July 30, 1968 C. R. YOUNG 3,394,762

WELL TOOLS

Filed Dec. 11, 1964 3 Sheets-Sheet 1

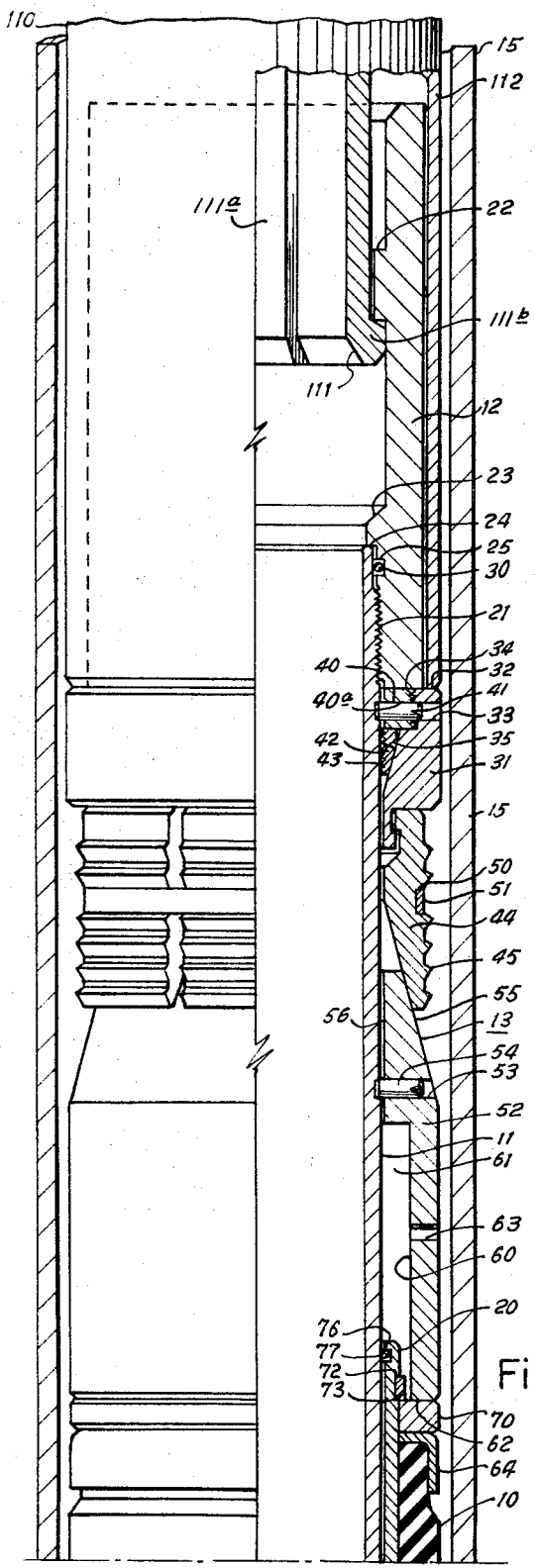


Fig. 1

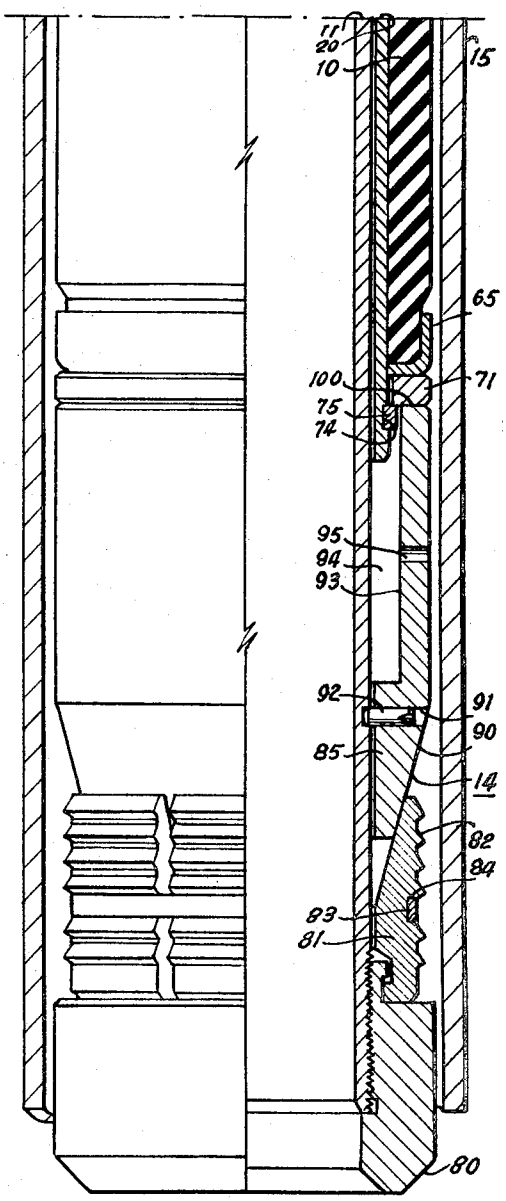


