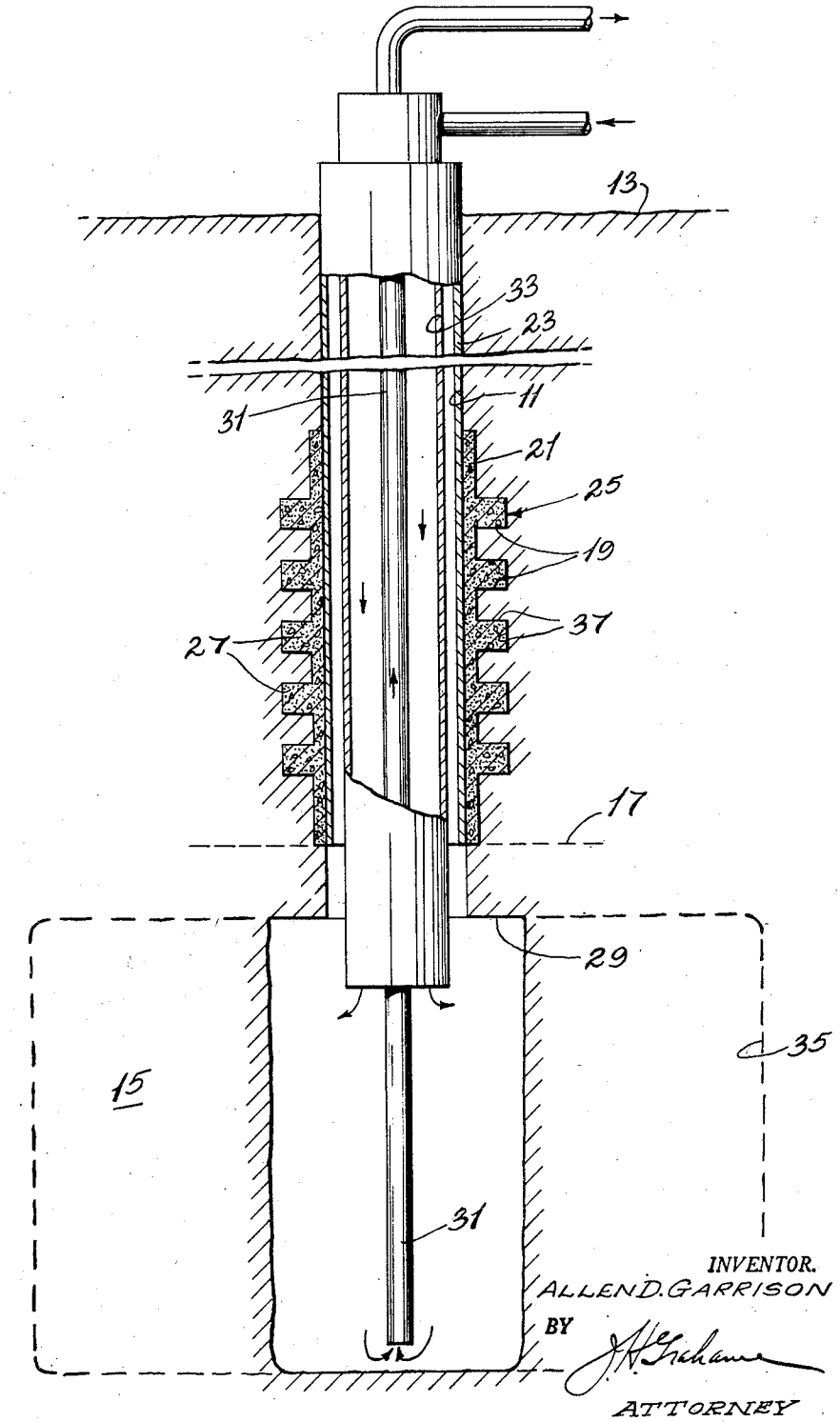
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WELLS

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WELLS

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This invention relates to a novel well seal, and to a method for forming such a seal.

It has recently been proposed that large storage cavities be formed deep within the earth for the storage of such liquids as liquefied petroleum gases. Such storage cavities can be formed in underground formations of materials such as salt or clay by drilling a deep hole from the surface of the earth into the formation, casing the hole, and then washing out a large cavity below the casing. Ingress and egress for the fluid to be stored are obtained through the hole. While success has been attained, one of the problems involved has been to protect the seal between the casing and the surrounding earth from being washed out by the liquid used for forming the cavity. When the seal is thus lost, liquefied petroleum gas will leak past the casing when the cavity is subsequently used for storage purposes.

In accordance with the present invention there is provided a new kind of seal between the casing and the wall of the hole which is proof against being washed out by the liquid employed for forming the storage cavity. Briefly, this new seal involves the placing of cement in sealing engagement with the casing and the surrounding earth in such a way as to provide a zig zag stepped interface between the cement and the earth which cannot be traversed by the high pressure liquid employed for washing out the cavity. Such a novel seal is provided at any selected locality by forming a plurality of relatively short annular grooves extending outwardly from the hole at positions spaced from one another lengthwise of the hole. Then the steel well casing is positioned with its outside spaced from the wall of the hole in the vicinity of the grooves, and cement is placed within the grooves and the annular space surrounding the adjacent casing to form an integral tubular cement seal having a plurality of longitudinally spaced annular flanges anchored in the earth and connected together with cement in the annular space along the outside of the casing.

