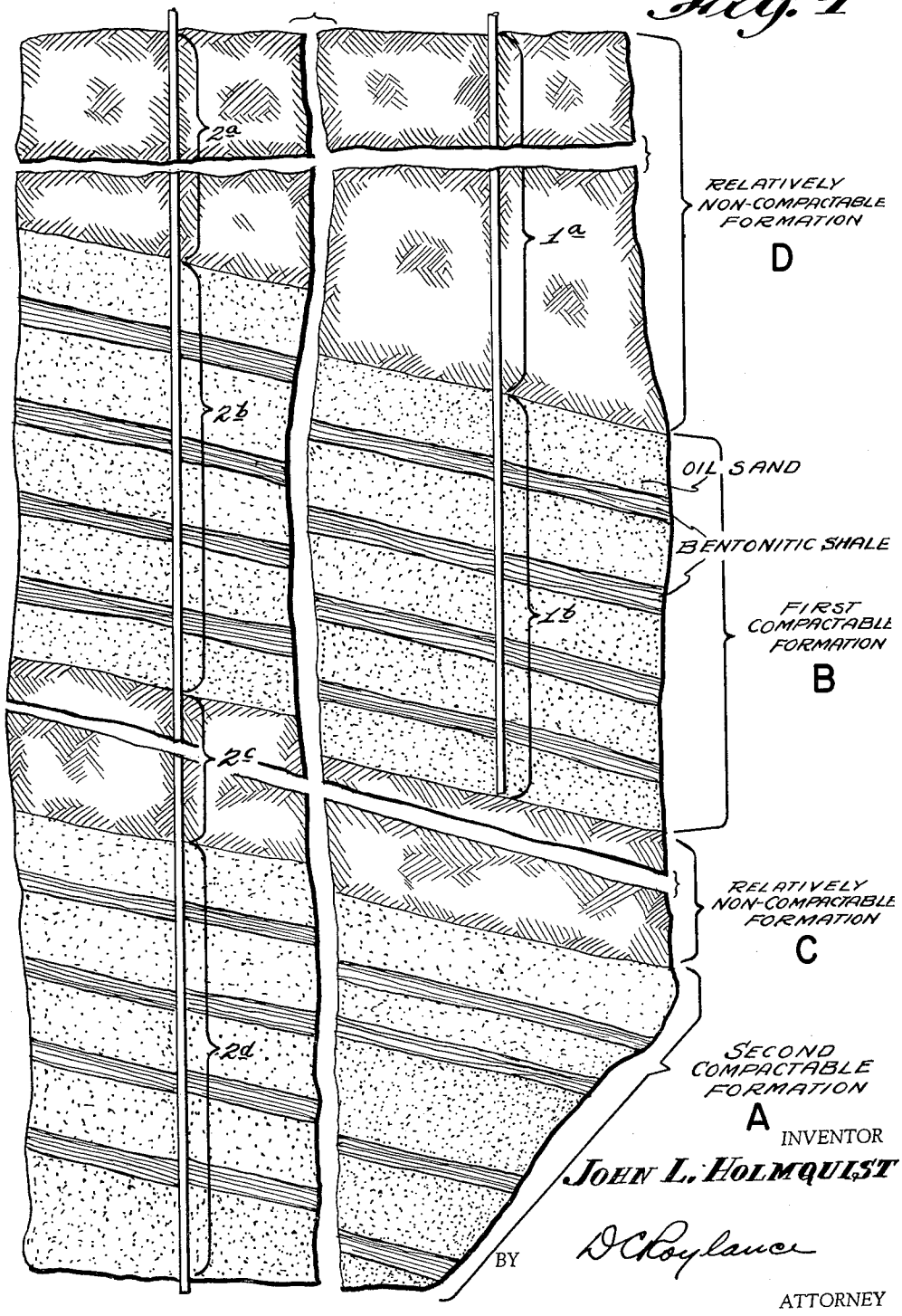
Feb. 13, 1962 J. L. HOLMQUIST 3,020,962

WELL INSTALLATIONS AND IMPROVED TUBING THEREFOR

Filed Feb. 3, 1958 2 Sheets-Sheet 1

Fig. 1



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Filed Feb. 3, 1958 2 Sheets-Sheet 2

