WELL COMPLETION SYSTEMS

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ABSTRACT

Well completion system for wells penetrating a permafrost zone in the earth. The system comprises a protective casing and a production casing extending to a subterranean formation. The production casing is suspended from the protective casing at a downhole location in order to reduce loading at the wellhead. Also disclosed are means for supporting other tubular goods within the well rather than at the wellhead.

12 Claims, 1 Drawing Figure
WELL COMPLETION SYSTEMS

BACKGROUND OF THE INVENTION

This invention relates to well completions and more particularly to completion systems for wells which extend through permafrost zones of the earth.

Permafrost is encountered in arctic oil producing regions such as those found in northern Canada and on the North Slope of Alaska. Permafrost is a frozen ground mass which underlies the surface tundra and which remains perennially at a temperature of 32°F or less. In most areas the permafrost has a thickness within the range of about 800 to 1,500 feet, although it may vary from only a few hundred feet or less to as much as 2,000 feet.

The presence of permafrost poses serious difficulties in regard to the completion and production of wells in arctic regions. One particularly hazardous problem is presented by the tendency of the permafrost to melt in the vicinity of the production wells. Crude oil as it is recovered from a production well is at an elevated temperature, typically on the order of 160°F. Thus, in the absence of appropriate meliorative procedures, the operation of a production well will result in progressive melting of the permafrost with the passing of time. Such thawing is particularly serious in the upper 50 to 200 feet of the permafrost zone. This portion of the permafrost contains a significant amount of so-called “free ice.” As this melts, the resulting decrease in volume causes subsidence of the permafrost zone which may result in damage to casing strings and other components of the well completion system. Various techniques may be employed to lessen the likelihood of subsidence in the permafrost zone and attendant damage to the well completion equipment. For example, insulation may be provided about tubing or casing strings in order to prevent or at least delay thawing of the permafrost. In addition, the well may be provided with refrigeration equipment in order to achieve this same result. Another technique involves the provision of one or more shear connections in casing strings within the permafrost zone. Thus, as subsidence occurs, these joints are sheared to avoid stresses in other parts of the completion system.

SUMMARY OF THE INVENTION

In accordance with the present invention, there is provided a new and improved well completion technique system wherein a significant portion of the casing load in the well is supported downhole so as to reduce the deleterious effects of subsidence within the permafrost zone. The well system of the present invention comprises a protective casing within the well which extends downwardly from the wellhead into the permafrost zone. In addition, the well is provided with a production casing extending through the protective casing to a subterranean formation such as an oil reservoir. A lower section of the production casing is suspended from the protective casing by means of suitable support means located at a downhole location within the protective casing. Thus, most of the weight of the production casing is supported within the well rather than at the wellhead. Preferably, the lower section of the production casing is supported at a depth either below the permafrost zone or, if within the permafrost zone, at a depth of at least 500 feet from the wellhead. At this depth the permafrost contains little or no free ice. Thus, if the permafrost should thaw at this depth, little or no subsidence results.

In one embodiment of the invention the wellhead is provided with stuffing box means which functions to seal the annulus between the production and protective casings while allowing for relative longitudinal movement of these casings at the wellhead. A tubing string is located within the production casing and suspended therefrom by means of suitable surface support means at the wellhead.

In a further embodiment of the invention, the well is provided with a surface casing externally of the protective casing. The protective casing is provided with a second support means which is located above the support means for the production casing. This second support function suspends a lower section of the protective casing within the surface casing.

DESCRIPTION OF THE DRAWING

The drawing is an illustration partly in section showing a well completed in accordance with the present invention.

DESCRIPTION OF SPECIFIC EMBODIMENTS

With reference to the drawing, there is illustrated a well 10 which extends from a wellhead 12 at the earth's surface to a subterranean formation 14 which is productive of oil and/or gas. As shown, the well extends through an overburden including a layer of tundra 16, a permafrost zone 17, and an unfrozen section 18.

The well is equipped with an outer casing or conductor pipe 20 which extends from the wellhead 12 a relatively short distance into the permafrost zone. This casing conventionally is cemented from its total depth to the surface of the well to provide a cement sheath 22. As the well is drilled it is provided with progressively smaller casing strings including, as shown, a surface casing 24, a protective casing 25, and a production casing 26 which extends from the wellhead to formation 14. The upper portion of casing 25 is enlarged, as shown, in order to provide sufficient clearance for the installation of a heat barrier between casings 25 and 26. For example, refrigeration coils may be implaced between these casings or insulation may be wrapped around the upper section of casing 26. The well also is equipped with a tubing string 28 which extends within production string 26 for the flow of fluids between formation 14 and the surface. The wellhead 12 is equipped with a valve 30 and, for the tubing 28, the tubing annulus 29, and the production casing annulus 33, respectively, in order to provide for the egress or ingress of fluids. The production casing 26 is cemented as indicated by reference character 34 and is provided with perforations 35 which define an open production interval within formation 14.

