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APPARATUS FOR PRODUCTION OF FLUIDS FROM WELLS

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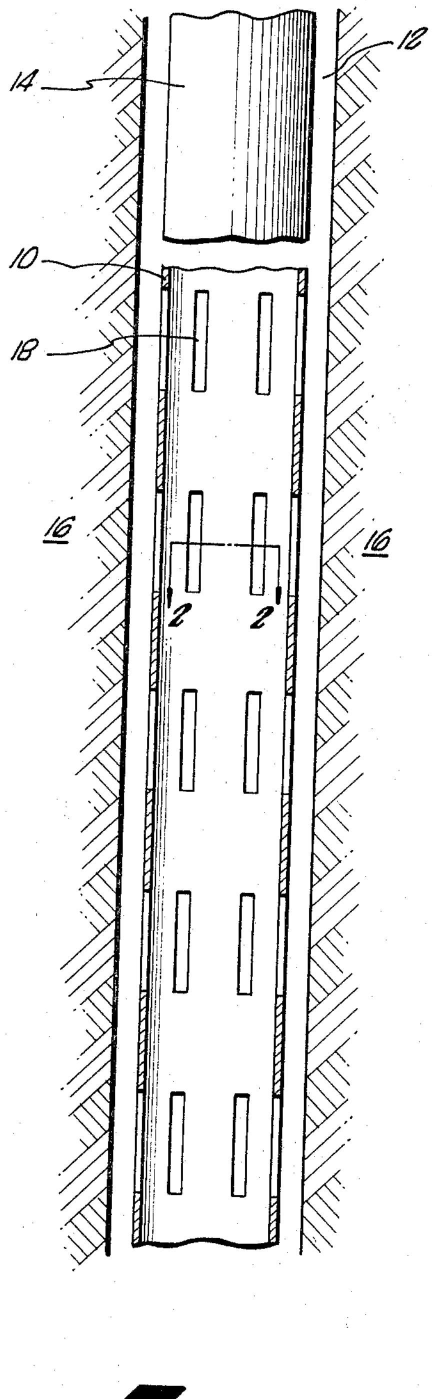

FIG. 1

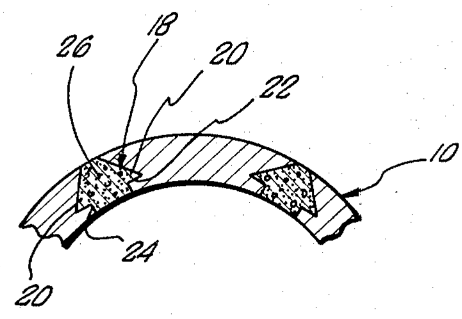

FIG. 2

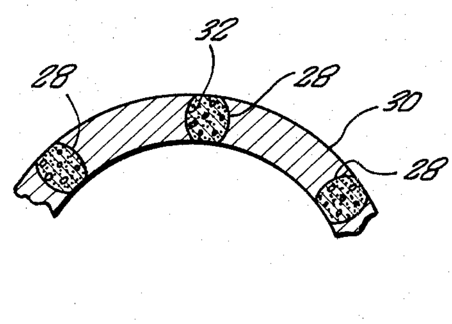

FIG. 3

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APPARATUS FOR PRODUCTION OF FLUIDS FROM WELLS

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This invention relates to a liner for producing fluids from subsurface wells and, more particularly, to a well liner having slots packed with a permeable matrix. The invention further relates to methods for producing fluids from wells.

In the completion of wells that produce oil, water, or other fluids, production of fluids from loosely consolidated formations containing sand, silt, or clay presents substantial problems. Such formations contain little or no naturally-occurring binding or cementing materials. As a result, normal fluid flow conditions tend to cause particles from the formations to run into the well bore with attendant deteriorative effects upon fluid production from the well. Clogging of well screens and damage to pumping equipment are examples of problems resulting from sand-flow.

For the foregoing reasons, proper well completion for production of fluids from loosely consolidated formations requires use of some means to prevent entry of any substantial quantities of formation particles into the well liner. To this end, control of sand flow in wells is commonly provided by a sand or gravel pack placed exteriorly of the well liner. One practice is to pack the space between the well liner and the unconsolidated formation with sand or gravel after the liner is set in place. Another practice is to use a pre-filled liner in which said or gravel is packed within the annular space formed between inner and outer liners.

In the use of sand or gravel packs, control of sand flow is accomplished because the majority of the formation particles are entrapped as they are carried by produced fluids through the interstices of the pack. This occurs as a result of "bridging," by which phenomenon a stable structure of solid particles is built within an opening several times the diameter of the particles that might be expected to flow through the opening. The effectiveness of sand control may be improved by selection of pack particles containing a gradation in sizes, as disclosed for example in U.S. Patent No. 2,905,245.

The present invention controls entry of formation particles into a well liner in an effective and economical manner. One aspect of the present invention is a well liner comprising an elongate tubular member having a plurality of slots disposed longitudinally and circumferentially of the tubular member. The slots extend through the tubular member. A permeable matrix is disposed within each of the slots. In a preferred form of the invention, the configuration of the slots is such that there is a surface of the tubular member against which a consolidated permeable matrix is forced by pressure differentials. The shape of the slot therefore prevents the matrix from being dislodged by high pressure differentials between the inside and outside of the liner.

