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WELL TREATING METHOD

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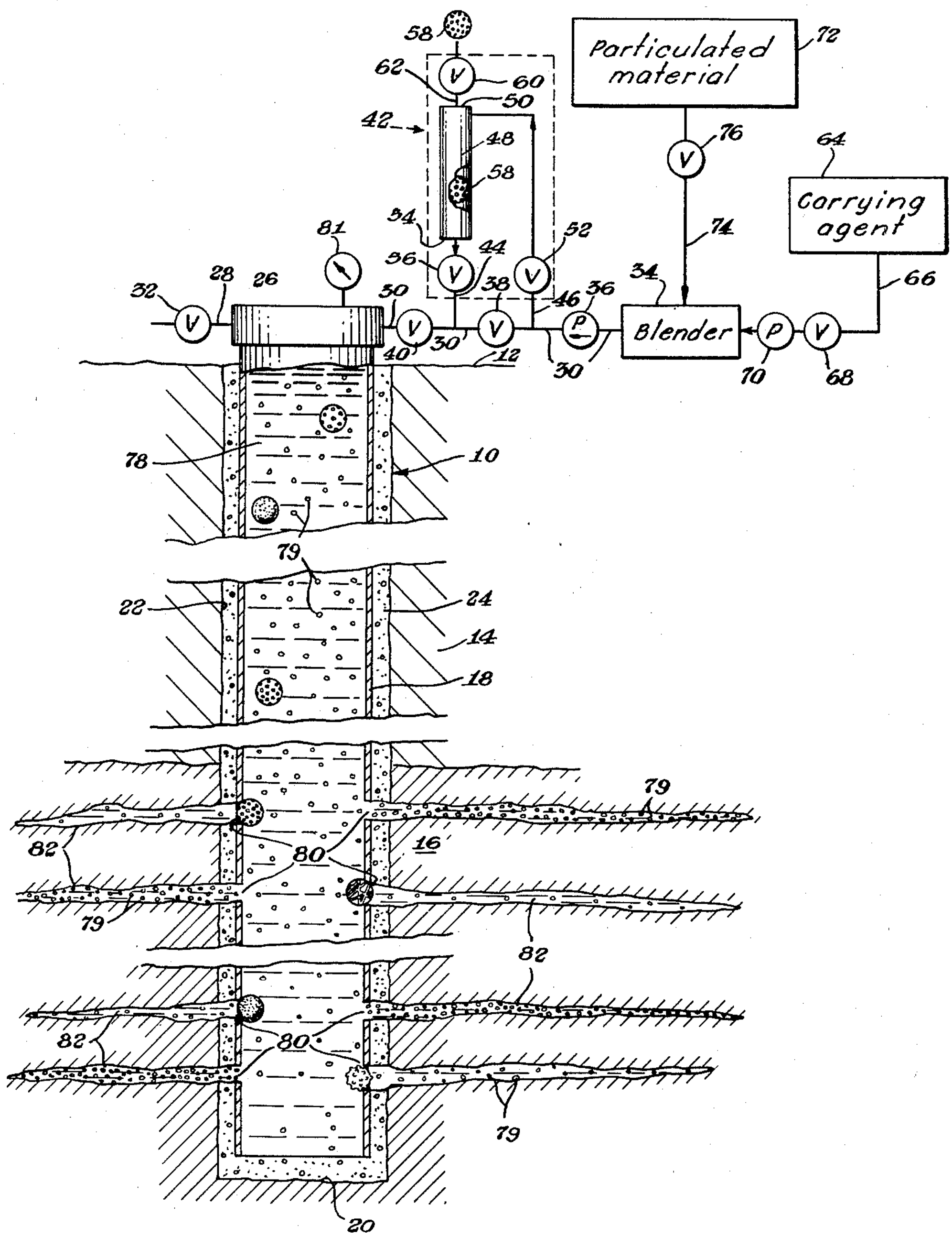