Fig. 1-A

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WELL TOOLS

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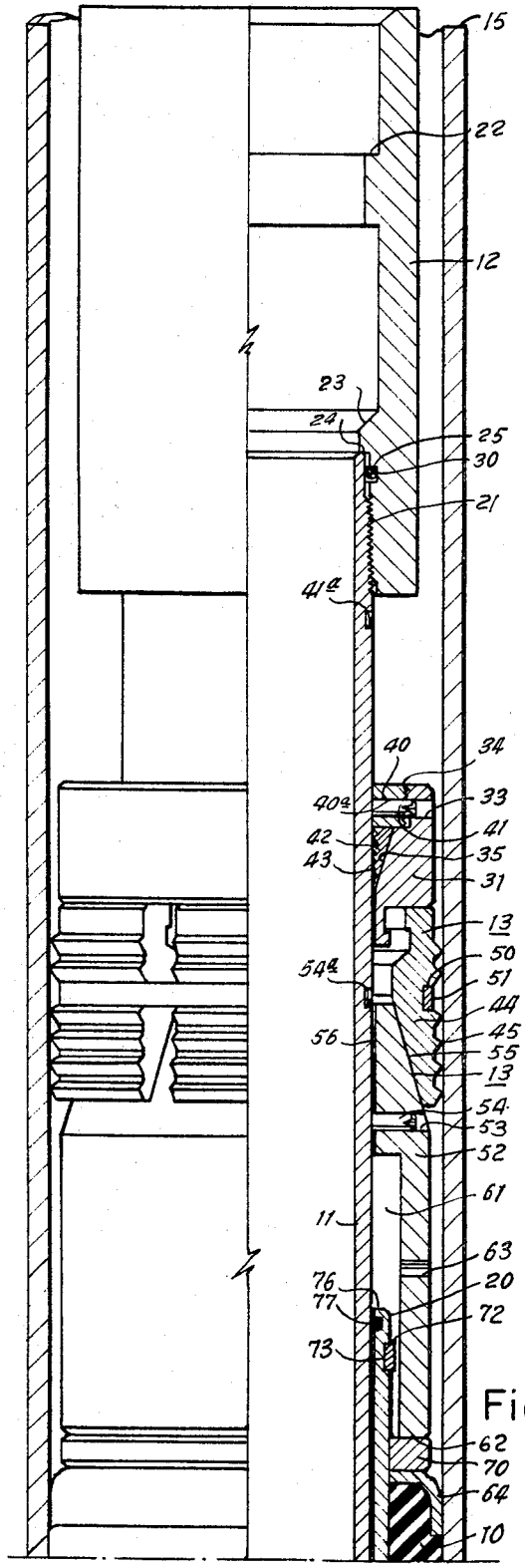