The matrix packed in the slots of the liner according to the present invention is formed from any particulate hard natural or synthetic material mixed to form a pack. Examples of materials that can be used are sand, gravel, crushed quartz, ground glass, shot, or glass beads. Preferably, a binding or cementing agent is added to a mixture of graded particulate matter and the material is packed into the slots of a pre-slotted well liner. The binding agent is added as a semi-fluid mixture in an amount sufficient to consolidate the particulate material upon hardening without blocking the interstices. In this manner, a permeable matrix is provided within the slots.

The present invention furnishes a well liner having a substantially greater area of relatively high permeability available for flow of produced fluids than is available in prior art liners. Use of the latter with sand or gravel packs requires liner openings sufficiently small so that pack particles cannot flow through the openings. Alternatively, prior art liners are wrapped with wire mesh having openings sufficiently small to prevent flow of pack particles through the wire. In either case, the permeability of the well system to flow of production fluids is reduced.

As another aspect of the invention, some or all of the slots of the liner are packed with matrices, formed as described above, in which the interstices are filled with a waxy substance or wax. The term "waxy substances" or "waxes" is used herein to refer to the group of animal, vegetable, mineral, and synthetic waxes which are characterized by an ability to melt to liquids of relatively low viscosities. The melting points of the waxy substances in different groups of slots differ by a number of degrees, with each melting point being in excess of the formation temperature. The lowest melting point of a waxy substance used as described herein is preferably about 10° to 15° F. in excess of the particular formation temperature. When a well liner having some of its matrices filled with waxes is run into the hole, production initially takes place only through slots containing wax-free matrices. As production continues and formation sand flow through the matrices begins to reduce the permeability to fluid flow of some or all of these matrices, a second group of slots is opened by pumping into the well liner a heated fluid having a temperature sufficient to melt the waxy substance having the lowest melting point. Melting of the wax opens the interstices of the matrices within the second group of slots and permits fluid flow from the formation into the well liner. If plugging of the second group occurs due to sand flow, a fluid at a temperature sufficient to melt the obstructing wax in a third group of slots is injected. The procedure can be sequentially repeated to open additional groups of slots in the event plugging of previously opened groups occurs from sand flow.

As yet another aspect of the present invention, the well liner having slots and a matrix material as previously described is incorporated as part of the drilling string when the production zone of the well is first penetrated. When drilling through the production zone is completed, the position of the well liner is such that it can act as a production casing. The necessity for running of a production string following completion of drilling is avoided.

The present invention and its advantages will be better understood from the following description made in conjunction with the accompanying drawings in which:

FIG. 1 is a sectional elevation of a well liner in accordance with one embodiment of the present invention;

FIG. 2 is an enlarged fragmentary view generally taken along line 2—2 of FIG. 1; and

FIG. 3 is an enlarged fragmentary cross-sectional view of a well liner incorporating another embodiment of the present invention.

With reference to FIG. 1, a tubular member or pipe **10** is run into a well bore **12** at the end of a production string, of which one section **14** is shown in the drawing. The pipe is landed adjacent producing formation **16** in accordance with well-known practices for completion of wells. A plurality of slots **18** are longitudinally and circumferentially disposed in the pipe. The length of each slot is several times its width. The slots can be oriented with their lengths parallel to the longitudinal axis of the pipe, as shown in FIG. 1, or with their lengths transverse to the longitudinal axis.

As viewed in cross-section in FIG. 2, gradually diverging walls 20 increase the width of slot 18 as it extends inwardly from the exterior wall until a maximum width is attained to form shoulders 22 within the wall of the pipe. The remaining inwardly extending portion 24 of the slot has a width less than the maximum width.

A particulate hard natural or synthetic material of the type previously described is packed in each slot to provide a permeable matrix 26 filling the slot. The binding agent added to consolidate the particulate material is one that will harden after the mixture is packed in the preformed slot. Various resinous materials such as epoxy resins or phenol-formaldehyde resins can be used. Additionally, Portland cement can be used. The binding agent is added in an amount sufficient to coat the surfaces of the particulate material so that, upon hardenening of the binding agent, the particles adhere to each other without blocking the flow passages. Permeability of the matrix can be adjusted by gradation of particle size or by the amounting of binding agent used.

After hardening of the binding agent, there is both adherence between particles of the matrix and coherence between the particles and the pipe walls defining each slot. However, the strength characteristics of the liner assembly are improved by a cross-sectional slot configuration adapted to retain the consolidated matrix in place. The particulate material-binding agent mixture is packed into each slot in an unconsolidated semi-fluid condition. The consolidated matrix produced upon hardening of the binding agent is retained in place by a slot configuration such as shown in FIG. 2. Where, as is usually the case, the pressure exteriorly of the pipe is greater, the matrix is urged against shoulders 22. Where, as may occur during remedial operation, the pressure interiorly of the pipe is greater, the matrix is urged against walls 20. By providing a maximum slot width intermediate the inner and outer surfaces of tubular member 10, the consolidated matrix cannot be dislodged unless the pressure exceeds the fracturing pressure of the matrix or the bursting strength of the pipe.

