Nov. 15, 1966 H. J. URBANOSKY 3,285,343

PERMANENTLY SET BRIDGE PLUG

Filed March 11, 1964

Fig. 1

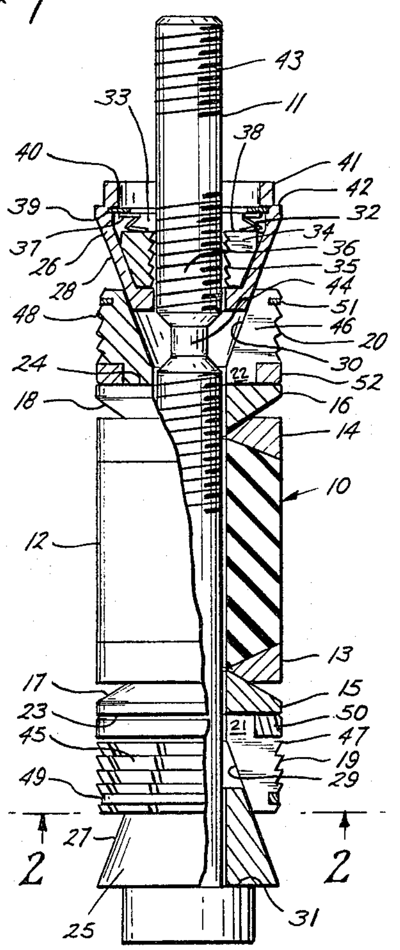
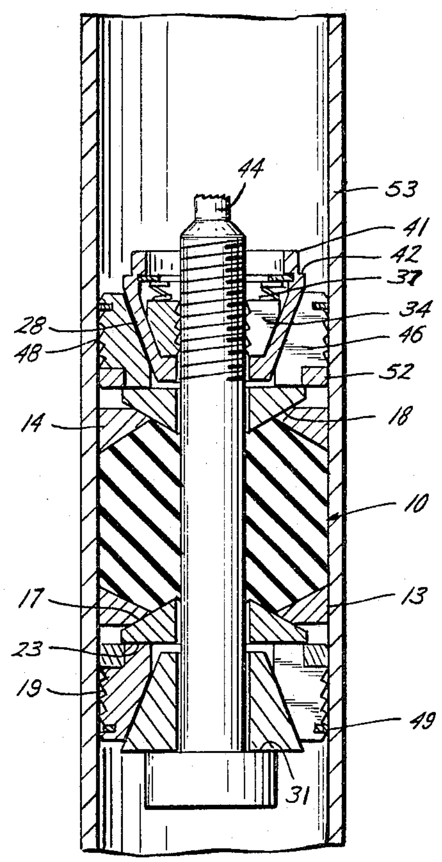



Fig. 3



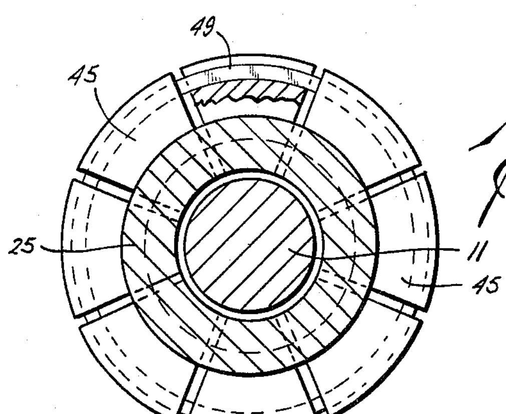




Fig. 2

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PERMANENTLY SET BRIDGE PLUG

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This invention relates to a bridge plug for use in packing-off a well bore, and, more particularly, to a bridge plug designed to be set permanently in place within a cased well bore.

A bridge plug typically includes a mandrel on which is mounted an elastomeric sleeve or packing element disposed between sets of reversely directed, extendible, slip elements operatively mounted around tapered expander elements, with the slip elements being releasably held thereon in an inoperative or retracted first position, and a body lock which maintains the elements in an operative second position. Setting of such a bridge plug in a well bore is conventionally accomplished by use of a setting tool which applies increasingly greater and oppositely directed forces to the bridge plug in such a manner that the packing element is expanded into sealing engagement and the slip members are extended into engagement with the well casing to anchor the bridge plug in place at a particular depth.