Fig. 1

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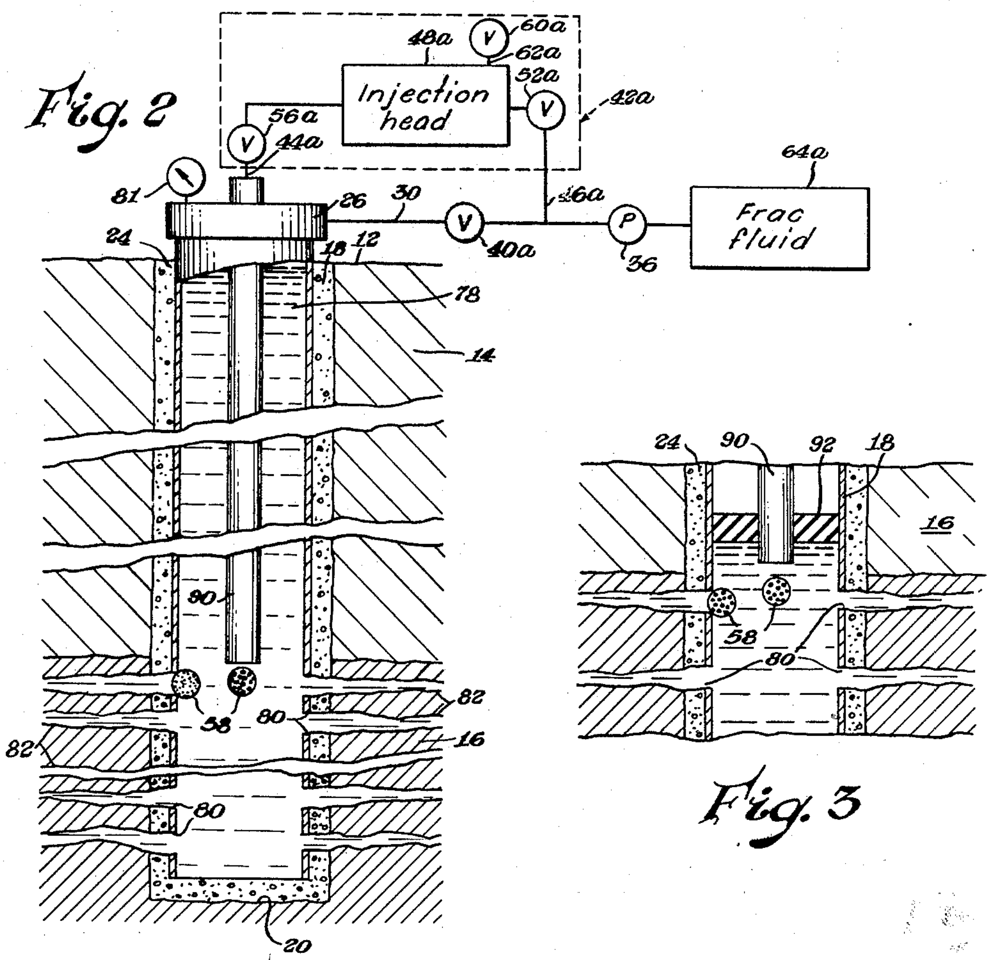

Fig. 2

Fig. 3

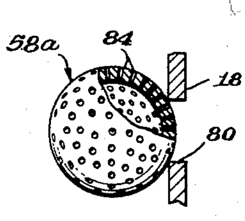

Fig. 4

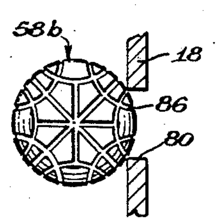

Fig. 5

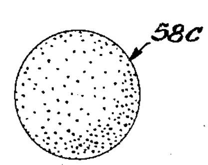

Fig. 6

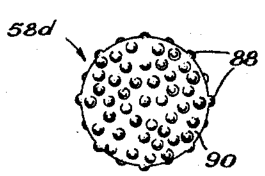

Fig. 7

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WELL TREATING METHOD

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7 Claims. (Cl. 166—42)

This invention relates to a method of treating cased earth wells and particularly to a method of temporarily restricting the amount of flowable material which may pass through perforations in the casing of earth wells.

When oil, water, or gas wells are given formation fracturing treatments, acidizing treatments, or other treatments where fluids are pumped through casing perforations and into the adjacent earth formations, often a disproportionately large amount of the treating fluid or pumpable slurry passes through one or more of the several perforations in the casing.

The flow of a disproportionately large amount of treating material through one or a few perforations in the casing may be attributed, usually, to the higher permeability of the formation adjacent to those perforations.

If the fluid or pumpable slurry may be easily pumped through one or a few perforations, it is often impossible to pump enough fluid into the well to build up a sufficient hydrostatic pressure in the well bore to force fluid or slurry through the perforations communicating with only slightly permeable or generally impermeable sections of the earth formations.

