Nov. 21, 1944. M. SCHLUMBERGER 2,363,269

METHOD FOR SEALING BORE HOLE CASINGS

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Fig. 1

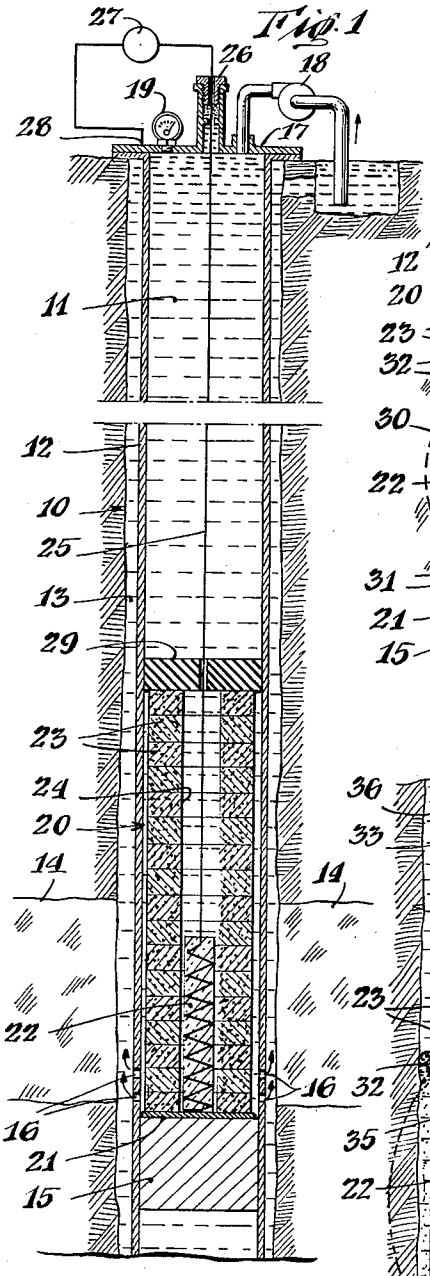


Fig. 2

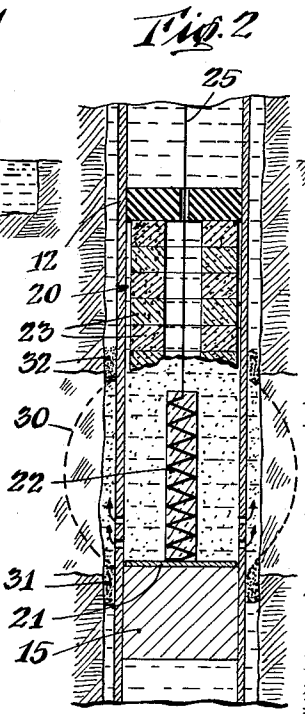


Fig. 3

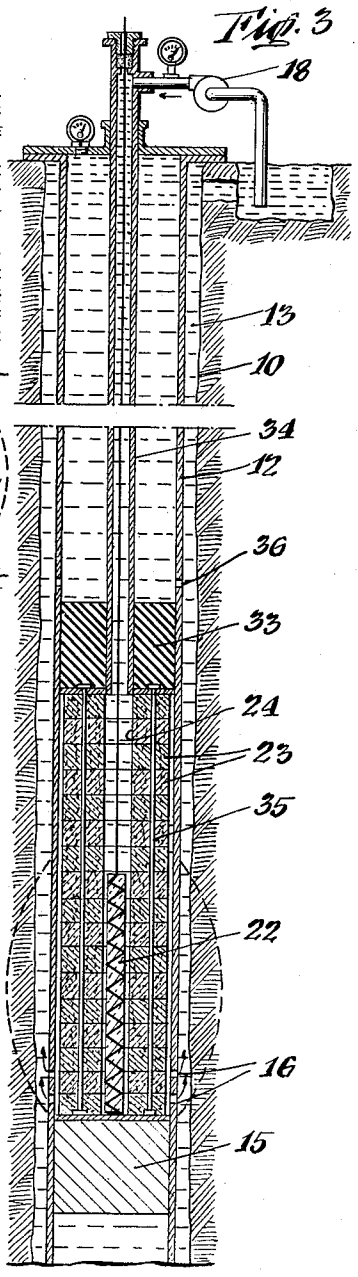
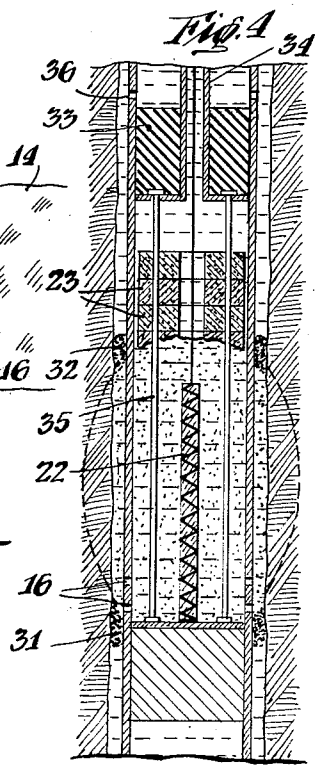