Heretofore, it has been conventional to utilize various arrangements of frangible shear rings or pins for releasably holding the slip members on the expanders in a retracted first position to allow the bridge plug to be easily positioned in a well bore. These shear members are generally arranged in such a manner that, as the forces applied by the setting tool increase, the members will fail in a particular order and release the slip members in accordance with a predetermined sequence.

Usually, in setting a typical bridge plug with a conventional wireline setting tool, at least one of the slip members is released and dragged along the casing before the packing element has been completely displaced, which dragging can break some of the casing-engaging teeth around the slip members. Furthermore, with a wireline setting tool having a tension-stud release, it will be appreciated that such dragging can reduce the degree of expansion of the packing element should the additional drag cause the tension-stud to release the setting tool before the packing element has been fully set.

With those bridge plugs having slip members composed of a group of frangibly connected segments mounted around the expanders, upon failure of the frangible connections the individual segments are then free to move independently of their companion segments. Thus the individual segments are no longer coordinated and will not necessarily maintain their initial angular spacing or axial alignment. Accordingly, when finally engaged with the casing, the segments may be tilted and erratically spaced which distributes the anchoring forces unequally around the casing. Moreover, when such a bridge plug is used in an inclined well bore, one side of the slip members will lay against the casing, and, when the slip members are released, the segments at the opposite or upper side of the slip members must advance further along the expander before engaging the casing than those initially resting against the casing. Thus, the bridge plug will usually remain eccentrically disposed which may prevent the packing element from sealing completely and uniformly around its periphery.

Conventional shear pins have not been entirely satisfactory for other reasons as well. For example, when a large number of bridge plugs are mass-produced, it is



difficult to drill holes for receiving shear pins in the separated members with sufficient precision that the holes will be accurately aligned when the members are finally assembled. Accordingly, it is customary to assemble the members, drill the necessary holes, and then disassemble the members to remove burrs and the like before reassembling and inserting the pins.

Furthermore, it is not uncommon for the sudden shock which is imparted to a bridge plug when a shear member fails to crack a cast component of the bridge plug. It has also been found that a shear member will sometimes break irregularly and leave a projection which retards or even prevents the free relative movement of the elements after they are supposedly freed.

Accordingly, it is a particular object of the present invention to provide a reliable bridge plug assembly in which shear member connections between the slip members and expander elements are eliminated.

It is a further object of the invention to provide means for coordinating the extension of slip members whereby the individual segments of the slip members will maintain a uniform angular spacing and remain axially aligned as they are being extended into anchoring engagement with a well casing.

These and other objects of the present invention are obtained by a bridge plug which includes, among other things, expansible restraining means for yieldably holding extendible slip members in a first retracted position and allowing the slip members to be controllably extended radially into anchoring engagement with the casing with little or no longitudinal movement of the members across the casing.

The bridge plug of the present invention includes a central mandrel carrying at each end thereof opposed sets of frusto-conical slip expanders operatively engaged with extendible slip members. An elastomeric packing element is disposed between the opposed slips and expanders with its ends preferably being confined within expansible anti-extrusion members. A body-lock arrangement is provided for maintaining the members in their operative positions after the setting tool has been disengaged.

The extendible slip members are yieldably retained in a retracted position by one or more expansible circumferential band members so arranged that when the setting forces reach a predetermined magnitude, the bands will stretch without breaking so that the slip members will be uniformly and controllably extended radially into engagement with the casing in a particular predetermined sequence.

The novel features of the present invention are set forth with particularity in the appended claims. The present invention, both as to its organization and manner of operation together with further objects and advantages thereof, may best be understood by way of illustration and example of certain embodiments when taken in conjunction with the acompanying drawings, in which:

FIG. 1 illustrates a bridge plug, partly in section employing one arrangement of the novel expansible slip-restraining members of the present invention;

FIG. 2 is a section taken along the lines **2—2** of FIG. 1; and

FIG. 3 is a view showing the bridge plug of FIG. 1 set into sealing and anchoring engagement within a well casing.