One suggested solution to the above problem involves temporarily plugging at least some of the perforations communicating with permeable sections of earth formations during an injection of fluids or materials so that such fluids or materials are forced into the less permeable sections of the earth formation through other perforations which remain open. Ball sealing elements, usually made of rubber or made of a hard core and resilient outer surface layer, are inserted into the well as fluid is pumped through the perforations. The balls are carried along by the flowing stream of fluid and seat against the casing perforations through which considerable fluid passes, that is, those perforations communicating with permeable sections of earth formation. Once seated against a perforation, the ball sealer element plugs the perforation and is held in place by the pressure against it of the fluid in the casing and prevents passage of the fluid in the casing through the perforation.

Some disadvantages inure to the above described method. First, if the plugging ball or element becomes lodged in the perforation or is driven through a casing perforation by the high pressure within the casing, that perforation would be more or less permanently sealed off, resulting in a decrease in production from the well.

Secondly, if no fluid is pumped into the permeable sections of the formation which communicate with the plugged perforations, the application of high pressures through other perforations may crush or collapse the plugged off permeable section.

Also, sealing or plugging off one or more of the permeable sections creates a high pressure differential between the casing, the cement sheath about the casing, and the formation, and may cause casing ruptures and shattering or channeling of the cement sheath. Since the pressure differential which can be withstood by the

casing and cement is often an important factor which limits the flow rate of fluid or slurry pumped into the well, the practical importance of avoiding localized stresses in casing and cement can readily be appreciated.

Accordingly, a principal object of this invention is to provide an improved method of restricting the flow of material from a well through a perforation in the well casing.

Another object of this invention is to provide an improved method of restricting the flow of material from a well bore through a perforation and into an earth formation which obviates the danger of permanently sealing off flow from the earth formation into the well bore.

A further object of this invention is to provide an improved method of equalizing the flow of materials through various well bore perforations during a well treating operation in which material is pumped through said perforations.

This invention provides a method of restricting the amount of material which may be pumped into an earth formation through a perforation by inserting ball-like flow restricting elements into the stream of material pumped or injected into the well. The flow restricting elements are drawn to the perforation or perforations by the streams flowing through the perforations and become seated there as long as fluid inside the casing tends to pass outwardly through such perforation, as when the casing pressure exceeds the back pressure of the earth formation adjacent to the perforations. The ball-like flow restricting elements contain bores, channels, pores, or have an irregular surface which, although the element is seated against the perforation in the casing, does not close the perforation, but assures that a part of the material being pumped into the well will flow past or through the flow restricting element and into the earth formation.

This invention, as well as additional objects and advantages thereof, will best be understood when the following detailed description is read in connection with the accompanying drawings, in which:

Fig. 1 is a sectional view of a cased earth well, with the surface equipment shown schematically, undergoing a formation fracturing treatment with flow restricting elements in accordance with this invention;

Fig. 2 is similar to Fig. 1 except that the flow restricting elements are fed into the well through a string of tubing;

Fig. 3 is a fragmentary sectional view showing a packer set above the perforations to close off the annulus between the tubing and casing;

Fig. 4 is a side elevational view, partly broken away, of a flow restricting element having a multiplicity of bores extending through the ball-like member; the element being shown seated against a perforation;

Fig. 5 is a side elevational view of a ball-like flow restricting element, having a plurality of grooves or channels in the outer surface thereof, seated against a casing perforation;

Fig. 6 is a side elevational view of a porous flow restricting element, and

Fig. 7 is a side elevational view of a flow restricting elements having a multiplicity of small bumps or projections on the outer surface thereof.

Referring to Fig. 1, there is shown a well bore, indicated generally by the numeral **10**, which extends from the earth's surface **12** through one or more earth formations **14** and into an earth formation **16** which contains petroleum, gas or mixtures thereof. A string of casing **18** extends from the earth's surface **12** to, or near to, the bottom **20** of the well bore **10**. The space between the well casing **20** and the wall **22** of the well bore **10** is filled with cement **24**. The cement **24** extends, as illustrated, from the top to the bottom of the well bore 10, although in practice the casing-well bore wall space, while filled with cement where the casing traverses the fluid producing formation 16, may not be filled with cement completely to the surface 12 of the earth. The casing 18 is capped by a suitable casing head 26 to which are coupled flow lines 28 and 30. The line 28 is coupled to or through a valve 32 and usually serves as a vent line at the beginning of a well treatment.

