United States Patent

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[54] **TENSIONED WELL BORE LINER AND TOOL**
18 Claims, 7 Drawing Figs.

[52] **U.S. Cl.** **166/208,** 166/212, 166/285
[51] **Int. Cl.** **E21b 43/10**
[50] **Field of Search** 166/206, 208, 207, 212, 215, 242, 243, 75, 285

[56] **References Cited**

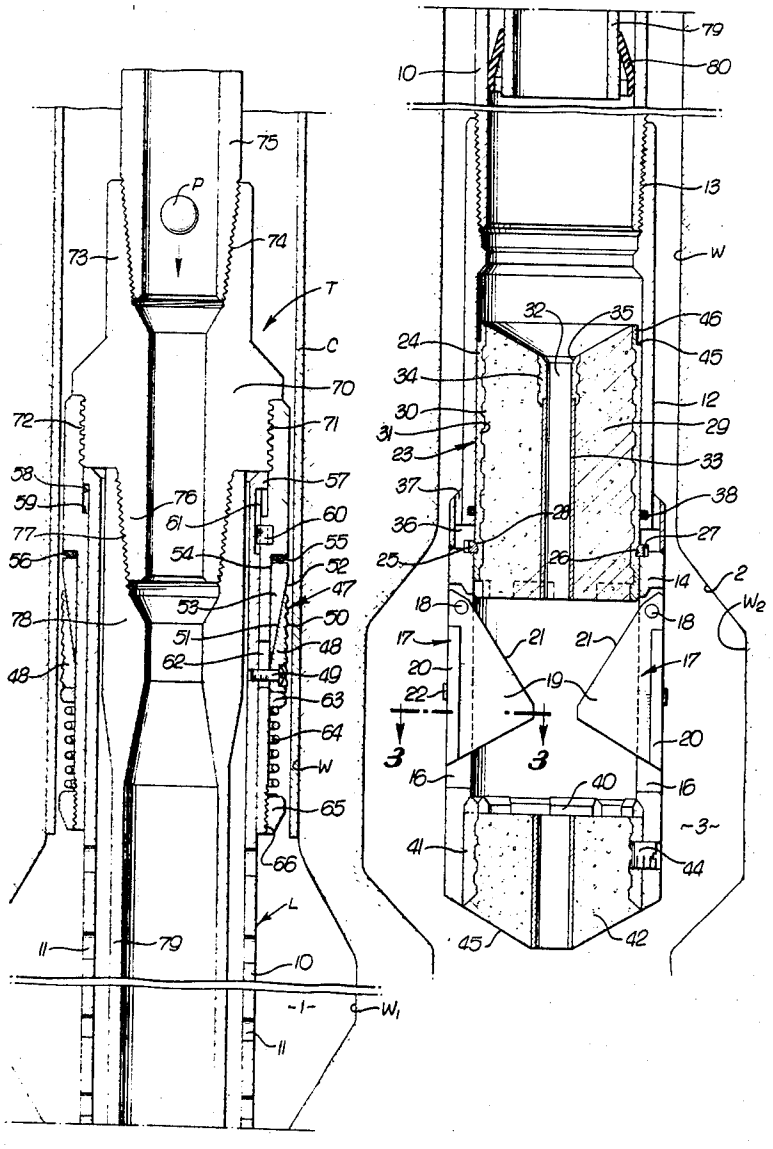
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ABSTRACT: A well bore liner apparatus and a running tool, the liner apparatus having expansible anchor members at its lower end expansible into an underreamed section of the well bore to anchor the liner against upward movement, the liner also having upper anchor elements engageable in a previously set well casing, the tool being employed to tension the liner body between the lower and upper anchors. Such a construction in which the running tool is releasable from the liner before cementing of the lower anchor in the enlarged bore hole section.

It is sometimes desirable to set perforated or slotted liners in well bores which traverse unconsolidated oil producing formations. In some instances, gravel is packed outside the liner to fill the annular space. On occasions, it may be desirable to apply heat to the formation or to the gravel pack by the injection of steam into the well, such heat tending to expand the usual liners and causing problems, such as release of the liner hanger.



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FIG. 1a.