Turning now to FIGS. 1 and 2, one embodiment of a bridge plug **10** constructed in accordance with the principles of the invention is shown with portions thereof in section for purposes of greater clarity. The mandrel **11** is an elongated cylindrical member around which is slidably mounted an elastomeric packing sleeve or element **12** which has its ends confined by oppositely directed conventional lower and upper expansible anti-extrusion rings **13, 14**, respectively. Oppositely directed lower and upper washer or spacer members **15, 16** are slidably mounted around mandrel **11** at opposite ends of the anti-extrusion rings **13, 14**, with each washer having an inwardly directed, tapered, surface **17, 18** complementarily engaged with the outer faces of the anti-extrusion rings. Lower and upper extendible slip members **19, 20**, as will be later described in detail, are slidably disposed around the mandrel **11** with their base portions **21, 22** respectively engaged with the flattened outer ends **23, 24** of lower and upper washer members **15, 16**. Lower and upper frusto-conical slip-expander members **25, 26** are oppositely directed and slidably mounted around the mandrel **11** with their tapered surfaces **27, 28** respectively engaged within complementarily formed tapered surfaces **29, 30** of lower and upper slip members **19, 20**. The lower slip-expander member **25** rests against an upwardly facing shoulder **31** around the lower end of mandrel **11**.

Upper slip-expander member **26** has an upwardly directed and outwardly diverging tapered surface **32** forming an annular recess **33** for receiving a complentarily tapered split-nut **34**. Split-nut **34** has ratchet teeth **35** around its axial bore cooperatively engaged with downwardly facing ratchet teeth **36** cut around the upper end of mandrel **11**. A spring member **37** is operatively engaged between the upper end **38** of split-nut **34** and a snap-ring **39**, which is in turn held against a downwardly facing circumferential shoulder **40** formed around the upper end of recess **33**. Spring member **37** is preferably an assembly of two opposed springs, with each spring consisting of a single flat ring having resilient projecting tabs interlocked with the tabs of the other spring. These springs, when nested together, make a compactly arranged spring member with flattened annular end surfaces.

The upper end of upper slip-expander member **26** has a reduced outer-diameter portion **41** providing an upwardly facing shoulder **42** which is sized and arranged for receiving the lower end of the outer sleeve or pushing member of a conventional setting tool (not shown). External threads **43** are provided around the upper end of mandrel **11** for coupling to the inner mandrel or pulling member of the setting tool. A reduced-diameter or necked portion **44** near the upper end of mandrel **11** is sized to fail whenever oppositely directed longitudinal forces of a predetermined magnitude are applied in the well-known manner by the setting tool.

The extendible slip members **19, 20** consist of a plurality of individual sectorially formed slip segments **45, 46**, which segments have a plurality of hardened casing-engaging teeth **47, 48** along their outer arcuate faces. Slip segments **45, 46** are symmetrically grouped at regular intervals around the slip-expanding members **25, 26**, respectively, with each group of segments being yieldably retained in engagement with tapered surfaces **27, 28**, by one or more expansible bands **49–52** of a ductile material, such as brass, which encircle and confine the individual segments. It will be understood, of course, that although a single expansible band on each slip member would be adequate, it is preferred to place an expansible band around each end of the slip members **19, 20** to ensure that all segments of a slip member act in unison as well as to provide a greater degree of control over the lateral movement of the segments as the slip-expanding members are moving to expand the slip members.

It will be appreciated that by varying the dimensions and selecting the ductile material of the annular restraining members **49–52**, the strength of these bands can be appropriately regulated so that they will not yield until a [illegible] of a predetermined magnitude is applied thereto, [illegible] is capable of stretching the bands sufficient- [illegible] the individual slip segments to extend radially [illegible] into engagement with the casing wall **53** (FIG. [illegible] more, it will be realized that so long as the [illegible] bands **49–52** hold the slip segments in their initial retracted position (FIG. 1), the longitudinally directed forces applied by a setting tool to the bridge plug **10** will act through the slip-expanding members **25, 26** and slip members **19, 20**, respectively, on the opposite ends of the packing element **12**. The element **12** will of course begin expanding into sealing engagement with the casing **53** in response to the increase of the setting forces, with the degree of expansion of the element at a particular magnitude of forces being governed by the properties of the elastomeric material selected and the dimensions of the element.

Accordingly, in the present invention, the ductile restraining members **49–52** are sized where they will not stretch until the setting forces have increased to a predetermined magnitude, which magnitude may be less than, equal to, or greater than the magnitude of force required to completely expand the packing element **12** against the casing **53**. Thus, it will be understood that by regulating the strength of the restraining members **49–52**, the degree of expansion of the packing element **12** is closely controlled.