Fig. 4



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METHOD FOR SEALING BORE HOLE CASINGS

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Fig. 5

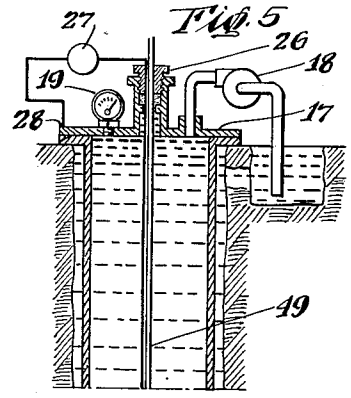


Fig. 7

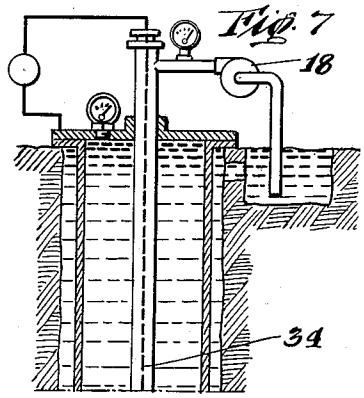
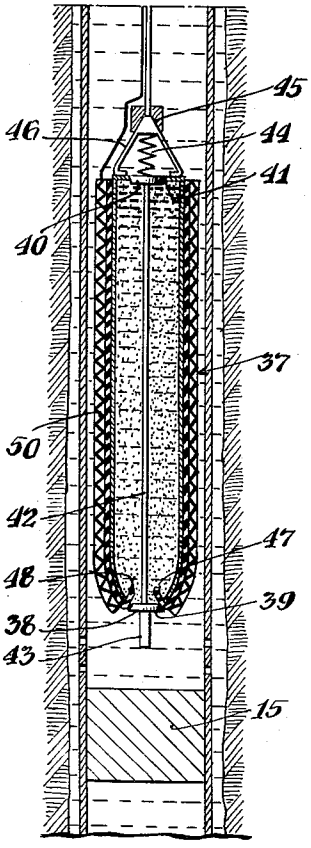
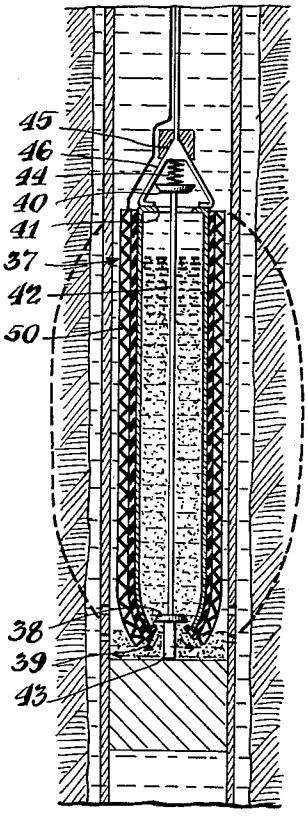
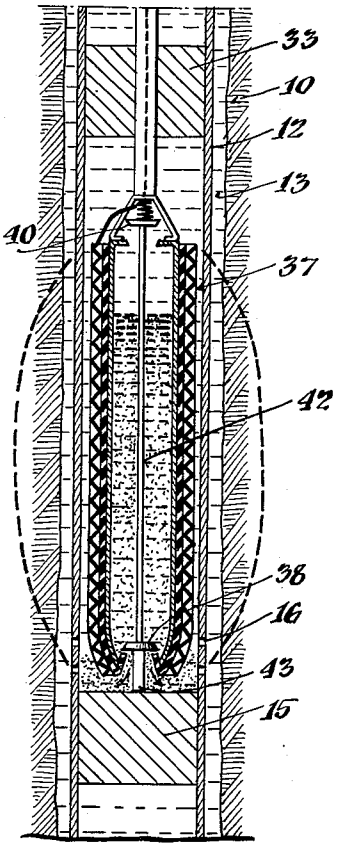


