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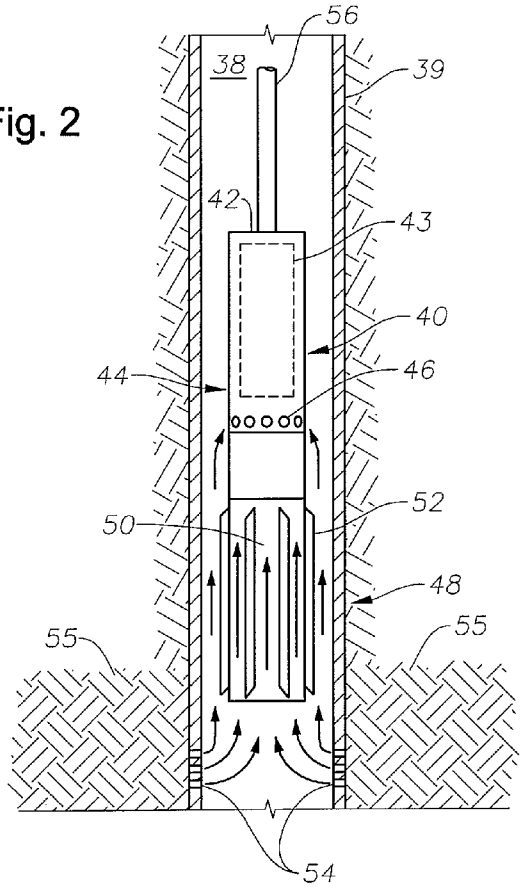


Fig. 2

(57) Abstract: A submersible pumping system for use downhole, wherein the system includes a pump, an inlet section for receiving fluid, a pump motor, and heat transfer fins on the motor housing. The fins increase the heat transfer area of the motor thereby providing enhanced cooling of the motor.

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ENHANCED COOLING FOR DOWNHOLE MOTORS

BACKGROUND

Field of Invention

The present disclosure relates to downhole pumping systems submersible in well bore fluids. More specifically, the present disclosure concerns an improved method of cooling pump motors used to drive the submersible pumping systems. Yet more specifically, the present disclosure involves enhancing the surface area of the pump motor for increasing the heat transfer between the pump motor and the well bore fluid flowing across the surface of the pump motor.

Description of Prior Art

Submersible pumping systems are often used in hydrocarbon producing wells for pumping fluids from within the well bore to the surface. These fluids are generally liquids and include produced liquid hydrocarbon as well as water. One type of system used in this application employs an electrical submersible pump (ESP). ESP's are typically disposed at the end of a length of production tubing and have an electrically powered motor. Often, electrical power may be supplied to the pump motor via an electrical cable. Typically, the pumping unit is disposed within the well bore above where perforations are made into a hydrocarbon producing zone. This placement thereby allows the produced fluids to flow past the outer surface of the pumping motor and provide a cooling effect.

With reference now to Figure 1, an example of a submersible ESP disposed in a well bore is provided in a partial cross sectional view. In this embodiment, a downhole pumping system 12 is shown within a cased well bore 10 suspended within the well bore 10 on production tubing 34. The downhole pumping system 12 comprises a pump section 14, a seal section 18, and a motor 24. The seal section 18 forms an upper portion of the motor 24 and is used for equalizing lubricant pressure in the motor 24 with the wellbore hydrostatic pressure. Energizing the motor 24 then drives a shaft (not shown) coupled between the motor 24 and the pump section 14. Impellers are coaxially disposed on the shaft and rotate with the shaft within respective diffusers formed into the pump body 16. As is known, the centrifugal action of the impellers produces a localized reduction in pressure in the diffuser thereby inducing fluid flow into the diffuser. In this embodiment, a series of inlets 30 are provided on the pump

housing wherein formation fluid can be drawn into the inlets and into the pump section 14. The source of the formation fluid, which is shown by the arrows, are perforations 26 formed through the casing 10 of the well bore and into a surrounding hydrocarbon producing formation 28. Thus the fluid flows from the formation 28, past the motor 24 on its way to the inlets 30. The flowing fluid contacts the housing of the motor 24 and draws heat from the motor 24.