Restraining members **49–52** are preferably sized and proportioned to restrain the outward extension of the slip members **19, 20** until such time that packing element **12** has a least been substantially expanded against the casing **53**. Thus, by properly correlating the amount of force required to stretch the restraining bands or members **49–52** to the amount of force required to displace the packing element **12**, the slip segments **45, 46** can be delayed from engaging the casing **53** until the packing element **12** has first been displaced a predetermined amount during the setting operation.

It is of equal importance to the invention that the expansible bands **49–52** are arranged to stretch without breaking. By selecting a ductile material for the bands and by sizing them properly, the bands will stretch circumferentially which will allow the individual segments **45, 46** to move outwardly only in unison. Thus, the restraining influence provided by the bands as they stretch will maintain the axial alignment and angular relationship of the individual segments as slip-expanding members **25, 26** drive the segments outwardly against the casing **53**.

It should also be noted that by arranging restraining members **50, 52** on the inward side of the slip members **19, 20**, whenever the slip members are engaged with the casing **53**, the annular restraining members **50, 52** completely close any sectorial spaces remaining between the individual segments **45, 46** which otherwise would exist between the outer periphery of the washer members **15, 16** and the casing wall **53**. Thus, annular restraining members **50, 52** also serve as additional anti-extrusion members should the elastomeric packing element **12** not be wholly confined by anti-extrusion rings **13, 14**.

It should be further noted that by sizing restraining members **49–52** to prevent the full extension of the slip members **19, 20** until the packing element **12** has been substantially displaced against the casing **53**, the hardened teeth **47, 48** of the slip members will not contact the casing until the movable members of the bridge plug have nearly reached their final positions. Thus, when the slip segments **45, 46** do engage the casing, it will be appreciated that the teeth **47, 48** are not dragged across the casing walls but instead remain substantially where they first engage the casing.

When the bridge plug **10** of FIG. 1 is to be used, a conventional setting tool (not shown) is attached to the upper end of bridge plug **10**. The pulling member or inner mandrel (not shown) of the setting tool is threadedly attached to threads **43** at the upper end of mandrel **11** and the pushing member or outer sleeve (not shown) of the setting tool is cooperatively engaged with the upwardly facing shoulder **42** of upper slip-expander member **26**.

When the bridge plug has been correctly positioned within a cased well bore, the setting tool is then operated in the conventional manner to pull mandrel **11** and lower slip-expander member **25** along with slip member **19** upwardly as the setting tool sleeve forces upper slip-expander member **26** and slip member **20** downwardly. As the upper slip member **20** and slip-expander members **26** advance toward the lower slip member **19** and slip-expander member **25**, it will be appreciated that gradually increasing and oppositely directed setting forces will be applied from the setting tool through the slip members **19**, **20** and spacer members **15**, **16** against the opposite ends of the packing element **12**, which forces will first begin foreshortening and displacing the packing element radially outwardly into sealing engagement with the casing wall **53**.

When the setting forces have increased to a predetermined magnitude, restraining members **49–52** then yield and being to slowly stretch, which stretching then allows the tapered slip-expander members **25**, **26** to move inwardly relative to the slip members **19**, **20** and being extending the individual slip segments **45**, **46** radially outwardly in unison as they slide along tapered surfaces **27**, **28**. When restraining members **49–52** have stretched sufficiently, the hardened teeth **47**, **48** of the individual slip segments **45**, **46** will contact the casing **53** and the continued inward travel of the slip-expander members **25**, **26** relative to the segments will subsequently drive the hardened teeth radially into the casing.

When the setting tool is actuated and the mandrel **11** first begins to travel upwardly, ratchet teeth **36** on the mandrel will slide under ratchet teeth **35** on split-nut **34** to expand the split-nut. Accordingly, split-nut **34** is free to alternately expand and contract, and each time it expands, it will begin sliding relatively upwardly and outwardly along the tapered surfaces **32** of upper slip-expander member **26**. As split-nut **34** begins to slide upwardly, however, spring member **37** is compressed and then expands to drive the split-nut inwardly and downwardly to force ratchet teeth **35** into engagement with the next group of ratchet teeth **36** around the mandrel. This alternate compression and expansion of spring member **37** tends to drive split-nut **34** downwardly while preventing any "backlash" or retrograde movement of the packing element. It will be appreciated, therefore, that the split-nut **34** will be continuously driven over the lowermost ratchet teeth **36** of the mandrel that the ratchet teeth **35** can engage.