Fig. 6







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Fig. 8

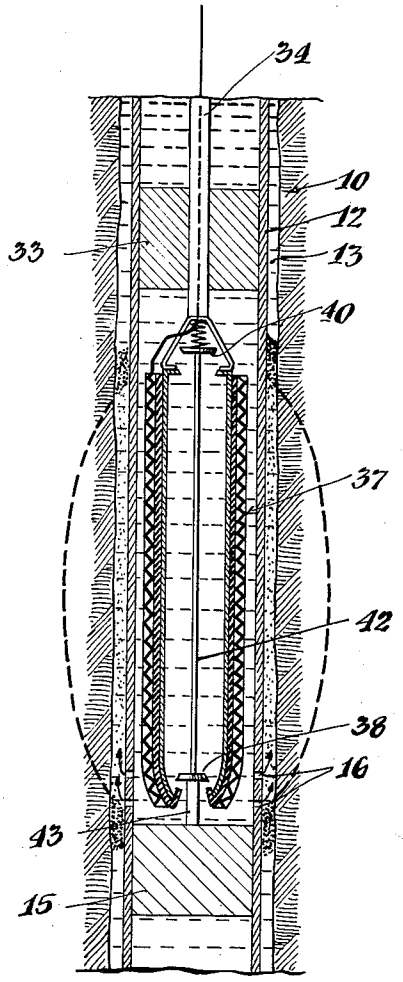
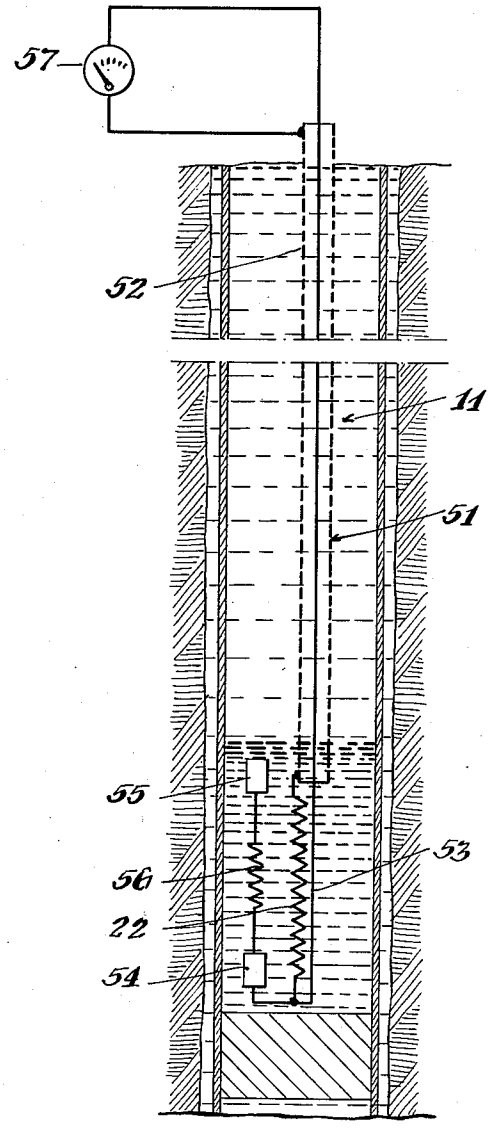


Fig. 9



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UNITED STATES PATENT OFFICE

2,363,269

METHOD FOR SEALING BOREHOLE CASINGS

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Application July 26, 1940, Serial No. 347,647
In France July 29, 1939

3 Claims. (Cl. 166—22)

The present invention relates to methods for sealing off the space between the wall of a bore hole and its casing for the purpose of preventing the flow therealong of fluids such as gas or water, for example.