In spite of the heat transfer between the fluid and the motor 24, over a period of time the motor 24 may become overheated. This is especially a problem when the fluid has a high viscosity, a low specific heat, and a low thermal conductivity. This is typical of highly viscous crude oils. The motor 24 may be forced to operate at an elevated temperature, past its normal operating temperature, in order to reject the internally generated heat. This temperature upset condition can reduce motor life and results in a reduction in operational times of the pumping system.

SUMMARY OF INVENTION

The present disclosure includes a downhole submersible pumping system comprising, a pump, a pump motor coupled to the pump, and a heat transfer member disposed on the pump motor outer surface. The pumping system is configured for being disposed within a well bore. The pumping system may further comprise a fluid intake, wherein the fluid intake is configured to receive downhole fluid and is disposed adjacent the pump motor. The downhole fluid received by the intake may create a flowpath flowing across the heat transfer member that absorbs thermal energy from the heat transfer member. In one embodiment, the entire outer surface of the heat transfer member is fully contactable by wellbore fluid. The heat transfer member may have a substantially rectangular cross section, a "T" shaped cross section, or it may be elongated and disposed substantially parallel to the pumping system axis. Optionally, the heat transfer member may be disposed at an angle to the pumping system axis. The system may further comprise a multiplicity of elongated heat transfer members disposed substantially parallel to the pumping system axis.

The present disclosure may include another embodiment of a wellbore pumping system submersible in a downhole fluid, where the system comprises a housing, a pumping device disposed in the housing, an intake in fluid communication with the housing, wherein the intake provides fluid communication with the outside of the housing and

the pumping device inlet, a motor disposed in the housing mechanically coupling to the pumping device and a heat conducting fin disposed on the housing adjacent to the motor, wherein the fin freely extends away from the housing wherein its entire outer surface is in contact with the downhole fluid. The wellbore pumping system may have a pump discharge that communicates with production tubing.

BRIEF DESCRIPTION OF DRAWINGS

Some of the features and benefits of the present invention having been stated, others will become apparent as the description proceeds when taken in conjunction with the accompanying drawings, in which:

Figure 1 shows a prior art downhole submersible system in a partial cross sectional view.

Figure 2 shows a side view of a pumping system in accordance with the present disclosure disposed within a cased well bore.

Figure 3 provides a schematic cross sectional view of a portion of the pumping system having a heat transfer member extending therefrom.

Figure 4 shows a side view of a portion of the pumping system of the present disclosure illustrating fluid flow over a heat transfer member.

Figure 5 is a cross sectional view of an embodiment of a heat transfer member.

Figure 6 is a cross sectional view of an alternative embodiment of a heat transfer member.

Figure 7 is an overhead view of an alternative view of a heat transfer member.

Figure 8 is a side view of an embodiment of a pumping system having laterally disposed fins.

While the invention will be described in connection with the preferred embodiments, it will be understood that it is not intended to limit the invention to that embodiment. On the contrary, it is intended to cover all alternatives, modifications, and equivalents, as

may be included within the spirit and scope of the invention as defined by the appended claims.

DETAILED DESCRIPTION OF INVENTION

The present invention will now be described more fully hereinafter with reference to the accompanying drawings in which embodiments of the invention are shown. This invention may, however, be embodied in many different forms and should not be construed as limited to the illustrated embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be through and complete, and will fully convey the scope of the invention to those skilled in the art. Like numbers refer to like elements throughout.

The present disclosure provides embodiments of a downhole submersible pumping system for producing fluids from within a well bore up to the surface. One embodiment of the pumping system disclosed herein includes a pump, an intake system for providing fluid intake to the pump, and a motor for providing a mode of force for the pump. The cooling system described herein is a largely passive system that can maximize the heat transfer surface area on the outer body of the submersible motor. Examples of a passive system include a heat transfer member, such as a fin, extending along a portion of the length of the housing of the motor.