Fig. 2

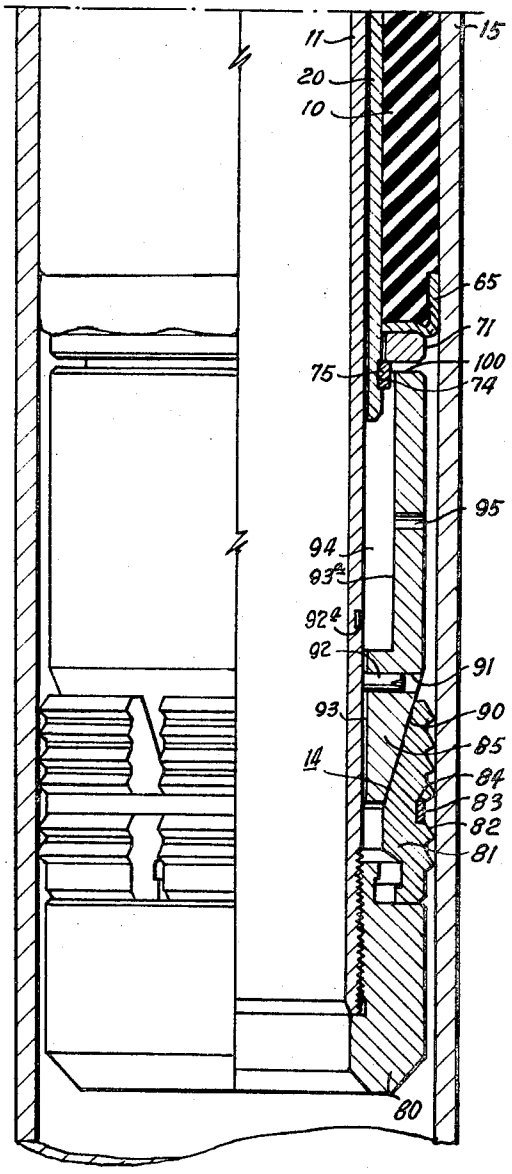


Fig. 2-A

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WELL TOOLS

Filed Dec. 11, 1964 3 Sheets-Sheet 3

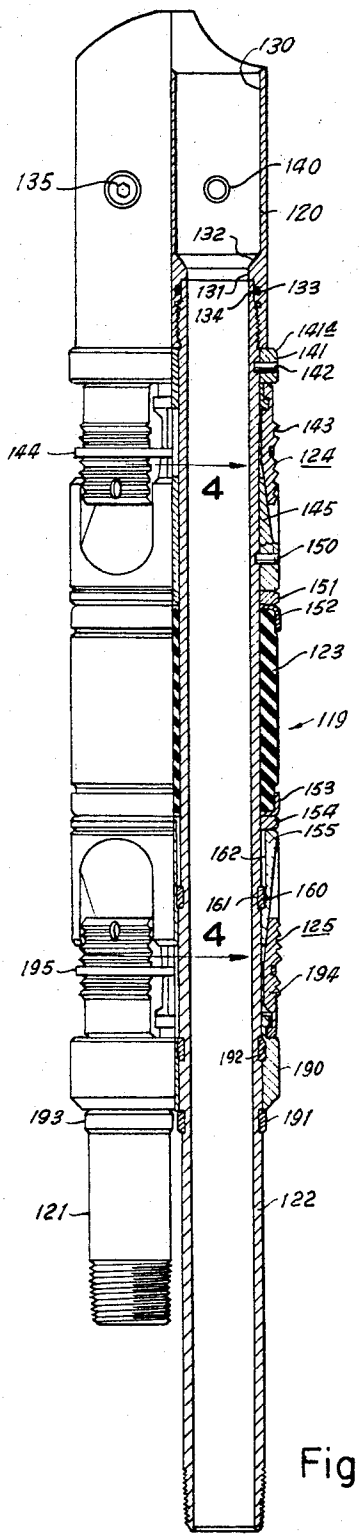


Fig. 3

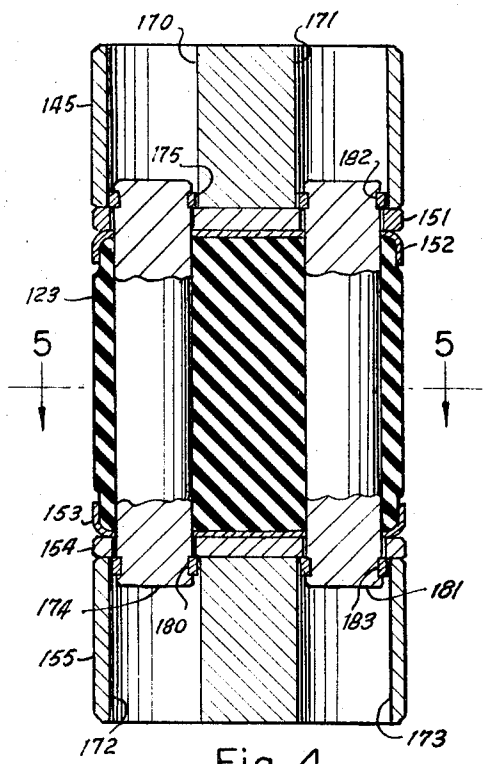


Fig. 4

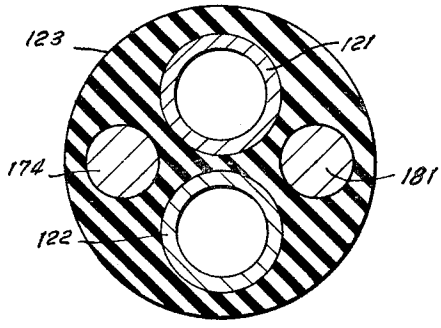


Fig. 5

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3,394,762

WELL TOOLS

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20 Claims. (Cl. 166—123)

ABSTRACT OF THE DISCLOSURE

A well packer, either single or multiple conductor string, having a sealing element thereon initially stressed mechanically to a predetermined desired expanded condition for sealing between the packer mandrel and the well conductor, and provided with pressure responsive means for imposing additional stress in the packer as a result of fluid pressure differentials across the sealing element to increase the sealing effect and prevent leakage across the packer in either direction longitudinally of the packer.

This invention relates to well tools and more particularly to well packers.

It is an object of this invention to provide a new and improved well packer for closing the annulus between an inner flow conductor and an outer flow conductor in which the inner conductor is disposed.

It is a further object of the invention to provide a well packer which will form a tighter sealing relationship with the wall of a well bore as the pressure within the well bore increases after the initial setting of the packer.

It is a still further object of the invention to provide a well packer having a resilient element for establishing a sealing relationship with the wall of a well bore, such element being expanded into tighter sealing relationship in proportion to the pressure differential being exerted across the element.

It is another important object of the invention to provide a well packer in which the resilient sealing element of the packer effects a sealing relationship with the well bore wall in response to a pressure differential in excess of the initial pressure differential whether such differential is in an upward or downward direction across the element.

It is a still further object of the invention to provide a well packer which may be locked and sealed in a well casing with its sealing element having been compressed to build up a stress of a certain value therein and which will subsequently respond to a higher than the initial pressure differential and the seal element will then be stresed to a higher value to effectively seal the well bore against such differential for preventing leakage around the packer after it has been set.