Fig. 2

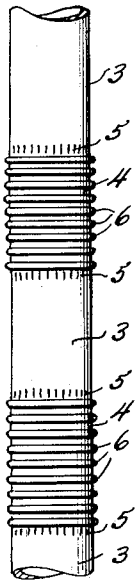
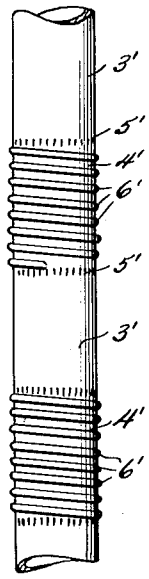


Fig. 3



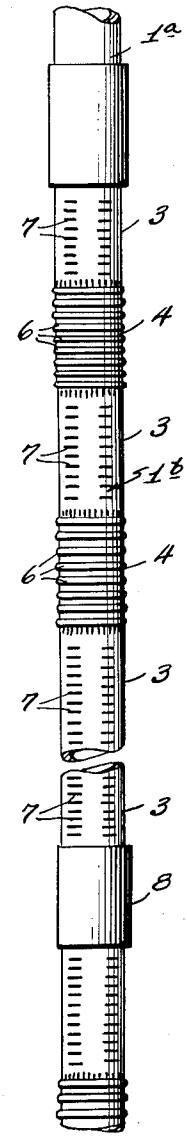


Fig. 6

Fig. 4

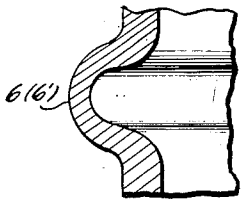


Fig. 5

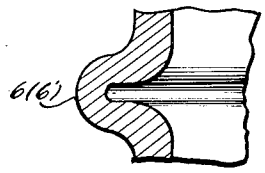
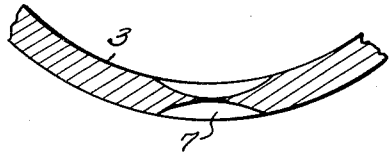


Fig. 7



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WELL INSTALLATIONS AND IMPROVED TUBING THEREFOR

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6 Claims. (Cl. 166—242)

This invention relates to deep well installations for producing oil and other fluids from underground formations, and particularly to apparatus useful in connection with such installations wherein the bore hole traverses a formation subject to being compacted by reason of the weight of earth above the formation.

In modern oil field practice, it is common for a single formation to be tapped by a number of wells. Considering a given producing well or bore hole, the same may traverse one such formation, extending therebelow, or may terminate therein. Many formations are of such porous nature that, as fluid is withdrawn therefrom, the weight of the overlying earth causes the formation to be progressively collapsed or compacted. This phenomena has heretofore caused considerable difficulty in oil field work.

In most instances involving a compactable formation traversed by a cased bore hole, the casing is gripped tightly by the compacting formation, less tightly by the non-compacting formation. It appears that, in the non-compacting formations, there is relatively less tendency for the material of the formation to slough off and pack around the casing. In the compacting formation, however, there is a marked sloughing off of material and this material becomes so tightly packed about the casing that there is great frictional resistance to relative movement between the compacting formation and the casing. When the formation compacts, due to loss of fluid therefrom, the portion of casing traversing the compacting formation is subjected to a large, progressive, axial compressive force, since the material of the compacting formation cannot slide along the surface of that casing portion. If no special provisions are made to accommodate such force, the result will be a severe distortion of the casing portion to which the force is applied. This distortion will usually be of such nature as to decrease the effective inner diameter of the casing portion, so that well tools cannot be passed therethrough, and the casing must therefore be repaired.

While primarily concerned with situations of the type just referred to, it is also contemplated that the invention will be applicable to situations where, because of the nature of the particular earth formations involved, the casing will be tightly gripped by the non-compacting formations and less tightly gripped by the compacting formation. In that event, when a non-compacting formation overlies the compacting formation, the overlying formation will sink as compacting of the lower formation occurs. Sinking of the overlying formation tends to force the casing downwardly. Then, assuming the casing to be firmly held below the compacting formation, that portion of the casing extending through the compacting formation will be subjected to an axial compressive force increasing in magnitude as the overlying formation sinks.

