April 4, 1967 H. KOPLIN 3,312,280

OIL WELL COMPLETION

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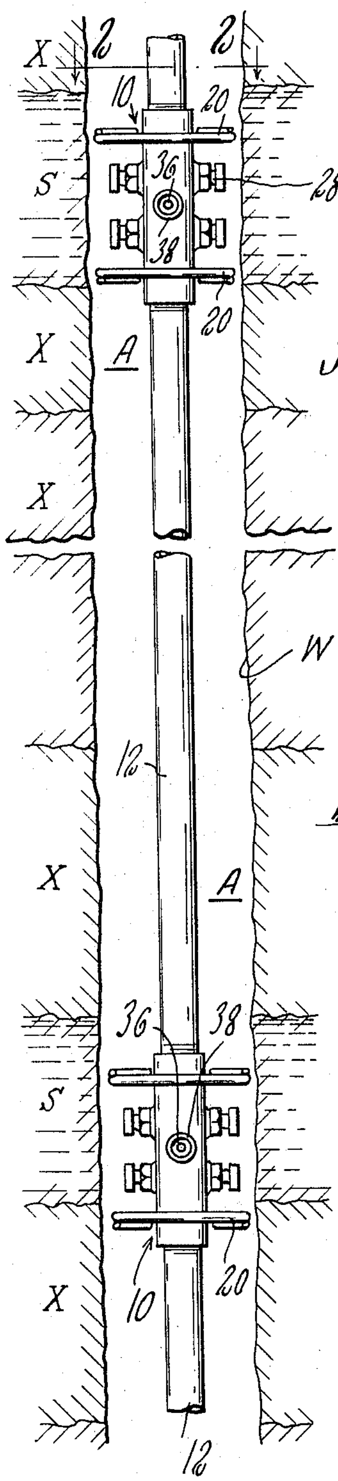

Fig. 1.

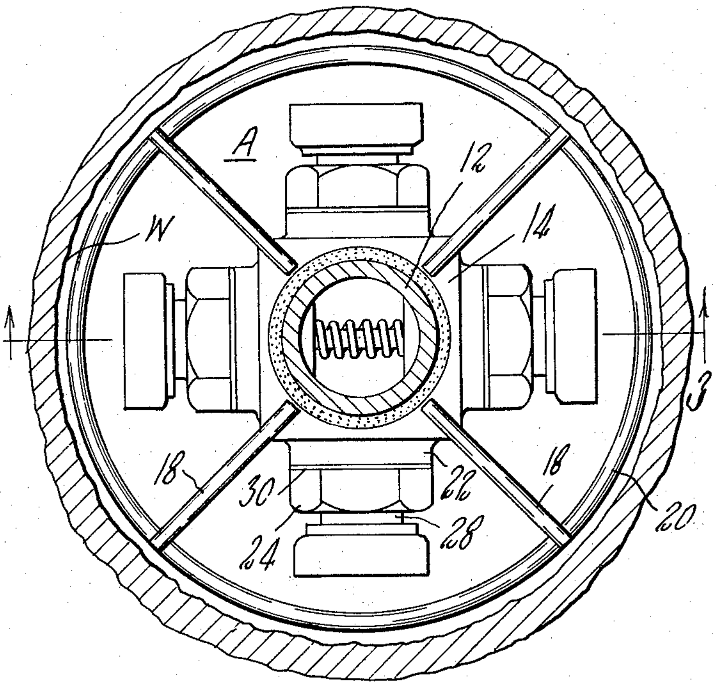

Fig. 2.

