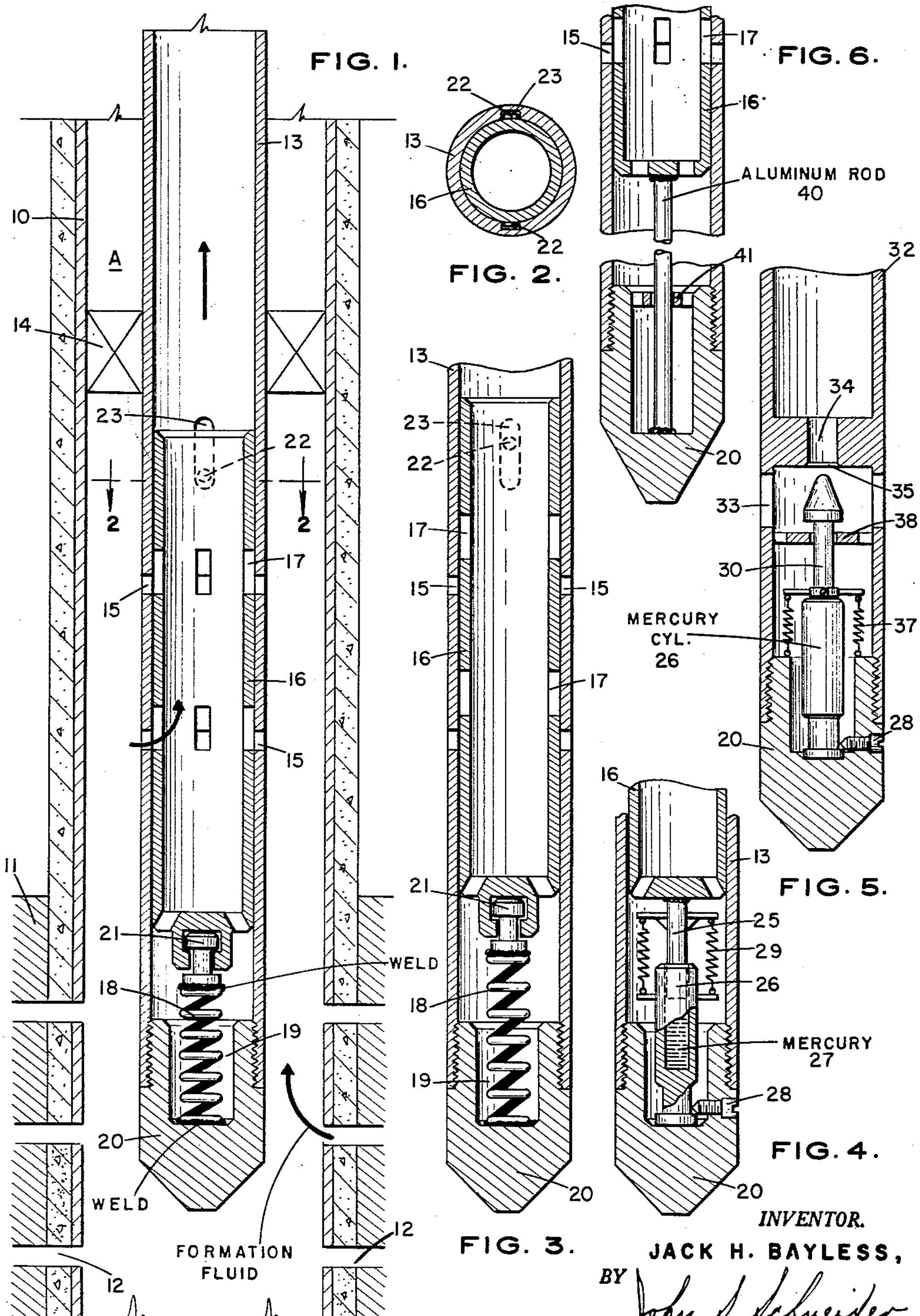
Feb. 4, 1964 J. H. BAYLESS 3,120,267

FLUID FLOW CONTROL IN WELLS

Filed Dec. 5, 1960



INVENTOR.
JACK H. BAYLESS,
BY John S. Schneider
ATTORNEY.

