sand face gets (larger/smaller).

30. If the reservoir cannot maintain pressure near the sand face, production eventually ____________.

Flow in the Well-Bore

31. When a shut-in well is put into production, the valves at the well head are opened to let fluid ____________ to the surface through the tubing.

32. At the well head, the annulus is usually kept closed off by the casing valve.



As long as the casing valve is closed, fluid is removed from the well-bore only through the (tubing/annulus).

33. The flow of fluid in the well-bore is usually not as restricted as it is in the formations.

After the fluid passes the sand face, it flows more freely, and the pressure of the fluid suddenly (increases/decreases).

34. In the well-bore, there are few narrow openings to restrict the flow, and the change in velocity is (great/slight) after the fluid enters the tubing.

35. The pressure on the fluid at the bottom of the well-bore is a combination of reservoir pressure, hydrostatic pressure, and back pressure.

As these pressures change, the make-up of the fluid (changes/does not change).

36. Hydrostatic pressure depends on the height of fluid above the point of measurement.

As the fluid rises in the tubing, it is under (more and more/less and less) hydrostatic pressure from the fluids above it.

37. At the reservoir, the proportion of gas in solution depends on the ____________ pressure.

38. At high pressures, a large part of the gas in the fluid is (held in solution/released in bubbles).

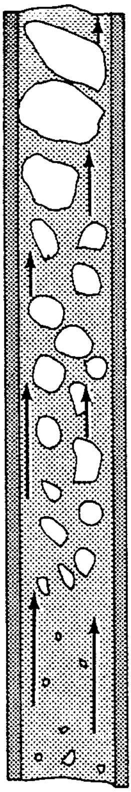
39. Gas is released when the pressure on the fluid is (above/below) the bubble point.

40. When all the gas in the fluid is dissolved with the liquid, the flow is called a *liquid flow.*

Liquid flow occurs when the pressure of the fluid is (above/below) the bubble point.

41. If the pressure in the tubing is above the bubble point all the way to the surface, all the fluid is in (liquid/bubble) flow.

42. *Bubble flow* occurs when the pressure of the fluid drops below the bubble point.



As the fluid flows up the tubing, hydrostatic pressures decrease, and the liquid flow may change to a ____________ flow.

43. As fluid is removed from the reservoir, the pressure in the reservoir near the sand face may drop below the bubble point.

Then gas bubbles are carried into the ____________-____________ with the liquid.

44. When the fluid passes across the sand face into the well-bore, pressure ____________ still more, and more ____________ form.

45. The higher the fluid flows up the tubing, the (higher/lower) its pressure becomes and the (more/fewer) gas bubbles are released.

46. In a bubble flow, there are always more bubbles (higher/lower) in the tubing.

47. As the lighter gas bubbles occupy more and more space in the liquid, the density of the fluid in the well-bore (increases/decreases).

48. As fluid density decreases, hydrostatic pressure (increases/decreases).

49. The lowered pressure allows more ____________ to form in the liquid and causes the hydrostatic pressure to further (increase/decrease).

50. Let's review what happens when the well-bore pressures drop below the bubble point:

    gas ____________ are released;

    fluid density (increases/decreases);

    hydrostatic pressure (increases/decreases);

    with this change in pressure, more ____________ are released.

51. When the well-bore pressure begins to drop below the bubble point, the gas bubbles that are formed are small.

    As pressure continues to decrease, the bubbles become (larger/smaller).

52. Bubbles get larger because:

    (more/less) gas is released from solution;

    the released gas bubbles continue to ____________.

53. The release and expansion of gas in the tubing makes the volume of the gas-liquid mixture at the well head many times as great as the volume that enters the well-bore from the reservoir.

    For all this gas and liquid to get out of the tubing, at the well head, it must flow out much (faster/slower) than it came in.

