

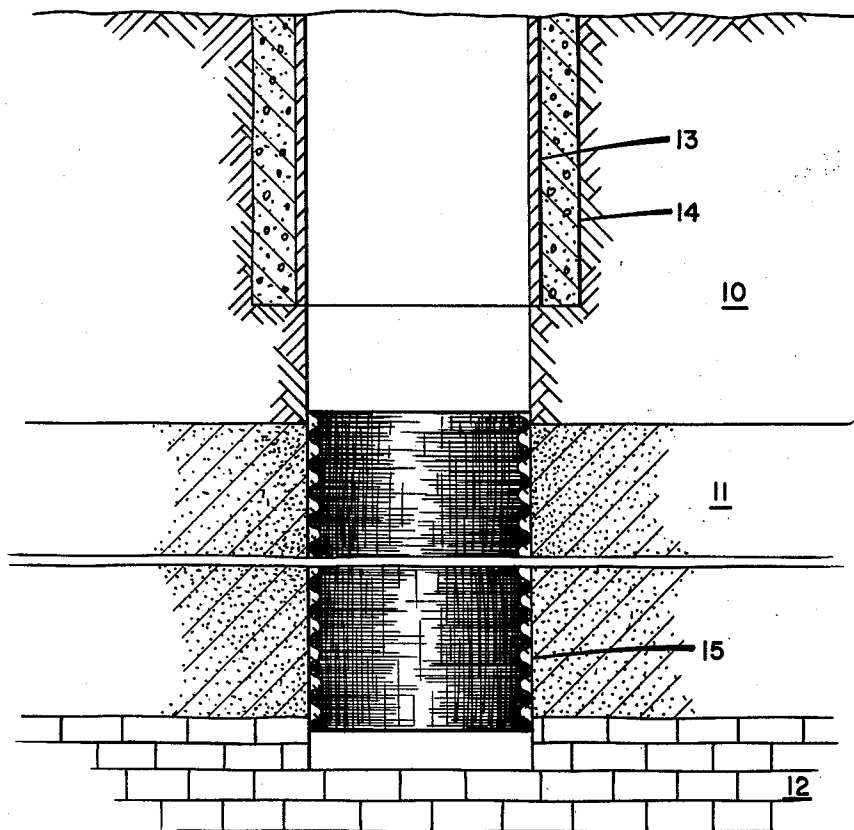
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RESTRAINING FLOW OF SAND INTO WELLS

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RESTRAINING FLOW OF SAND INTO WELLS

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This invention relates to decreasing the flow of sand into wells from loosely consolidated fluid-producing formations. More particularly, it relates to a permeable liner set against the well wall to prevent movement of sand and a method for setting the liner.

For many years the entry of sand into wells from fluid-producing formations has been a problem. Screens, gravel packs and the like have been employed to decrease the flow of sand. The screens are expensive and usually become quickly plugged, so the desired fluids cannot enter the well tubing. Gravel packs in general do not become so quickly plugged, but are rather difficult and expensive to place properly. In addition, flow of fluids through the gravel pack sometimes tends to cause a shifting of the pack to open flow channels through which the sand can move. A particular problem occurs in pumping wells where the pump is connected to a screen in the gravel pack. The action of the pump in such cases tends to move the screen relative to the gravel pack and disturbs the sand-restraining ability of the pack.

With the above problems in view, an object of this invention is to provide a simple and inexpensive sand-restraining means which can be easily set opposite fluid producing formations. A more specific object is to provide a sand-restraining means which will not become quickly plugged. Another object is to provide a sand-restraining means which will leave the well open to substantially its full diameter for operation of well equipment.

I have found that if plugging of a sand-restraining means is to be prevented, movement of the body of formation sand should be prevented. For example, when a screen to restrain sand is set in a well and the formation sand is permitted to move into the space surrounding the screen, the movement causes the large grains to lodge in the screen. The intermediate sand grains then bridge between the larger sand grains and the finer ones bridge the holes between those of intermediate size. The result is that the screen is quickly plugged. When initial movement of the formation sand is prevented, however, the individual sand grains tend to remain in their original positions and the permeability remains high. This is believed to be one of the principal reasons why gravel packs are usually more successful than screens. The gravel packs are placed against the sand faces which form the well wall. Movement of the formation sand is thus fairly well prevented unless shifting of the pack occurs. In sand screens, however, a space is left between the screen and the well wall. When the well is produced, the sand moves into this space with the undesirable results noted above.