It is an additional object of the invention to provide a well packer for effecting a pressure responsive seal within a well bore around either single strings of pipe or multiple strings of pipe.

It is a further object of the invention to provide a well packer having a longitudinally slidable, pressure responsive member which is movable when exposed to a pressure differential across the seal element of the packer to cause the seal element to form a tighter seal than originally established.

It is another object of the invention to provide a well packer in which well pressure causes a tighter seal than the seal which can mechanically be established by the packer upon initial setting.

Additional objects and advantages of the invention will be readily apparent from the reading of the following description of a device constructed in accordance with the invention, and reference to the accompanying drawings thereof, wherein:

FIGURES 1 and 1*a* taken together represent a longitudinal view, partially in section and partially in elevation, of a single string packer constructed in accordance with the invention;

FIGURES 2 and 2*a* taken together constitute a view, partially in elevation and partially in section, of the packer illustrated in FIGURE 1 with the slips set and the seal element expanded into contact with the well casing;

FIGURE 3 is a longitudinal view, partially in elevation and partially in section, of a multiple string well packer constructed in accordance with the invention;

FIGURE 4 is a view, partially in elevation and partially in section, taken along line 4—4 of FIGURE 3; and

FIGURE 5 is a view in section taken along the line 5—5 of FIGURE 4.

Referring to FIGURES 1 and 1*a*, a single string packer constructed in accordance with the invention generally comprises a resilient seal element **10** supported on a mandrel **11** which is secured to a head **12**. An upper slip assembly **13** and a lower slip assembly **14** secured on the mandrel are utilized to anchor the packer within well casing **15**. The resilient seal element is supported around the mandrel on a longitudinally slidable sleeve or piston means **20** which is exposed at opposite ends to the pressure above and below the seal element causing the sleeve to be displaced toward the lower pressure.

