May 16, 1967 D. V. CHENOWETH 3,319,717

MULTIPLE ZONE INJECTION APPARATUS FOR WELL BORES

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FIG. 1.

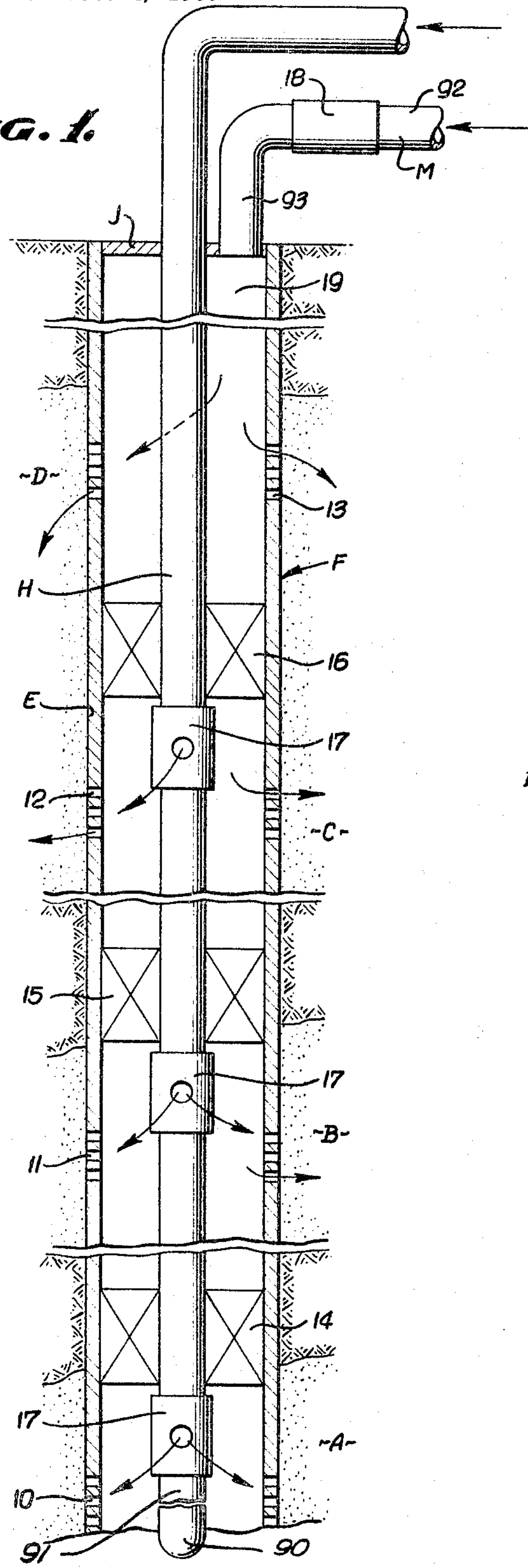
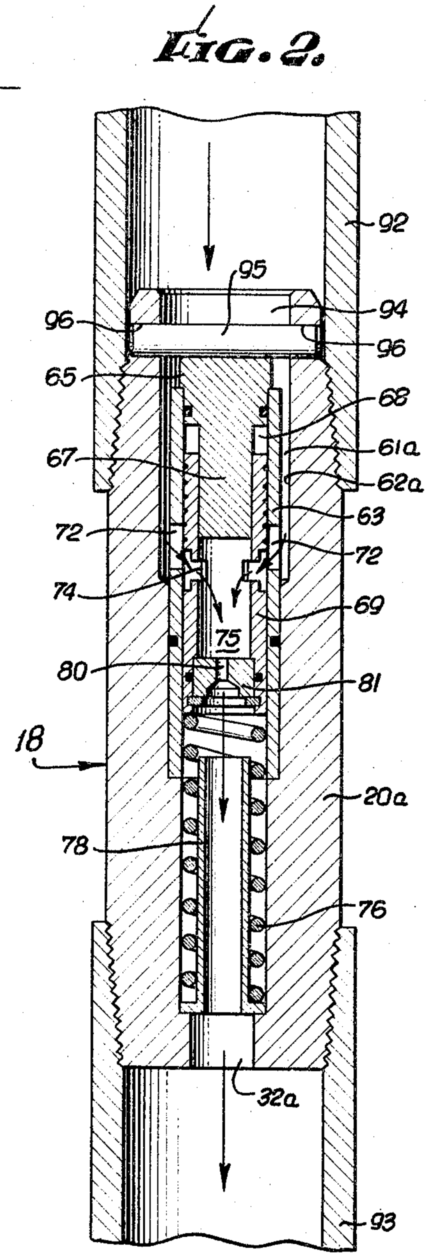


FIG. 2.



INVENTOR.
DAVID V. CHENOWETH
BY Bernard Kriegel
ATTORNEY.