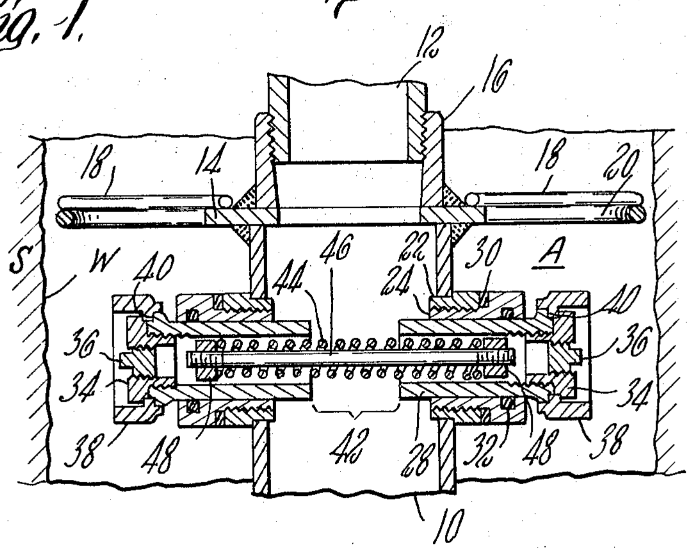

Fig. 3.

OIL WELL COMPLETION

Filed March 10, 1965 2 Sheets-Sheet 2

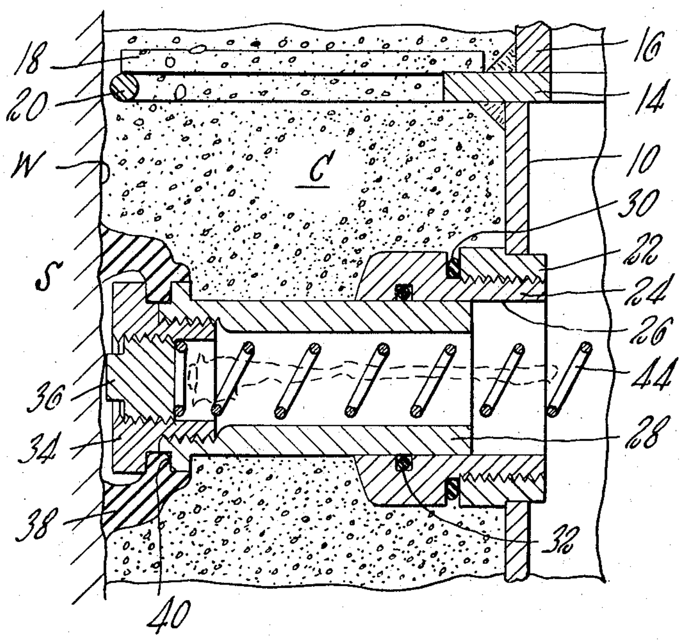

Fig. 4.

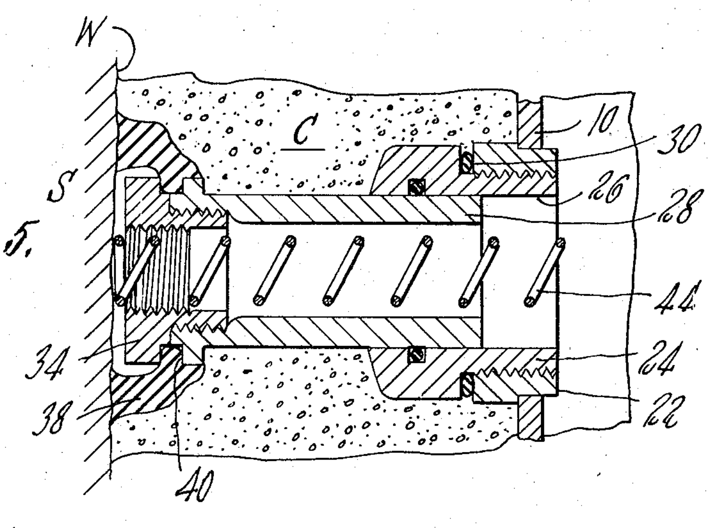

Fig. 5.