In Figure 2, one embodiment of a pumping system with enhanced cooling is provided in a side view. In this embodiment, the pumping system 40 comprises a pump section 42, an inlet section 44, and a motor section 48. The pump section includes a pump 43 shown in a dashed outline. Formed in the inlet section 44 are inlets 46 for providing a fluid inlet path to the pump 43. Examples of pumps useful in this system include centrifugal pumps, positive displacement pumps, progressing cavity pumps as well as multi-stage centrifugal pumps. With regard to the inlet section 44, the specific inlets 46 may comprise the circular orifices as shown, other embodiments may be included, such as elongated slits and other shaped orifices allowing fluid flow into the pumping unit. In this embodiment production tubing 56 is included, thereby enabling fluid communication between the pumping system 40 and the surface.

With regard to the motor section 48 of Figure 2, it comprises a motor housing 50 that surrounds and protects a motor disposed therein. Provided on the outer surface in the housing 50 are a series of heat transfer members 52 for increasing the effective heat

transfer surface area of the motor housing 50. Maximizing this heat transfer surface area thereby maximizes the heat transfer from the motor through the housing 50 into the fluid flowing past these heat transfer members 52. In this embodiment, the fluid is shown flowing into the well bore via perforations 54 formed through the wellbore casing 39. Formation fluid from the formation 55 flows through the perforations 54 into the wellbore 38. The heat transfer members 52 of Figure 2 are shown as elongated fins, however as will be discussed below, the members 52 can take on many forms and are not limited in scope to the embodiment illustrated.

Heat transfer from the motor housing 50 to the flowing fluid can be modeled with the following equation: $Q=hcA(T_s-T_f)$. Here, Q equals the rate of heat transfer; hc equals the heat transfer coefficient; A equals the surface area; T_s equals the temperature of surface; and T_f equals the temperature of the fluid. For a given amount of heat generated by the motor, increasing the surface area and/or the heat transfer coefficient can lower the operating temperature of the motor within the housing. The heat transfer coefficient represents the complex interaction of the fluid thermophysical properties, the temperature differentials, the velocity of flow and, and the geometry of the flow path. The thermophysical properties of a fluid at any given temperature are relatively fixed and unalterable. Increasing the velocity of flow has only a small effect on the heat transfer coefficient of highly viscous fluids.

In one embodiment of the heat transfer member disclosed herein, the member 52 outer surface is fully contacted by the fluid flowing past the member 52. Thus in this embodiment a single flow of fluid is in contact with the member and receives thermal energy from the member 52, and thus the pump motor 48. This configuration is also referred to herein as a heat transfer member that freely extends from the housing into the cooling fluid. The motor housing is normally formed of a steel material that is machined from a cylinder. The members 52 (or fins) may also be of steel or another material. Preferably the fins are a contiguous part of the motor housing 50. Alternatively the fins could be machined into the housing if the housing initial configuration has extra thick walls. The number of fins, their length, protrusion, configuration etc., are determined by a combination of fluid mechanics considerations, the space available and heat transfer analysis. It is within the capabilities of those skilled in the art to determine fin number and configuration. In general the annular

space between the motor housing and the casing inner diameter determines the protrusion. In one embodiment, the fin length will be substantially equal to the motor housing length.

Figure 3 schematically illustrates an embodiment of a section of the pumping system having a single freely extending heat transfer member 52a rather than the plurality of fins shown in Figure 2. This portion shown in Figure 3 is a cross sectional axial view of a semi-circular section of the motor section 48a with the heat transfer member 52a also shown in cross section. The heat transfer member 52a extends along a radial plane of the axis of the motor housing 50a. In this embodiment, the heat transfer member 52a has a substantially rectangular cross section. Fluid flowing along the axis of the pumping system 40a is illustrated by a series of dots 58. Arrows are shown illustrating the flow of thermal energy from within the motor, through the heat transfer member 52a, and out into the fluid 58. This provides one illustration of how the surface area of an added heat transfer member can increase heat transfer away from a motor 49.

