166-308

CROSS REFERENCE

61
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July 18, 1967 J. S. OSBORNE 3,331,206

UNDERGROUND STORAGE RESERVOIR FOR LIQUIDS AND GASES AND PROCESS FOR FORMING THE SAME

Filed Nov. 17, 1961 2 Sheets-Sheet 1

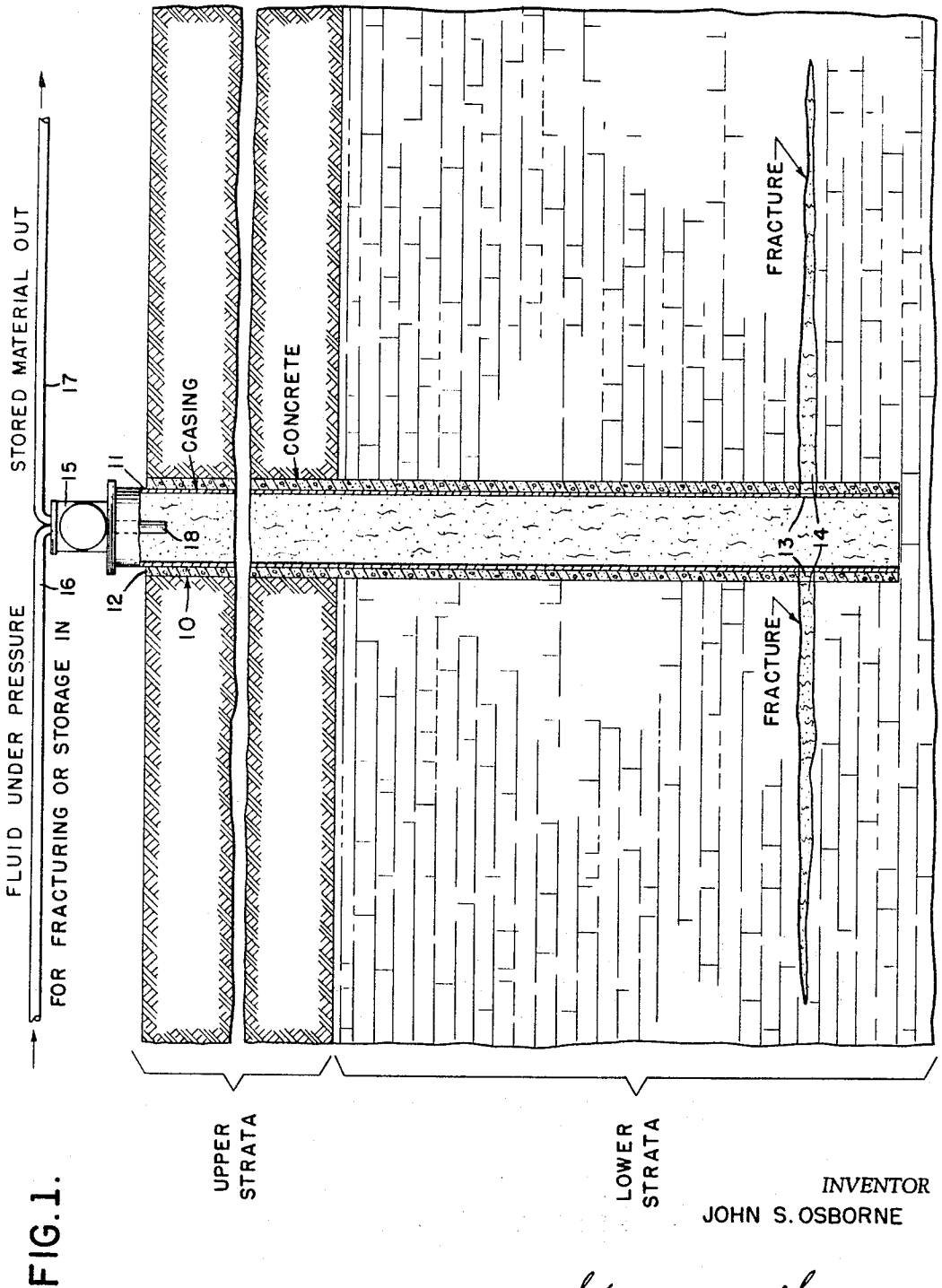


FIG. 1.