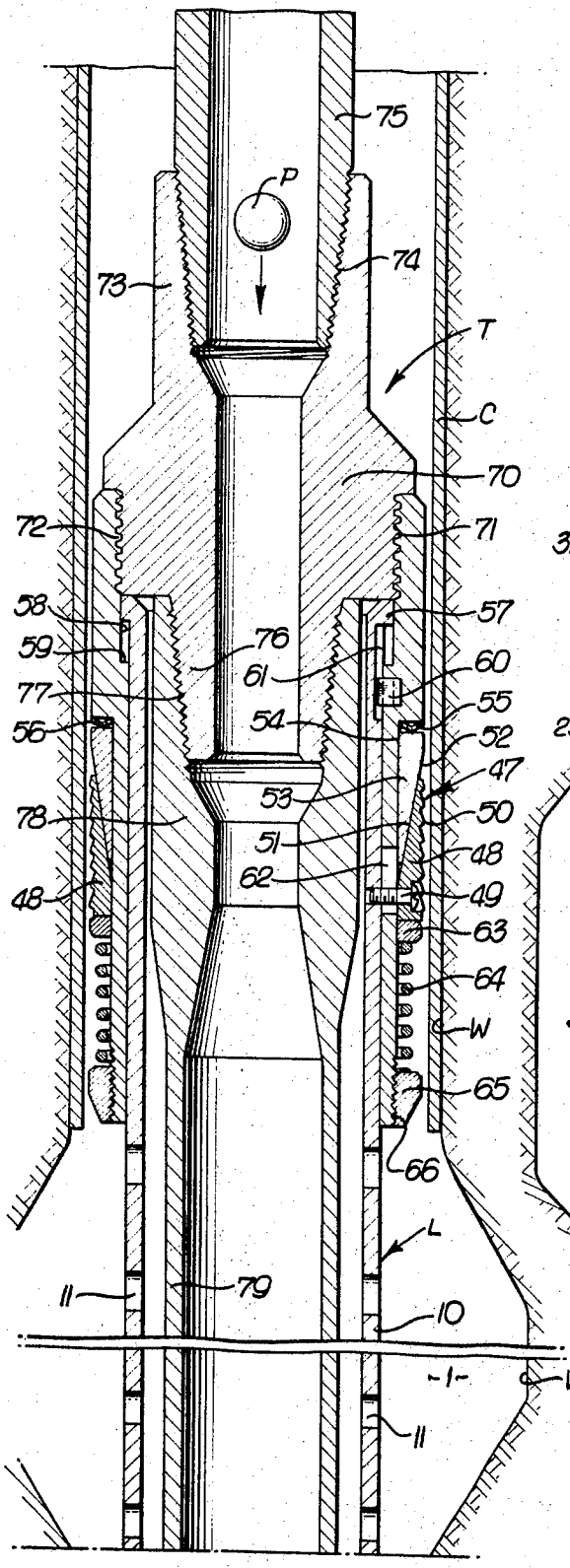
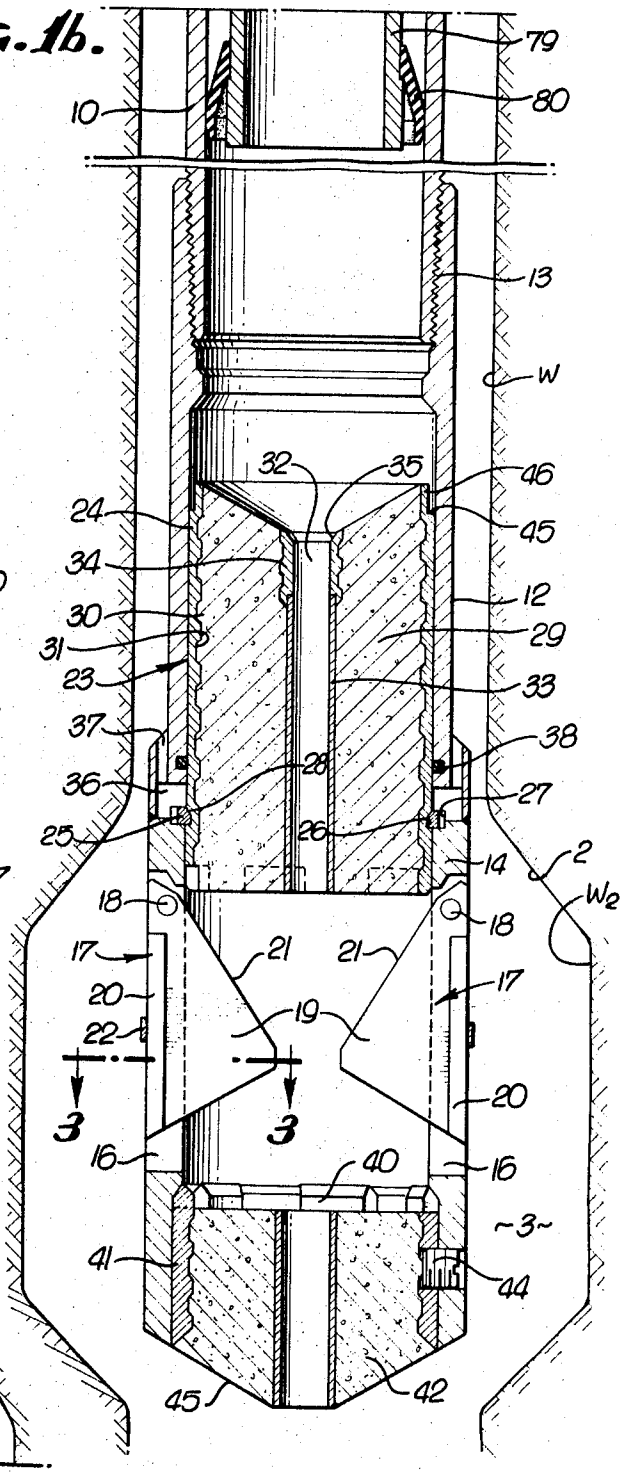