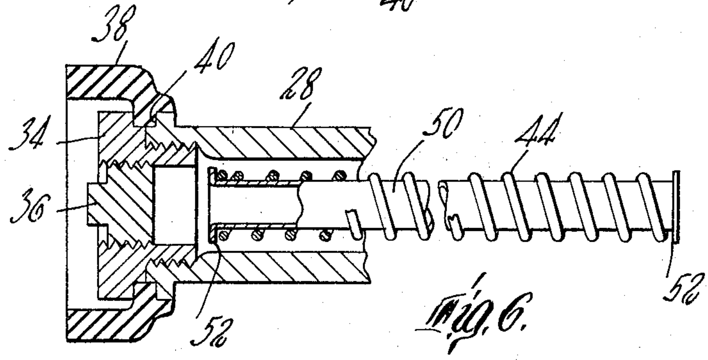

Fig. 6.

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OIL WELL COMPLETION

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This invention relates to oil well completion techniques and devices for selectively connecting sections of well casings to various strata. In most oil well bores there are zones of permeability interspersed with water sands, shale sands, or non-oil bearing zones or layers. It is desired that these various non-oil bearing strata all be excluded from connection to the well output for obvious reasons, and therefore, it has been the practice in some oil well completion methods, after drilling of the well bore, to line the bore with a casing of cement, and then to perforate certain portions or strata levels of the cement casing by means of explosive shots, often using nitroglycerin for this purpose. This cementing and perforating by "shooting" is often unsuccessful in obtaining the best results because sometimes the shots fracture the cement used to line the casing in the well bore at undesired points. Sometimes also the shots fail to explode or fail to penetrate the cement lining. At other times, the high temperatures generated by the explosive may glaze the surface of the surrounding soil or sand and cause it to become less permeable than is desired. The use of explosives is also hazardous in itself.

Because of the various shortcomings of this method of oil well completion, other techniques have been developed, calling for the insertion of a tubular metallic casing into the well bore, this casing having thereon transversely slidable or extensible strata connection elements forcibly moved outwardly from the tubular casing by hydraulic pressure applied from within the casing. When extended, these connection elements are intended to contact with and provide ducts leading to preselected oil bearing strata. In this method the cement is placed in the annular space between the outside of the casing and the walls of the well bore by being forced downwardly through the casing and outwardly into the annular space surrounding the casing at the bottom, flowing into and filling the space from the bottom upwardly to a level above the duct-providing strata connection elements. In this method the connection elements can be extended hydraulically before the cement is introduced or shortly after the cement is introduced but before it has time to set. In either case, special precautions have to be taken or arrangements made to avoid having the cement enter the connection elements and the excess cement in the tubular casing must be removed in some fashion before the well can produce. Any cement inside the casing must be removed because the final step in establishing connection through the duct-providing connection elements is to dissolve or destroy a closure plug or core in each of the elements by means of chemicals or heat applied from within the tubular casing and cement in the casing prevents this. Besides requiring a source of hydraulic pressure at the well site, another drawback in this technique is the need for making all joints in the casing and between the casing and connection elements sufficiently tight that the hydraulic pressure used will force the connector elements outwardly in the proper fashion at the desired time. Otherwise, enough pressure may not be available to operate all of the desired connection elements, or some of them may be only partly extended and fail to make proper contact with the selected portions of the well bore.

The present invention avoids the hazards and difficulties inherent in the above-described well completion methods, and simplifies the equipment used and its manipulation so that oil well cementing and completion can be less expensive and more certain than formerly.

Accordingly, among the objects of this invention are to provide a method and a tool for completing and cementing an oil well whereby a cement well bore lining will be kept free from cracks or voids; whereby transverse connection from a central tube is dependably made to selected strata outside of the central tube and the cement well bore lining; and wherein the central tube is kept clear of the cement surrounding the tube. Explosives and hydraulic pressure are not required or used in this method or in the tool for carrying out oil well completion according to the invention.

One object is to provide a method and means for well completion and cementing in which no special tools or rigs are required other than the completion tool itself. Another object is to provide a tool of simple design, using a number of standard, readily available structural parts, but one that easily may be adapted or converted in the field to satisfy changing conditions that may be encountered. A further object is to provide extendable strata connection elements operated mechanically in a dependable fashion from within a tubular well casing, these elements making self-adjustable resilient contact with the well bore. Still another object is to trigger the extension of the connection elements by the application of acids or other chemically active materials against chemically destructible spring-holding members in the tubular casing.