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FIG. 3a.

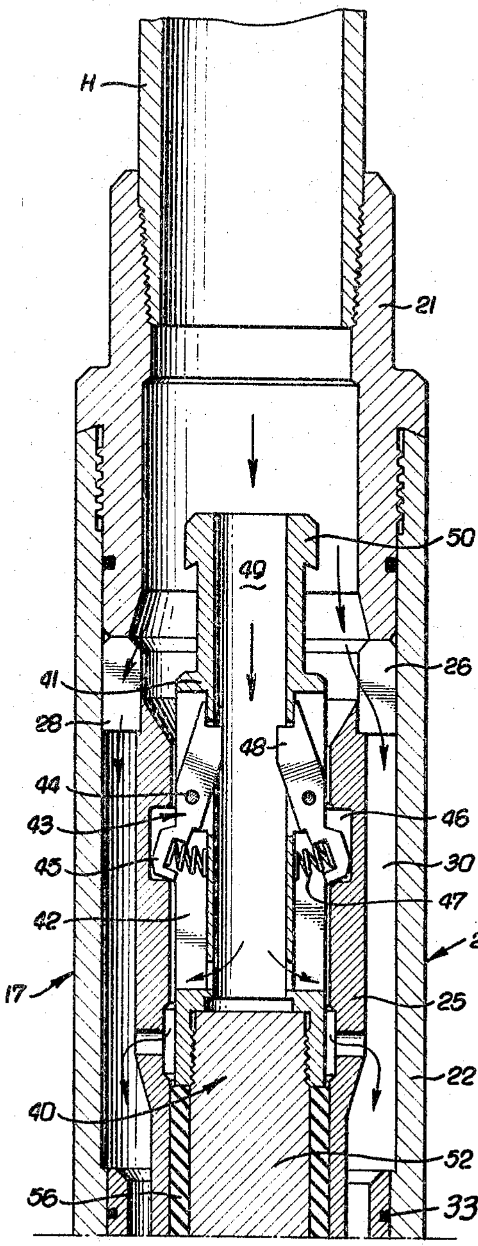
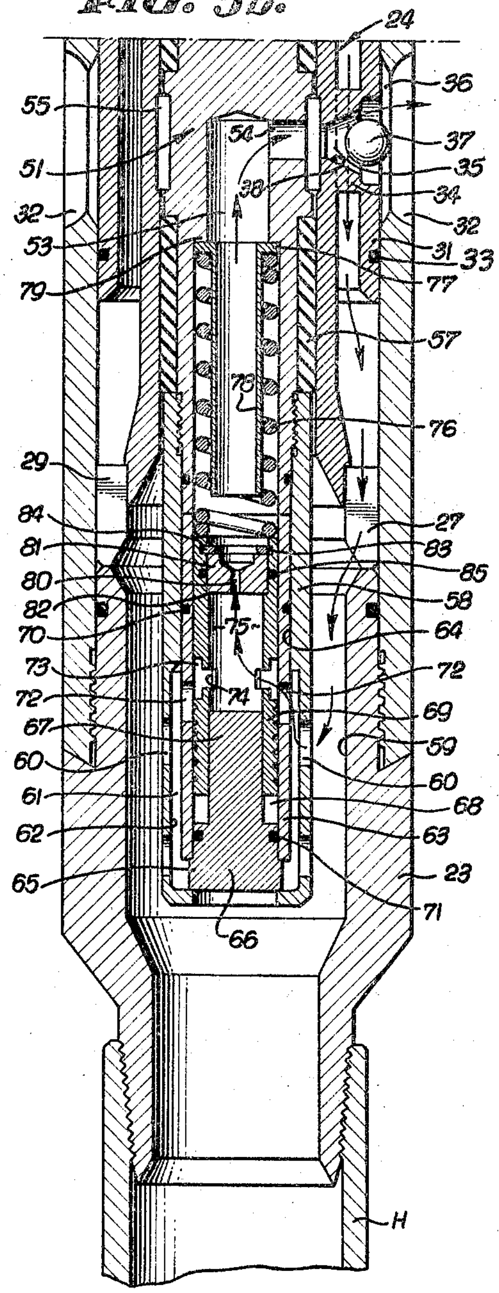


FIG. 3b.



INVENTOR.
DAVID V. CHENOWETH
BY Bernard Kriegel
ATTORNEY.

