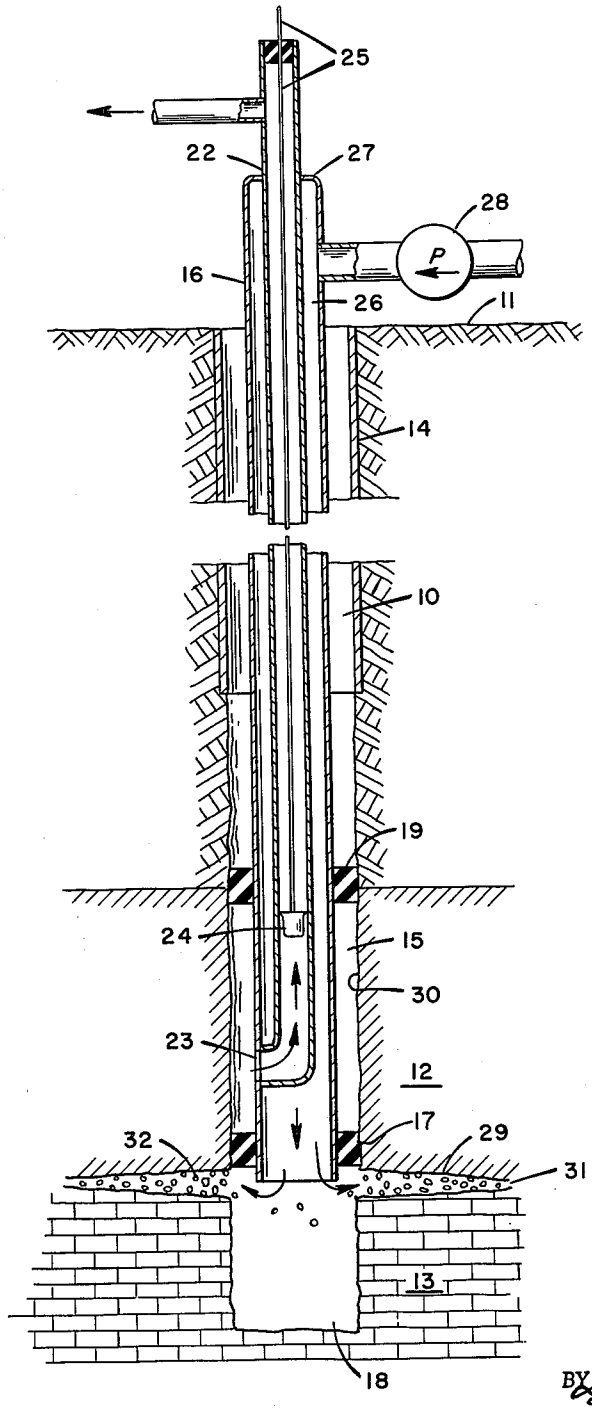
166-308

SEARCH ROOM

Aug. 21, 1962 C. R. FAST ET AL 3,050,119

METHOD OF FRACTURING FORMATIONS

Filed Dec. 30, 1958



CLARENCE R. FAST
GEORGE C. HOWARD
ARTHUR LUBINSKI
INVENTORS

BY C. Goodwin

ATTORNEY

United States Patent Office 3,050,119 Patented Aug. 21, 1962

3,050,119

METHOD OF FRACTURING FORMATIONS

Clarence R. Fast, George C. Howard, and Arthur Lubinski, Tulsa, Okla., assignors to Pan American Petroleum Corporation, Tulsa, Okla., a corporation of Delaware

Filed Dec. 30, 1958, Ser. No. 783,870
6 Claims. (Cl. 166—42)

This invention relates to an improved method of horizontally fracturing formations. More particularly, this invention relates to a method of hydraulically fracturing subterranean formations wherein horizontal fractures are selectively produced.

Permeable formations penetrated by a well have been fractured by the application of a high hydraulic pressure in the well as disclosed in Re. 23,733, reissued to Riley F. Farris on November 10, 1953. We have found that while that process, as previously disclosed and practiced, normally produces horizontal fractures, i.e., fractures along bedding planes intersected by the well, occasionally a vertical fracture, i.e., a fracture longitudinally of the well, is sometimes produced. While vertical fractures are in some instances desirable, generally they are undesirable, particularly when the extend vertically into water or gas producing horizons adjacent a fractured oil producing formation. We have found that a horizontal fracture can to a large extent be selectively produced by minimizing the vertical forces on the formation to be fractured, i.e., by reducing to a minimum the effective overburden pressure on that formation.

This invention may, therefore, be described in brief as an improved method for hydraulically fracturing a subterranean formation penetrated by a well wherein a horizontal fracture is selectively produced by substantially reducing the effective overburden pressure thereon. This overburden pressure is reduced by temporarily reducing the fluid pressure in a zone within the well which zone encompasses or spans a plastic, i.e., a pliable, formation such as shale that is adjacent to the formation to be fractured.