Figure 4, which illustrates an embodiment of the pumping section of Figure 3 from a side view, also illustrates heat transfer from the motor section 48 into a surrounding fluid. In this embodiment, arrow A_I illustrates fluid flow over a heat transfer member 52a. A series of arrows, represented by A_Q illustrate thermal energy flowing from the motor section 48 into the heat transfer member 52. The continuous flow of thermal energy is further illustrated by arrows A_{QI} being directed from the heat transfer member 52 into the flow of fluid. Preferably the heat transfer member 52a extends substantially along the full length of the motor 48.

Figures 5 through 5c illustrate some other alternative embodiments of heat transfer members. Figure 5 is a cross sectional view looking axially along the length of a heat transfer member 52b and the motor housing 50b. In this embodiment, the heat transfer member 52b has a largely rectangular base with a tapered top terminating into an outer edge 60. Such a taper may be useful in reducing dynamic frictional drag losses along the length of the motor section.

Figure 6 illustrates an alternative embodiment, where the heat transfer member 52c has a largely T-shaped cross section for further maximizing motor housing surface area and thereby heat transfer. The heat transfer member 52c comprises a web 62 extending

from the motor housing 50c that supports a flange 64 perpendicularly disposed on its terminal end.

Figure 7 shows an overhead view of one section of a heat transfer member 52d. In this embodiment, the leading edge 66 (lower portion) and trailing edge 68 (upper portion) of the heat transfer member 52d is tapered, as well as its outer terminal edge 60a, in an attempt to reduce dynamic pressure losses across the heat transfer member. The heat transfer member 52d is shown disposed on an embodiment of the motor housing 50.

It should be pointed out however that the arrangement of the heat transfer member can include any number of heat conducting elements extending out from the body of the pumping system 40. These members are not limited to being located on the motor section but can be included along any portion, or just a single portion of the pumping system 40. Moreover, the arrangement is not limited to a series of elongated fins on the outer surface of the motor housing 50, but can be a series of relatively shortened members having a matrix like pattern along the length of the housing. The arrangement of the heat transfer members (fins) is not limited to being substantially aligned with the pumping system axis, but can take a helical arrangement around the body of the motor or can simply be at some lateral angle with respect to the length of the axis. Optionally, protrusions 53 may be included with any embodiment of the fins herein for creating a turbulent boundary layer adjacent the fin surface for increasing heat transfer.

Figure 8 illustrates an alternative embodiment of a heat transfer member 52e being disposed at an angle with respect to the axis of the motor section 48b. This angle can range from substantially coaxial and to substantially perpendicular to the axis of the motor section.

In one example of use of the present system of concept fins in accordance with the embodiment of Figure 2, were added to an electrical submersible pump motor. Temperature results of the finned motor were tested and compared with temperature results of an unfinned pumping system. Mathematical heat transfer modeling and actual physical testing was performed. The results of this analysis are outlined in the following tables.

EXAMPLE 1

In one example, electrical submersible pumps with finned and unfinned motors were analyzed in a flowing fluid, wherein the fluid had the following properties, a density of 62.0 lb/ft^3, a viscosity of 0.00458 lbm/ft sec, and a flow rate of 969.7 lbm/min. The flow velocity in the finned annulus was 1.04 ft/sec and 0.928 ft/sec in the un-finned annulus. Each motor outside diameter was 7.25 inch outside diameter with a 10.2 inch casing inner diameter. The analysis assumed 45 fins on the finned motor, each fin being 82 inches long, 0.525 inches in height, and 0.187 inches thick. The calculated temperature rise for the finned motor was 27.67 °F and 91.78 °F for the unfinned motor.