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MULTIPLE ZONE INJECTION APPARATUS FOR WELL BORES

David V. Chenoweth, Houston, Tex., assignor to Baker Oil Tools, Inc., City of Commerce, Calif., a corporation of California

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17 Claims. (Cl. 166—115)

ABSTRACT OF THE DISCLOSURE

Apparatus for injecting fluids from the top of a well bore through a single string of tubing individually into a plurality of formation zones, an individual flow regulator in the tubing at each zone embodying an orifice through which the fluid is forced, the pressure drop through each orifice being held substantially constant by a throttle valve device to insure substantially constant rate of flow through the orifice regardless of variations in upstream or downstream pressures. In addition, each regulator inlet from the tubing is substantially below the regulator outlet to cause solids in the tubing fluid stream to drop to the bottom of the tubing and prevent their interfering with operation of each regulator.

The present invention relates to well bore apparatus, and more aprticularly to apparatus for injecting fluids into a well bore.

There are economic advantages to injecting fluid into a plurality of well bore formation zones through use of a single string of tubing, since it eliminates the need for installing multiple tubing strings in the well bore and the provision of associated relatively costly multiple string packers and related equipment. In the present case, a single string of tubing is used for injecting fluids into a plurality of zones in a well bore, the injection of fluid into each zone occurring at a predetermined and constant volumetric rate through use of an individual flow regulator, the rate of injection remaining constant despite variations in the fluid pressure in the tubing string or in the formation zone, or both. The flow regulator is so disposed in the tubing string as to prevent solids entrained in the fluid stream from passing through the regulator and possibly plugging it or interfering with its proper operation. The flow regulators may be of the retrievable type, in that they may be moved through the tubing string and latched in desired position therein, and, if desired, withdrawn through the tubing string to the top of the well bore. Since only a single tubing string is used in the well bore, the packers associated therewith in isolating the formation zones from one another can be relatively simple, being either of the permanent or retrievable type.

This invention possesses many other advantages, and has other purposes which may be made more clearly apparent from a consideration of a form in which it may be embodied. This form is shown in the drawings accompanying and forming part of the present specification. It will now be described in detail, for the purpose of illustrating the general principles of the invention; but it is to be understood that such detailed description is not to be taken in a limiting sense, since the scope of the invention is best defined by the appended claims.

Referring to the drawings:

FIGURE 1 is a diagrammatic view of a cased well bore, with apparatus embodying the invention therein for injecting fluids into longitudinally spaced formation zones;

FIG. 2 is a longitudinal section through one form of flow regulator for injecting fluid into the well bore;

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FIGS. 3*a* and 3*b* together constitute a longitudinal section through a flow regulator installed in the tubing string, FIG. 3*b* being a lower continuation of FIG. 3*a*.

As disclosed in the drawings, it is desired to inject fluid at a predetermined rate into each of a plurality of zones A, B, C, D in a well bore E, in which a string of casing F has been installed, the casing string having longitudinally spaced perforations **10**, **11**, **12** or **13** therethrough at each formation zone. The zones are separated from one another by well packers **14**, **15**, **16** set in leakproof relation in the casing and also sealed with respect to a tubing string H connected to each of the packers, and which extends through a well head J at the top of the well bore. These well packers may be of the permanent or retrievable type, as desired. As disclosed, a flow regulator **17** is incorporated in the tubing string below the lowermost packer **14** and between the packers **14**, **15** and **15**, **16** for the purpose of controlling the rate at which fluip pumped down through the tubing string H can be injected through the perforations into each formation zone A, B, C. Each flow regulator is of the type that will cause the fluid to be injected at a constant volumetric rate into the formation zone.

The flow regulators connected to the tubing string are disclosed in FIG. 1 for purposes of convenience of illustration as being of larger diameter than the inside diameter of the diagrammatically illustrated packers **14**, **15**, **16** which are in sealed relation with the tubing string. It is to be understood, however, that the flow regulator portions of the tubing string may have a diameter no greater than the passage through the packers, assuming the latter to be of the permanent type, so that the tubing string can be withdrawn from the well bore, if desired. In the event that the packers are of the retrievable type, then the flow regulators can be of a larger diameter than the diameter of the packer passages, since they can be withdrawn from the well bore simultaneously with the release and elevation of the well packers from and within the well casing.

As illustrated in FIG. 1, the uppermost zone D, if desired, can be separated injected with fluid pumped through tubing M that has a surface flow regulator **18** therein, the fluid from the surface flow regulator discharging into the annulus **19** above the uppermost well packer **16** and between the tubing string H and casing F.