Referring now to the accompanying drawing for a more detailed description of this invention, a well **10** extends from the surface **11** down through a number of subsurface formations including a plastic shale formation **12** and into a permeable formation **13** which is to be fractured. The well is desirably completed in such manner that the shale is not completely confined by the well apparatus. While perforated casing in the shale zone of the well provides some room for flow and relaxation of the shale, the open-hole completion technique is preferred. In open-hole completions the casing **14** is landed in or above the shale formation **12** so that the well is open or uncased throughout the permeable formation **13** and at least part of the shale formation. An apparatus is then run into the well to provide means for fracturing the permeable formation **13** and for removing fluid pressure from a first isolated zone **15** in the well which encompasses at least a portion of the shale formation **12**. This apparatus includes a first conduit or outer tubing string **16** having at least one formation packer **17** near the lower end to segregate the first isolated low pressure zone **15** of the well from the pressure fluid zone **18** of the well which is within the permeable formation **13**. In some cases an upper packer **19** is placed on the outer tubing string and spaced from the lower packer **17** to segregate zone **15** from the remainder of the well. A second conduit **22** is run into the well preferably through the outer tubing string **16** as shown so that its lower end is at the elevation of and is in fluid communication with the bottom of the low pressure zone **15**. The lower end of this inner tubing string, i.e., conduit **22**, is connected, as by means well-known in the art and as shown schematically in the drawing, to an opening **23** in the outer tubing string **16** near the lower packer **17** so that any liquid in the low pressure zone **15** can be produced through conduit **22** by pumping with any means such as a swab **24** which is run into and withdrawn from the conduit on a swab line **25** or the like. The annular space **26** between outer tubing string **16** and conduit **22** is sealed at the top by a head **27** so that pressure fluid from pump **28** can be injected through the annular space into the pressure zone **18** at the bottom of the well.

In operation, after the shale formation **12** has been located by cuttings analysis, drillers log, electric log, or the like, and particularly after the shale-permeable formation interface **29** has been located, the well apparatus is installed as above described. The lower formation packer **17** is set on or adjacent to the interface **29** so that it isolates the low pressure zone **15** from the high pressure zone **18**. The pressure on the shale is then removed by, for example, pulling up on swab line **25** to remove the weight of the liquid column in tubing **22** and thereby substantially reduce the liquid pressure in the low pressure zone **15**. Fluid pressure above the lower packer may also be reduced or minimized by removing liquid from the well as by swabbing the liquid from low pressure zone **15** through the conduit **22**. When a substantial part or preferably all of the liquid in this zone has been removed or the pressure therein has otherwise been substantially reduced so that the pressure on the face **30** of the shale formaion is at least temporarily decreased, preferably to substantially atmospheric pressure, this shale formation at least partially relaxes, i.e., flows to some extent into the well, simultaneously reducing the vertical stress in the plastic shale for a substantial distance radially into the formation. This movement of the shale and the resulting reduction of the vertical stress, i.e., effective overburden pressure, thus either initiates a fracture at the interface **29** or, due to the reduction of this effective overburden pressure on the shale-permeable formation interface **29**, a fracture is initiated at a relatively low pressure when hydraulic pressure is subsequently applied. While we do not wish to be limited to any theory of operation, it appears that in some cases the movement of the shale into the well produces shear at the interfaces, e.g., interface **29**, between a shale zone and an adjacent rock formation, and thereby contributes to the initiation of a fracture at the interface. In some cases it may be desirable to maintain this low pressure in this isolated zone for a relatively long period of time, e.g., an hour or more, so that adequate time is provided for the relaxation of the shale to propagate a substantial distance radially from the well. This partial relaxation of the shale reduces the effective overburden on the permeable formation **13** for a relatively great distance from the well. When the fluid pressure in the isolated zone **15** has been substantially reduced and the effective overburden thereby decreased and preferably before the shale is again in equilibrium and any fracture previously initiated has had time to heal, e.g., within a period of time less than about a day, preferably within about an hour or less, a quantity of fracturing fluid is injected via high pressure pump **28** and the annular space **26** into the high pressure zone **18** of the well. In some cases as a limit the two operations, i.e., swabbing and fracturing, are conducted simultaneously. The period of time allowed to elapse after reducing the pressure in the isolated zone and before applying pressure in the high pressure zone depends, however, upon a number of variables including well depth, shale plasticity and temperature and generally the period decreases as each of these variables increase. Fracturing fluid in this high pressure zone then enters any horizontal fractures initiated by the previous relaxation and movement of the shale or otherwise places the permeable formation **13** under sufficient stress to produce or other-

wise extend a horizontal fracture 31 in or adjacent to the permeable formation 13. Generally this fracture is along the interface 29. Formation props 32 are thereby placed in the fracture and remain there when the job is completed so that when the well is placed on production and fluid flows from the permeable formation into the well, a highly permeable path is provided.