The packer head **12** is engaged with the upper end of the mandrel **11** by a threaded connection at **21**. The packer head is provided with an internal annular flange **22** which is engageable with a suitable running tool. Formed within the packer head is a downwardly and inwardly sloping shoulder or seat **23** and a downwardly facing shoulder **24** which engages the upper end of the mandrel **11** when the packer head and mandrel are secured together. An internal annular seal ring groove **25** is formed within the packer head below the shoulder **24**. A seal ring **30** is positioned within the groove **25** to establish a seal between the upper end of the mandrel and the packer head above the threaded connection between the mandrel and the head. Positioned around the mandrel below the head is a slip carrier **31** which is an annular member fitted in sliding relationship around the mandrel with the upper end of the carrier forming a shoulder **32** which engages the lower end of the packer head. The slip carrier is provided with one or more smooth laterally extending shear pin bores **33**. The slip carrier is also provided with an internally threaded longitudinal bore **34** in its upper portion which interconnects with a downwardly and inwardly sloping bore **35**. Threadedly engaged in the bore **34** is a ring **40** which is fitted in sliding relationship around the mandrel and has a bore **40***a* to coincide with the bore **33** in the slip carrier. The slip carrier and the ring **40** are secured to the mandrel by a shear pin **41** which is positioned through the bores **33** and **40***a* in the slip carrier and the ring. The inward end of the shear pin engages the mandrel maintaining the slip carrier in the position illustrated in FIGURE 1 so long as the shear pin is intact. Confined between the ring **40** and the bore **35** within the slip carrier are plurality of ring segments **42** which have plurality of inwardly facing teeth **43** adapted to engage the external surface of the mandrel. A plurality of slips **44** are operatively engaged with and supported from the lower end of the upper slip carrier. Each of the slips is provided with external teeth **45** adapted to engage the internal wall of the casing **15**. Each of the slips is provided with a groove **50** for an annular retaining band **51** extending entirely around the packer in engagement with all of the slips included in the upper slip assembly. The retaining band holds the slips in position and ex-

pands or ruptures in response to a predetermined load to allow the slips to engage the casing wall.

An upper slip cone **52** is fitted in sliding relationship around the mandrel below the upper slips. The slip cone is provided with one or more smooth lateral bores **53** in which a shear pin **54** is fitted to initially secure the slip cone to the mandrel. The upper portion of the slip cone is provided with an upwardly and inwardly sloping surface **55** along which the slips slide into engagement with the casing. The bore **56** of the upper slip cone is enlarged along a major portion **60** of its length extending from the lower end of the cone forming an annulus **61** around the mandrel within the cone. The lower end of the cone forms a shoulder **62**. A port **63** extends through the cone into the annulus **61**.

The sleeve **20** fits in sliding relationship around the mandrel within the seal element **10** which is confined at opposite ends by an upper backup shoe **64** and a lower backup shoe **65** each of which is an annular shaped member having a rim extending over a portion of the seal element with which it is engaged to aid in preventing extrusion of the seal element. An upper annular pressure ring **70** is slidably fitted around the sleeve between the shoe **64** and the shoulder **62** on the upper cone. A lower annular pressure ring **71**, see FIGURE 1*a*, is slidably fitted around the sleeve below the lower shoe **65**. The sleeve is provided with an upper external annular groove **72** in which is fitted a snap ring **73** and a lower external annular groove **74** in which is engaged a snap ring **75**. The snap rings **73** and **75** are positioned above the ring **70** and below the ring **71**, respectively, so that the rings **70** and **71** may not slide off the sleeve. The rings **70** and **71** acting through the backup shoes cause expansion of the seal element in response to longitudinal movement of the sleeve **20** caused by a pressure differential across the seal element. An internal seal groove **76** in the upper end of the sleeve contains a seal ring **77** to prevent leakage along the mandrel-sleeve surfaces.