Well 10 may be operated in any suitable mode. For example, the well may be produced through the tubing annulus 29, with tubing 28 left available as a “kill
string” in the event it becomes necessary to pump fluid down the well in order to kill the well. Alternatively, fluids from formation 14 may be produced through the tubing string in which case the tubing annulus 29 may be closed with a suitable downhole packer (not shown). The well also may be employed as a dual-zone producer in the event the well penetrates two producing formations. In this case, casing string 26 may be perforated opposite an upper producing formation (not shown) and a packer set in the tubing annulus 29 between the two formations. The lower formation then may be produced through the tubing string and the upper formation through the annulus 29.

It is to be recognized that the completion components thus far described are merely exemplary and that the well may be completed by other techniques consistent with the practice of the present invention. For example, rather than providing a production interval by means of perforation 35, as shown, the casing string 26 may be set and cemented to the top of the formation 14. Thereafter, the well may be drilled deeper into formation 14 in order to provide an “openhole” completion.

As noted previously, thawing of the permafrost zone is accompanied by subsidence which is particularly pronounced in the upper free-ice section of the permafrost zone. Such subsidence results in increased compressive stresses within the various casings employed in completing the well. For example, should the permafrost zone melt adjacent casings 20 and 24, frictional engagement between the subsiding ground mass and these casings will exert a downward force on the casings. This force, in addition to the column load on the casings due to their own weight and also the weight of equipment supported thereon, will increase the compressive stress in these casing strings ultimately to the point where buckling may occur.

In accordance with the present invention, the problems associated with such subsidence are alleviated by suspending the greater portion of production casing 26 from the protective casing 25 by means of a downhole support means 38. Thus, the load of the lower section of the production casing below support means 38 is transferred to casing 25 at the level of the support means and from there through the surrounding cement to the adjacent formation. Where the support 38 is located within the permafrost zone, as shown, it is desirable to position it below the free-ice section where little or no subsidence will occur from thawing of the permafrost. Preferably, the support will be located at a depth of at least 500 feet from the wellhead in order to ensure that it is well below the free-ice section. Alternatively, particularly where the permafrost zone is relatively thin, the support 38 may be positioned in the unfrozen section 18 of the overburden below the permafrost zone.

Above support 38, production casing 26 is provided with a normally closed circulating valve 39 and a releasable connection 40 such as back-off joint 40. Connection 40 will enable withdrawal of the upper portion of casing 26 without disturbing the lower section suspended from support 38.

In addition to supporting the production casing downhole, it is preferred in carrying out the invention to likewise support a lower section of the protective casing at a downhole location. Thus, in accordance with this embodiment of the invention, a second support 41, which is located above support 38, is employed to suspend a lower section of protective casing 25 from the surface casing 24. Thus, all tension loading carried by the protective casing below the support 41 is transferred through the surface casing and surrounding cement to the adjacent ground mass.

Supports 38 and 41 may be of any suitable type and normally will take the form of “liner hangers” such as are conventionally employed in supporting liners within wells. The liner hangers may incorporate packers which when set provide a positive fluid seal between the adjacent casings to prevent fluid flow past the hanger.

Preferably, the casings 24 and 25 are only partially cemented in order to lessen the compressive stresses induced in these casings by subsiding permafrost. Thus, protective casing 25 is provided with a cement sheath 42 which extends from below to above the support 38. Normally cement sheath 42 will extend from the total depth of casing 25 to a position above support 41, as shown. Similarly, surface casing 24 is provided with a cement sheath 44 which extends from below support 41 and terminates above this support. The annulus 46 and 48 above the cement sheaths are loaded with a liquid in order that the permafrost will not seize a purchase if subsidence occurs. Normally a thixotropic liquid such as gelled oil or drilling mud will be used to load the annuli. Such use of a thixotropic liquid is especially beneficial with respect to annulus 48 which is open to the adjacent ground mass since it reduces fluid loss from the annulus. If drilling mud is employed, sufficient salt should be added to bring its freezing temperature to a level well below 32° F., e.g., to 15° F.

Since the oil produced through casing string 26 and/or tubing string 28 is at a high temperature, these strings will tend to undergo thermal expansion relative to protective casing 25. This effect will be particularly pronounced where the annulus 33 is provided with heat barrier means such as insulation or refrigeration. It is preferred to compensate for this by providing the wellhead with a Stuffing box 50 between the upper sections of casings 25 and 26. Stuffing box 50 functions to seal the annulus between casings 25 and 26 while at the same time allowing for relative longitudinal movement between these casings at the wellhead. In addition, by this arrangement, the weight of the upper part of casing 26 is carried by support 38 rather than at the wellhead 12.

The tubing string 28 and production casing 26 will undergo little or no thermal expansion relative to one another. Thus, it is preferred to suspend tubing 28 from the production casing 26 at the wellhead by means of a surface support 52. By this arrangement, the weight of tubing 28 as well as the upper portion of casing 26 is carried at downhole support 38 to avoid these loads being transferred to the wellhead. In addition to providing a surface support for tubing 28, it is preferred to support the tubing in casing 26 at a depth at least as great as support means 38. Thus, a lower section of tubing 28 is suspended from casing 26 by means of a downhole support 56. By this arrangement only the section of tubing 28 above support 56 is carried by the upper section of the production casing in compression.