While in the foregoing description reference has been made to a subterranean formation in which the permeable formation is located below the plastic formation, it will be apparent that when the pressure in the zone of the well opposite the plastic formation is at least temporarily substantially reduced preferably to atmospheric pressure and the shale formation is thereby relaxed, the vertical pressure on formations overlying the shale formation is also reduced. Consequently, it can be seen that our method of producing horizontal fractures is not limited to fracturing those producing formations underlying plastic formations but can in some cases be applied to producing such fractures in formations overlying plastic formations and that the procedure for fracturing such overlying formations can be readily adapted from the above-described procedure. That is, after removing the fluid pressure on the plastic shale zone, fracturing fluid can be injected into the well either above or below the low pressure zone and pressure can be applied thereto to fracture an adjacent formation. It can thus be seen that this invention is susceptible to a wide variety of embodiments and should therefore be construed not to be limited by the above description but should be construed to be limited only by the scope of the appended claims.

We claim:

1. A method of producing a horizontal fracture in a subterranean permeable formation penetrated by a well comprising temporarily substantially reducing the fluid pressure in a first zone which extends through and is in fluid communication with a plastic formation and is adjacent to said permeable formation penetrated by said well, maintaining the reduced fluid pressure for sufficient time to at least partially relax said plastic formation, and then while said plastic formation is relaxed injecting a fracturing liquid into a second zone which extends through said permeable formation of said well and which is isolated from said first zone, said fracturing liquid being injected into said second zone under sufficient pressure to produce said horizontal fracture in said permeable formation.

2. A method of producing a horizontal fracture in a subterranean permeable formation penetrated by a well where said well also penetrates a plastic formation which is adjacent to said permeable formation comprising isolating a first zone in said well which extends through and is in fluid communication with said plastic formation from a second zone in said well which extends through said permeable formation, removing liquid from said first zone to reduce substantially the fluid pressure on said plastic formation whereby said plastic formation relaxes and flows plastically toward said well and initiates a formation fracture, and then while said pressure on the face of said plastic formation is substantially reduced injecting a fracturing liquid into said second zone under sufficient pressure to extend said fracture.

3. A method of producing a horizontal fracture in a subterranean permeable formation penetrated by a well where said well also penetrates a plastic formation which is adjacent to said permeable formation comprising isolating a first zone in said well which extends through and is in fluid communication with said plastic formation from a second zone in said well which extends through said permeable formation, removing liquid from said first zone to reduce the fluid pressure on said plastic formation to substantially atmospheric pressure, and then while said pressure on the face of said plastic formation is substantially atmospheric injecting a fracturing liquid into said second zone under sufficient pressure to fracture said permeable formation.

4. In a well completion process wherein said well penetrates a permeable formation and a plastic formation adjacent said permeable formation the steps of isolating a first zone in said well which extends through said plastic formation from a second zone in said well which extends through and is in fluid communication with said permeable formation, pumping liquid from said first zone to reduce the pressure on the face of said plastic formation to substantially atmospheric pressure and relax said plastic formation, and then, while said plastic formation is relaxed, injecting a fracturing liquid into said second zone under a pressure great enough to fracture said permeable formation.

5. In a well completion process wherein said well penetrates and is in fluid communication with a permeable formation and a plastic formation adjacent to said permeable formation the steps of isolating said plastic formation from fluid communication with said permeable formation through said well, removing liquid from said well adjacent said plastic formation to reduce the fluid pressure on the face of said plastic formation and relax said plastic formation and then, while said plastic formation is relaxed, injecting a fracturing liquid into said permeable formation under sufficient pressure to fracture said permeable formation.

6. In a well completion process wherein said well penetrates a permeable formation and an open plastic formation adjacent to said permeable formation the steps of lowering into said well a first tubing string which extends into said permeable formation and has at least one packer thereon, setting said at least one packer in said well to isolate a first zone in said well which extends through said plastic formation from a second zone in said well which extends through said permeable formation, running a second tubing string into said well to a depth sufficient to place its lower end in the bottom of said first zone, pumping liquid from said first zone through said second tubing string to decrease the pressure on the face of said plastic formation to substantially atmospheric pressure, then while said pressure is maintained at substantially atmospheric injecting into said second zone of said well via said first tubing string a fracturing liquid under sufficient pressure to create a fracture in said permeable formation, and producing said well.

References Cited in the file of this patent

UNITED STATES PATENTS

2,753,940 Bonner ..... July 10, 1956