These and other objects of the invention are met by providing an elongated hollow casing in the form of a tubular element for insertion into a well bore and by providing this tubular element with transversely positioned strata connection elements retracted almost entirely within the tube but biased toward ejected positions by spring means within the tube. The springs are held in compressed condition and the connection elements are held in retracted position by means of chemically destructible elements such as bolts or links made of some metal that is readily dissolved by an acid or other suitable chemical. Ejection of the connector elements from the tube is caused by applying a suitable chemical to the destructible elements within the tube so that the springs are released and will thereafter extend themselves and forcibly eject the connectors from the tube into resilient contact with the walls of the well bore.

Only after the tool is in this condition, with connectors extended, is the cemented placed in the space between the outside of the tube and the well bore, and this placing of the cement is not done through the inside of the tubular member but only from entirely outside the tube in the annular space at the top of the well bore surrounding the tube.

After the cement has set, the same acid or other chemical in the casing that was used to destroy the spring-holding bolts or links (or added amounts of this chemical, or another chemical) is used to dissolve or destroy closure plugs in the extended strata connection elements so that clear passageways are provided in the elements from the strata in the well, through the cement liner and into the tubular well casing. The retractable connection elements, their closure plugs, the biasing springs and the spring-holding links are preferably designed for easy removal and replacement in the field before the tool is put into use, so that changes can be made in any particular tool to suit various conditions that may arise.

Other objects, some advantages and further details of that which is believed to be novel and included in this invention will be clear from the following detailed description and claims, taken with the accompanying drawings in which are illustrated some examples of oil well completion tools embodying the present invention and incroporating chemically destructible spring-holding elements and other features useful in carrying out the preferred method.

In the drawings:

FIG. 1 is a vertical sectional view of a well bore showing a tool according to the present invention inserted therein;

FIG. 2 is an enlarged transverse sectional view through the well bore and tool of FIG. 1 as if on the line **2—2** thereof;

FIG. 3 is a vertical sectional view of the bore and of the tool as if on the line **3—3** of FIG. 2;

FIG. 4 is a further enlarged cross-section similar to a portion of FIG. 3 but with parts in a different condition and showing cement applied in the annular space between the outer walls of the tube and the bore of the well;

FIG. 5 is another cross-section like FIG. 4 but showing parts of the device in still another condition, and

FIG. 6 is an enlarged view like a portion of FIG. 3 showing a modified form of chemically destructible spring-holding element.

The tool

Preferred embodiments of a tool useful in carrying out this invention are shown in the drawings. Some further modifications of this tool are not illustrated but are described hereafter at appropriate points.

As shown in FIG. 1, one or more tool sections **10**, each of any desired length, are joined to pipe sections **12**, which may be any desired standard threaded pipe lengths, to form an elongated hollow casing or tubular tool element intended to be inserted lengthwise into a well bore W. The body of the tool section may be square in cross-section as shown, or it may be round. This elongated tube, with as many tool sections and as many pipe sections as required, is preferably tightly closed at the bottom and open at the top. In the example shown, at the top and bottom of each tool section **10** is an end plate **14**, carrying a threaded pipe fitting **16** adapted to be coupled to the end of a pipe section **12**. The end plates and fittings may be welded together and to the tool section. For purposes that will appear later, the end plates may also carry a number of radially extending feeler arms **18**, and the outer ends of these arms may or may not be joined by a guard ring **20** to hold the outer ends of the feelers in proper position. Welds again may be used to hold these parts together.