What is claimed is:
1. In a well extending from a wellhead through a permafrost zone of the earth to an underlying subterranean formation, the combination comprising:
   a protective casing within said well extending downwardly from the wellhead into said permafrost zone,
   a production casing within said protective casing extending from the wellhead through said permafrost zone to the subterranean formation,
   support means at a downhole location within said protective casing and below the top of said permafrost zone for suspending a lower section of said production casing from said protective casing,
   stuffing box means at the wellhead for sealing the annulus between said production casing and said protective casing while allowing for relative longitudinal movement of said casings at the wellhead,
   a tubing string within said production casing, and
   surface support means at said wellhead for suspending said tubing string from said production string.
2. The system of claim 1 further comprising tubing support means at a depth at least as great as said first-named support means for suspending a lower section of said tubing from said production casing.
3. In a well extending from a wellhead through a permafrost zone of the earth to an underlying subterranean formation, the combination comprising:
   a protective casing within said well extending downwardly from the wellhead into said permafrost zone,
   a production casing within said protective casing extending from the wellhead through said permafrost zone to the subterranean formation,
   support means at a downhole location within said protective casing and below the top of said permafrost zone for suspending a lower section of said production casing from said protective casing,
   a surface casing within said well externally of said protective casing and penetrating said permafrost zone, and
   second support means for suspending a lower section of said protective casing in said surface casing at a subterranean location above said first-named support means.
4. The system of claim 3 further comprising a cement sheath in the annulus surrounding said protective casing and extending from a location below said first-named support means to above said first-named support means, and a column of liquid in said annulus above said cement sheath, said liquid having a freezing temperature substantially below 32°F. to maintain it in a liquid state.
5. The system of claim 4 further comprising a cement sheath in the annulus surrounding said surface casing extending from a location below said second support means to above said second support means, and a column of liquid in said annulus above said cement sheath, said last-named liquid having a freezing temperature substantially below 32°F. to maintain it in a liquid state.
6. The system of claim 5 wherein said liquid in the annulus surrounding said surface casing comprises a thixotropic liquid.
7. In a well extending from a wellhead through a permafrost zone of the earth to an underlying subterranean formation, the combination comprising:
   a protective casing within said well extending downwardly from the wellhead through said permafrost zone to a location below said permafrost zone,
   a production casing within said protective casing extending from the wellhead through said permafrost zone to the subterranean formation,
   support means within said protective casing for suspending a lower section of said production casing from said protective casing at a location below said permafrost zone,
   a surface casing within said well externally of said protective casing, and
   second support means for suspending a lower section of said protective casing in said surface casing at a subterranean location above said first support means.
8. The system of claim 7 further comprising stuffing box means at the wellhead for sealing the annulus between said production casing and said protective casing while allowing for relative longitudinal movement of said casing at the wellhead.
9. In a well extending from a wellhead through a permafrost zone of the earth to an underlying subterranean formation, the combination comprising:
   a protective casing within said well extending downwardly from the wellhead through said permafrost zone to a location below said permafrost zone,
   a production casing within said protective casing extending from the wellhead through said permafrost zone to the subterranean formation,
   support means within said protective casing for suspending a lower section of said production casing from said protective casing at a location below said permafrost zone,
   a surface casing within said well externally of said protective casing,
   second support means suspending a lower section of said protective casing in said surface casing at a subterranean location above said first support means,
   stuffing box means at the wellhead for sealing the annulus between said production casing and said protective casing while allowing for relative longitudinal movement of said casings at the wellhead,
   a tubing string within said production casing, and
   surface support means at said wellhead for suspending said tubing string from said production casing.
10. The system of claim 9 further comprising tubing support means at a depth at least as great as said first-named support means for suspending a lower section of said tubing from said production casing.
11. The system of claim 10 further comprising a cement sheath in the annulus surrounding said protective casing and extending from a location below said first-named support means to above said first-named support means, a column of liquid in said annulus above said cement sheath, a second cement sheath in the annulus surrounding said surface casing extending from a location below said second support means to above said second support means, and a column of liquid in said last-named annulus above said second cement sheath.
12. In a method of completing a well extending from a wellhead through a permafrost zone of the earth to an underlying subterranean formation, the steps comprising:
   a. locating within said well a surface casing which extends downwardly from the wellhead into said permafrost zone,
   b. locating within said well and within said surface casing a protective casing which extends downwardly from the wellhead into said permafrost zone,
   c. suspending a lower section of said protective casing from said surface casing at a downhole location above the location hereinafter set forth in step (e),
   d. locating within said well and within said protective casing a production casing which extends from the wellhead through said permafrost zone to the subterranean formation, and
   e. suspending a lower section of said production casing from said protective casing at a downhole location within said protective casing and below the top of said permafrost zone.

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