After the bridge plug has been completely set in anchoring and sealing engagement with the casing, the setting tool forces continue to increase until weakened portion **44** of mandrel **11** fails, which failure will release the mandrel from the setting tool and allow the setting tool to be retrieved in the conventional manner. Thus, when bridge plug **10** is finally anchored and the setting tool disengaged, it will be appreciated that the bridge plug will effectively resist either upwardly or downwardly directed forces.

With any bridge plug having an elastomeric packing element, it will be appreciated that after the element is set, longitudinally directed forces on the packing element will proportionately increase the radial loading of the element against the casing. Thus, when there is a pressure differential across a bridge plug engaged in a well casing, well pressure is applied on the annular cross-sectional area of the packing element which increases the casing loading. This same well pressure is also applied on the circular cross-section of the mandrel; and with a conventionally arranged bridge plug, the resulting force on the mandrel is transmitted through the packing element to the slip member opposing forces in that direction, which pressure force further increases the radial loading of the packing element against the casing.

It should be noted that in contrast to conventionally arranged bridge plugs, in the bridge plug **10** of the present invention, the upper slip member **20** is provided with downwardly facing casing-engaging teeth **48** whereas the teeth **47** on the lower slip member **19** are directed upwardly. Accordingly, it will be appreciated that the upper slip member **20** will primarily resist downwardly directed



loads and that the lower slip member **19** will primarily resist upwardly directed loads.

It will be appreciated, therefore, that with the bridge plug **10** of the present invention, longitudinally directed loads on the mandrel **11** are not transmitted to the packing element **12** but are instead imposed directly on the slip member opposing forces acting in that direction. For example, an upwardly directed load on the mandrel is directly transmitted from the mandrel **11** and lower slip expander member **25** into lower slip member **19**, which is engaged with the casing in such a manner as to oppose such upwardly directed forces. Similarly, a downwardly directed force is transmitted directly to the upper slip member **20**. Thus, once the bridge plug **10** of the present invention is set, pressure forces acting on the mandrel **11** will not be transmitted to the packing element **12** which accordingly reduces the likelihood that additional loading of the element might bulge or split the casing or perhaps crack cement behind the casing **53**.

It will be further appreciated that the expansible retaining bands **49–52** of the present invention may be employed with equal success on conventionally arranged bridge plugs where the relative positions of the expanders and slip members are reversed from that shown in FIG. 1. In such instances, where the expanders are abutted against opposite ends of the packing element with the slip members being carried on the outer ends of the expanders, the expansible bands may be advantageously utilized in several manners. For example, with a conventional bridge plug, the upper slip member has upwardly directed teeth and is usually extended into anchoring engagement before the lower slip member. Then, as the setting tool forces continue to increase, the packing element is radially displaced and foreshortened with the upper slip member remaining fixed against the casing to serve as a back-up. The lower slip member is finally allowed to extend as it is pulled upwardly until failure of the tension-stud releases the setting tool.

Where this particular sequence of operation is desired, a relatively weak restraining band or a set of such bands arranged around the upper slip member would be proportioned to stretch under a fairly light load which will allow the upper slip member to anchoringly engage the casing before the packing element is expanded. Another stretch band or a set of bands arranged around the lower slip member would be proportioned to withstand a considerably higher force. Accordingly, extension of the lower slip member would be controllably delayed until the packing element has been substantially displaced or even until it has been completely displaced against the casing. It will be appreciated, therefore, that with this particular arrangement, the restraining bands on the lower slip member will prevent the teeth of the lower slip from engaging the casing until the bridge plug has been shifted to substantially its final position. Thus, with this controlled delay, the teeth on the lower slip member will be dragged along the casing at best only a short distance, if at all. In any event, the restraining influence of the bands as they are stretched will ensure that all slip segments maintain a uniform angular relationship as well as remain axially aligned as they are being extended into engagement with the casing.