FIG. 1b.



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FIG. 2a.

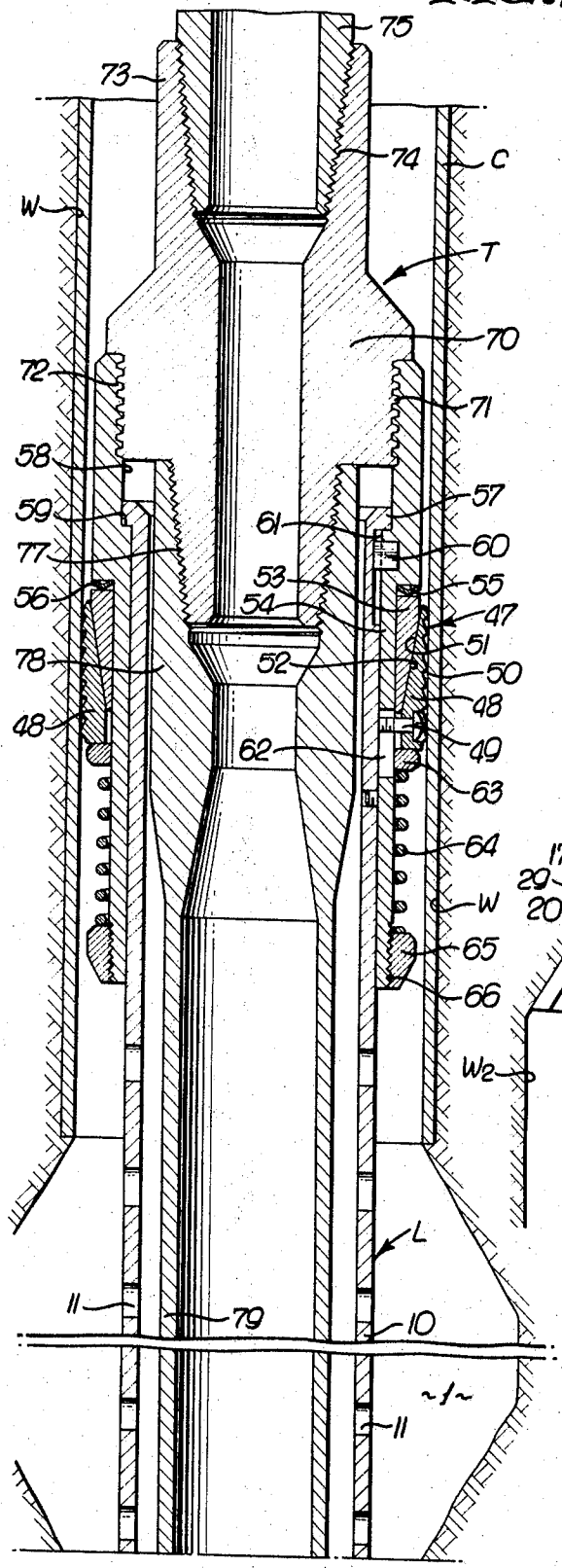
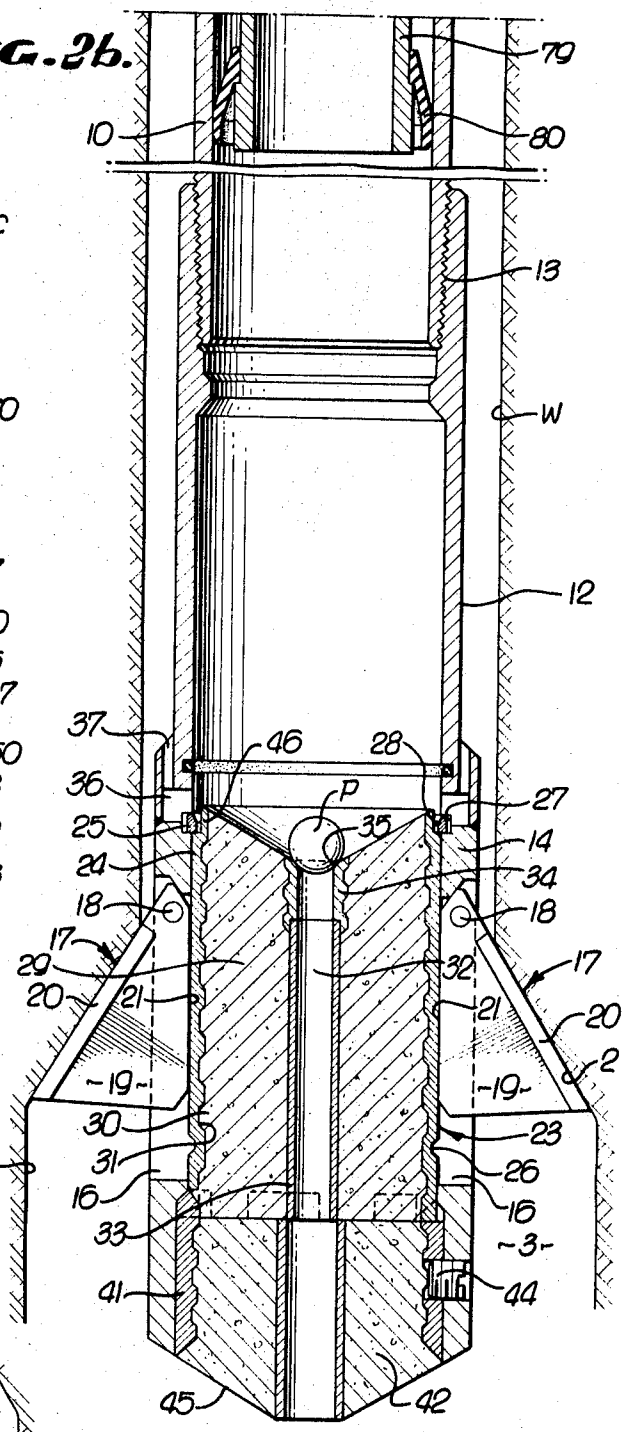