A lower slip carrier **80** is threadedly engaged on the lower end of the mandrel to support and actuate the slips **81** which are supported around the carrier. The slips have external teeth **82** for engagement with the inner wall of the casing. An annular retaining band **83** is fitted around the slips in a groove **84** formed in each of the slips. A lower slip cone **85** is slidably engaged around the mandrel above the lower slips. The lower portion of the lower slip cone is provided with a downwardly and inwardly sloping surface **90** along which the lower slips slide as they are moved toward the cone into engagement with the casing. The lower cone is provided with a smooth lateral bore **91** through which a shear pin **92** is engaged with the mandrel. The bore **93** of the lower cone is enlarged along a major portion **93***a* extending from the upper end to provide an annulus **94** around the mandrel. A port **95** extends through the cone wall into the annulus **94**. The upper end of the lower cone forms a shoulder **100** which is engageable with the lower pressure ring **71**.

In FIGURE 1 a portion of a conventional setting tool **110** is illustrated engaged on the upper end of the packer. One suitable setting tool is illustrated in the patent to Bonner, 3,160,209, though others may be used for actuating the internal collet member **111** and the sleeve **112** forming the lower portion of the setting tool and used for operatively connecting the setting tool to the packer. The setting tool has a movable internal collet member **111** whose fingers **111***a* have external bosses **111***b* which engages the internal flange **22** within the packer head **12**. The sleeve **112** of the setting tool fits over the packer head with the lower end of the sleeve engaging the shoulder **32** on the upper end of the upper slip carrier **31**.

FIGURES 2 and 2*a* illustrate the packer set in engagement with the casing **15** with the resilient seal element expanded into sealing relationship with the casing by both normal setting action and by a pressure differential across the packer with the higher pressure below the packer. In order to set the packer within the casing a suitable setting tool is engaged with the packer head as illustrated in FIGURE 1. The packer is lowered to the point within the casing **15** where it is desired that it be engaged with the casing. The member **111** of the running tool is lifted in an upward direction relative to the sleeve **112**. Since the collet **111** is engaged with the internal flange **22** within the packer head, the head is pulled upwardly causing the mandrel **11** which is threadedly engaged to the packer head to also be pulled in an upward direction. The sleeve **112** of the running tool presses against the shoulder **32** on the upper slip carrier to prevent the slip carrier and the upper slips from moving upwardly with the mandrel which results in the shearing of the pins **41**. With the pins **41** sheared, the mandrel is free to move upwardly relative to the upper slip carrier and slips and the various elements secured to the mandrel below the upper slips also move with the mandrel because their respective shear pins still are intact. The upper cone, therefore, is carried upwardly with the upward movement of the mandrel. Upward movement of the surface **55** on the upper cone relative to the upper slips causes the slips to be expanded into locking engagement with the inner wall of the casing. The restraining band **51** expands or ruptures with the outward movement of the slips. Upward movement of the upper slip carrier relative to the mandrel is prevented by the ring **42**. Since the teeth on the locking ring segments **42** point in an upward direction any upward movement of the carrier or downward movement of the mandrel relative to the carrier will cause the teeth to engage the outer surface of the mandrel effecting a wedging of the ring segments between the outer surface of the mandrel and the sloping inner surface **35** of the upper slip carrier.

When the upper slips are fully engaged with the casing the upper cone can no longer move upwardly with the mandrel and further movement of the mandrel results in shearing the pins **54** to allow the mandrel to move relative to the upper cone. With the pins **54** sheared the mandrel moves upwardly while the upper end of the resilient seal element **10** is restrained from upward movement by the lower end of the upper slip cone acting through the shoulder **62**, the ring **70**, and the backup shoe **64** which holds the upper end of the seal element. The lower cone is, however, still secured to the mandrel by means of the shear pins **92**. The lower cone thus continues upwardly with the mandrel and acting through the shoulder **100**, the ring **71**, and the lower backup shoe **65** the lower cone expands the seal element into sealing relationship with the inner wall of the well casing. With the upper end of the seal element being held against upward movement and the lower end being pushed upwardly, the stress induced in the seal element forces it to expand outwardly.