If the well treatment is a formation fracturing treatment as illustrated in Fig. 1, the pipe line 30 extends between the casing head 26 and a blender unit 34. A pump 36 is disposed in the pipe line 30 adjacent to the blender unit 34 and valves 38, 40 are disposed in the line 30 between the pump 36 and casing head 26. A flow restricting element injection assembly, indicated generally by the numeral 42, is coupled, by means of the pipe lines 44, 46, into the pipe line 30 across the valve 38.

The flow restricting element injection assembly 42 includes an injection chamber 48 which is coupled near its end 50 to the line 30 through the line 46 and valve 52. The lower end 54 of the injection chamber 48 is coupled, through the pipe line 44 and the valve 56 to the line 30 between valves 38, 40. The flow restricting elements to be used in the well treatment, indicated generally by the numeral 58, are fed into the injection chamber 48 through the valve 60 in the pipe line 62 which enters the end 50 of the chamber 48.

The well treating fluid or slurry is composed of a fluid carrying agent which is disposed in a reservoir or tank 64 which is coupled to the blender 34 through the pipe line 66, valve 68, and pump 70.

A particulated material (shown as the particles 79 in Fig. 1), such as sand, for example, is contained in a hopper 72 which is coupled to the blender 34 through the feed line 74 and suitable flow control means 76.

In operation, with valves 38 and 40 open and pump 36 operating, and with valve 68 open and pump 70 operating, fluid carrying agent 78 is pumped into the well bore through the line 30. Gases trapped within the casing 18 may, if desired, be vented from the casing 18 by opening the valve 32 in the line 28 which is coupled to the casing head 26. (The valve 32 is, of course, closed when all the gas is vented.)

Pressure is applied to the fluid 78 in the casing 18 by means of pump 36. The casing 18 has a plurality of perforations 80 which extend both through the casing 18 and the cement 24, and the pressure applied to the casing 18 is thus asserted against the earth formation 16 adjacent to each perforation 80. The pressure is raised until the formation "breaks down" and one or more fractures 82 are produced in the formation 16.

The breakdown of the formation 16 is normally indicated at the earth's surface 12 by a drop in injection pressure, a change in pitch of the noise made by the engines or motors driving the pump 36 (or group of pumps, since several pumps may be used simultaneously in making the treatment) or by an increase in flow rate in the line 30 without any increase in line pressure.

Once the formation breakdown has occurred the flow control means 76 is opened and particulated material 84 from hopper 72 is fed into the blender 34 and there mixed with the fluid carrying agent, which may be any suitable carrying agent such as water, an oil, acid, thickened water (water plus a jelling agent), oil or acid, or mixtures thereof, such as an emulsion of an oil and an aqueous liquid, to cite some examples, to form a pumpable slurry.

It should be emphasized that if the breakdown conditions of the formation 16 are known and the well casing 18 and other equipment which is subject to high pressures during the well treatment are capable of withstanding the formation breakdown pressures expected to be encountered, then a slurry instead of clear carrying agent may be initially pumped into the well. The initial pumping of carrying agent as described above prevents a sandout which would be certain to occur if the formation 16 did not break down to permit particulated material to be pumped into the formation.

As the pumping of the slurry of carrying agent 78 and particulated material 79 into the fractures 82 proceeds, it may be found to be impossible to pump the slurry into the casing 18 at a pressure high enough to enlarge and extend the fractures 82. Usually the cause of such a condition is that one or more of the fractures 82 is enlarged to an extent that most of the slurry being pumped down the casing 18 may be pumped therein.

Then, in accordance with this invention, with the valves 56 and 52 closed and the valve 60 opened, one or more flow restricting elements 58 are inserted through valve 60 and the line 62 into the injection chamber 48. The valve 60 is then closed and the valves 52 and 56 opened to permit the flow restricting elements 58 to be injected into the line 30 and thence into the casing. (It may be desirable to partially close the valve 38 in the line 30 to insure that the elements 58 are rapidly injected into the line 30 from chamber 48.)

The flow restricting elements 58 preferably have approximately the same specific gravity (or apparent specific gravity) as that of the slurry or fluid being injected into the casing 18 in order that the elements 58 flow with the slurry or fluid rather than merely float or sink rapidly through it.

As the flow restricting elements 58 approach the section of the casing 18 having the perforations 80, the flow restricting element or elements 58 are carried along by the stream of slurry or fluid entering the fracture or fractures 82 through one or more perforations 80 and the elements 58 seat against the perforations 80 through which the slurry or fluid passes. The flow restricting elements 58 permit the passage of some slurry or fluid through or around each element 58, preventing the undue localized strain on the casing 18 and cement 24 which would occur if the perforation were plugged by the element 58. Also, the restricted amount of fluid or slurry flowing past the element 58 permits the fracture to be enlarged and expanded and propping agent (particulated material 79) to be deposited therein, but not at the expense of other fractures 82 in less permeable parts of the formation 16.