I propose to obtain the advantages of both the screen and the gravel pack without their disadvantages by forming a screen against the well wall. The screen, being against the well wall, prevents movement of the sand and the screen cannot shift like a gravel pack to permit sand movements after the screen is placed. The screen is formed of fiber-reinforced plastic threads or, considered in another way, the screen is formed of a woven fabric the threads of which are impregnated with plastic.

The screen is formed by impregnating the threads of a sleeve of the fabric with a liquid resin capable of being set to a hardened state while leaving resin-free spaces

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between the threads, expanding the sleeve in the well and holding it in expanded shape until the resin cures to a hardened condition.

The invention will be more clearly understood from the drawing in which the bottom portion of a well is shown penetrating three formations 10, 11, and 12. Formations 10 and 12 are strong formations, but formation 11 is unconsolidated or loosely consolidated sand which contains oil. In completing the well it is drilled to near the bottom of formation 10. Casing 13 is then set in the well and cemented in place by cement 14. The well is then drilled on through formations 10 and 11 and into the top of formation 12. A sleeve of glass fabric is then impregnated with enough liquid resin to saturate the threads but insufficient to fill the holes between the threads. A sleeve or tube of the fabric is then lowered into the well to a level opposite the sand zone 11. The tube is expanded and held against the well wall until the resin hardens. The result is a sand-restraining, hard, strong, rigid, but permeable liner 15 pressed against the unconsolidated sand. This restrains flow of the sand into the well but permits entry of oil. The well is left open to substantially its entire diameter for operation of well equipment.

Apparatus suitable for expanding the resin-impregnated fabric in the well has been previously described in references such as U.S. patent application S.N. 769,941, filed by E. R. Jennings on October 27, 1958, now U.S. Patent 3,028,915. These references describe apparatus and methods involving the use of an expandable tube or bag for setting impermeable fabric-reinforced plastic liners in wells by forcing the liner out against the well wall before the plastic has set. The apparatus and methods which I employ are similar except for the preparation of the expandable sleeve of fabric.

When liquid resin is applied to the sleeve, a sufficient amount should be used to insure complete impregnation of all the threads. This usually means that an excess is used which tends to fill the spaces between the threads and form an impermeable sheet. Several methods can be used to avoid this difficulty. One method is to apply the resin with a hairy roller. A vigorous rolling action fills all the threads with resin while the hairs on the roller tend to force the resin out of the spaces between the threads. Thus, if the resin is applied sparingly and rolled vigorously with the hairy roller, the threads become thoroughly saturated but the spaces between the threads are left resin-free.

Another method is to apply a slight excess of resin, remove the excess by rubbing with rags, and finally roll with a hairy roller to force the resin from the spaces between the threads.

Still another technique consists of applying an excess of resin by any desired means and then removing the excess by exposing the resin-filled fabric to a stream of high-velocity gas, such as compressed air, bottled nitrogen, or the like.

Theoretically, the sleeve can be mounted on the expandable bag and then impregnated with resin. It is generally more convenient, however, to impregnate the fabric first and then mount it on the expandable bag or tube. The preferred procedure is to use a split sleeve which is really simply a flat piece of fabric. This flat fabric can be easily impregnated and then wrapped around the expandable tube, the ends of the fabric overlapping enough to permit at least the anticipated amount of expansion. It may be desirable in some cases to use an unsplit sleeve having several times the diameter of the collapsed expandable tube. This large sleeve is impregnated, slipped over the expandable tube, the excess sleeve brought together to form a double layer and this double layer

wrapped around the expansible tube. After wrapping either form of the sleeve around the bag or tube, the sleeve may be held in place by tying with cotton string or ribbon, copper wire, light metal bands, or the like which can be easily broken when the bag is expanded in the well.

If high-strength screens are required to stabilize the formation as well as prevent inflow of sand, a multiple-layer permeable liner or screen may be desired. It is usually best to tack the layers together with overlapping edges as more fully described in U.S. patent application S.N. 846,893 filed by R. P. Vincent on October 16, 1959, now U.S. Patent 3,047,065. The layers may be impregnated with resin before or after being attached together. After attachment, the assembly is wrapped around the expansible tube or bag just as a single layer would be. It is possible to wrap multiple layers separately around the tube, but it is sometimes difficult to expand such a system because of the large amount of relative motion required between the layers. Frequently, however, the same results may be obtained by using a single layer of very heavy weave fabric.