It is the current oil well practice, after a well has been lined with a casing and plugged at the bottom with cement, to seal off the space between the wall of the well and the casing at the upper and lower boundaries of an oil sand which is to be exploited, in order to prevent water or gas from other formations from having access thereto.

Heretofore this has been accomplished by perforating the casing in the vicinity of the formation to be exploited and by forcing liquid cement through the perforations in the casing into the space between it and the wall of the bore hole. For a number of reasons this method has not been found to be entirely satisfactory.

For one thing, the cement mixture must be pumped long distances through supply piping, and in order that it may have the proper consistency to enable this to be done, it must contain water in a proportion very much higher than is required for good setting and hardening properties, so that the seal obtained is not always satisfactory.

Moreover, the fluid cement mixture, after it has been injected through the perforations in the casing, tends to follow the line of least resistance in a longitudinal direction along the casing, without spreading laterally. Hence, the cement mixture tends to accumulate only in those portions of the space between the casing and the wall of the bore holes where the resistance to its flow is low. This phenomenon is known in the art as "channeling" and it produces an unsatisfactory seal.

It is an object of the invention to provide a new and improved method for sealing off the space between the wall of a bore hole and its casing which is free from the above noted defects of the prior art and which enables a highly satisfactory seal to be obtained.

Another object of the invention is to provide a novel method of the above character whereby the extent of flow of the sealing material longitudinally of the casing is limited so that it tends to spread laterally to the end that "channeling" may be effectively prevented.

A further object of the invention is to provide a novel method of the above character wherein the extent of flow of the sealing material longitudinally of the casing is controlled by the influence of a physical field in the bore hole.

The objects of the invention are attained by creating at a given level in the bore hole, a physical field which is capable of retaining the sealing material injected into the space between the wall of the bore hole and the casing between predetermined longitudinal limits, so that it will tend to spread laterally in the space between these limits, thereby constituting an effective sealing ring between the casing and the wall of the bore hole.

In a preferred embodiment of the invention, a sealing material comprising a substance which is normally solid at the temperature of the formations at the depth where the seal is to be formed, is injected in the molten state into the space between the wall of the bore hole and the casing at that depth. Meanwhile, a predetermined length of the casing and the surrounding formations in the vicinity of the point of injection of the sealing material are maintained at a temperature above the melting point of the sealing material.

It will be readily apparent that after the sealing material has been injected through the perforations in the casing, it will remain in the molten state and will continue to flow until it passes beyond the limits of the thermal field where the temperature is lower. Here it solidifies, causing the still molten material to spread laterally until the entire space between the bore hole and its casing is effectively sealed between the limits imposed by the thermal field.

Further objects and advantages of the invention will become apparent from the following detailed description taken in connection with the accompanying drawings in which:

Figure 1 illustrates a cased bore hole together with the apparatus for sealing off the space between it and the wall of the bore hole according to the invention;

Figure 2 illustrates the manner in which the seal is formed in accordance with the method of the invention;

Figure 3 illustrates a modified form of the invention in which the method is carried out between a pair of spaced apart plugs in the bore hole;

Figure 4 shows the manner in which the seal is formed by the apparatus shown in Figure 3;

Figures 5 and 6 illustrate a modified form of the invention utilizing a ladle for lowering the sealing material to the desired level in the bore hole;

Figures 7 and 8 illustrate a further modification in which a ladle is employed in conjunction

with a pair of spaced apart plugs to practice the invention;

Figure 9 is a view in vertical section illustrating diagrammatically apparatus for determining the level of the sulfur in the bore hole.

Considering Figure 1, a bore hole 10 is shown in vertical section, containing the liquid or mud 11. The bore hole 10 is lined with a metallic casing 12 which is slightly smaller in diameter than the diameter of the bore hole 10, forming an annular space 13 therebetween. For the sake of convenience, it will be assumed that it is desired to seal off the space between the wall of the bore hole 10 and the casing 12 in the vicinity of an oil sand 14 which is known to exist at a given depth in the bore hole 10.