As each flow restricting element 58 seats against one of the perforations 80, a pressure rise is ordinarily noted at the surface, as on the pressure gauge 81 on the casing head 26, for example. The pressure rise is a result of the decrease in the rate of passage of slurry or fluid into the formation 16, assuming that the same horsepower is applied to the pump or pumps 36 before and after the element 58 seats.

It may be, and often is, desirable to inject flow restricting elements 58 into the casing more than once during the well treating operation. For example, as each fracture occurs (or is noted at the surface 12 as a pressure drop at the casing head 26, for example), it may be desirable to restrict the flow of slurry or fluid into that fracture 82 in order to facilitate the making or enlarging of still more fractures communicating with other perforations 80.

When all of or the desired amount of the treating slurry or fluid has been pumped into the casing 18 and the well flushed with clear carrying agent the treatment is completed and the pressure on the casing 18 may, or may not, be immediately released, depending on the wishes of the well owner. When the casing pressure is released, however, the formation pressure will normally exceed the casing pressure and the flow restricting elements 58 will be unseated from their respective perforations 80 and will either fall to the bottom of the well or, if light enough, will be carried to the surface 12 by the flow of fluid upwards through the casing 18.

The flow restricting or semi-obturating elements 58 may take a variety of forms, some of which are illustrated in Figures 4 through 7. The ball-like flow restricting element **58a** shown in Fig. 4 contains a multiplicity of small bores **84** which extend through the element. The diameter of the bores **84** are large enough to permit passage therethrough of the slurry of particulated material and fluid carrying agent used in the treatment. The number of the bores and their disposition are matters of choice. However, each element **58a** must provide at least one bore **84** which, when the element **58a** is seated against a perforation **80**, permits passage of slurry or fluid through the element **58a** and through the perforation **80**, regardless of the orientation of the element **58a** with respect to the perforation **80**. The element **58a** (and other elements **58** in general) may be solid except for the passageways therethrough, may have a hollow core to reduce the apparent specific gravity, and may be made of any material capable of withstanding the pressures encountered in the well treating operation. It is assumed that the element **58a** (and other elements **58**) will not be made of a material which is readily attacked by the slurry or fluid used in the well treatment in which the elements **58a** (or **58**) are used.

Fig. 5 shows a ball-like flow restricting element **58b** seated against a perforation **80** in the casing **18**. The element **58b** contains a multiplicity of channels **86** in the outer surface of the element. The channels are disposed so as to permit the flow of some slurry or fluid around the element **58b** and through the perforation **80** regardless of the orientation of the element **58b** with respect to the perforation **80** while seated thereagainst.

Fig. 6 shows a ball-like flow restricting element **58c** which is porous and permits the passage of well treating fluid, in restricted amounts, through the element **58c** and through the perforation **80**. This form of flow restricting element, when the pores are fine, is especially useful with treating fluids which do not contain particulated material. Porous elements with larger pores may be used with slurries which contain particulated material. The element **58c** may be either "solid" or may have a hollow non-porous, light weight core to reduce the apparent specific gravity of the element **58c**.

Fig. 7 shows a flow restricting element **58d** having a maze of "bumps" **88** along the surface **90** of the element **58d**. The amplitude (height above the surface **90**) of each "bump" **88** and the pattern and number of the "bumps" **88** may be chosen to provide a predetermined flow capability past the element **58d** and through the perforation **80**. The pattern should be such that any circle having at least the diameter of the perforation **80** could not be drawn on the element **58d** without running through at least one bump **88**.

The flow restricting elements **58** may be made of such materials as nylon, aluminum, magnesium, bronze, steel, or solid state plastic or other material of suitable apparent specific gravity and capable of withstanding the pressures encountered without excessive deformation. Metallic flow restricting elements **58** may be of solid granules or particles sintered or partly fused together to provide, if desired, for example, a porous element **58c**. It is also sometimes advantageous to have a resilient coating or layer on the surface of the element to assure proper seating of the element **58** with respect to a perforation **80** but without providing a complete closure of the perforation **80**. Also, the resilient coating or layer should not be of such thickness or nature that the fluid flow passages are closed when the element **58** is subjected to the high pressures encountered in well treating operations.