At selected spacings along each tool section a number of oppositely positioned holes are provided, in each of which is suitably secured an internally threaded fitting **22**. Each fitting threadedly receives an outside threaded shouldered nut **24**, having an inner smooth bore **26** that slidably receives a laterally extendable member shown as a sleeve **28**. A suitable sealing ring **30**, between the shoulder on nut **24** and the end of fitting **22**, may be used to make a fluid-tight joint between these members. A similar ring **32** of O-shape, located in a groove inside the nut **24**, may provide a sliding fluid-tight joint with the sleeve **28**.

The outer end of each slidable sleeve **28** is closed as by a removable closure member **34**, threadedly received at the end of the sleeve, and having a core or plug portion **36**, made of zinc, magnesium, aluminum, or other metal or material that is easily dissolved or destroyed by an acid or other chemical. The rest of the assembly above-described, including the pipe sections and tool body sections, is made of iron, steel or other material that is not destroyed by the application of the acid or other chemical that will destroy the plug. If desired, the entire closure member **34** may be made out of chemically destructible material like the plug portion, in which case the plug need not be a separate element.

In order to make a seal with the bore of the well, when the slidable sleeve is extended outwardly from the tool as will be later described under operation of the tool, the outer end of each sleeve carries a cup-like gasket **38** made of neoprene, rubber, or similar resilient and acid resistant material. In the example shown, this gasket is held against a shoulder **40** on sleeve **28** when the closure member **34** is screwed into place. The free outer edges of the gasket extend beyond the outermost end of the closure **34** and its plug portion **36** to make sealing contact with the wall of the well bore before these elements are destroyed. In some situations the gaskets may not be required and in those cases the outer faces of the closure members and of the dissolvable plug are contoured to match the curvature of the well bore to form a tight fit with the well bore when the sleeves are extended.

When the tool is assembled prior to insertion into a well, the slidable sleeves of each pair are positioned inwardly of the tool as far as possible so that their outer ends project a minimum distance therefrom. Friction of the sealing rings **32** holds the sleeves in this retracted position. It should be noted that, when both sleeves of a pair of the sleeves **28** are fully retracted, as shown in FIGS. 2 and 3 for example, there remains a clear space **42** between the inner ends thereof, this space lying near the axial center of the pipe sections **12** and tool sections **10** of the hollow elongated tool.

Spring means are provided to extend the sleeves transversely outwardly of the tool at the proper time and to hold the outer ends of the sleeves resiliently in sealing contact or engagement with walls of the well bore. Shown here is a compression spring **44**, located within both sleeves **28** of a pair, this spring in fully extended condition spanning the space between the inside of the closure member **34** of one sleeve **28** and the inside of the closure member of the opposite sleeve of the pair, the spring extending the sleeves outwardly to their fullest extent and pressing the outer ends of both sleeves into firm engagement with portions of the walls of the well bore. This position or condition of one sleeve is shown in FIG. 4.

Obviously, it is not desired that the sleeves be extended while the tool is being positioned within the well, and to keep them in their retracted position each of the springs **44** is compressed to a length less than the space between the closure members of a pair of the sleeves when in retracted position. The compressed spring is held in this condition by a link or bolt **46** and end nuts **48**, as shown in FIG. 3. This spring-holding link (and the nuts, if used) is of chemically destructible material similar to or the same as that of the closure plugs **36**. FIG. 6 shows a different form of destructible spring-holding link in the shape of a tube **50** with flared ends **52** engaging the ends of a compressed spring **44**.

Whether the destructible spring-holding link takes one form or another, its central portion, and the central part of the spring that it holds, extends across the clear space **42** between a pair of retracted sleeves, lying generally in the longituidnal axis of the hollow elongated tool. Adjacent pairs of the sleeves, which may be located as close together as three inches, are preferably positioned at right angles to each other as shown, so that when the sleeves in a tool assembly are extended they will center the hollow elongated tool in a well bore and provide an annular space A in the bore surrounding the tool on all sides. This central location of all the links, in the clear spaces **42** between the retracted connection sleeves, makes it easy to apply acid or other destructive chemicals to the links.