First of all, a plug 15 which may be of metal, for example, is placed in position in the casing 12 a short distance below the lower boundary of the oil sand 14. This may be accomplished in any known manner as, for example, by pumping it down the casing 12 in the usual fashion. A plurality of holes 16 are then bored in the casing 12 a short distance below the lower boundary of the formation 14, by means of a gun perforator of the type disclosed in prior Patent No. 2,141,827, for example.

Pressure is then applied to the column of liquid 11 in the bore hole 10 to force it through the holes 16 and up through the space 13 between the casing 12 and the bore hole 10, for the purpose of removing any mud which may have collected in the space 13 adjoining the oil sand 14.

For this purpose, the casing 12 is provided with a cover plate 17 which communicates with a pump 18 whose function it is to supply liquid 11 under pressure to the bore hole within the bore hole casing 12. The cover plate 17 is also provided with a conventional type liquid pressure gauge 19 which serves to provide indications of the actual pressure of the liquid 11 within the casing 12.

After the cleaning operation has been completed, sealing material in the fluid state may be injected through the holes 16 into the space 13 between the casing 12 and the bore hole 10 for the purpose of sealing it off as indicated above.

In the embodiments employing a thermal field, which are illustrated in Figures 1–9 of the drawings, the sealing material should comprise preferably a substance having the following characteristics:

(*a*) It should have a melting point which is higher than the normal temperature of the earth formations at the place where it is to be used.

(*b*) Its melting point should be lower than the vaporization point of the liquid contained in the bore hole at the pressure encountered at the depth where it is to be injected.

(*c*) It should have maximum fluidity in the molten state in order that it may flow readily through the perforations in the casing and into the space between the casing and the wall of the well.

(*d*) It should have relatively high mechanical strength in the solid state.

(*e*) It should be insoluble or only slightly soluble in water or oil.

Substances like sulfur and low melting point alloys, particularly lead base alloys such as mixtures of lead and tin have been found satisfactory for the purpose. Bitumen may also be used, but care should be exercised to prevent it from coming into contact with oil. Of these substances, sulfur is preferred for use in the method, since it is readily available, inexpensive and because it melts at a temperature considerably higher than the normal temperature of the formation surrounding a bore hole without requiring excessive quantities of heat.

If desired, the sealing material, sulfur, for example, may be lowered to the desired level in the bore hole 10 and there melted by the application of heat as shown in Figure 1. To this end an assembly 20 is lowered into the bore hole 10, which comprises a conducting plate 21 which is adapted to rest upon the metal plug 15 and which has secured to the central portion thereof a conventional type heating element 22, capable of dissipating about 10 kw. in the form of heat.

Seated on the plate 21 are a plurality of sulfur disks 23, each of which is provided with a central aperture 24 of greater diameter than the outside diameter of the heater 22, forming a cylindrical passage in the lower portion of which the latter is disposed. The entire assembly 20 is supported on a cable 25 which passes up through a packed bushing 26 in the cover plate 17 to suitable apparatus located at the surface of the earth (not shown) for raising and lowering the assembly 20 in the bore hole 10.

The electrical heater 22 is connected at its lower end to the metal plate 21 which is in contact with the metal plug 15 in the bore hole 10, and its upper end is connected through the single conductor in the cable 25 to one terminal of a generator 27 located at the surface of the earth, the other terminal of which is grounded to the casing at the point 28.

In order to prevent heat from being carried away by convection currents through the liquid 11 contained within the casing 12, it may be desirable to provide a washer plug 29 on top of the uppermost sulfur disk 23. The washer plug 29 may be of rubber or any other suitable material and it should preferably be somewhat larger in diameter than the inside diameter of the casing 12 and acts as a plug. As a further precaution, mud of relatively high viscosity might be deposited in any suitable manner above the plug 15 prior to the insertion of the assembly 20 therein for the purpose of reducing convection losses through the bore hole liquid 11. Obviously, the density of the viscous mud so deposited should be less than the density of the molten sulfur, or whatever other substance is used as the sealing material.