FIG. 2b.



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FIG. 4.

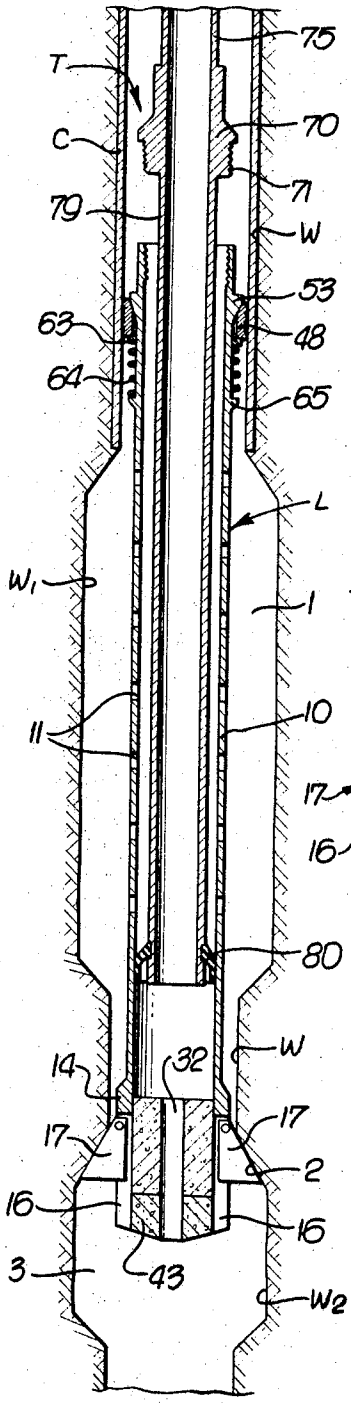


FIG. 3.