While the invention has been specifically described in connection with formation fracturing treatments, it is equally applicable to any well treating operation in which it is desired to restrict the flow of material through a well bore perforation. Well acidizing is a typical example of such a treatment.

The size of the ball-like elements is of some importance. They must, of course, be of larger diameter than the diameter of the casing perforation. For ⅜ inch perforations elements having a nominal ¾ inch diameter have proven to be satisfactory although elements of other diametrical measurements may be used with such perforations. The ¾ inch flow restricting elements seat well with a ⅜ inch perforation yet are large enough that they resist being driven into the formation **16**. The ¾ inch diameter is, as applied to the elements **58d**, the diameter measured through two diametrically opposite "bumps" **88** on the surface **90** rather than the diameter of the sphere having the surface **90**. In flow restricting elements **58a** bores having a diameter of 1/16 inch have proven satisfactory.

The relative rate of flow through a ⅜ inch perforation **80**, for example, and through a flow restricting element **58** of the size adapted to seat against such a perforation is a matter of choice, depending on such well factors as the condition of the casing **18** and cement **24**, the available flow rate which can be maintained by the pump **36**, and the pressure required to fracture the formation **16**. The flow rate through a perforation **80** against which an element **58** is seated should be between 10 percent and 50 percent of the open flow rate through the perforation **80**. Flow rates through an element **58** greatly exceeding 50 percent are, as a matter of practice, unnecessary in most wells to prevent undue strain on the casing **18** or to prevent collapsing of existing fractures **82** communicating with the perforation **80** against which the element **58** is seated. Further, larger flow rates than are necessary are wasteful of treating material and of pumping capacity.

The term flow restricting element, as used herein, is intended to include ball-like elements which, when lodged or seated against a casing perforation, materially reduce but do not completely cut off the flow of well treating fluid through the element or between the element and the perforation.

We claim:

1. A method of treating an earth formation penetrated by the bore of a well provided with the usual cemented casing, said casing having perforations at a plurality of levels opposite the formation to be treated, said method comprising the steps of introducing into the well and thence into the earth formation through the said perforations a pumpable treating agent and injecting into the well along with the treating agent ball-like semi-obturating elements which are larger in diameter than the diameter of said perforations and have a specific gravity such that said elements are carried along the bore by said treating agent and become lodged against those perforations taking a disproportionately large amount of the treating agent and partly obturates each such perforation, the semi-obturating elements each being provided with an array of discrete treating agent flow paths so disposed that at least one flow path provides communication between the interior of the casing and the perforation regardless of how the semi-obturating element is oriented with respect to the perforation against which it is lodged, and then introducing additional treating agent under pressure sufficient to break down said earth formation and force additional treating agent through said perforations against which no semi-obturating elements are lodged.

2. A method in accordance with claim 1, wherein a semi-obturating element has a plurality of walled flow paths in the outer surface thereof.

3. A method in accordance with claim 1, wherein said flow paths extend through the semi-obturating element.

4. A method in accordance with claim 1, wherein said semi-obturating element has an array of protuberances so disposed on the outer surface of the element that at least one flow path between the protuberances provides an open communication from the interior of the casing

through the perforation when the element is lodged against said perforation.

5. A method in accordance with claim 1, wherein a semi-obturating element is hollow.

6. A method in accordance with claim 1, wherein a semi-obturating element has an outer part of higher specific gravity than an inner part thereof.

7. A method of treating an earth well whose bore extends from the earth's surface into a desired earth formation and in which a cemented casing has been perforated where the casing penetrates said desired earth formation, the formation being so broken down that during a well treatment in which pumpable material is pumped into said well a disproportionately large amount of said material passes through certain perforations, said method comprising introducing ball-like semi-obturating elements into said well which are larger in diameter than the diameter of said perforations and of such specific gravity that they are carried along the bore as said material is pumped into the well, said semi-obturating elements having an array of discrete flow paths so disposed that at least one flow path is provided through whichever one of said certain perforations against which it lodges regardless of the orientation of an element with respect to the perforation, pumping said materials and elements down said well and through said perforations to carry said semi-obturating elements down said well and lodge them against the said certain perforations through which a disproportionately large amount of said material passes, observing at the surface any change in well treating conditions which is indicative that said semi-obturating elements are lodged against said certain perforations through which material is being pumped, and then pumping material into said well at higher pressure to further break down said formation and force additional material through others of said perforations.

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