The flow regulators **17** below the lowermost packer and between the packers can be of essentially the same type, such as of the retrievable type illustrated in FIGS. 3*a* and 3*b*. They could also be of a non-retrievable type, if desired. As shown therein, each flow regulator **17** includes an outer housing structure **20** consisting of an upper sub **21** threadedly secured to a section of the tubing string H thereabove, and which is also threadedly secured to the main outer housing or body section **22**, the lower end of which is threadedly attached to a lower housing or body sub **23**, which is, in turn, threadedly secured to a lower section of the tubing string H. Disposed within the outer housing **20** is an inner housing **24**, which comprises a central cylindrical or sleeve-like portion **25** having an upper flange **26** adapted to bear against the lower end of the upper sub **21** and a lower flange **27** adapted to bear against the upper end of the lower housing sub **23**. These flanges have longitudinal passages **28**, **29** therethrough to permit fluid to flow through the upper housing sub **21** and the passages **28**, between the annular space **30** between the inner housing **24** and outer housing section **22**, and through the lower flange passages **29** into the lower sub **23**. Spaced outwardly from the inner housing portion **25** is a sleeve **31** extending across circumferential spaced ports **32** in the outer housing member **22**, and which has seal rings **33** thereon on opposite sides of the ports sealingly engaging the inner wall of the housing section **22**. A boss **34** interconnects the inner housing portion **25** and the outer sleeve **31** which has a port **35** extending therethrough opening into a peripheral groove **36** in the outer housing which communicates with the outer housing ports **32**. A check valve or back pressure valve member **37** is located in the boss and is adapted to move laterally inwardly into engagement with a valve seat **38** surrounding the boss passage to prevent inward flow of fluid through its port **35**. Outward movement of the ball valve element is limited by its engagement with the outer housing member **22**. The outer ports **32** are formed as slots having a width less than the diameter of the ball valve member **37**, so that the latter will be retained within the passage **35** extending through the boss.

The main portion of the flow regulator device is located within the inner housing member **24** and is releasably retained therewithin. Such device includes a central mandrel **40** composed of several sections. An upper tubular lock section **41** is provided having a plurality of circumferentially spaced slots **42** therein in which locking dogs or latch members **43** are mounted on pivot pins **44** extending across the slots and suitably secured to the mandrel section. The lower lock portions **45** of these lock dogs **43** are adapted to be received within an internal circumferential groove **46** in the upper portion of the inner housing member **24**, being urged outwardly into such groove by helical compression springs **47** bearing against the inner base of each slot and also against the dog portions **45**. When the lock dogs have been expanded outwardly into the groove **46**, which will prevent downward movement of the lock mandrel **41** within the housing structure, upper nose portions **48** of the lock dogs or latches project partially into the central passage **49** through the mandrel section. Through use of a suitable retrieving tool (not shown) of a known type, a probe of the latter will extend into the mandrel passage **49**, engaging the noses **48** of the lock dogs to shift their upper portions outwardly and retract their lower portions **45** inwardly from the housing groove **46**, thereby releasing the mandrel from the housing. At the same time, as is known in the art, an overshot, or the like, on the retrieving tool moves over the upper head portion **50** of the lock section for the purpose of elevating the mandrel **40** through the tubing string H.

The lower end of the lock section **41** is threadedly secured to a flow section **51** of the mandrel that has a solid upper head portion **52** and a central passage **53**, the upper end of which opens through a side port **54** into a peripheral groove **55**. This groove is disposed opposite the passage **35** through the inner housing member **24** and its boss **34** when the lock dogs **43** are expanded outwardly into the groove **46**. The flow mandrel section **51** carries a suitable seal ring **56** for sealing against the wall of the inner housing portion **25** above the port **35**, and also a lower seal ring **57** for sealing against the wall of the inner housing section below the port, as illustrated in FIGS. 3*a* and 3*b*. The upper seal **56** is held on the flow mandrel section **51** by the lock mandrel section **41**, and the lower seal **57** is held on the flow mandrel section by a regulator housing section **58** of the mandrel structure **40** that will extend downwardly into the lower housing sub **23** in spaced relation to the inner wall **59** of the latter.

The regulator housing **58** has a plurality of circumferentially spaced side ports **60** for the flow of fluid from the lower sub **23** into an annular space **61** between the lower inner wall **62** of the housing and a cylinder sleeve **63** within the housing, the upper end of which is disposed within a smaller internal diameter portion **64** of the housing **58** and abuts the lower end of the flow mandrel section **51**. The lower end of the cylinder sleeve **63** engages a flange **65** of a lower plug **66** piloted within the lower end of the cylinder sleeve **63** and having a reduced diameter stem portion **67** extending upwardly within the latter and in spaced relation therewith to define an annular cylinder space **68** therewithin in which a piston or valve sleeve **69** is slidable, this piston or valve sleeve also being slidable along the inner wall of the cylinder sleeve **63**. Leakage of fluid in an upward direction between the cylinder sleeve **63** and housing **58** is prevented by a suitable seal ring **70** on the cylinder sleeve engaging the inner wall **64** of the housing; whereas, leakage of fluid between the plug **66** and the cylinder **63** is prevented by a suitable side seal ring **71** on the plug engaging the inner wall of the cylinder sleeve.