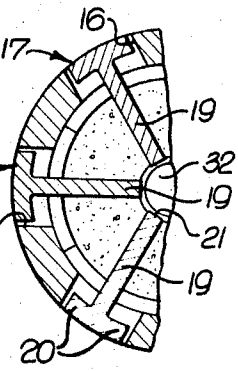
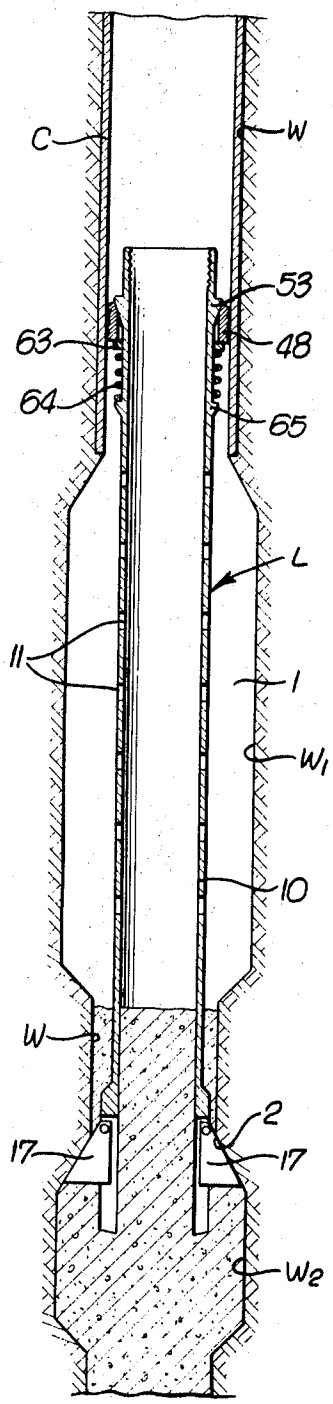


FIG. 5.



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TENSIONED WELL BORE LINER AND TOOL

The present invention provides liner anchoring apparatus whereby the liner may be suitably pretensioned, particularly if it is anticipated that the liner may later by subjected to heat, such as incident to steam injection, or otherwise.

The present invention has for its purposes the attachment of the lower end of the liner to the borehole wall, the tensioning of the liner, and the anchoring of the upper end of the liner in a previously set well casing, with the body of the liner under the desired tension so that the liner will be, for practical purposes, unaffected by the application of steam or other heat to the formation in which the liner is disposed, or to the liner itself.

In accomplishing the foregoing, the invention provides a number of normally retracted, but laterally expansible, anchor dogs or holding members at the lower end of a tubular liner, these dogs being adapted for anchoring engagement when expanded with a downwardly facing shoulder formed in the well bore, these holding members enabling the liner body to be tensioned by applying an upward pull thereto. In order to retain the liner body in a tensioned condition, the liner is also provided with downwardly holding anchor slips adapted to be expanded or set in engagement with a previously set well casing responsive to the application of the tensioning strain to the liner body.

The invention provides, also, a removable liner running tool for applying the tension to the liner and for allowing the displacement of cement into the bore in the vicinity of the holding members, whereby the anchor and the bore are reinforced. Thereafter, the running tool may be removed from the liner to allow the flow of production fluid into the well casing through the liner perforations.

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.

Referring to the drawings:

FIGS. 1*a* and 1*b* together constitute a longitudinal section through the liner, running tool, and upper and lower anchors, in an initial condition in the well bore, FIG. 1*b* being a downward continuation of FIG. 1*a*;

FIGS. 2*a* and 2*b* together constitute a section similar to FIGS. 1*a* and 1*b*, showing the lower holding dogs expanded and the upper anchor engaged in the well casing;

FIG. 3 is a fragmentary detail view in section, as taken on the line 3–3 of FIG. 1*b*;

FIG. 4 is a diagrammatic view showing the liner anchored in the well and the running tool released thereon; and

FIG. 5 is a view similar to FIG. 4, showing the tensioned liner fully installed and cemented in place.

As seen in the drawings, the invention involves a liner L which is to be anchored in a well bore W, which has been underreamed at W1 to form an annular space 1 through which the liner extends and which is adapted to be packed with gravel, as is customary in certain wells. At a location spaced downwardly from the enlarged bore W1 is a second enlarged or underreamed portion W2 of the borehole which provides a downwardly facing shoulder 2 above the enlarged space 3.

Above the underreamed space 1, the well bore W has a casing C set therein. If desired, the casing may, itself, be tensioned in accordance with the disclosure in the pending application for Letters Patent of the United States for "Casing Apparatus and Method for Tensioning Casing Strings," filed Nov. 25, 1968, Ser. No. 778,403. However, for illustrative purposes, the casing C is shown simply as set in the bore W in a conventional manner.

The liner apparatus L includes an elongated tubular body 10, portions of which are slotted or perforated, as at 11, to provide for the passage of well fluids from the bore W2 into the liner after the latter has been set. At its lower end, the liner body 10 has a tubular member 12 threaded at 13 to the body 10. At its lower end, the tubular member 12 includes a tubular anchor carrier portion 14 having a suitable number of longitudinally extended and angularly spaced slots 16 therein, in which slots are anchor dogs or holding members 17.