54. A bubble flow is faster at (the well head/well bottom).

Types of Bubble Flow

55. As the fluid in the well-bore flows upward, the gas tends to rise (faster/slower) than the liquid.

56. Gas rises faster because it has a (higher/lower) density than liquids.

57. Very small bubbles tend to be held down by the liquids around them.

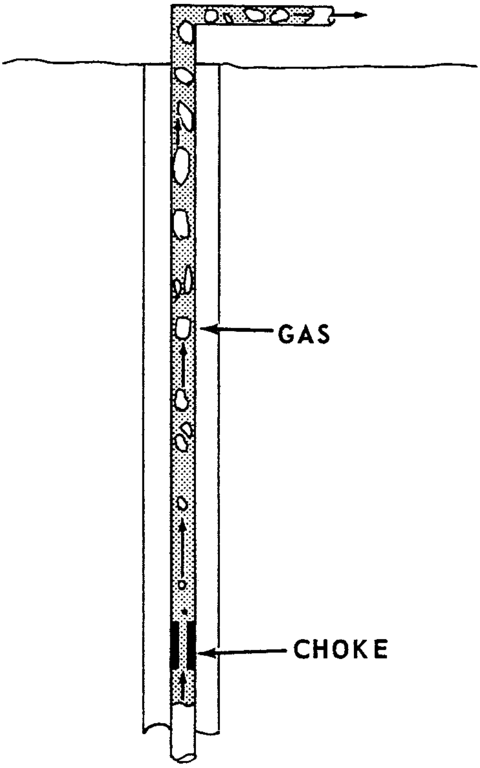
    Gas rises faster when the bubbles are (large/small).

58. Larger bubbles are also *lighter* than smaller bubbles.

    As the gas expands into a larger volume, its density (increases/decreases) and the bubbles rise (faster/slower) in the tubing.

59. The gas bubbles become larger as tubing pressures (increase/decrease).

60. Sometimes bottom-hole chokes are used to increase production from a slow-flowing well.



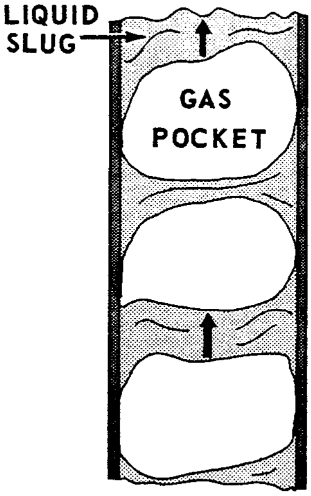
    The pressure drop at the choke causes (more/less) gas to be released in the tubing.

61. This gas may help to ____________ the liquid to the surface.

Now turn the page, turn the book over, and go on.

62. Gas gives more help in lifting liquid when the bubbles are (large/small).

63. When the gas forms pockets as large as the tubing ID, the fluid is in *slug flow*.

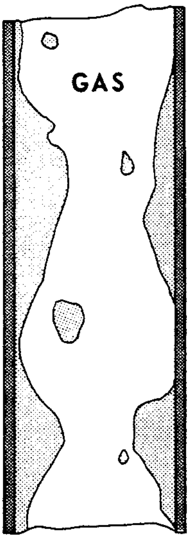


A slug is a short section of ____________ trapped between two pockets of ____________.

64. These fast-rising pockets of gas lift the ____________ of liquid to the surface.

65. When the fluid is in slug flow, the gas (helps/does not help) to maintain production through the tubing.

66. At even lower pressures, the gas pockets may break through the liquid slugs.



Then the center of the tubing is filled with fast-rising ____________.

67. This kind of flow is called *annular* flow.

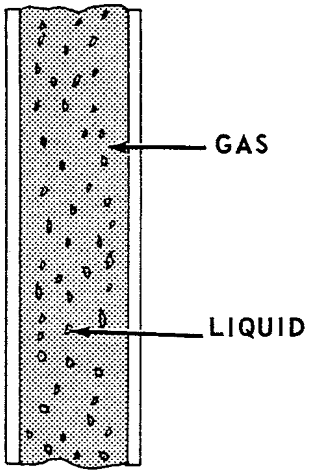
In annular flow, most of the liquid is pushed to the ____________ of the tubing.