Accordingly, it will be appreciated that a bridge plug constructed in accordance with the present invention will be suitable for high-pressure service in well conduits with the slip members carrying most of the additional loads imposed thereby. Furthermore, the segments of the slip members will be extended in unison and maintained in a uniform disposition to provide a uniform loading against the casing as well as to ensure that the bridge plug is centralized within the casing. The ductile restraining bands of the present invention also eliminate the necessity for the various shear member arrangements wherever they have been used heretofore for holding slip members in a retracted position around their respective slip-expanding members. Thus, as a setting tool is setting a bridge plug employing principles of the present invention, the slip members will move positively to their anchoring positions without any sudden shock being imparted to the bridge plug as is the case when a conventional shear member connection fails.

While particular embodiments of the present invention have been shown and described, it is apparent that changes and modifications may be made without departing from this invention in its broader aspects and, therefore, the aim in the appended claims is to cover all such changes and modifications as fall within the true spirit and scope of this invention.

What is claimed is:

1. In a packer device having a central body member with an expansible packing element operatively mounted and arranged thereon for expansion into sealing engagement with a well bore in response to a force of a first predetermined magnitude; a frusto-conical slip-expanding member on said body member adjacent one end of said packing element; an extendible slip member complementarily fitted and slidably mounted around said slip-expanding member and arranged to be expanded outwardly thereby from a retracted first position into anchoring engagement with a well bore at an extended second position in response to relative advancement of said slip-expanding member into said slip member; and means cooperating with said packing element and said members for expanding said element and said slip member into engagement with a well bore, the improvement comprised of: means for releasably retaining said slip member in said retracted first position including an expansible ring member of a ductile material around a portion of said slip member, said ring member being stretchable in response to a force of a second predetermined magnitude greater than said first magnitude to release said slip member and allow said slip member to expand into said extended second position after said packing element has been expanded.

2. In a packer device having a central body member with an expansible packing element operatively mounted and arranged thereon for expansion into sealing engagement with a well bore in response to a force of a first predetermined magnitude; first and second oppositely directed frusto-conical slip-expanding members respectively mounted on said body member adjacent opposite ends of said packing element; first and second extendible slip members respectively complementarily fitted and slidably mounted around said slip-expanding members and arranged to be expanded outwardly thereby from a retracted first position into anchoring engagement with a well bore at an extended second position in response to relative advancement of each of said slip-expanding members into its respective slip member; and means cooperating with said packing element and said members for expanding said element and said slip members into engagement with a well bore, the improvement comprised of: means for releasably retaining one of said slip members in said retracted first position including an expansible ring member of a ductile material around a portion of said one slip member, said ring member being stretchable in response to a force of a second predetermined magnitude greater than said first magnitude to release said one slip member and allow said one slip member to expand into said extended first position.



3. In a packer device having a central body member with an expansible packing element operatively mounted and arranged thereon for expansion into sealing engagement with a well bore in response to a force of a first predetermined magnitude; first and second oppositely directed frusto-conical slip-expanding members respectively mounted on said body member adjacent opposite ends of said packing element; first and second extendible slip members respectively complementarily fitted and slidably mounted around said slip-expanding members and arranged to be expanded outwardly thereby from a retracted first position into anchoring engagement with a well bore at an extended second position in response to relative advancement of each of said slip-expanding members into its respective slip member; and means cooperating with said packing element and said members for expanding said element and said slip members into engagement with a well bore, the improvement comprised of: means for releasably retaining said slip members in said retracted first position including first and second expansible ring members of a ductile material respectively mounted around said first and second slip members, said ring members being stretchable respectively in response to forces of a second and third predetermined magnitude to release said slip members and allow said slip members to expand into said extended second position.

4. The apparatus of claim 3 wherein said second predetermined force magnitude is greater than said first predetermined force magnitude.

5. The apparatus of claim 3 wherein said second predetermined force magnitude is greater than said first predetermined force magnitude and said third predetermined force magnitude is less than said first predetermined force magnitude.

6. The apparatus of claim 3 wherein said second and third predetermined force magnitudes are equal to one another and greater than said first predetermined force magnitude.

7. In a well tool having a body, slip and expander means on said body operable in response to longitudinally directed setting forces applied thereto for anchoring the tool in a well conduit, said slip means being movable outwardly of said body, and a packing means on said body expandable in response to said setting forces for packing off the well conduit, the improvement comprising, in combination, annular restraining means encircling and engaging said slip means, said restraining means being constructed of a ductile, stretchable material with a predetermined yield strength such that the operation of said slip and expander means can be delayed until said packing means can be substantially expanded and, after yielding, said restraining means can function to control outward movement of said slip means.


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