Fluid flowing through the housing ports **60** and into its annular passage **61** can flow through a pair of diametrically opposite side ports **72** in the cylinder sleeve into a peripheral groove **73** in the piston that communicates through a pair of opposed ports **74** with the interior passage **75** of the piston above the plug stem **67**. The piston **69** is urged in a downward direction within the housing and along the plug stem **67** by a helical compression spring **76**, the lower end of which engages the upper end of the piston, and the upper end of which bears against the flange **77** of a protector tube **78** disposed within the spring, the flange bearing against the downwardly facing shoulder **79** of the flow mandrel section **51**. The spring **76** urges the piston **69** downwardly to its fullest extent in which it fully opens the cylinder sleeve ports **72**, so that fluid can flow through the full area of such ports and through the piston ports **74** into the interior **75** of the latter. The fluid flows upwardly within the piston and then through a choke orifice **80** provided centrally through an orifice plate **81** mounted in the piston or sleeve valve, the lower end of this plate bearing against an upwardly facing piston shoulder **82**, the plate being retained thereagainst by a split snap retaining ring **83** overlying the orifice plate and disposed within an internal groove **84** in the piston. Leakage of fluid around the exterior of the orifice plate **81** is prevented by a side seal ring **85** on the piston sealing against the periphery of the plate.

The fluid pressure acting upwardly upon the orifice plate **81** tends to shift the piston **69** upwardly along the cylinder sleeve **63** against the force of the spring **76** to move the piston partially across the ports **72** of the cylinder sleeve for the purpose of decreasing their effective area and throttling the flow of fluid therethrough and through the piston ports **74** to the interior **75** of the piston. The area of the orifice **80** is chosen to obtain a desired fluid pressure drop therethrough. If this fluid pressure drop tends to vary, the piston is shifted longitudinally in the cylinder sleeve **63** to correspondingly vary the extent of throttling of the ports **72** through the cylinder sleeve **63** and the pressure of the fluid on the upstream side of the orifice plate **81**. Thus, if the upstream pressure tends to increase relative to the downstream pressure, or the downstream pressure drop relative to the upstream pressure, so as to increase the pressure differential across the orifice plate **81**, the piston **69** is shifted upwardly within the cylinder sleeve against the force of the spring to reduce the flow area through the sleeve ports **72** and throttle the flow of fluid therethrough to lower its pressure to the desired value to produce the proper pressure drop through the orifice plate. Similarly, should the downstream pressure on the orifice plate increase, or the upstream pressure decrease, the pressure drop across the orifice plate would decrease, the spring **76** shifting the piston **69** downwardly to increase the flow area through the cylinder ports **72** and causing the fluid pressure passing into the piston passage **75** to increase, thereby again restoring the pressure drop across the orifice plate to the desired value. By maintaining this pressure drop constant, the rate of flow of fluid through the orifice **80** is maintained at a constant value.

The fluid discharging from the orifice plate **81** passes upwardly through the protector sleeve or tube **78** and into the central passage **53** of the flow mandrel section, flowing outwardly through the side port **54** and through the boss port **35** and the housing ports **32** to the exterior of the housing structure **20**.

Each flow regulator **17** in the tubing string will have a required area of orifice **80** through its orifice plate, depending upon the pressure drop through the orifice plate desired, which is determined by the rate fluid is to flow through the orifice plate **81**. This governs the rate of flow of fluid that will be pumped through the perforations in the casing into the associated formation zone. Assuming that all of the well packers **14**, **15**, **16** are set in the well casing F, as disclosed in FIG. 1, and with all of the flow regulators **17** in place, fluid is pumped down through the tubing string H, passing downwardly through the annular space **30** between the housing sleeve **22** and the inner housing section **24** into the lower sub **23** of the uppermost regulator **17**. A portion of the fluid will flow through the housing ports **60** of the uppermost regulator and through the cylinder ports **72** and piston ports **74** to the interior **75** of the piston **69**, flowing through the orifice **80** and up through the protective tube **78** and the mandrel passage **53** for outward movement through the mandrel port **54**, inner housing port **35**, and outer housing ports **32** into the well casing, from where the fluid will pass through the casing perforations **12** into the formation zone C between the uppermost and intermediate well packers **16**, **15**. The uppermost flow regulator **17** will regulate the flow of fluid passing therethrough by the throttling action of the piston **69** on the cylinder ports **72** to maintain the pressure drop across the orifice plate **81** substantially constant.

Fluid in the tubing string H will also be pumped downwardly from the lower housing sub **23** at the zone C through the tubing string H therebelow for continued downward passage into the flow regulator **17** between the intermediate and lower well packers **15**, **14**, such fluid passing around the exterior of the regulator housing **58** and upwardly through the internal regulator mechanism for discharge through the housing ports **32** into the well casing and for outward passage through the perforations **11** into the formation zone B between the intermediate and lower packers.