United States Patent Office

3,120,267
Patented Feb. 4, 1964

1

3,120,267

FLUID FLOW CONTROL IN WELLS

Jack H. Bayless, Houston, Tex., assignor, by mesne assignments, to Jersey Production Research Company, Tulsa, Okla., a corporation of Delaware

Filed Dec. 5, 1960, Ser. No. 73,727
5 Claims. (Cl. 166—53)

The present invention concerns controlling the flow of well fluids in response to temperature changes of the fluids.

In many instances when a subsurface reservoir containing oil or gas or both is subjected to an in situ combustion process by injection of air or oxygen into the reservoir, fluids produced from the reservoir are at elevated temperatures because of the combustion front moving by or into a producing well or by backflow of heated fluids into an injection well.

Produciton of these fluids at high temperatures may result in extensive damage to well equipment, e.g., packers, well pipe, etc., because of the high fluid temperatures or the high corrosion rates accelerated by the high fluid temperatures.

A primary object of the present invention is to prevent damage to well apparatus from this cause by providing a valve mechanism designed to automatically restrict or close off the flow of production fluids from wells in response to increased temperatures of these fluids above a predetermined or selected temperature level and to open and permit partial or unrestricted fluid flow upon a decrease in fluid temperatures to below the predetermined temperature level.

Essentially, the invention comprises a method of controlling flow of production fluids from wells in response to variations in temperature of the production fluids. Included in the inventive concepts are different forms of heat responsive apparatus for controlling fluid flow from the wells.

The above object and other objects and advantages of the invention will be apparent from the following more detailed description of the invention when taken in conjunction with the drawings wherein:

FIG. 1 is a vertical, partly-sectional view of a well bore having arranged therein a production tubing in which is positioned a temperature-sensitive valve device arranged in its fully open position;

FIG. 2 is a view taken on lines 2—2 of FIG. 1;

FIG. 3 is a vertical, partly-sectional view of the temperature-sensitive valve device shown in FIG. 1 arranged in its fully closed position;

FIG. 4 is a vertical, partly-sectional view of a modification of the temperature-sensitive valve device of FIGS. 1 and 3;

FIG. 5 is a vertical, partly-sectional view of another type temperature-sensitive valve device; and

FIG. 6 is a vertical, partly-sectional view of still another type temperature-sensitive valve device.

Referring to the drawings in greater detail, in FIG. 1 is shown a casing pipe string **10** set in a borehole which penetrates a subsurface formation **11**. Pipe string **10** and formation **11** are perforated by perforations **12**. A production tubing string **13** for conveying to the earth's surface production fluids from formation **11** is arranged in pipe string **10**, and a pack-off **14** arranged on tubing string **13** closes off the annulus A between tubing string **13** and casing pipe **10** above a series of openings **15** in the lower end of tubing string **13**. A movable sleeve **16** provided with openings **17** is arranged in tubing string **13** and is connected at its lower end to a temperature-sensitive spring **18**, which is supported in a recess **19** in a plug **20** closing the lower end of tubing string **13**.

2

Spring **18** may be of any material having suitable strength and a sufficiently high coefficient of expansion, i.e., greater than 10×10^{-6} per in. per degree C. These materials could be steel, silver, bronze, stainless steel, brass, etc. However, the preferred material is a bimetallic element composed of two strips of different metals firmly bonded together by any suitable means, such as soldering either with soft solder or silver solder, brazing, welding, or pressure fusing. The two metals should have widely different coefficient of thermal expansion. For instance, aluminum and Invar steel (36% nickel steel) have coefficients of 24×10^{-6} and 0.9^{-6}, respectively, and consequently would make a good bimetallic spring element. Other metals that may be used together with their coefficients of expansion (in./in.° C.) are magnesium, 27×10^{-6}; lead, 25×10^{-6}; aluminum, 24×10^{-6}; silver, 19×10^{-6}; brass, 19×10^{-6}; bronze 18×10^{-6}; annealed steel, 11×10^{-6}; chromium, 7×10^{-6}; tantalum, 7×10^{-6}; molybdenum, 5×10^{-6}; tungsten, 4×10^{-6}. Invar steel, 0.9×10^{-6}.