EXAMPLE 2

In another example, two electrical submersible pumps having finned and an unfinned motors were analyzed in a flowing fluid having a temperature of 40 °F, density of 61.2 lb/ft^3, a viscosity of 1.344 lbm/ft sec, a specific heat of 0.48 btu/lbm °F, thermal conductivity of 0.075 but/hr ft °F, with a flow rate of 2386.2 lbm/min. The fluid used in this example was oil. The flow velocity in the finned annulus was 2.89 ft/sec and 2.46 ft/sec in the un-finned annulus. Each motor outside diameter was 7.25 inch outside diameter with a 10.2 inch casing inner diameter. The motor horsepower was 1500 hp. The analysis assumed 57 fins on the finned motor, each fin being 816 inches long, 0.5 inches in height, and 0.2 inches thick. The calculated internal temperature for the finned motor was 193.56 °F with an external temperature of 94.82 °F, the calculated internal temperature was 577.77 °F for the unfinned motor with an external temperature of 479.04 °F.

EXAMPLE 3

In another example, two electrical submersible pumps having finned and unfinned motors were analyzed in a flowing fluid having a temperature of 174 °F, density of 61.2 lb/ft^3, a viscosity of 0.15456 lbm/ft sec, a specific heat of 0.48 btu/lbm °F, thermal conductivity of 0.075 but/hr ft °F, with a flow rate of 2386.2 lbm/min. The fluid used in this example was oil. The flow velocity in the finned annulus was 2.89 ft/sec and 2.46 ft/sec in the un-finned annulus. Each motor outside diameter was 7.25 inch outside diameter with a 10.2 inch casing inner diameter. The motor horsepower was

1500 hp. The analysis assumed 57 fins on the finned motor, each fin being 816 inches long, 0.5 inches in height, and 0.2 inches thick. The calculated internal temperature for the finned motor was 327.56 °F with an external temperature of 228.82 °F, the calculated internal temperature was 711.77 °F for the unfinned motor with an external temperature of 613.04 °F.

EXAMPLE 4

Table 1 illustrates a comparison of simulated electrical submersible pump temperature increases versus actual measured temperature increases. Two electrical submersible pumps were analyzed, one with a finned motor and one without.

Horse Power (hp)	Fin?	Velocity (ft/sec)	Calculated temperature rise (°F)	Measured temperature rise (°F)
50	Yes	2	3.4	4
50	No	2	6.3	9
75	Yes	2	5.1	5
75	No	2	9.5	12.5
100	Yes	2	6.8	5
100	No	2	12.6	15
130	Yes	2	8.9	8
130	No	2	16.4	19

Table 1

The results provided in Table 1 demonstrate good agreement between the calculated and measured temperature rises. Additionally, these results listed in this table further illustrate the advantages of using a finned motor over an unfinned motor with an electrical submersible pump for the purposes of lowering motor temperature.

Figure 6 is a plot illustrating respective temperatures rises of finned and. unfinned motors versus the horsepower (HPf) the motor dissipates as heat. The analysis used to create the graphed values assumed a 7.25 inch motor outside diameter, 45 fins being 0.525 inch high, 0.187 inches wide, and 82 inches long. The analysis further assumed a 2 rotor motor with 100 hp, a flowrate of 117 gpm inside of a 10.2 inch inner diameter casing. The HPf values shown cover a range of motor loading from 46% to 132% all at 84.8% motor efficiency.

It is to be understood that the invention is not limited to the exact details of construction, operation, exact materials, or embodiments shown and described, as modifications and equivalents will be apparent to one skilled in the art. In the drawings and specification, there have been disclosed illustrative embodiments of the invention and, although specific terms are employed, they are used in a generic and descriptive sense only and not for the purpose of limitation. Accordingly, the invention is therefore to be limited only by the scope of the appended claims.

Claims

1. A downhole submersible pumping system comprising:

a pump;

a pump motor filled with a dielectric fluid;

a seal section located between the pump and the motor for reducing a pressure differential between the dielectric fluid and pressure of wellbore fluid; and

at least one heat transfer member disposed on the pump motor outer surface for immersion in the fluid of a wellbore.

wherein the pumping system is configured for being disposed within a well bore.

2. The pumping system of claim 1, wherein the heat transfer member protrudes outward from the motor relative to a longitudinal axis of the motor.