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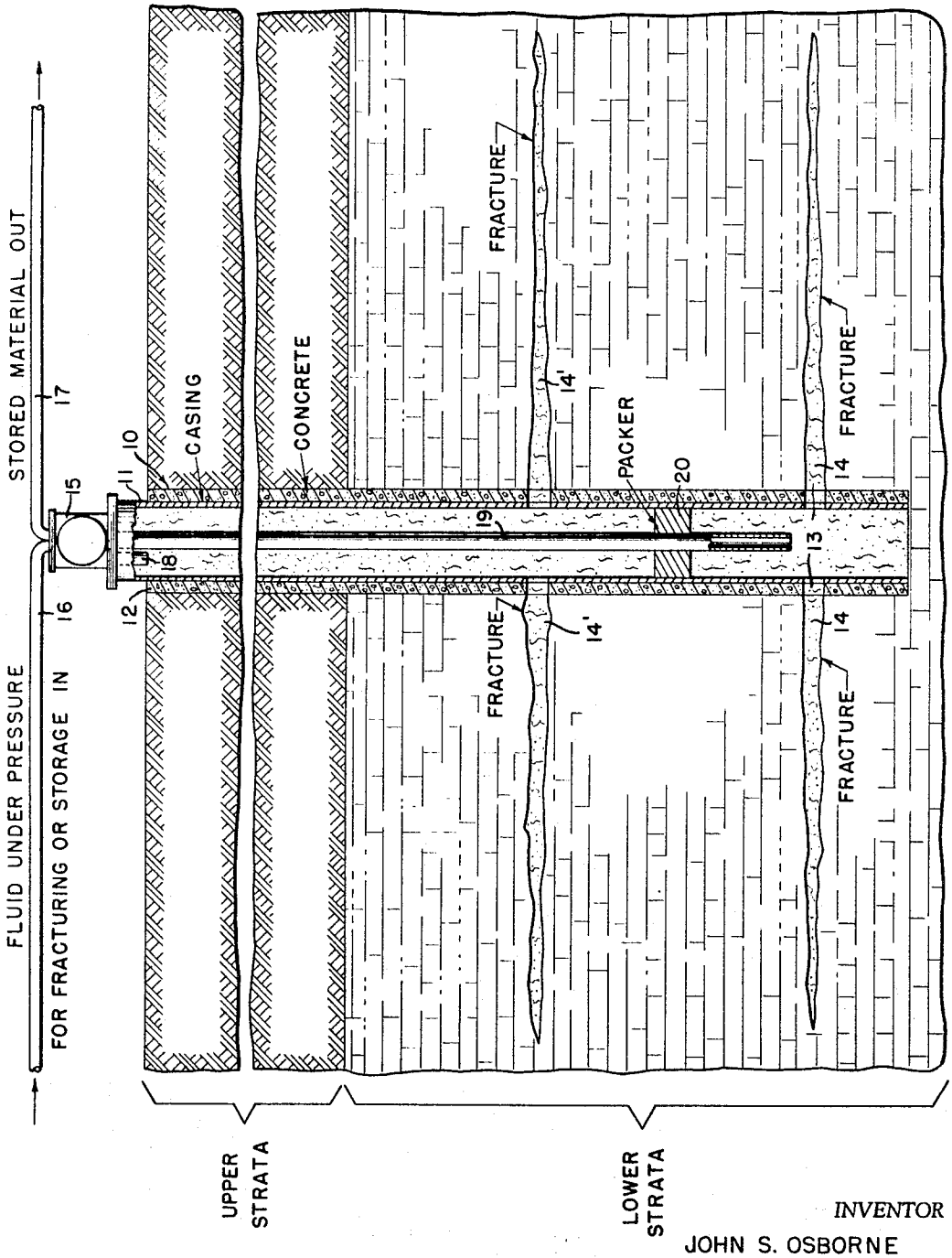


FIG. 2.

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3,331,206

UNDERGROUND STORAGE RESERVOIR FOR LIQUIDS AND GASES AND PROCESS FOR FORMING THE SAME

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1 Claim. (Cl. 61—.5)

This invention relates to an underground storage reservoir for liquids and gases, and to a process for forming the same.