68. Friction between the liquid and the tubing wall (speeds up/slows down) the flow of liquid through the tubing.

69. In annular flow, the gas carries only small drops of ____________ through the tubing.

70. Most of the liquid flows very slowly because of ____________ between the liquid and the walls of the tubing.

71. At even lower pressures, the fluid is in *mist flow.*

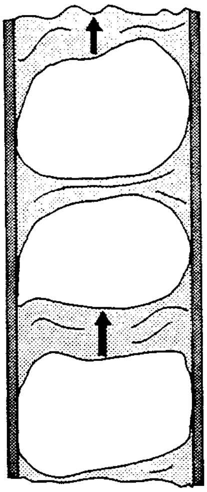


In mist flow, the entire tubing is filled with ____________ carrying small droplets of ____________.

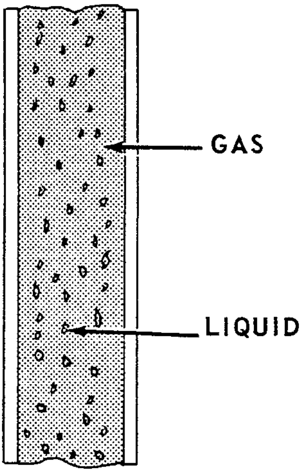
72. The *lowest* production of liquid occurs when the fluid is in (slug/annular/mist) flow.

73. In both annular and mist flow, large quantities of ____________ rise through the liquid.

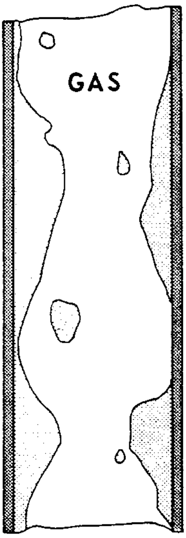
74. Identify these three types of bubble flow.



A. ______________________________



B. ______________________________



C. ______________________________

75. Of these three types of bubble flow, ____________ flow requires the *highest* tubing pressure.

76. The lowest tubing pressure that can put the line in bubble flow will cause (slug/annular/mist) flow.

77. At pressures below the pressure needed for mist flow, the tubing may contain only dry ____________.

Review

78. The amount of liquid lifted to the surface in the well-bore depends on the type of fluid flow developed in the tubing.

The greatest amount of liquid is raised in (bubble/liquid) flow.

79. The type of flow depends on the pressure in the tubing and on the characteristics of the ____________ entering from the reservoir.

80. If there is no gas in the reservoir, all flow will be ____________ flow.

81. Gas gives the greatest help in lifting liquid when the fluid is in ____________ flow.

82. Many wells used to be produced through the full width of the production casing.

In these wells, the velocity of flow was usually (higher/lower) than with modern production methods.

83. At lower velocities, fluids are (more/less) likely to separate in the well-bore.

84. Suppose a well is allowed to flow at too-low a velocity.

As the fluids begin to separate, the ____________ will rise more rapidly than the liquids.

85. When gas is produced rapidly, the GOR (increases/decreases).

86. As the GOR rises, reservoir pressure (rises/falls) rapidly.

87. When the reservoir is depleted of gas, the flowing fluid consists of ____________ and ____________ from the reservoir.

88. At low velocities, these liquids may also separate out, with the lower-density ____________ rising above the ____________ in the well-bore.

89. If the oil is produced faster than the water, the well-bore will eventually load up with high-density ____________.

90. When the well-bore loads up with water, hydrostatic BHP (increases/decreases) and flow may ____________ altogether.

91. One way of preventing early separation of fluids in the well-bore is by keeping the velocity of flow (high/low).

92. Velocity is kept high by producing through a string of ____________.

93. Another way to prevent early separation is to maintain a (high/low) tubing pressure.

94. Surface chokes put back pressure on the tubing.

A surface choke tends to (cause/prevent) the separation of fluids in the well-bore.

95. Less separation occurs when tubing ____________ is kept high.

96. To put a well in slug flow, a bottom-hole choke may be used.

Bottom-hole chokes (increase/decrease) the tubing pressure downstream from the choke.

97. The type of flow developed in the tubing depends on:

the reservoir pressure near the ____________ ____________;

the relative proportions of gas and ____________ in the fluid;

the bottom-hole pressure in the well-bore, which depends on the ____________ pressure, the ____________ pressure, and the ____________ pressure;

the flow rate, which depends on the ____________ drop in the well-bore;

the velocity of flow, which depends on the pressure drop and the ____________ size.