As disclosed, the upper portion of each holding member 17 is pivotally mounted on a hinge pin 18 extending across the body slot and suitably secured to the body, as by welding, or the like. The main portion of the holding member is T-shaped in cross section, including a central web 19 extending substantially inwardly of the carrier 14 when the holding member is in retracted position, this web being integral at its outer end with oppositely directed transverse arms 20 (see FIG. 3) extending longitudinally along a substantial portion of the web. When the holding member 17 is in its retracted position within the peripheral confines of the main body of the shoe or carrier 14, the arms 20 are located within the slot 16. When in retracted position, the holding members or feet 17 have inclined downwardly tapering surfaces 21, with the outer surfaces of the arms 20 extending substantially parallel to the axis of the shoe. The holding members 17 are retained initially in retracted position within the carrier 14 by a readily breakable strap 22 which encompasses them.

The holding members 17 are shiftable laterally outwardly and held in their outward expanded condition by an expander member 23 which is hydraulically actuated and which functions as a piston. This piston 23 includes an outer sleeve 24 slidable along the inner wall of the main body member 12 of the shoe and disposed initially above the holding members 17, being retained in such initial upper position by a releasable latch member 25 in the form of a split, inherently contractable ring mounted in an external groove 26 in the sleeve and also within an opposed internal groove 27 in the shoe body. The upper inner corner 28 of the ring 25 is tapered in a downward direction and is engageable with a companion tapered side of the sleeve groove 26, so that when sufficient downward force is imposed on the piston or expander member 23, the ring is cammed or expanded outwardly further into the body groove 27 and completely from the sleeve groove 26 to permit the expander 23 to move downwardly along the anchor dogs or holding members 17.

As disclosed, the piston member 23 has a concrete body 29 therewithin anchored to the sleeve by concrete ribs 30 cast within companion grooves 31 in the sleeve, there being a central passage 32 through the concrete defined by a drillable hollow tube 33 of any suitable material, such as fiber, the upper end of which engages an inner readily drillable tube 34 providing an upwardly facing valve seat 35, the upper end of the sleeve 24, concrete body 29 and the valve seat 35 being tapered in a downward direction to provide a guide surface toward the passage 32.

The body member 12 has a plurality of circumferentially spaced ports 36 therein defined by radial openings extending through the carrier and communicating with upwardly opening passages 37 in the main body 12. A suitable side seal ring 38 is mounted on the body and seals initially against the periphery of the shifting sleeve or piston 23 above the ports 36, 37 to prevent fluid leakage between the body and sleeve. The lower end of the sleeve 24 has a plurality of axial clutching teeth 39 companion to clutching teeth 40 in the upper end of a lower sleeve 41, so as to lock the piston 23 to the lower sleeve against rotation. This sleeve 41 forms part of a tapered guide formed as a concrete mass 42 provided with a tapered nose 43, so as to guide the shoe past obstructions that might be encountered in the well bore during lowering of the liner L therein. In addition, the nose 42, and more particularly the sleeve 41, which is held in the carrier 14 by a suitable number of screws 44, limits downward movement of the piston 23.

When the piston 23 has been shifted downwardly to its fullest extent, an upwardly facing latch shoulder 45 on the upper end of the sleeve 24, provided by a reduced diameter portion

46 of the sleeve, will be disposed immediately below the latch ring 25 which will recontract across the shoulder 45 and prevent inadvertent upward shifting of the piston member 23. When the piston member is in this position, the cementing ports 36, 37 are open, as disclosed in FIG. 2*b*.

As will be hereinafter described, the holding members or dogs 17 are adapted to hold the lower end of the liner body 10 against upward movement. At the upper end of the body 10, anchor means 47 are provided for holding the upper end of the body 10 against downward movement so that the body 10 may be retained in a pretensioned state.

This anchor means 47 includes a number of slip elements 48 secured to the body 10 in circumferentially spaced relation by shearable means, such as screws 49, each slip having downwardly facing teeth 50 on the outer surface and an inner downwardly tapered surface 51, which is engaged with a companion downwardly tapered surface 52 of an expander or cone 53 disposed about a cylindrical anchor sleeve or body 54 below a downwardly facing shoulder 55 on the sleeve 54. An annular spring washer or Belleville spring 56 is interposed between the shoulder 55 and the expander 53.

At its upper extremity, the liner body 10 has an outstanding flange 57 slidably disposed in a bore 58 in the anchor sleeve 54, the bore 58 terminating in an upwardly directed shoulder 59 adapted to abut with the flange 57 upon upward movement of the sleeve 54 relative to the liner body 10. A key 60 and a companion key slot 61 are provided to prevent relative rotation between the anchor sleeve 54 and the liner body 10.