It has long been realized that since natural gas consumption is governed by weather, due to its widespread use for heating, adequate storage facilities must be provided near the locus of use in order to meet the demands of the consumer during peak heating periods. Similar storage problems exist in maintaining an adequate supply of other fluids. The advantages of underground storage facilities for liquids and gases are well known in the industry. Natural geologic traps, such as depleted oil and gas reservoirs, have in the past been used for this purpose, illustrative of which is Patent No. 1,921,358 issued Aug. 8, 1933. Unfortunately, suitable geologic traps are not strategically located to fulfill their maximum potential, even in those areas where such geologic traps exist. It is further known that unnatural or man-made storage reservoirs may be created as, for example, by dissolving and removing the salt in a natural salt bed, to form a subterranean storage cavern, illustrative of which is Reissue Patent No. 24,318 issued May 14, 1957, and Patent No. 2,880,587 issued Apr. 7, 1959. This type of storage reservoir is of limited value since it requires a rock salt formation and is restricted in use to the storage of materials that will not dissolve salt.

It is an object of this invention to provide an underground storage reservoir for liquids and gases, formed by hydraulically or pneumatically fracturing impermeable subterranean formations to provide an interstice into which the liquid or gas to be stored is injected under pressure.

Another object is to provide a process for storing liquids and gases underground which comprises drilling a well, fracturing an impermeable formation at a predetermined depth in the well under hydraulic or pneumatic pressure, to provide an interstice into which a liquid or gas is injected for storage, under sufficient pressure to maintain the size of the interstice constant until the gas or liquid is removed.

Other objects are to provide a process of the character described, wherein the stored fluid may be recovered when needed without the use of pumping equipment, the fluid being expelled from the interstice under the storage pressure and by pressure exerted on the stored material by the uplifted overburden in closing the fracture; to provide an underground reservoir which does not require the physical removal of material from the storage area prior to use; to provide an underground reservoir in which substantially all of the stored fluid can be recovered at an even rate; and to provide a series of interstices produced by fracturing impermeable formations radiating from a single well, for the selective storage of liquids and/or gases.

FIG. 1 is a schematic view illustrating the manner of forming an underground storage reservoir by fracturing impermeable formations in accordance with the present invention and showing the reservoir adapted for the storage of gas; and

FIG. 2 is a view similar to FIG. 1, showing the formation of a plurality of storage reservoirs by use of a single well.

In carrying out the objects of the present invention a suitable site for the storage reservoir is located, at which geological tests disclose the presence of impermeable subterranean formations. These formations may be of various types of rock, such as hard, horizontally laminated shales, shaley sandstones, silt stones and shaley limestones or combinations thereof, as well as granite or any other suitable impermeable formations. In forming the reservoir, a well **10** is first drilled to a suitable depth. High strength casing **11** is placed in the well and cemented at **12** to form a seal around the casing. As indicated in the drawing, the casing extends downwardly through the upper strata of the earth into the lower strata a predetermined distance where an impermeable formation is located.

A conventional hydraulic fracture initiator is inserted into the casing to the level of the impermeable formation, at which point it is actuated to cut an opening **13** through casing **11**, cement **12** and into the shale. This opening preferably extends through an angle of 360° so that the initial fracture in the shale radiates from the entire periphery of the casing. Gas or liquid is then injected under pressure into the casing and applied to the shale through opening **13** under sufficient pressure that the shale fractures along a natural line of weakness extending radially from casing **11** for the desired length. The pressure of the gas or liquid in the fracture forces the fracture to open to form an interstice **14**. This fracture will remain open as long as the pressure of the gas or liquid is maintained. The pressure under which the gas or fluid is applied to the fracture will be dependent upon the depth at which the fracture is located from the surface of the earth, in accordance with well known geological principles. The gas or liquid which is used to fracture the shale may be the gas or liquid to be stored, or some other fluid if desired.

In accordance with the present invention the upper end of casing **11** is fitted with a valve unit **15** in communication with an inlet line **16** and an outlet line **17**. A pipe **18** depends from unit **15** into casing **11**. In use, the fluid to be stored is fed through pipe **16**, valve unit **15** and pipe **18** into the casing under a predetermined pressure, to hydraulically or pneumatically fracture the impermeable formation and thereby form a storage interstice **14** of the desired size. After the fluid has been fed through the casing to the interstice to fill the latter, the upper end of the casing is sealed to maintain the pressure within the casing and interstice. The fluid will remain in storage as long as the pressure is maintained.