Any resin which will cure or set hard, either naturally or artificially, in the well may be employed. Typically, these resins are thermosetting resins, i.e., resins which are capable of undergoing a permanent physical change under the influence of well temperature or an artificially induced higher temperature. Polyester or epoxy resins are examples. Other suitable resins include urea, resorcinol, and phenol formaldehydes, and the like. Epon 828, an epoxy resin manufactured by Shell Chemical Company, is an example of a preferred epoxy resin. As is well known in this art, these resins may be combined and various catalysts or curing agents employed in various concentrations so that the setting or curing time or pot life for various well depths or various temperatures may be controlled. Versamid resin 140, a polyamide manufactured by General Mills, Inc., is an example of a preferred catalyst which, in the ratio of about 30 parts by volume to 70 parts of the Epon 828 epoxy resin, has a pot life at room temperature of about 3 to 3½ hours. Such resins when set, i.e., when they are cured sufficiently to be self-supporting and relatively rigid, are referred to herein as plastics.

The most critical part of my permeable sand-restraining liner is the fabric itself. The preferred fabric is a woven glass cloth in which the threads are spun from glass fibers on the order of 0.001 inch in diameter or even smaller. Such threads provide considerable space between the fibers for resin. When the resin is cured to a hard plastic, the result is a small strong rod of plastic reinforced by strong inert glass fibers.

Threads may be spun from other fibers such as rock wool or even from organic fibers, such as cotton, silk, wool, or the like. Glass fibers are very much preferred, however, because of their low cost, high strength, and particularly their inertness to the action of well fluids and their constant properties even at elevated temperatures.

The threads of which the fabric is woven may be of almost any diameter. In some cases small threads are even twisted or braided to form larger threads or ribbons from which the fabric is woven. Larger threads have the advantage of forming stronger reinforced plastic rods and therefore stronger permeable sand-restraining liners. Larger threads have the disadvantage of leaving fewer fluid conducting spaces or holes per unit area of liner. Liners formed from fabric having threads as large as ⅛ inch in diameter are strong, but have low permeabilities. If the threads are as small as 1/100 inch, on the other hand, the permeability of the resulting liner is high, but the liner is rather weak. It is generally advisable to use threads in the range of 1/64 to 1/16 inch in diameter to obtain high permeability, strength being obtained by the use of a multiplicity of layers.

More important than the size of the threads is the size of the spaces between threads in the fabric. Regardless of the size of threads, if the space between the threads is too great, sand will flow through. An ordinary glass-reinforced plastic window screen, for example, would not be suitable for restraining flow of sand from most fluid-producing formations. The spaces must be much smaller, sufficiently small to restrain the flow of the sand. This does not mean that the spaces must be smaller than the smallest sand grain. Previous work with sand screens has shown that if sand is placed against a screen having openings larger than a majority of the sand grains, little flow of sand occurs since the larger grains bridge the openings and prevent movement of the smaller grains.

I have found that the maximum size of openings can be determined in several ways. In one method a sample of sand from the well is subjected to sieve analysis. There will be some size of sieve which will retain about 10 percent of the sand by weight, permitting the remainder to pass through. If the openings in the permeable liner are less than twice the size of the openings in this sieve, little movement of sand occurs and the permeability of the liner remains high. For example, if a fabric is used with spaces between threads about twice the size of spaces in the sieve, then when the threads of the fabric are impregnated with plastic, the space between the threads will be decreased considerably to prevent passage of the sand. When reference is made to the spaces between the threads having twice the size of spaces of the sieve, maximum dimensions of the two openings are intended. Ordinarily, both openings will be square in shape so the width of the space in the fabric should be less than twice the width of the space in the sieve.