In operation, electrical energy is supplied to the heater 22 from the source 27 for a sufficient length of time to melt the sulfur surrounding it and to produce a thermal field in the adjoining part of the casing 12 and the surrounding formations, in which the temperature is above the melting point of the sulfur. The boundaries of this field are indicated generally by the dotted lines 30 in Fig. 2. Inasmuch as the density of the melted sulfur is greater than that of the liquid 11 within the casing 12, the former will tend to displace the liquid 11 and accumulate above the plug 15.

When the desired quantity of sulfur has been melted and the desired thermal field has been produced, the pump 18 is operated to increase the pressure of the liquid 11 above the washer 29, thereby forcing the melted sulfur through the holes 16 and into the space 13 between the wall of the bore hole 10 and the casing 12. The sulfur thus injected into the space 13 will flow upwardly and downwardly therein until it reaches the upper and lower limits of the heated zone,

as indicated by the dotted line 30, where it will solidify. The sulfur which is still in the molten state will then tend to spread laterally until finally upper and lower sealing rings 32 and 31, respectively, of solid sulfur are formed.

It will be noted that if any "channeling" occurs initially, it will continue only until the sulfur has reached one of the limits indicated by the dotted line 30. When these limits are reached, the sulfur will solidify, thus preventing any further longitudinal flow and forcing the molten sulfur behind to flow laterally. In this fashion continuous sealing rings may be obtained which are effective and entirely satisfactory.

When the solid sulfur sealing rings 31 and 32 have been formed, it will be impossible to inject further quantities of melted sulfur through the holes 16 into the space 13, and this will be indicated by an increased reading of the pressure gauge 19. At this point the operation can be regarded as terminated and the assembly 20 may be raised to the surface of the earth.

However, in certain cases, it may be advantageous to continue the heating operation by means of the heater 22 after the sealing rings 31 and 32 have been formed. In this fashion, further quantities of sulfur may be melted within the casing 12 as well as part of the sulfur comprising the sealing rings 31 and 32. When this occurs, additional quantities of melted sulfur may be forced through the holes 16 into the space 13, pushing before it the remelted sulfur therein, until the latter again passes beyond the limits of the thermal field set up by the heater 22, thereby effecting the operation in successive steps.

In certain cases, particularly in deep holes, the pressure required to force the sulfur into the space 13, together with the normal head of the liquid 11 contained within the casing, may be excessive and may damage the casing 12. This difficulty may be avoided by applying the pressure to the sulfur between a pair of spaced apart plugs in the bore hole 10, as indicated in Figures 3 and 4.

In this modification, the plug 15 will be placed in position, the holes 16 perforated in the casing 12 and the space 13 cleaned out in the same manner as indicated above in connection with Figs. 1 and 2. A second plug 33, secured to a hollow rod 34 is then lowered into the casing 12. The plug 33 has a plurality of sulfur disks 23 secured to its lower face by means of the cables 35, which disks are provided with centrally located apertures 24 forming a cylindrical passage within which the heater 22 may be disposed.

In operation, electrical energy is supplied from the source 27 at the surface of the earth to the heater 22 in the same manner as described above in connection with Figs. 1 and 2. When the requisite amount of sulfur has been melted, the pump 18 is connected to the hollow rod 34 and is operated to force liquid under pressure therethrough to the space between the plugs 33 and 15 in the bore hole, thereby forcing the melted sulfur through the openings 16 into the space 13 between the bore hole 10 and the casing 12. This operation is continued until the formation of the sealing rings 31 and 32 has been completed as indicated above in connection with Figs. 1 and 2.

In certain cases it may be advantageous to drill a plurality of openings 36 in the casing at a position above the plug 33 to permit the mud displaced by the injection of the sulfur into the space 13 to re-enter the casing 12.

If desired, exo-thermic chemical reactions might be utilized instead of the electrical heater 22 for the purpose of heating the sulfur in the bore hole 12. In this connection, mixtures of the type used in alumino-thermal technique may be employed to advantage. In particular, the sulfur might be melted by igniting a mixture of sulfur and iron filings in a closed vessel within the casing, thereby releasing a quantity of heat sufficient to effect the melting of the sulfur mass.