When it is desired to use the fluid, the pressurizing force thereon is removed by opening valve **15** and the fluid moves out of interstice **14** into casing **11** and upwardly into outlet pipe **17**. During this time, the uplifted overburden of the earth maintains a constant pressure on the remaining stored material. When all of the fluid has been recovered, the fracture is closed. The shale or other impermeable formation is thus returned to its original condition except for the fracture which remains as an unnatural plane of weakness.

If the same well is to be employed for storage again, the fluid is applied thereto as before and the existing fracture will be reopened until it is again filled with fluid as in the original fracturing. In this way, storage and recovery may be accomplished as often as desired.

In FIG. 2 there is illustrated a modified form of the present invention wherein, in addition to the interstice **14** formed in the impermeable formation, a second interstice **14'** is formed in a place in spaced relationship to the plane of interstice **14**. For this purpose, a pipe **19** is inserted into casing **11**, the upper end of which is connected to valve unit **15** and the lower end thereof extends to a point adjacent the locus of lower interstice **14**. A packer

20 is inserted between the outer periphery of pipe 19 and the inner periphery of casing 11 at a point intermediate interstice 14' and the lower end of pipe 19. In this way fluid under pressure may, if desired, be selectively supplied to either storage interstice 14 or 14'. It is therefore possible to store a liquid and a gas in the same reservoir, one of which is stored in interstice 14 and the other in interstice 14'. More than two fractures may be made in the impermeable formation at the locus of a single well to provide many storage reservoirs if desired.

It is further within the contemplation of the present invention to employ a plurality of wells in a given area, which wells may be in communication by virtue of fractures in the formation extending from one well to the other, so that the fluid stored may be recovered from either well. These wells may also be employed to control the area of fracture of the impermeable formation.

The present invention is of particular advantage in the storage of compressible fluids, such as natural gas. In injecting the gas into the well casing under pressure to produce the interstice in the impermeable formation, the fluid is compressed, thereby enabling considerable quantities of the gas to be stored than would otherwise be possible.

The unnatural or man-made reservoir of the present invention does not require the previous existence of a natural underground reservoir and can be used in localities where such do not exist, are not available, or are not suitable for storage. Furthermore, it does not require the removal of material from the storage area prior to use.

The present reservoir will maintain a constant pressure on the stored fluid irrespective of the total amount in storage so that all of the stored liquid or gas can be recovered without a reduction in the rate of recovery. By reason of the pressure under which the fluid is stored, together with the energy stored in the uplifted overburden, the liquid or gas is expelled without dependence on pumping equipment or the addition of energy to the reservoir. The rate of flow into and out of the present reservoir is larger and more constant than the rate of flow in a natural reservoir since the fluid in the latter moves through the small openings between the grains of the reservoir rock, an impediment which is greatly reduced when the flow is through open fractures.

While I have herein shown and described preferred embodiments of my invention, it is nevertheless to be understood that various changes may be made therein without departing from the spirit and scope of the appended claim.

What is claimed is:

A process for the subterranean storage and recovery of fluids which includes the steps of drilling into the earth a sufficient depth to reach an impermeable earth formation to form a well, depositing a first casing in the well, horizontally incising the casing and surrounding earth at the locus of the impermeable formation to produce a first fracture, horizontally incising the casing and surrounding earth at a second point in spaced relation to the first fracture, to produce a second fracture, inserting a packing between the outer periphery of the second casing and the inner periphery of the first casing, at a point intermediate the two fractures, injecting fluid into the two fractures under pressure to force the latter to open and uplift the overburden to form interstices, maintaining the fluid in the first and second casings constant during storage of the fluid, temporarily sealing the upper end of the first and second casing, to maintain the fluid under pressure in the two casings and interstices during storage, selectively unsealing the upper end of the first and second casings, to permit the pressurized fluid to move upwardly out of the first and second casing to be recovered, and squeezing the fluid out of the interstices into the casings for recovery under pressure of the uplifted overburden, with subsequent closing of the fractures.

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