Thus, in both of the situations referred to, that portion of the casing which traverses the compacting formation is subjected to a compressive force resulting from subsidence of that formation, and, if there is sufficient subsidence, distortion of the casing will result. Insofar as I have been able to determine, no satisfactory method for preventing such deformation has heretofore been proposed.

It is accordingly the general object of the present invention to provide an improved apparatus for preventing or minimizing destructive deformation of well casing extending through a relatively highly compactable formation.

Another object of the invention is to provide a deep well installation wherein the well casing structure is so constructed and arranged that the portion thereof traversing a compactable earth formation is capable of being axially distorted, as the earth formation compacts or subsides, without decreasing the internal diameter of the casing in such area, and without causing the casing to be laterally deformed.

A further object of the invention is to provide a novel well casing structure for such use.

In order that these and other objects of the invention may be understood in detail, reference is had to the accompanying drawings, which form a part of this specification, and wherein:

FIG. 1 is a diagrammatic illustration of two wells drilled in an area where there is a formation subject to being compacted as fluid is withdrawn therefrom;

FIG. 2 is an elevational view of a portion of a length of well casing constructed in accordance with one embodiment of the invention;

FIG. 3 is an elevational view of a portion of a length of well casing constructed in accordance with another embodiment of the invention;

FIG. 4 is a detail longitudinal sectional view taken through a portion of the well casing structure of either FIG. 2 or FIG. 3, the section being taken axially of the casing;

FIG. 5 is a view like FIG. 6, illustrating the manner in which the corrugations provided in accordance with the invention flatten, under compressive forces directed axially of the well casing, to allow shortening of the casing without substantial decrease in the internal diameter thereof;

FIG. 6 is an elevational view of a portion of well casing constructed in accordance with a further embodiment of the invention, and

FIG. 7 is a detailed fragmentary transverse sectional view, on an enlarged scale, taken through the well casing of FIG. 5, and illustrating the manner in which portions of such well casing are perforated to allow fluid to enter the casing.

The problem to which the invention is directed will be apparent from FIG. 1, where A represents an oil-bearing formation and B represents a second oil-bearing formation lying above and spaced from formation A. Between formations A and B is an intervening earth formation C. Formation B is overlain by earth formation D. Assuming that the formations A and B are relatively highly porous, it will then be understood that, as oil is withdrawn therefrom, the formations A and B will be progressively compressed or compacted by reason of the great weight of the overlying earth formations.

In the usual situation to which the invention will be applied, the compactable formation or formations will comprise alternate layers of oil sand which, relatively speaking, is not highly compactable, and a highly compactable material such as bentonitic shale, as indicated by the legends in FIG. 1. Where the compacting layers are of bentonitic shale, such layers will have a total subsidence, as the water of such layers is lost to the bore hole, of about 10%. The compactable formation consisting of about 50% oil sand and 50% bentonitic shale, the ultimate decrease in thickness of the compactable formation as a whole will be about 5%, substantially no compacting of the oil sand occurring.

It frequently happens that both formations A and B will be tapped by a fairly large number of wells, so

that the amount of oil withdrawn from the formations is relatively large, over a given period, even though the wells are operating under legal production limitations. Thus, the formation B may be tapped by a first well established by drilling a bore hole into formation B and lining the same with a well casing 1 having an upper portion 1^a, disposed above formation B and a lower portion 1^b disposed in the formation B.

A second well may tap formation A alone, or may tap both formations A and B. This well may be provided by drilling a bore hole to formation A and lining the same with casing 2 comprising a portion 2^a extending downwardly to formation B, an intermediate portion 2^b traversing formation B, a second intermediate portion 2^c extending downwardly to formation A and a lower end portion 2^d disposed in formation A.

In accordance with the invention, the well casing portions 1^a, 2^a and 2^c are of plain, conventional lengths of plain well casing engaged relatively loosely by the surrounding earth. Casing portions 1^b, 2^b and 2^d, on the other hand, are so constructed as to be capable of shortening under the axial compression forces applied thereto as formations A and B subside. This is accomplished by providing these casing portions with transversely disposed corrugations extending outwardly of the wall of the casing.