Instead of melting the sulfur mass in situ within the tubing, it might be melted at the surface of the earth and thereafter lowered to the desired level in the casing by any suitable means, such as, for example, a ladle or bucket, preferably heat proofed, as illustrated in Figs. 5, 6, 7 and 8.

Referring to Fig. 5, the ladle or bucket 37 may be of any conventional type and it is provided with a lower valve 38 seated in a port 39 and an upper valve 40 seated in a port 41, the valves 38 and 40 being connected by a common actuating rod 42. The rod 42 is provided with a downwardly extending portion 43 which is adapted to be thrust against the plug 15 when the ladle 37 is lowered in the bore hole 12, to open the valves 38 and 40 and permit the sulfur contained therein to pour out.

The valves 38 and 40 are normally maintained in the closed position by means of a spring 44 which is seated between the upper face of the valve 40 and a bearing element 45 formed upon a bail 46 by means of which the ladle 37 is suspended in the bore hole 12. A pair of inwardly extending springs 47 and 48 are secured to the ladle 37 adjacent the lower port 39 which are adapted to cooperate with the valve 38 to maintain it and the valve 40 in the open position once they have been opened.

In operation, the ladle 37 is lowered into the bore hole upon the cable 49 until the downwardly extending portion 43 on the rod 42 comes into contact with the plug 15. At this point the valves 38 and 40 open and are thereafter maintained open by the springs 47 and 48. This permits the sulfur contained in the ladle 37 to flow into the casing above the plug 15, where it may remain for a sufficient length of time to heat the surrounding portion of the casing 12 and formations in the manner described above.

If desired, the ladle 37 may be provided with a heating resistance 50 in its outer wall which will prevent the loss of heat and the solidification of the sulfur contained in the ladle 37 during the period of its descent within the casing 12. The heating resistance 50 may at the same time serve to heat the casing 12 and the surrounding formations when the ladle has come to rest on the plug 15, in such fashion as to produce the requisite thermal field for limiting the flow of the sulfur.

The heating resistance 50 is grounded at its lower end to the ladle 37 and its upper end is connected to a conductor in the cable 49, the upper end of which is connected to the source of electrical energy 27 at the surface.

As a modification, the valves 38 and 40 might be dispensed with and the ports 39 and 41 temporarily closed by suitable fuses adapted to be melted electrically after the ladle 37 has been lowered to the desired level in the bore hole 12.

In the embodiment illustrated in Figs. 7 and 8,

the ladle 37 is secured to the hollow rod 34 on which the upper plug 33 is fitted. In this modification, the ladle 37 is lowered into the casing 12 in the usual manner until the downwardly extending portion 43 of the rod 42 comes into contact with the plug 15, thereby opening the valves 38 and 40 and permitting the sulfur contained within the ladle 37 to pour into the casing 12 above the plug 31.

The plug 33 is then secured to the casing in any conventional manner and the pump 18 is operated to force water under pressure into the hollow rod 34, thereby injecting the sulfur above the plug 15 in the casing 12 through the holes 16 into the space 13 between the wall of the bore hole 10 and the casing 12. From this point on, the operations are exactly the same as indicated above in connection with the other modifications in the invention.

If desired, after the valves 38 and 40 in the ladle 37 have been opened, the ladle 37 may be raised until all of the sulfur contained therein has been emptied into the casing 12 above the plug 15, whereupon the plug 33 may be secured to the casing 12 at any desired height in the conventional manner.

Obviously any other suitable means may be employed for increasing the pressure between the plugs 15 and 33. For example, a container of gas under pressure might be lowered with the ladle 37 into the bore hole 12 and gas might be released therefrom after the plugs 15 and 33 are locked in position in the casing 12, for the purpose of forcing the sulfur through the holes 16 into the space 13.

In order to avoid a plurality of raising and lowering operations, the requisite plugs, suitable perforating mechanism for boring the holes 16 in the casing 12 and the ladle 37 containing the melted sulfur, might be combined into a unitary assembly adapted to be lowered into the bore hole.

It will be understood, of course, that where a heat proofed ladle is used, the heating elements thereof may be utilized to supply heat to the sulfur and to maintain the requisite thermal field in the surrounding formations.