Using the tool

The well hole is drilled in any desired fashion and the bore washed clean if necessary. A log is made, using core samplings or electronic logging equipment or other methods to determine the location of potential production strata or zones S or levels at which it will be desired to make connection. There will be other levels X at which connections definitely will not be desired, and the locations of these also will be determined by the well log.

Knowing the levels at which connections to strata S are desired, in carrying out the preferred method of this invention a tool as above-described will be prepared, having plain pipe sections **12** covering the well levels X that are not to be connected, and tool sections **10** with appropriate pairs of extendable sleeves **28** at the desired production or connection levels. If extensive production zones are found, the length and number of tool sections **10** may be increased accordingly, and as many sets of crosswise pairs of the sleeves **28** be provided as are desirable to handle the expected flow.

In one method of using the tool, the feelers **18** may not be provided, but a relatively thin metal protective casing with open bottom (not shown) is placed in the well bore and the tool is then carefully lowered into the casing to the bottom of the well so that the sildable connection elements are positioned opposite the perdetermined locations for connection to the strata S. The protective casing is then removed, if following this method, and further steps followed as explained below.

In a variation of the method, not requiring the protective casing described immediately above, feelers **18**, with or without the guard rings **20**, are provided as part of the tool assembly and the tool is lowered into the well bore to the bottom or until the slidable sleeves are located opposite the potential production strata. In place of the feeler arms **18** other guiding and centering arrangements might be used for the tool, these having also the function of protecting the projecting parts of the sleeves **28** from being damaged while the tool is being lowered into proper position in the well. Discs or fins may be provided instead of the feeler arms **18** and these should extend radially outwardly far enough to protect the ends of the retracted slidable sleeves, but not far enough or through sufficient area to impede the subsequent placement of cement in the annular space A as explained below. As shown, the outer diameter of the main body of the tool is substantially less than the inner diameter of the well bore at any point.

After insertion and proper positioning of the tool within the well by either of the methods above-described, an appropriate link-dissolving acid or other link-destructive chemical is introduced through the open top end of the tool and the spring-holding links will be attacked and destroyed. As each link loses its holding power, the spring held by that link will extend itself, forcing apart the opposite sleeves between and within which it is located and resiliently pressing the outer ends of the sleeves into sealing engagement with the opposite walls of the well bore on either side of the tool. The spring, of course, is made of a material not affected by the destructive chemical. By proper selection of the link material, its cross-section, and the nature and concentration of the destructive chemical, a wide range of time of operation of the springs can be obtained, suitable to many different conditions or requirements. Because the nuts **24**, the assemblies of the slidable sleeves **28**, the closure members **34**, the plug portions **36**, and the springs and holding links are all removable and replaceable before use, various combinations of sizes and properties of these parts may be made in the field when preparing a tool to suit different well conditions that may be encountered in any particular case.

If the same metal is used for the spring holding links as is used in the end plugs, and the same acid or chemical is used to destroy both link and plug, the metal of the links should be no more than about one-third the thickness of the metal of the plugs, so that the plugs are not dissolved at this point and the ends of the springs, when released, will have sufficient material against which to press to extend the slidable sleeves. Of course, if a differtn material is used for the destructible plugs, and one that is not destroyed by the link-dissolving chemical, then differences in thickness of link and plug are not significant, but a second chemical must be introduced at the proper stage and in the proper amount to destroy the plugs.

Having properly located the tool in the well bore and having extended the sliding strata-connecting sleeves by applying the link-destroying acid or chemical within the tubular tool, the equipment is in the condition shown in FIG. 4, but the annular space surrounding the tool is empty. The next step is to fill this annular space with cement C. This is done by using a relatively fine fluid slurry and pouring or pumping the cement slurry from the open top of the well around the tool, entirely outside of the tool. If necessary, the cement may be forced into this annular space and around and between the extended strata connecting sleeves by using a small diameter tubing of a size to fit within the available space outside the tool, withdrawing the tubing as required and vibrating or tamping the cement if necessary as the space is filled up. Because the bottom end of the tool is closed and the connection sleeves are sealed by their O-rings and at the well walls by the cup-like gaskets, no cement should enter the tool and the ends of the sleeves where they contact the well bore should be free from cement. When the cement is at a level above the topmost strata that is to be connected, cementing can be stopped, and the cement is allowed to set. This is the condition shown in FIG. 4.