Fluid in the tubing string will also be pumped downwardly through the tubing string H below the intermediate flow regulator **17** for passage between the inner and outer housing structures **24**, **20** of the lower regulator **17** into the lower housing or body sub **23** of the lower regulator for upward passage through its internal regulator mechanism and for discharge through the ports **32** into the casing below the lower packer **14** for passage through the lowermost set of perforations **10** into the well formation zone A therearound.

The fluid in the single tubing string H is caused to be discharged from each flow regulator **17** into the casing at a predetermined rate of flow. Such rates of flow may be equal for all flow regulators, if desired, or the proper orifice size can be selected to secure a different rate of flow at two or more of the regulators. The fluid being discharged from each flow regulator **17** into the well casing is independent of the fluid being discharged from the other regulators, but will, nevertheless, result in the injecting of the desired volumetric rate of liquid flow through the perforations of each zone.

In the event that fluid tends to flow reversely from a formation zone back through the regulator, such action is prevented by the check valve, the ball valve member **37** of which will shift laterally inwardly into engagement with its companion seat **38**. Thus, in the event that one of the flow regulator devices is removed or retrieved from the housing structure **24**, the formation fluid cannot flow reversely into the tubing string H.

It is to be noted that the injected fluid must pass downwardly around the exterior of each flow regulator within the tubing H and must completely reverse its direction of flow in passing upwardly through the interior of the flow regulator. This change in flow direction causes entrained solids to drop out of the liquid stream into the tubing string H, preventing them from passing up through the regulator mechanism. The entrained solids will be carried downwardly past the lowermost regulator and will drop downwardly therebelow into the tubing string, which has a plug **90**, or is bullnosed at its lower end, for catching the entrained solids. The tubing **91** below the lowermost regulator **17** may have an adequate length to insure its capacity to retain all of the entrained solids in the fluid pumped into the tubing string H.

The flow regulators illustrated in FIGS. 3*a* and 3*b* are of the retrievable type. If desired, the tubing string H can be run in and placed in sealed relation with the well packers **14**, **15**, **16**, or the tubing string and well packers may be run in together, the housing structures **20**, **24** being appropriately located in the tubing string. The lowermost flow regulator is then lowered through the tubing string on a suitable running-in tool (not shown) which retains its latches **43** in their retracted position until the lowermost regulator housing **24** is reached, at which time the latches are released and will be expanded by their springs **47** into the circumferential lock groove **46**, which locates the mandrel seals **56**, **57** on opposite sides of the housing port **35**, and which also prevents the fluid pumped subsequently down through the tubing string from shifting the mandrel and regulator device from the housing **24** therearound.

The flow regulators in upward sequence are then run successively into the tubing string H and placed in their companion housing structures **20**, **24**, with the lock dogs **43** being permitted to be expanded out into their respective lock grooves **46**, until all of the flow regulators are in place.

Fluid in the desired volume and under the required pressure is then pumped down through the tubing string H and through the flow regulators **17** through the several perforations **10**, **11**, **12** into the different zones A, B, C, the flow regulators maintaining the rate of flow at their respective desired constant values in the manner described above. The well packers **14**, **15**, **16** may have previously been set against the well casing F, or they may be of the hydraulically expandable type in which the fluid pressure in the tubing string will effect expansion of the packers against the wall of the well casing.

If at any time the regulators are to be removed from the tubing string, a suitable retrieving tool (not shown) is lowered on a wire line through the tubing string H to retract the lock dogs **43** and become coupled to the upper head portion **50** of the lock mandrel section **41** of each regulator, permitting the entire regulator mechanism to be removed from the inner housing and withdrawn through the tubing string to the top of the well bore. The uppermost, intermediate, and lowermost regulators are thus successively retrieved.

It is accordingly, apparent that a multiple zone injection apparatus has been provided which will insure the injection of the desired quantity of fluid into each of the formation zones. As many packers and regulators can be used as necessary in connection with the single string of tubing, assurance being had that the desired quantity of fluid will be injected from each regulator between each pair of well packers, and also from the regulator below the lowermost packer. Such injection can take place with the use of one string of tubing, eliminating the need for multiple or parallel strings of tubing and their associated relatively complex well packers.

If desired, fluid may be injected into a zone D above the uppermost well packer **16** through use of a surface flow regulator **18**. As disclosed in FIG. 1, perforations **13** are provided in the well casing opposite this uppermost zone above the uppermost well packer **16**, and the tubing string M is connected to the well head J for discharging fluid into the annulus **19** between the other tubing string H and the well casing F. The surface flow regulator **18** is of the same type as the flow regulator illustrated in

FIGS. 3*a* and 3*b*. As shown, it includes a main housing or body **20***a* threadedly secured to sections **92, 93** of the tubing M to hold them in spaced relation. Fluid will flow from one tubing section **92** through the inlet end **94** of the housing and into an annular space **61***a* between the cylinder sleeve **63** and the enlarged bore **62***a* of the housing, flowing inwardly through the cylinder ports **72** and through the ports **74** of the piston **69** which is slidable in the cylinder, and also in the annular space **68** between the plug stem **67** and the cylinder, the plug being piloted within the cylinder with its flange **65** engaging the end of the latter and being held in place by a cross pin **95** at its outer end extending in opposed bores **96** in the outer end portion of the housing.