Thus, as seen in FIG. 2, casing portions 1^b, 2^b and 2^d may comprise lengths of casing made up of alternate plain cylindrical sections 3 and corrugated sections 4 connected in end-to-end relation by circular post welds 5. In this embodiment, the corrugations 6 of sections 4 are each complete circles disposed in spaced planes lying at right angles to the axis of the length of casing.

Alternatively, as seen in FIG. 3, the corrugations 6' of sections 4' can be of helical configuration. In either case, the corrugations have semi-circular cross-sections and extend wholly outwardly of the inner surface of the casing, no portion of the corrugation extending inwardly of the casing.

Advantageously, the corrugations have a wall thickness materially less than the plain portions disposed between the corrugations. Such difference in thickness is illustrated in FIG. 4. Thus, it is advantageous to have the wall thickness of the corrugations slightly more than one-half that of the casing portions lying between adjacent corrugations. By making the walls of the corrugations thinner than the adjacent plain portions of the sections 4, 4', greater assurance is had that shortening of the sections 4, 4' under compressive load will occur substantially entirely because of deformation of the corrugations, there being no inward buckling of the main, cylindrical wall. In normal practice, it is advantageous to have the wall thickness of plain sections 3 equal to the wall thickness of the sections between the corrugations, though it will be understood that sections 3 may have thicker walls.

Since the corrugations are disposed wholly outwardly of the inner surface of the casing, forces applied axially to the casing do not result in any material change in the inner diameter of the casing. Thus, assuming that the casing portion illustrated in FIGS. 2, 3 is subjected to axial compression, the corrugations tend to collapse or flatten, as illustrated in FIG. 5, substantially without bending or canting of the intermediate plain portions. In FIG. 5, it will be noted that collapse or flattening of the corrugations does not cause any portion of the casing wall to project inwardly of the casing. This is in sharp contrast to the results obtainable with more conventional corrugations wherein the corrugations corresponding to those seen at 6, 6' would be separated by inwardly directed corrugations.

The manner of constructing the first well assembly mentioned in connection with FIG. 1 is illustrated by an actual installation made at Lake Maracaibo, Venezuela. The bore hole was conventionally drilled through the overlying earth D to the surface for formation B. This bore hole portion was then lined with conventional, plain, tubular, 7" well casing in the usual manner. Using a 6¼ bit lowered through the casing portion 1^a so established, the bore hole was then further drilled to extend to the bottom of formation B, and the drill string removed. Lengths of casing connected together to form casing portion 1^b were then lowered through the casing portion 1^a. As indicated in FIG. 6, such casing lengths were made up of alternate plain sections 3 and corrugated sections 4 welded together in end-to-end relation. A packer (not shown) was provided at the top of casing portion 1^b to seal the same to casing portion 1^a in fluid-tight relation, casing portion 1^b thus being hung from portion 1^a by means of the packer.

Since this well assembly was to produce from formation B, the interior of casing portion 1^b was placed in communication with the formation by providing transversely disposed, longitudinally spaced slots 7 in the plain portions 3. As seen in FIG. 7, such slots were provided by making circular cuts in the casing wall from both the inside and the outside, these cuts being deep enough to combine to form the desired casing perforation.

In the particular application of the invention referred to, the total depth of the well was appoximately 4,500 ft. In this application, it was found that the corrugated casing sections, having an outside diameter of $5\frac{13}{16}$", passed readily through the bore hole extension provided by the 6¼ bit. Depending upon the particular formation, the bore hole extension may be under-reamed to provide more space for the corrugated sections.

Since a considerable amount of well casing comprising corrugated sections will normally be employed in each well, numerous sections of the corrugated well casing are assembled by means of conventional threaded couplings 8, FIG. 6.

When the casing portions 1^a and 1^b were in place, a 3" tubing was run down the casing and a production packer employed to seal off the space between the tubing and well casing, additional 3" tubing then being run to the tubing head from the production packer, and oil was produced from formation B by means of the tubing in the usual manner.