Upward movement of the anchor sleeve 54 is employed to condition the anchor means 47 for anchoring engagement within the well casing C. Thus, the slip supporting screws 49 extend through slots 62 in the anchor sleeve 54 into the liner body 10, so that upward movement of the sleeve 54 will shear the screws 49, releasing the slips for expansion by the cone surface 52. To expand the slips 48, a slip expander ring 63 is slidably disposed about the anchor sleeve 54 beneath the slips 48, and this ring 63 is normally biased upwardly by a coiled compression spring 64 seating on a stop ring or seat 65 threadedly connected at 66 to the anchor sleeve 54.

It will now be apparent that, as seen in FIG. 2*a*, when the screws 49 have been sheared, the spring 64 moves the slips upwardly along the cone surface 52 and outwardly to effect engagement of the wickers or teeth 50 of the slips with the casing wall. Such engagement of the slips will prevent downward movement of the anchor sleeve 54, but will not prevent upward movement of the sleeve 54, since the teeth 50 will slide upwardly in the casing C. Thus, in order to tension the liner body 10 and anchor its upper portion against releasing the tension, it is only necessary to pull upwardly on the anchor sleeve 54 to shear the slip supporting screws 49 and pull upwardly on the liner body 10 by engagement of the internal shoulder 59 in the sleeve 54 with the external flange 57 at the upper end of the body 10.

A running tool T is provided for effecting such an upward pull. This tool T includes a body 70 having a section which is externally threaded at 71 for engagement in the internal threads 72 at the upper end of the anchor sleeve 54. At its upper end, the tool body 70 has an internally threaded box section 73 for threaded engagement at 74 with a running string of pipe 75 extending to the top of the well. At its lower end, the tool body 70 is provided with a threaded pin 76 for engagement at 77 in the threaded box 78 at the upper end of a stinger or length of tubing 79 which extends downwardly through the perforated liner body 10. At its lower end, the stinger 79 has a packing cup 80 mounted thereon and forming a seal against the upward flow of fluid between the liner body 10 and the stinger 79.

In the use of the present invention, the well bore W of the desired diameter is first drilled, the casing C set, and the bore is then enlarged to form the underreamed portions W1 and W2 by the use of an appropriate hole enlarging tool, such as the rotary expansible drill bit disclosed in U.S. Pat. No. 2,941,785.

The liner assembly L is then connected to the tool T and run into the well on the running-in pipe string 75. The liner assembly during running is in the condition shown in FIGS. 1*a* and 1*b*; that is, the piston 23 being in the upper position, the holding members in retracted position, and with the slips 48 held in retracted position by the shear screws 49. When the assembly is located in the well with the holding dogs 17 at a level below the shoulder 2 and in the enlarged bore W2, a plug P, herein shown as a ball valve element, is dropped through the tubing string 75 and stinger 79, coming to rest on the valve seat 35 at the upper end of the passage 32 through the piston 23.

The fluid in the tubing string 75 may then be subjected to pressure to force the piston 23 downwardly, the retainer ring 25 being cammed outwardly to allow such downward movement of the piston 23. Such downward movement of the piston 23 will cam the dogs or holding members 17 outwardly into a position below the shoulder 2. The running string 75 is then raised to effect engagement of the dogs 17 with the formation shoulder 2, and, thereafter, permit the liner body 10 to be stretched or tensioned.

Following engagement of the dogs 17 with the shoulder 2, as just described, upward movement of the tool T will cause the slip supporting screws 49 to be sheared, releasing the spring 64 for expanding the slips 48 upwardly along the expander 53 and outwardly against the casing C. The shoulder 59 in the anchor sleeve or body 54 engages the external flange 57 of the liner body, whereupon the required pull can be taken on the tubing string 75 to stretch or tension the liner body 10. During this stretching or tensioning, the expander 53 and slips 48 are urged upwardly by the spring 64, the slips remaining in contact with the casing and the expander 53, and the expander held against the conical spring 56 bearing against the shoulder 55, so that when the upward pull is relaxed on the running string 75, the tension in the liner body 10 exerts a downward force on the expander 53, which immediately wedges the slips 48 further outwardly against the casing, digging the teeth 50 into the casing wall to hold the liner body 10 in a tensioned condition.

Thereafter, the running tool T may be unscrewed from the body 54 at the left-hand threads 71 and elevated a short distance, as shown in FIG. 4. With the packing cup 80 seated in the liner below its perforation 11, cement can be pumped down the running string 75, stinger 79 and through the ports 36 to cement the lower end of the liner in the hole W below its underreamed portion W1. The running tool T and stinger 79, with the cup thereon, may then be removed from the well bore.