During the time the cement is being applied and is setting, the acid or other chemical in the tool may be working on the destructible plugs in the ends of the extended strata connecting sleeves. In one arrangement that has been found satisfactory, zinc plugs were used, and zinc spring-holding links, the plugs being of a thickness calculated to be eaten out by means of an acid introduced into the tool in a period of about 72 hours after the well was cemented. This gives ample time for the cement to set, and after the plugs are destroyed the entire tubing forming the tool may be swabbed out or the spent acid neutralized by introducing a suitable neutralizing base into the tool. If preferred, water under pressure may be put into the pipe section at the top of the tool and the spent acid can be injected into the oil bearing sands, when acid injection seems to be indicated for the purpose of starting production. If the connected well formations can produce by natural or artificial pressure, the well is now ready for use. Each of the extended sleeves now provides a clear passageway from a preselected stratum, through the cement liner and into the central tubular casing formed by the tool. The cement liner effectively seals off strata to which no connection is deisred, prevents collapse of the well bore, and reinforces the central casing against excess pressure damage. FIG. 5 shows the tool after cementing and after destruction of the closure plugs.

The tool and method above-described have been found to be useful for the cementing and completion of oil well bores having depths of the order of 3,500 feet and less and diameters of about 9 inches. These sizes, although given as practical limitations with the materials and equipment presently available, are not to be considered as limiting the invention. Also, as will be evident from the foregoing description, certain aspects of this invention are not limited to the particular details set forth as examples, and it is contemplated that various and other modifications and applications of the invention will occur to those skilled in the art. It is therefore intended that the appended claims shall cover such modifications and applications as do not depart from the true spirit and scope of the invention.

What is claimed and is desired to be secured by Letters Patent of the United States is:

1. An oil well completion method comprising the steps of

placing into a well bore an elongated tubular casing of smaller diameter than said bore, leaving an annular space between the outside of said casing and the walls of said bore, next resiliently forcing opposite pairs of extensible tubular connector members laterally outwardly from said tubular casing, to span said annular space at selected points in said bore located at levels corresponding to strata in the well bore to be connected to said casing, the outer ends of said connector members, when extended, making sealing contact with said strata and carrying chemically destructible closure plugs therein, then

filling the said annular space and around each of the extended said connector members with a sealing cement by introducing the cement downwardly into said annular space from the top thereof and entirely outside of said casing,

allowing the sealing cement to set, and finally

destroying the closure plugs in said connector members by the application of chemicals thereto introduced from the inside of said tubular casing,

whereby passageways are opened from said strata through said connector members and into said tubular casing.

2. An oil well completion method according to claim 1 in which the step of resiliently forcing opposite pairs of said extensible tubular connector members laterally outwardly is performed by

first compressing spring means between said connector members and holding said spring means in compressed condition by a chemically destructible spring-holding link and then

releasing said spring means from said holding link by the application of chemicals to said link to destroy the same,

whereby the released spring means will resiliently force said connector members outwardly.

3. An oil well completion method comprising the steps of

placing into a well bore an elongated tubular casing of smaller diameter than said bore, leaving an annular space between the outside of said casing and the walls of said bore, next

chemically releasing a spring means and thereby resiliently forcing an extensible tubular connector member laterally outwardly from said tubular casing, to span said annular space at a selected point in said bore located at a level corresponding to stratum in the well bore to be connected to said casing, the outer end of said connector member, when extended by said released spring means, making sealing contact with said stratum and carrying a chemically destructible closure plug therein, then

filling the said annular space and around the extended said connector member with a sealing cement by introducing the cement downwardly into said annular space from the top thereof and entirely outside of said casing,

allowing the sealing cement to set, and

destroying the closure plug in said connector member by the application of a chemical thereto introduced from the inside of said tubular casing,

whereby a passageway is open from said stratum through said connector member and into said tubular casing.