The single figure of the drawing is a schematic, vertical sectional view taken through a well constructed in accordance with the invention.

More specifically in accordance with the invention, a deep hole **11** is first drilled from the surface **13** of the earth down into the formation **15** from which material is to be removed to form the storage cavity. When the hole **11** has reached a desired level **17** slightly above the top of the intended storage cavity, the drilling tool is removed and replaced with an underreaming tool which is operated to form a plurality of relatively short (say five to fifteen feet) annular grooves **19**, five, for example, extending radially outwardly from the wall of the hole **11** at positions spaced from one another lengthwise of the hole. The vertical distance between grooves **19** can be of the order of five to fifteen feet and the lateral extension from the hole wall at least three feet.

Ordinarily it is also advantageous to underream the wall of the hole to a lesser depth, such as six inches, to

form a relatively long off-set annulus **21** which extends lengthwise from a position spaced say ten feet above the topmost groove **19** to a position spaced say ten feet below the lowermost groove **19**. This can best be done before the grooves **19** are formed.

A steel casing **23** is then run into the hole to a position adjacent the level **17** and sealing cement is placed in the grooves **19** and in the annular space between the outside of the casing and the wall of the hole, including the offset annulus **21** when such is employed. The resultant integral tubular seal **25** includes a plurality of longitudinally spaced annular flanges **27** which are anchored securely in the earth and are connected together longitudinally by the cement in the annulus surrounding casing **23**.

Conventional cements of the type employed in oil well cementing, such as Portland cements, can be employed to form the seal **25**; and the placing of the cement can be accomplished by any of the well-cementing techniques which are well known to those skilled in the art. Suitable cements and cementing techniques are described in Petroleum Production Engineering, by Uren, third edition, published by McGraw-Hill Book Company, Inc.

Upon completion of the cement seal **25** the hole **11** is then extended to a greater depth below the level **17** by drilling and underreaming in a well known manner. To assist in preserving the seal **25** it is desirable that underreaming start at a position a substantial distance below the seal, as at **29**.

While the preferred procedure has been described above it is evident that the hole **11** can also be drilled to the full depth before underreaming and cementing to form the seal **25** are done.

When the hole has been extended to the bottom of the proposed storage cavity a pair of concentric washing pipes **31** and **33** is placed within the hole and material-removing liquid such as water, alone or containing suitable chemicals to enhance material removal, is passed down through the outside pipe **33** to pick up material from the formation and form a deep pool of liquid within the hole. Liquid which is laden with material removed from the formation is forced up through the inside pipe **31** to the surface **13**. This washing operation is continued to extend the diameter of the hole until a storage cavity **35** of the desired size is obtained.

During the washing operation the pool of liquid in the hole may have a tendency to wash down the roof of the cavity to some extent as at **29**, and with a conventional cement seal the material around the seal itself may be washed out. The novel cement seal **25** described in detail above, however, is protected against being washed out by the liquid because a zig zag stepped interface **37** is provided between the cement and the surrounding earth.

After the cavity **35** has been completed the liquid to be stored, such as liquefied petroleum gas, is forced down under pressure through the pipe **33** or the casing **11** and expels wash liquid from the cavity through the pipe **31**. Even at very high pressures the leakage of liquefied petroleum gas past the outside of the casing **11** is prevented by the novel cement seal **25** described in detail above.

Obviously, many modifications and variations of the invention as hereinbefore set forth may be made without departing from the spirit and scope thereof, and therefore only such limitations should be imposed as are indicated in the appended claims.

I claim:

1. A method for forming a fluid-tight seal between a well casing and the earth surrounding a hole drilled therein, which method comprises reaming a relatively long offset annulus in the wall of said hole, and a plurality

of relatively short annular grooves extending outwardly from said long annulus at positions spaced from one another lengthwise of said hole; positioning said well casing in said hole and within said long annulus; and placing cement within said long annulus and said grooves between the walls thereof and the external wall of said casing, thereby forming a tubular cement seal having a plurality of longitudinally spaced annular flanges anchored in said earth and connected together with cement along the external wall of said casing.

2. A well comprising a well casing located in a deep hole within the earth, a length of said hole between the ends thereof and concentric therewith being reamed to a greater diameter than said hole above said length, the wall of said hole in said length also having a plurality of longitudinally spaced annular grooves reamed therein; and an integral seal within said length engaging said

casing and the earth surrounding said casing, said seal comprising a tubular body of cement between said casing and the adjacent wall of said hole and a plurality of annular projections extending outwardly from said tubular body and fitting snugly into said grooves to provide a zig zag interface between said seal and said earth.

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