3. The pumping system of claim 2, wherein the heat transfer member extends substantially along the length of the motor.

4. The pumping system of claim 2, wherein the heat transfer member extends along a portion of the length of the motor.

5. The pumping system of claim 1, wherein the heat transfer member has a substantially rectangular configuration in a transverse cross section.

6. The pumping system of claim 1, wherein the heat transfer member has a "T" shaped transverse cross section.

7. The pumping system of claim 1, wherein the heat transfer member is elongated and disposed substantially parallel to a longitudinal axis of the pumping system.

8. The pumping system of claim 1, wherein the heat transfer member is disposed at an angle to a longitudinal axis of the pumping system.

9. The pumping system of claim 1, wherein said at least one heat transfer member comprises a plurality of fins disposed in radial planes substantially parallel to a longitudinal axis of the pumping system.

10. The pumping system of claim 1, wherein the heat transfer member has a tapered outer edge.

11. A wellbore pumping system comprising:

a string of tubing for extension into a well;

an electrical submersible pump assembly suspended on the tubing, the pump assembly having a rotary pump driven by an electrical motor having a motor housing; and

a plurality of fins disposed on the motor housing and extending outward therefrom for immersion in the wellbore fluid flowing to the pump.

12. The pumping system of claim 11, wherein the fins protrude outward from the motor relative to a longitudinal axis of the motor.

13. The pumping system of claim 11, wherein the fins extend substantially along the length of the motor.

14. The pumping system of claim 11, wherein the fins have a substantially rectangular configuration in a transverse cross section.

15. The pumping system of claim 11, wherein the fins have a "T" shaped transverse cross section.

16. The pumping system of claim 11, wherein the fins are elongated and disposed substantially parallel to a longitudinal axis of the pumping system.

17. The pumping system of claim 11, wherein the fins are disposed at an angle to a longitudinal axis of the pumping system.

18. The pumping system of claim 11, wherein said fins comprise are disposed in radial planes substantially parallel to a longitudinal axis of the pumping system.

19. The pumping system of claim 11, wherein fins have a tapered outer edge.

20. A method of pumping fluid from a well comprising:

providing a motor for an electrical submersible pump assembly with at least one heat transfer member protruding outward therefrom;

coupling the motor to a pump to make up the pump assembly, connecting the pump assembly to a conduit and lowering the pump assembly into a wellbore; and

supplying power to the motor to rotate the pump, which draws well fluid past the motor discharges the well fluid into the conduit, the heat transfer member being immersed in the well fluid as it flows past the motor to dissipate heat from the motor.

21. The method of claim 20, wherein the heat transfer member protrudes outward from the motor relative to a longitudinal axis of the motor.

22. The method of claim 20, wherein the heat transfer member extends substantially along the length of the motor.

23. The method of claim 20, wherein the heat transfer member has a substantially rectangular configuration in a transverse cross section.

24. The method of claim 20, wherein the heat transfer member has a "T" shaped transverse cross section.

25. The method of claim 20, wherein the heat transfer member is elongated and disposed substantially parallel to a longitudinal axis of the pumping system.

26. The method of claim 20, wherein the heat transfer member is disposed at an angle to a longitudinal axis of the pumping system.