FIG. 3 is a fragmentary cross-sectional view of another slot configuration which has advantages similar to those described with reference to the configuration shown in FIG. 2. Slots 28 in pipe 30 have curved side walls which provide a cross-section in the general shape of an ellipse truncated at its ends. A matrix material 32 is packed within the slots in the manner already described.

It will be understood that the slot configurations shown in FIGS. 2 and 3 are illustrative and that, based upon the description given herein, others within the scope of the invention will become apparent.

After the well liner is landed adjacent the producing formation and production is initiated, formation fluids pass into the interior of the pipe through the interstices of the matrices in the slots. Any formation sand carried by the fluids bridges within the matrix material and does not pass into the interior of the pipe.

Where it is desired to open slots sequentially for fluid production after initial landing of the well liner, as previously described, a waxy substance in a molten state is initially mixed with the binding agent and the particulate matter in an amount sufficient to fill the interstices of some of the matrices. For this purpose, the amount of waxy substance required may be readily approximated by measuring the porosity of an aliquot of an unconsolidated pack formed from a given mixture of particulate material. After the mixture is packed in the slots, hardening of the binding agent consolidates the matrix while hardening of the waxy substance fills the interstices to produce an impermeable matrix. Alternatively, the interstices may be filled by flowing molten wax through the consolidated matrix within the slots and allowing the waxy substance to harden by cooling.

As has been previously described, waxes of incrementally increasing melting points, preferably 15° to 20° F.

apart, are used in matrices within different groups of slots. Permeability to flow is imparted to groups of slots by filling the well liner with a fluid at a temperature sufficient to melt the waxy substance in a particular group of slots. Preferably, the waxes are either animal or vegetable waxes since these exhibit slight or no solubility in crude oils. Illustrative examples of animal waxes are Chinese wax and crude grades of stearic acid. Illustrative examples of vegetable waxes are carnauba, Japan, and candelilla. In addition, various synethetic paraffins and low molecular weight polyethylenes may be employed. Gradation of melting points may be achieved by mixtures of waxes of different melting points or by initial fractionation by means of solvents.

The well liner of the present invention can be adapted to enable determination of the location of water or hydrocarbon-bearing strata adjacent the well liner. For example, to determine the levels from which oil is being produced, matrices at different vertical levels in the well liner are coated with different oil-soluble, water-insoluble materials. Flow of oil dissolves the substance coating the particular matrices through which flow occurs. The dissolved substance is detected by surface analysis of the produced oil. In this manner, the particular levels through which oil flow is occurring can be determined. Through use of water-soluble, oil-insoluble materials, similar determination can be made with respect to water flow. Dependent upon the materials selected, surface detection can be carried out by radioactive or chemical analytical techniques.

The incorporation of the well liner of the present invention in a drilling assembly to provide an in-place production casing requires that no significant rotational torque be imparted to the well liner during drilling. The normal rotational torque induced in drill pipe during drilling operations would act to fracture the matrices within the slots of the liner. One method of avoiding rotational torque is through use of a turbine drill in the drilling assembly. A bit is joined to a sub which in turn is connected to the well liner through a ball race. A turbine inside the liner is operatively connected to the bit. A safety joint enables removal of the turbine after drilling is completed.

Upon completion of drilling through a production zone, the turbine is removed while the bit is left in place. The well liner and the pipe connecting it to the surface remain in the well bore to provide an in-place production string when drilling is completed.

Various modifications and changes, particularly in the slot shapes, matrix materials, and waxy impregnating substances, will become apparent from the foregoing detailed description. All such modifications and changes that fall within the scope of the following claims are intended to be included therein.

I claim:

1. A well liner comprising an elongate tubular member having a plurality of slots disposed longitudinally and circumferentially of, and extending from the outer surface to the inner surface of, the tubular member, said slots having a maximum width intermediate said inner and outer surfaces, and particulate material packed within the slots and consolidated with a binding agent to provide a permeable matrix filling the slots.

2. A well liner comprising an elongate tubular member having a plurality of slots disposed longitudinally and circumferentially of, and extending from the outer surface to the inner surface of, the tubular member, said slots having a first width intermediate said inner and outer surfaces, a second width intermediate the inner surface and the first width, and a third width intermediate the outer surface and the first width, the second and third widths being less than the first width; and particulate material packed within the slots and consolidated with a binding agent to provide a permeable matrix filling the slots.

3. A well liner comprising an elongate tubular member having a plurality of slots disposed longitudinally and circumferentially of, and extending from the outer surface to the inner surface of, the tubular member, said slots having a first portion diverging inwardly from the outer surface to define a shoulder at the point of maximum divergence intermediate said inner and outer surfaces, and a second portion extending from the inner surface to open into the first portion and having a width at said opening less than the width of the first portion at maximum divergence; and particulate material packed within the slots and considated with a binding agent to provide a permeable matrix filling both portions of each of the slots.

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