After the seal element has expanded laterally into sealing relationship with the casing the lower end of the seal element resists further upward movement of the lower cone effecting a severing of the shear pin **92** to permit the mandrel and lower slip carrier to move upwardly relative to the lower cone. Since the lower slip carrier is secured to the lower end of the mandrel the upward movement of the carrier forces the lower slips **81** upwardly and outwardly along the surface **90** on the lower cone. The lower slips are thus expanded into engagement with the inner wall of the well casing. After engagement of the slips with the casing, the mandrel may continue upward movement dragging the slips along the casing with the seal element further expanding until the stress in the seal element reaches a predetermined value at which time the setting tool disengages from the packer head and may be withdrawn from the well. The teeth on the upper and lower slips "bite" into the casing wall to keep the packer engaged and the seal element expanded.

FIGURES 2 and 2*a* represent the packer after the setting tool has been withdrawn and the seal element is in sealing engagement with the well casing and the upper and lower slips are set into locking relationship with the inner wall of the well casing. These figures also show additional stressing of the seal element due to a pressure differential across the element with the higher pressure below the element. Examination of the FIGURES 2 and 2*a* will reveal that the inward ends of the shear pins **41**, **54** and **92** are shown within the mandrel at positions substantially above the major portions of the shear pins which remain in the upper slip assembly, the upper cone, and the lower cone, respectively, evidencing that all the shear pins have been severed by the upward movement of the mandrel during the setting of the packer. The inward, severed ends of the shear pins **41**, **54**, and **92** are referred to in FIGURES 2 and 2*a* by the reference numerals **41***a*, **54***a* and **92***a*, respectively. The upper slips and the lower slips are each in locking engagement with the inside wall of the well casing. The ring segments **42** within the upper slip assembly are engaged with the outer surface of the mandrel to resist any downward movement of the mandrel relative to the upper slip assembly. The lower end of the resilient seal element has been forced closer to the upper end of the element resulting in the lateral expansion of the element into sealing relationship with the wall of the well casing.

Inasmuch as the lower slips engage the casing before the stress in the resilient seal element reaches an ideal value the lower slips are dragged along the inner surface of the well casing resulting in both a waste of energy and dulling of the slip teeth. The seal element is therefore not compressed by the normal action of the setting of the packer to the extent that it should be. When pressure conditions within the well bore cause a differential to be exerted across the seal element in an amount in excess of the stress which has been set up in the element, the element would ordinarily allow fluid to pass between it and the wall of the well casing. Thus, after the packer has been set, pressure differentials across the seal element may result in leakage around the packer if the pressure differentials exceed the stress set up in the seal element.

The sleeve **20** together with the upper and lower pressure rings **70** and **71**, and with the locking rings **73** and **75**, respectively, are slidable as a unit on the carrier mandrel between the mandrel and the seal element. Also, the rings **70** and **71** are slidable along the surface of the sleeve. The pressures on opposite sides of the seal element are imposed on the ends of the sleeve assembly through the ports **63** and **95** in the upper and lower cones, respectively. Thus, the lower end of the sleeve assembly may be exposed to a high pressure while the upper end of the sleeve assembly is exposed to a lower pressure. Such pressure differential on the sleeve assembly causes the sleeve to move in an upward direction relative to both the seal element and the mandrel. The upper end of the seal element is restrained from upward movement by the shoulder **62** on the upper cone acting through the ring **70**. Therefore, as the sleeve moves upwardly the lock ring **75** on the lower end of the sleeve engages the ring **71** carrying the ring upwardly away from the upper end of the lower cone as illustrated in FIGURE 2*a*. The ring **71** pressing against the lower backup shoe **65** further stresses the seal element to cause it to seal more tightly with the casing wall to prevent leakage occurring across the seal element between the element and the inner casing wall. The extent to which the sleeve will move in an upward direction is, of course, dependent on or proportional to the magnitude of the pressure differential exerted across the seal element. It will be evident from FIGURE 2 that the upper end of the sleeve has moved upwardly and thus the lock ring **73** is displaced upwardly from the upper pressure ring. The upper pressure ring has been restrained from upward movement by the lower end of the upper cone. Leakage along the mandrel between the mandrel and sleeve has been prevented by the O-ring **77** positioned in the groove **76** in the sleeve around the mandrel near the upper end of the sleeve.