4. An oil well completion tool comprising an elongated hollow casing adapted for lengthwise insertion into the bore of a well,

a connector sleeve slidably mounted in a wall of said casing for extension transversely outwardly of said casing at a preselected location corresponding to stratum in the well bore to be connected to said casing when said casing is in said well,

means at the outer end of said connector sleeve adapted for sealing engagement with the well bore when said sleeve is extended from said casing,

a plug in said connector sleeve of a material readily destroyed by a chemical, said plug closing the outer end of said sleeve until destroyed by application of said chemical thereto,

a retractable spring in said casing extending adjacent said connector sleeve, said spring, when extended, forcing said sleeve transversely outwardly of said casing and into resilient engagement with the well bore, and

a holding link for said spring of a material readily destroyed by a chemical, said link holding said spring in retracted condition and against extension thereof until destroyed by application of said chemical,

whereby upon introduction of a destructive chemical to the interior of said casing, said link is destroyed and said spring is released to extend said connector sleeve outwardly into engagement with the bore of the well and said plug in said sleeve is destroyed to establish connection of a preselected stratum to said casing.

5. An oil well completion tool comprising an elongated hollow casing adapted for lengthwise insertion into the bore of a well,

pairs of oppositely directed tubular connector members slidably mounted in the walls of said casing for retraction therein and extension transversely outwardly of said casing at preselected locations corresponding to strata in the well bore to be connected to said casing when said casing is in said well,

means at the outer ends of said connector members adapted for sealing engagement with the well bore when said members are extended from said casing,

closure plugs in said connector members, of a material readily destroyed by a chemical, said plugs closing said members until destroyed by application of said chemical thereto,

a retractable spring in said casing extending between the opposite members of each pair of connector members, each said spring, when extended, forcing the associated members of each pair apart and outwardly into resilient engagement with the well bore, and

a holding link for each spring of a material readily destroyed by a chemical, each link holding a said spring in retracted condition and against extension thereof until destroyed by application of said chemical,

whereby, upon introduction of a destructive chemical to the interior of said casing, said links are destroyed and said springs are released to extend said connector members outwardly into engagement with the bore of the well and said plugs in said members are destroyed to establish connection of preselected strata to said casing.

6. An oil well completion tool according to claim 5 wherein

adjacent pairs of said slidably mounted tubular connector members are positioned transversely of said casing at 90° with respect to each other along the length of the tool.

7. An oil well completion tool comprising an elongated hollow casing adapted for lengthwise insertion into the bore of a well,

pairs of oppositely directed tubular connector members slidably mounted in the walls of said casing for retraction therein and extension transversely of said casing at preselected locations corresponding to strata in the well bore to be connected to said casing when said casing is in said well,

resilient means around the outer ends of said connector members adapted for sealing engagement with the well bore when said members are extended from said casing,

closure plugs in said connector members, of a material readily destroyed by a chemical, said plugs closing the ends of said members until destroyed by application of said chemical thereto, a retractable spring in said casing extending within and between the opposite members of each pair of connector members, each said spring, when extended, forcing the associated members of each pair to slide apart and outwardly into resilient sealing engagement with the well bore,

a holding link for each spring, of a material readily destroyed by a chemical, each link holding a spring in retracted condition and against extension thereof until destroyed by application of said chemical,

the material of said closure plugs and of said spring holding links being the same, and destroyed by application of the same chemical thereto, and

the thickness of said plugs being considerably greater than that of said links, the time of destruction of said links after application of said chemical thereby being considerably less than the time of destruction of said plugs after application of said chemical thereto,

whereby, upon introduction of a destructive chemical

to the interior of said casing, said links are first destroyed and said springs are released to extend said connector members outwardly into engagement with the bore of the well and thereafter said plugs in said members are destroyed to establish connection of preselected strata to said casing.

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