The upper end of spring **18** is welded to a coupling designated **21**, which in turn is connected to the lower end of sleeve **16**. The manner of construction and connection of spring **18** and sleeve **16** permits the spring to expand vertically but transmits no torque to sleeve **16**. Bimetallic elements usually are made in strips from 1/8 in. to 1/2 in. wide and of any lengths. By making spring element **18** from a bimetallic element wound with the flat axis perpendicular to the length of the spring, the primary movement of the spring is up and down, as illustrated in FIGS. 1–3. As seen in FIG. 2 more clearly, keys **22** positioned on the exterior surface of sleeve **16** are engaged with vertical slots **23** formed on tubing string **13**. If a spring of bimetallic material was arranged coiled with the flat face parallel to the length of the spring, then heating would impart a rotary motion to sleeve **16**, and the slot in tubing would be spirally configured. Thus, although not shown in any of the figures, spring **18** could be welded both to lower plug **20** and the lower end of sleeve **16** with the bimetallic element of spring **18** joined in a plane vertical to the spring body axis. In this form a spiral motion would be transmitted to sleeve **16** as it moved vertically in response to increased temperatures. One purpose of keying sleeve **16** to tubing string **13** is to maintain openings **15** and **17** in lateral or circumferential alignment. Sleeve **16** has a lower position in which openings **15** and **17** are aligned (FIG. 1) and an upper position in which openings **17** and **15** are out of alignment (FIG. 3) and intermediate positions in which parts of openings **15** are closed off by sleeve **16** (not shown).

As seen in FIG. 1, when openings **15** and **17** are aligned so as to provide openings **15** with full or unrestricted openings, production fluids from formation **11** pass into annulus A through aligned openings **15** and **17** and upwardly through tubing string **13** as indicated by the arrows.

When the temperature of the production fluids increases, spring **18** expands and moves sleeve **16** upwardly. Sufficient expansion of spirng **18** causes openings **17** to move out of alignment with openings **15**, which closes off flow of fluids through these openings, as seen in FIG. 3. the amount of fluid flow through openings **15** and **17** may be calibrated to any degree of temperature rise desired depending upon the type of materials used to construct bimetallic spring **18**. Spring **18** retracts upon cooling, since the metals forming the spring contract upon cooling, and returns sleeve **16** to its original position shown in FIG. 1. The weight of sleeve **16** should be sufficient to cause it to return to its original position. However, if desired, a light spring bias may be used to aid the return of sleeve **16** to its original position. Keys **22** are arranged in slots 23 to limit the travel of sleeve 16 so that openings 15 and 17 remain aligned (openings 15 fully open) even though the production fluids become cooler than the predetermined temperature at which the openings are aligned.

In FIG. 4 a modification of the temperature-sensitive portion of the apparatus shown and described with regard to FIGS. 1–3 is shown. In this figure inner sleeve 16 is connected through a piston member 25 to a pot or cylinder 26, which contains mercury 27. Pot 26 is retained in position by means of a screw 23 threaded through plug 20. The operation of this embodiment is the same as that of the apparatus of FIGS. 1–3. Thus, an increase in temperature of the production fluids heats mercury 27, which causes the merucury to expand and move piston member 25 and weighted sleeve 16 upwardly to restrict or close off ports or openings 15 in tubing string 13. A decrease in the temperature of the production fluids surrounding pot 26 cools mercury 27, which permits piston member 25 and sleeve 16 to return by gravity to their initial positions in which full or partial openings are provided through openings 15 in tubing string 13 depending upon the temperature. In this figure light springs 29 bias piston member 25 downwardly and aid return of sleeve 16 to its initial position.