If desired, the liner 10 can be gravel packed, in a known manner, certain equipment, such as a ported collar, being omitted from the drawings as not constituting a portion of the present invention.

The liner 10 is held in its pretensioned condition. If the liner expands and contracts as a result of injecting steam into the producing formation and discontinuing such injection, the liner will remain in place in its set condition because of having been prestretched, but not beyond its elastic limit.

I claim:

1. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means retaining said anchor means initially in retracted position, means for tensioning said body, and means responsive to tensioning of said body for releasing said retaining means and expanding said anchor means into engagement with said casing.

2. In apparatus as defined in claim 1, said holding means comprising initially retracted holding members mounted on said body for lateral expansion outwardly of said body for engagement with the formation shoulder, an expanding member shiftable in said body against said holding members to expand

said holding members laterally, and means for shifting said expanding member in said body.

3. In apparatus as defined in claim 2, said expanding member being shiftable and retained behind said holding members to prevent retraction of said holding members from their expanded position.

4. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said holding means comprising initially retracted holding members mounted on said body for lateral expansion outwardly of said body for engagement with the formation shoulder, an expanding member shiftable in said body against said holding members to expand said holding members laterally, means for shifting said expanding member in said body, and means engaging said expanding member to releasably retain said expanding member in its initial position prior to expanding said holding members.

5. In apparatus as defined in claim 4, and means engaging said expanding member to retain said expanding member in its final position after expanding said holding members.

6. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said holding means comprising initially retracted holding members mounted on said body for lateral expansion outwardly of said body for engagement with the formation shoulder, an expanding member shiftable in said body against said holding members to expand said holding members laterally, means for shifting said expanding member in said body, a fluid passageway comprising a fluid passage in said expanding member, said shifting means comprising a trip member movable through the casing string into engagement with said expanding member to close said fluid passage and enable fluid pressure to be built up in the casing string to hydraulically shift said expanding member in said body to expand said holding members, and means for opening said fluid passageway after said expanding member has expanded said holding members.

7. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said anchor means comprising initially retracted slips, and an expander for expanding said slips against the casing.

8. In apparatus as defined in claim 7 and releasable means holding said slips retracted, said releasable means being released responsive to tensioning of said body.

9. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said anchor means comprising initially retracted slip elements, shearable means connecting said slip elements to said body, a sleeve shiftable relative to said body, means for shearing said shearable means responsive to shifting of said sleeve relative to said body, and expander means engaging said slip elements following shearing of said shearable means to wedge said slips into engagement with said casing.

10. In apparatus as defined in claim 9, and spring means normally biasing said slip elements into wedging engagement with said expander means.

11. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said anchor means comprising initially retracted slip elements, shearable means connecting said slip elements to said body, a sleeve shiftable relative to said body, means for shearing said shearable means responsive to shifting of said sleeve relative to said body, expander means engaging said slip elements following shearing of said shearable means to wedge said slips into engagement with said casing, spring means normally biasing said slip elements into wedging engagement with said expander means, and said tensioning means including shoulder means on said sleeve and said body engageable to tension said body responsive to the application of a force to said sleeve.

12. In apparatus as defined in claim 11, and said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying said force to said sleeve.

13. In liner setting apparatus for tensioning a liner in a well between a well casing in the well bore and a downwardly facing formation shoulder: a tubular liner body, holding means carried by said body engageable with said formation shoulder, anchor means carried by said body engageable with said casing, means for tensioning said body, said anchor means comprising initially retracted slip means, a sleeve shiftable relative to said body and having expander means for expanding said slip means into anchoring engagement with said casing upon movement of said sleeve, and said tensioning means including coengageable parts on said sleeve and said body.

14. In apparatus as defined in claim 13, said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying a tension force to said sleeve.

15. In apparatus as defined in claim 13, said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying a tension force to said sleeve, said tool means including a tubular stinger extending into said body, and means forming a seal between said stinger and said body.

16. In apparatus as defined in claim 13, said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying a tension force to said sleeve, said tool means including a tubular stinger extending into said body and having a packing cup thereon sealingly engaged in said body to form a seal between said stinger and body.

17. In apparatus as defined in claim 13, said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying a tension force to said sleeve, said tool means and said sleeve having a thread releasably interconnecting said tool means and said sleeve.

18. In apparatus as defined in claim 13, said tensioning means further including tool means releasably engaged with said sleeve and connectable to a running-in string of pipe for applying a tension force to said sleeve, said tool means and said sleeve having a thread releasably interconnecting said tool means and said sleeve, and including key and a companion keyway between said sleeve and said body for preventing rotation of said sleeve on said body.