The fluid discharging through the piston ports **75** to its interior will flow through the orifice **80** of the orifice plate **81** and through the protector tube **78** and the central outlet **32***a* of the housing into the tubing section **93** on its downstream side, flowing therethrough into the tubing-casing annulus **19** for outward flow through the casing perforations **13** into the uppermost zone D. The spring **76** tends to shift the piston **69** to a position fully opening the cylinder ports **72**; whereas, the pressure differential across the orifice plate **81** tends to shift the piston in a downstream direction to throttle the flow of fluid through the ports **72**, in the same manner as the regulator disclosed in FIGS. 3*a* and 3*b*, for the purpose of maintaining the pressure drop across the orifice plate substantially constant, and consequently maintaining the rate of flow of fluid into the tubing-casing annulus **19** and through the perforations **13** into the uppermost zone D substantially constant.

I claim:

1. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore in sealed relation to said tubing string to isolate the formation zones from one another; a separate flow regulator in said tubing string at each zone to conduct fluid from said tubing string into each zone; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator for passage into its associated formation zone; each of said flow regulators further including means for maintaining the fluid pressure drop across its flow restricting means substantially constant.

2. In apparatus for injecting fluid into a plurality of formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and in sealed relation to said tubing string to isolate the formation zone regions from one another; a separate flow regulator in said tubing string at each formation zone region to conduct fluid from said tubing string into each formation zone region; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator for passage into its associated formation zone region; each flow regulator having an outlet through which fluid is discharged for passage into its associated formation zone region, and an inlet substantially below said outlet for receiving fluid from the interior of said tubing; each of said flow regulators further including means for maintaining the fluid pressure drop across its flow restricting means substantially constant.

3. In apparatus for injecting fluid into a plurality of formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and in sealed relation to said tubing string to isolate the formation zone regions from one another; a separate flow regulator in said tubing string at each formation zone region to conduct fluid from said tubing string into each formation zone region; each flow regulator including an orifice to reduce the pressure of the fluid flowing from the tubing string to its associated formation zone region, whereby reduced pressure fluid is discharge individually from each flow regulator for passage into its associated formation zone region, each flow regulator having an outlet through which fluid is discharged for passage into its associated formation zone region, and an inlet substantially below said outlet for receiving fluid from the interior of said tubing; each of said flow regulator further including means for maintaining the fluid pressure drop across its orifice substantially constant.

4. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore in sealed relation to said tubing string to isolate the formation zones from one another; a separate flow regulator in said tubing string at each zone to conduct fluid from said tubing string into each zone; each flow regulator including an orifice to reduce the pressure of the fluid flowing from the tubing string to its associated formation zone, whereby reduced pressure fluid is discharged individually from each flow regulator for passage into its associated formation zone; each of said flow regulators further including means for maintaining the fluid pressure drop across its orifice substantially constant.

5. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore in sealed relation to said tubing string to isolate the formation zones from one another; a separate flow regulator in said tubing string at each zone to conduct fluid from said tubing string into each zone; each flow regulator including an orifice to reduce the pressure of the fluid flowing from the tubing string to its associated formation zone, whereby reduced pressure fluid is discharged individually from each flow regulator for passage into its associated formation zone; each of said flow regulators further including means upstream of its orifice for maintaining the fluid pressure drop across its orifice substantially constant.

6. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore in sealed relation to said tubing string to isolate the formation zone regions from one another; a separate flow regulator in said tubing string at each formation zone region to conduct fluid from said tubing string into each formation zone region; each flow regulator including an orifice to reduce the pressure of the fluid flowing from the tubing string to its associated formation zone region, whereby reduced pressure fluid is discharged individually from each flow regulator for passage into its associated formation zone region; each flow regulator having an outlet above its orifice through which fluid is discharged for passage into its associated formation zone region, each flow regulator further including means upstream of and below its orifice for maintaining the fluid pressure drop across its orifice substantially constant.

7. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore in sealed relation to said tubing string to isolate the formation zones from one another; a separate flow regulator in said tubing string at each zone to conduct fluid from said tubing string into each zone; each flow regulator including a valve body having a port, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid flowing from said body port to its associated formation zone, whereby reduced pressure fluid at a substantially constant flow rate is discharged individually from each flow regulator for passage into its associated formation zone.

8. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zone regions from one another; a separate flow regulator in said tubing string at each formation zone region to conduct fluid from said tubing string into each formation zone region; each flow regulator including a valve body having a port, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve above said port to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid received from said body port, each flow regulator having an outlet above its orifice through which fluid is discharged for passage into its associated formation zone region, whereby reduced pressure fluid at a substantially constant flow rate is discharged individually from each flow regulator for passage into its associated formation zone region.

9. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator and through its associated tubing string outlet for passage into its associated formation zone; each of said flow regulators further including means for maintaining the fluid pressure drop across its flow restricting means substantially constant.

10. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator and through its associated tubing string outlet for passage into its associated formation zone; and valve means at each tubing string outlet for preventing reverse flow of fluid through said tubing string outlet.

11. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zone regions from one another; said tubing string having a separate outlet for each formation zone region; a separate flow regulator for each formation zone region movable through the tubing string from the top of the well bore to a location therein at an associated formation zone region and having an outlet communicating with said tubing string outlet at its associated formation zone region; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator and through its associated tubing string outlet for passage into its associated formation zone region; each flow regulator having an inlet substantially below the outlet of said flow regulator for receiving fluid from the interior of said tubing; each of said flow regulators further including means for maintaining the fluid pressure drop across its flow restricting means substantially constant.

12. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including a valve body having a port, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid received from said body port and flowing to its associated tubing string outlet and its associated formation zone, whereby reduced pressure fluid at a substantially constant flow rate is discharged individually from each flow regulator for passage into its associated formation zone.

13. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including a valve body having a port; a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid received from said body port and flowing to its associated tubing string outlet and its associated formation zone, whereby reduced pressure fluid at a substantially constant flow rate is discharged individually from each flow regulator for passage into its associated formation zone; and valve means at each tubing string outlet for preventing reverse flow of fluid through said tubing string outlet.

14. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zone regions from one another; said tubing string having a separate outlet for each formation zone region; a separate flow regulator for each formation zone region movable through the tubing string from the top of the well bore to a location therein at an associated formation zone region and having an outlet communicating with said tubing string outlet at its associated formation zone region; each flow regulator including a valve body having a port below said flow regulator outlet, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve between said flow regulator port and said flow regulator outlet to

shift said sleeve valve relative to said body port and to reduce the pressure of the fluid flowing from said body port to its associated formation zone region, whereby reduced pressure fluid at a substantially constant flow rate is discharged from each flow regulator outlet for passage through its associated tubing string outlet into its associated formation zone region.

15. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zone regions from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zone regions from one another; said tubing string having a separate outlet for each formation zone region; a separate flow regulator for each formation zone region movable through the tubing string from the top of the well bore to a location therein at an associated formation zone region and having an outlet communicating with said tubing string outlet at its associated formation zone region; each flow regulator including a valve body having a port below said flow regulator outlet, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve between said flow regulator port and said flow regulator outlet to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid flowing from said body port to its associated formation zone region, whereby reduced pressure fluid at a substantially constant flow rate is discharged from each flow regulator outlet for passage through its associated tubing string outlet into its associated formation zone region; and valve means in each tubing string outlet for preventing reverse flow of fluid through said tubing string outlet.

16. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including flow restricting means to reduce the pressure of the fluid received from said tubing string, whereby reduced pressure fluid is discharged individually from each flow regulator and through its associated tubing string outlet for passage into its associated formation zone; each flow regulator further including means for maintaining the fluid pressure drop across its flow restricting means substantially constant; and valve means in each regulator for preventing reverse flow of fluid from said tubing string outlet and through said regulator.

17. In apparatus for injecting fluid into a plurality of longitudinally spaced formation zones from the top of a well bore: a tubing string in the well bore; packing means adapted to be set in the well bore and being in sealed relation to said tubing string to isolate the formation zones from one another; said tubing string having a separate outlet for each formation zone; a separate flow regulator for each zone movable through the tubing string from the top of the well bore to a location therein at an associated zone and having an outlet communicating with said tubing string outlet at its associated zone; each flow regulator including a valve body having a port, a sleeve valve movable across said body port to control the effective area thereof through which fluid from said tubing string can flow, orifice means secured to said sleeve valve to shift said sleeve valve relative to said body port and to reduce the pressure of the fluid received from said body port and flowing to its associated tubing string outlet and its associated formation zone, whereby reduced pressure fluid at a substantially constant flow rate is discharged individually from each flow regulator for passage into its associated formation zone; and valve means in each regulator for preventing reverse flow of fluid from said tubing string outlet and through said regulator.

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CHARLES E. O'CONNELL, *Primary Examiner.*

D. H. BROWN, *Assistant Examiner.*