Another modification of the temperature-responsive valve apparatus of the invention is illustrated in FIG. 5. In this modification a tubing string 32, similar to tubing string 13 of the previous embodiments, is formed with lower outer openings 33 and an inner opening 34, which has formed on the lower side thereof a seat 35 for a valve rod 30, which is connected to cylinder 26 containing mercury 27. Light springs 37 interconnect plug 20 and rod 30 and aid in retracting rod 30 to its original position. A guide member 38 may be arranged in tubing string 32 to maintain rod 30 aligned with opening 34. In operation, when fluids surrounding cylinder 26 are sufficiently hot, the mercury 27 in the cylinder heats up and expands and forces valve rod 30 upwardly to restrict or close off the flow of fluids through openings 33 in tubing string 32 and opening 34. When cooler fluids surround cylinder 26, the mercury 27 cools permitting valve rod 30 to retract under the bias of springs 37, thereby reopening opening 34 for the flow of fluid therethrough. If the temperature of the fluids in the well bore rises above the temperature needed to close off opening 34, then rod 30 will be compressed and seat 35 will be subjected to undesirable forces. Therefore, if desired, a section of stiff spring may be placed in rod 30 to absorb any extra expansion of mercury 27 in cylinder 26 caused by the elevated temperature. A spring-biased slip joint in rod 30 also would accomplish this same relief.

In FIG. 6 a modification of the temperature-sensitive portion of the subsurface valve of FIGS. 1–3 is shown. As seen in this figure, a long rod of aluminum 40 has been substituted for spring 18 and coupling connection 21. The upper end of rod 40 is directly welded to the lower

end of sleeve 16, and a guide member 41 is arranged in the lower end of tubing string 13 to aid in maintaining rod 40 vertically aligned. The operation of this embodiment of the invention is the same as that described for the device of FIGS. 1–3; that is, upon increase in the temperature of fluids produced from formation 11 above a selected temperature, aluminum rod 40 expands causing sleeve 16 to move upwardly and seal off fluid flow through openings 15 in tubing string 13, and upon cooling of the production fluids to temperatures below the selected temperature, aluminum rod 40 retracts to its original position in which openings 15 and 17 are aligned, as seen in FIG. 6.

Having fully described the objects, nature, operation, and elements of my invention, I claim:

1. Apparatus for controlling flow of production fluids from a well comprising: a production tubing string arranged in said well and provided with openings located down-hole; packer means arranged on said tubing string above said openings for closing off the annulus between said tubing string and said well wall; and temperature responsive means arranged in said tubing string adjacent said openings adapted to vary the size of said openings to thereby vary flow of said fluids from fully free to fully restricted flow through said openings in response to increases in the temperature of said fluids and from fully restricted to fully free flow through said openings in response to decreases in the temperature of said fluids.

2. Apparatus as recited in claim 1 wherein said temperature responsive means includes a bimetallic spring element.

3. Apparatus as recited in claim 1 wherein said temperature responsive means includes a mercury containing cylinder.

4. Apparatus as recited in claim 1 wherein said temperature responsive means includes an aluminum rod.

5. Apparatus for controlling the flow of production fluids from a well comprising means arranged in said well providing a passage way for producing said fluids; and temperature responsive flow control means arranged down-hole in said well adapted to vary flow of said production fluids through said passage way from fully free to fully restricted flow in response to changes in temperature from lower to higher temperatures, respectively, of said fluids, and from fully restricted to fully free flow in response to changes in temperature from higher to lower temperatures, respectively, of said fluids.

References Cited in the file of this patent

UNITED STATES PATENTS

1,050,225	Nelson	Jan. 14, 1913
1,813,122	Moore	July 7, 1931
1,880,778	Byers	Oct. 4, 1932
1,961,280	Crites	June 5, 1934
1,992,424	Halliburton	Feb. 26, 1935
2,021,427	Peo	Nov. 19, 1935