As an alternative, molten sulfur might be poured into the space between the plugs 15 and 33 through the hollow rod 34. In such case, a heating conductor should be disposed therein and supplied with current in order to prevent the sulfur from solidifying and cooling in its passage from the surface of the earth to the place where it is to be used.

In Fig. 9 is shown apparatus for providing indications of the level of the molten sulfur within the casing 12. The apparatus comprises a single conductor cable 51 having a steel braid 52 which is connected to one end of the heater element 22, the other end of which is connected to the conductor 53 in the cable 51. At the junction point between the conductor 53 and the heater element 22 are connected a pair of electrodes 54 and 55 which define the desired lower and upper levels, respectively, of the melted sulfur contained above the plug 15 in the casing 12, between which is interposed a series resistance 56.

The electrodes 54 and 55 are made of metal whose electropositive value is different from that of steel so that they form a voltaic cell with the braid 52 of the cable 51 and the muds 11 in the bore hole 10. During the heating operation, the source of electrical energy 27 is connected across the steel braid 52 and the conductor 53 of the cable 51, but it is disconnected and replaced by the millivoltmeter 57, as shown in Fig. 9, when the sulfur level is to be ascertained.

The electrodes 54 and 55 may both be made of the same metal, copper for example, in which case the voltage indicated by the instrument 57 will have one value when the electrode 55 is in contact with the liquid 11 in the casing 12 and it will have a greater value when the lower electrode 54 is also in contact with the muds 11.

If, however, the upper electrode 55 is made of copper and the lower electrode 54 is made of zinc and the resistance 56 is given a value of about 100 ohms, the potential difference indicated by the instrument 57 will be of one sign when the electrode 55 is in contact with the mud 11, and the opposite sign when the electrode 54 is also in contact with the mud 11.

At the beginning of the process, when both of the electrodes 54 and 55 are immersed in molten sulfur, the instrument 57 will give a zero reading. As the level of the sulfur decreases and the upper electrode 55 comes into contact with the mud 11 contained in the casing 12, the indicating instrument 57 will give a reading of one sign. When the sulfur level is below the electrode 54, the indicating instrument 57 will give a reading of opposite sign.

The purpose of the resistance 56 between the electrodes 54 and 55 is to make the influence of the lower electrode 54 preponderant when they are both in contact with the mud 11 in the casing 12.

I claim:

1. A method of sealing off the space between the wall of a bore hole and its casing at a position located intermediate the top and bottom of the bore hole, the bore hole having a column of liquid therein, comprising locating a plug at a predetermined depth in the casing in the vicinity of said position, perforating the casing at a position above said plug, lowering a quantity of solid sulfur and an electric heater to the level of the plug, blocking off the casing above the sulfur and the heater to reduce heat transfer by convection therefrom through the bore hole liquid, supplying elecrical energy to said heater for a sufficient length of time to liquefy the sulfur and to create a thermal field in the adjoining part of the casing and its environs, in which the temperature is above the melting point of sulfur, applying pressure to the column of liquid in the casing to force the liquid sulfur through the perforations in the casing into the space between the wall of the bore hole and the casing, and continuing the application of pressure to the liquid in the bore hole until effective seals have been formed by the solidification of the liquid sulfur in the vicinity of the boundaries of said thermal field.

2. The method of sealing off a portion of the space between the bore hole and casing of a well at a desired level between the top and bottom thereof, the casing being provided at the desired level with perforations, comprising the steps of positioning a plug in the casing below said perforations, lowering a quantity of fusible material, and a cooperating electric heater, to the zone of said perforations, energizing the heater to melt the fusible material, and forcing the molten mass outwardly through the perforations so that it passes out of range of the heater and solidifies.

3. The method of sealing off a portion of the

space between the bore hole and casing of a well at a desired level between the top and bottom thereof, the casing being provided at the desired level with perforations, comprising the steps of positioning a plug in the casing below said perforations, lowering a quantity of sulfur, and a cooperating heater, to the zone of said perforations, energizing the heater to melt the sulfur, and applying pressure to the molten sulfur for forcing it outwardly through the perforations so that it passes beyond the thermal range of the heater and solidifies.

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