Another method of determining whether a particular fabric is suitable for forming a permeable liner for a particular sand is to impregnate the threads of the fabric while leaving the spaces between the threads resin-free, as described above. The resin is then cured to a hardened state. The resulting fabric-reinforced screen is placed in a filter press, a sample of the sand in question is placed on the screen, liquid is added, and a pressure is applied to the liquid. If the liquid from the filter press is substantially free from sand, that is, if it contains less than about 1 percent of sand, then the particular fabric may be considered satisfactory for this particular sand. The apparatus described in API Recommended Procedure 29 for testing the filtrate rate of drilling fluids may be used for this test, the reinforced screen being used in place of the filter paper described in the test. Procedure 29 recommends the use of 100 p.s.i. pressure over the liquid. In view of the high flow rates which will be involved, much lower pressure, usually merely a short hydraulic head, is ordinarily all that is required.

My method will be better understood from consideration of the following example in which a well has an oil-producing formation from 7542 to 7558 feet. A caliper of the well indicates it is about 8 inches in diameter at the level of the formation. Cores of the formation show it to be loosely consolidated. When the core is gently crushed by use of a rubber pestle and a mortar, for example, the sand grains break apart so they can be subjected to sieve analysis. This analysis shows that 10 percent by weight of the grains are retained on a No. 50 sieve in the U.S. Standard series. The width of opening in this sieve is 0.0117 inch.

To set a permeable liner for restraining flow of sand from this formation, a glass cloth is used in which the threads run at right angles to each other to form square openings. The fabric is woven from threads spun of glass fibers about 0.001 inch in diameter. The threads themselves are substantially round and are about 1/32 inch in diameter. Spaces between the threads are about 0.02 inch wide (20 threads to the inch). Two pieces of the fabric are cut 20 feet long and 30 inches wide. The threads of these are impregnated with Epon 828 resin

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containing Versamid resin 140 to catalyze curing of the resin. A hairy roller is used to impregnate the threads so the spaces between the threads remain resin-free. One layer of fabric is then laid over the other with the long edges offset about 8 inches. The sheets are stapled together in this position using ordinary steel staples. This stapled assembly is then wrapped around the center 20 feet of a 25 foot expansible tube with the long edges of the fabric being parallel to the axis of the tube. Cotton ribbons are tied around the wrapped sleeve every foot along this length to hold the sleeve in place.

The equipment described in U.S. patent application S.N. 769,941 Jennings is used to lower the sleeve into the well to the level of the oil-producing formation and to expand the sleeve out against the well wall. The sleeve is held in expanded shape until the resin cures to a hardened condition. This leaves a strong, permeable, plastic, sand-restraining liner reinforced by at least two layers of glass fabric pressed against the oil-producing formation around the entire circumference of the well and extending throughout the entire length of this formation. As soon as the resin has cured to form a hard, strong, glass-reinforced plastic, the expansible tube is collapsed and the setting apparatus is withdrawn from the well, leaving substantially the entire diameter of the well free for the operation of well equipment.

I claim:

1. A method for restraining the flow of sand into a well from a fluid-producing formation penetrated by said well comprising mounting a sleeve of fabric on an expansible bag, impregnating the threads of the fabric with a resin capable of being set to a hardened state, while leaving resin-free spaces between the threads, said spaces being sufficiently small to restrain the flow of said sand, lowering said sleeve and bag into said well to the level of said formation, expanding said bag to force said sleeve into contact with the well wall, maintaining said bag in expanded position until said resin has set to a hardened state, collapsing said bag, and withdrawing said bag from said

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well, whereby a strong, rigid, sand-restraining liner is placed against said formation to restrain entrance of sand and permit entrance of fluids while leaving said well open to substantially its full diameter for operation of well equipment.

2. The method of claim 1 in which said fabric is woven of threads spun from glass fibers, whereby the strength of said liner and its inertness to well fluids is increased.

3. The method of claim 1 in which said resin-free spaces between the threads are less than twice the size of openings in a sieve which will retain 10 percent by weight of the sand to be restrained.

4. The method of claim 3 in which said fabric is woven of threads spun from glass fibers.

5. A strong rigid sand-restraining liner opposite a fluid-producing formation penetrated by a well comprising a fabric pressed against the well wall at the level of said formation, the threads of said fabric being impregnated with a hardened resin, and said threads being spaced apart to leave resin-free spaces sufficiently small to restrain the flow of said sand.

6. The liner of claim 5 in which said threads are spun from glass fibers.

7. The liner of claim 5 in which said spaces are less than twice the size of openings in a sieve which will retain 10 percent by weight of the sand to be restrained.

8. The liner of claim 7 in which said threads are spun from glass fibers.

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