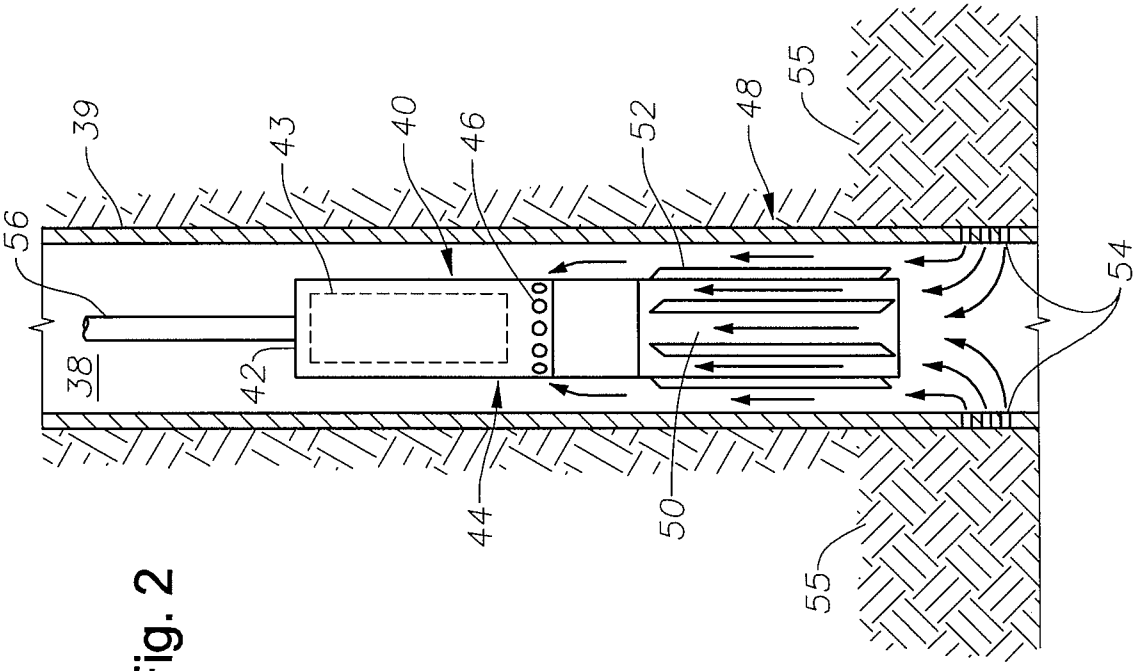


Fig. 2

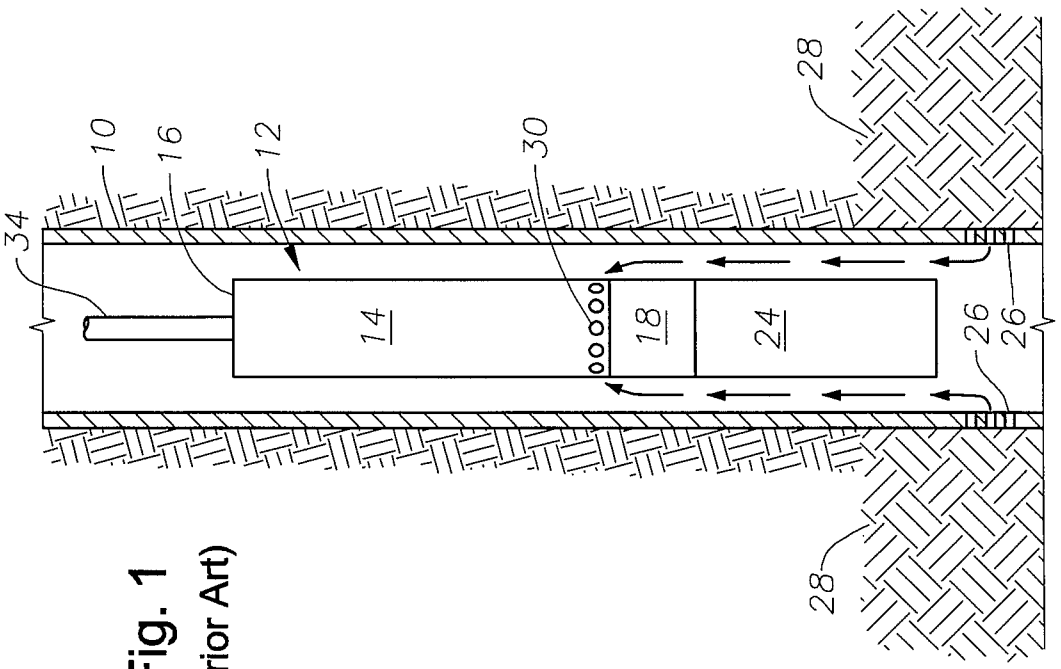


Fig. 1
(Prior Art)

Fig. 4

Fig. 3

Fig. 8

Fig. 7

Fig. 6

Fig. 5