When faced with a situation such as presented by the Lake Maracaibo well just discussed, the use of conventional telescopic slip joints to allow non-destructive shortening of the casing might be contemplated. Such devices are unsatisfactory, however, for a number of reasons. The most important of these is the fact that use of slip joints would provide a capacity for shortening of the casing only at relatively widely spaced points, there being little chance that, when the casing was in the bore hole, these spaced points would be at the level of the bentonitic shale, rather than at the level of the oil sand. This disadvantage is overcome in accordance with the invention because the corrugations in effect provide in casing a capacity for shortening thereof throughout that portion of the casing which traverses the compacting formation. The spacing between corrugated sections 4, 4' is sufficiently small to assure that the casing will always have capacity for shortening at the level of the bentonitic shale. Further advantages are obtainable in accordance with the invention by making that portion of the casing which traverses the compacting formation entirely of corrugated sections 4, 4'.

In situations where the bore hole extends not only through the formation B but also therebelow to the second formation A, the procedure for establishing the bore hole and lining the casing is substantially the same as just described. In such cases, however, intermediate casing portion 2^b can be either unperforated, as indicated in FIGS. 2 and 3 or perforated in the manner described with reference to casing portion 1^b, FIG. 6. Referring again to FIG. 6, it will be noted that the perforations

7 are provided in the plain sections of the lengths of casing, rather than in the corrugated sections. This is because it has been found to be extremely difficult to satisfactorily perforate the corrugated sections and because the relatively thicker plain walls can accommodate the perforations with less danger of weakening and attendant deformation.

The embodiments of the invention here illustrated are illustrative, and it will be understood that various modifications can be employed without departing from the scope of the appended claims. Thus, while it is advantageous to employ alternate plain sections 3, disposed between the corrugated sections, the lengths of casing can be corrugated throughout.

Where the term "corrugation" is employed herein, it is used to connote not only the independent, circular corrugations of FIG. 2, but also the adjacent turns of the continuous helical corrugations of FIG. 3.

What is claimed is:

1. In a deep well installation for producing fluid from an underground earth formation subject to being compacted as fluid is withdrawn therefrom, the combination of a casing lining said borehole and including a lower portion extending into said formation and an upper section extending through the earth overlying said formation, said lower casing portion being so tightly gripped by said compactable earth formation that relative movement between said formation and lower casing portion is substantially precluded as said formation is compacted during withdrawal of fluid therefrom, said lower casing portion comprising alternate plain and transversely corrugated sections, said corrugated sections including transversely disposed corrugations extending wholly outwardly from the casing, said corrugations each having a wall thickness substantially less than the casing proper and being effective to allow said intermediate casing portion to shorten, substantially without decrease in the inner diameter thereof, as said formation is compacted.

2. A deep well installation in accordance with claim 1 and wherein said plain portions are perforated.

3. In a deep well installation for producing fluid via a borehole which traverses an underground earth formation subject to being compacted by the weight of overlying earth, the configuration of plain well casing portions lining said borehole above and below said formation, an intermediate well casing portion lining said borehole in the area thereof traversing said formation, said intermediate well casing portion being so tightly gripped by said formation that relative movement between said formation and intermediate casing portion as said formation is compacted is substantially precluded, said intermediate casing portion comprising alternate plain and transversely corrugated sections, said corrugated sections including transversely disposed corrugations extending wholly outwardly therefrom, said corrugations each having a wall thickness substantially less than the casing proper and being effective to allow said intermediate casing portion to shorten, substantially without decrease in the inner diameter thereof, as said formation is compacted, and a lower end casing portion provided with means for entry of fluid to the casing.

4. A deep well installation in accordance with claim 3 and wherein said plain sections of said intermediate casing portion are perforated to allow fluid to enter the casing from said formation.

5. As a new article of manufacture, a length of well casing comprising alternate plain and transversely corrugated cylindrical tubular sections joined in end-to-end relation by circular welds, the corrugations of said transversely corrugated sections extending wholly outwardly of said length of casing, said corrugations being separated by cylindrical portions which are thicker walled than the walls of said corrugations and of smaller diameter than the diameter of said corrugations but equal to the diameter of the plain cylindrical tubular sections and being effective to allow axial distortion of said length of casing substantially without decrease in the inner diameter thereof.

6. A length of well casing constructed in accordance with claim 5 and wherein said plain sections are perforated.

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