If the pressure above the seal element exceeds the pressure below the element the sleeve assembly will shift in a downward direction to effect a tighter seal with the casing wall in a manner identical to that above described. The pressure above the seal element pushes the sleeve downwardly causing the split ring **73** to contact the upper pressure ring **70** exerting a force against the upper backup shoe proportional to the pressure differential being exerted across the seal element. Since the lower end of the seal element is now restrained from downward movement by contact with the lower pressure ring which is supported on the shoulder **100** on the upper end of the lower cone, the seal element is stressed and is forced to expand laterally into tighter sealing relationship with the well casing.

Thus, whether the pressure differential across the seal element is in an upward or a downward direction the principal feature of the invention functions in response to the pressure differential in that the sleeve assembly slides relative to the mandrel and seal element to cause lateral expansion of the seal element in proportion to the pressure differential being exerted across the seal element. Leakage around the packer is therefore prevented even though the pressure exceeds the initial stress set up in the seal element by the setting of the packer in the well casing by the running tool.

Referring now particularly to FIGURES 3–5, the packer **119** generally comprises a head **120** secured to the tubular mandrels **121** and **122** which support a resilient seal element **123** between the upper slip assembly **124** and the lower slip assembly **125**. The head is provided with dual bores to coincide with the mandrels **121** and **122**. Only the bore **130** which interconnects with the mandrel **122** is illustrated though it is to be understood that the other bore in the head is identical to the bore **130**. The head is provided within the bore **130** with an internal annular flange **131** which provides a downwardly and inwardly sloping seat **132** below which is formed an annular groove **133** for a seal ring **134** to effect a sealing relationship between the head and the mandrel **122**. While the other bore is not visible in FIGURE 3 it is to be understood that it is identically fitted with a seat, a groove, and a seal ring for connecting into and effecting a seal with the mandrel **121**. Lugs **135** and **140** are secured through the head into the bores of the head for engagement of a suitable running tool for setting the packer in a well bore. An upper slip carrier **141** is positioned around the mandrels and secured by a shear pin **142** which extends through the carrier into the outer surface of the mandrel. A plurality of slips **143** are supported from the upper slip carrier around the packer with a retaining band **144** fitted around the outside of the slips to hold the slips in retracted position. An upper slip cone **145** is fitted in sliding relationship around the mandrels and secured by a shear pin **150**. Positioned around the mandrels between the lower end of the upper cone and the upper end of the seal element is an upper pressure plate **151** which is fitted in sliding relationship on the mandrels. The resilient seal element **123** is confined between an upper backup shoe **152** and a lower backup shoe **153**. The upper pressure plate **151** rests on and in contact with the upper backup shoe **152**. A lower pressure plate **154** is slidably positioned around the mandrels below and in contact with the lower backup shoe **153**. The upper and lower pressure plates are interconnected as illustrated in FIGURES 4 and 5 and explained hereinafter. A lower slip cone **155** is fitted in sliding relationship around the mandrels below the lower pressure plate. A lock ring **160** is fitted in an annular groove around the mandrel **122**. The bore of the lower slip cone through which the mandrel **122** is positioned is enlarged at **162** so that the mandrel may move in an upward direction relative to the slip cone but may not move downwardly relative to the cone any farther than illustrated in FIGURE 3. The other bore of the lower cone which accom-

modates the mandrel 121 is similarly formed and a lock ring, not shown, is fitted around the mandrel 121 to slide within the cone. The upper slip cone 145 is provided with longitudinal bores 170 and 171 while, similarly, longitudinally extending bores 172 and 173 are formed within the lower slip cone. A piston rod or means 174 extends through the seal element into the bore 170 at the upper end and the bore 174 at the lower end. Split rings 175 and 180 are fitted around the rod 174 above and below the upper and lower pressure plates, respectively. The split ring 175 is secured around the rod so that it will contact the upper face of the upper pressure plate while the split ring 180 is secured around the lower end of the rod such that the split ring will contact the lower surface of the lower pressure plate. Another piston rod or means 181 extends through the seal element into the bore 171 in the upper slip cone and the bore 173 in the lower slip cone. Split rings 182 and 183 are engaged around the upper and lower ends, respectively, of the rod 181. The split ring 182 locks the upper end of the rod above the upper pressure plate while the split ring 183 locks the lower end of the rod below the lower pressure plate. The split rings on the ends of the rod are of such external diameter that they may slide freely within the particular bore in which they are positioned. The piston rods 174 and 181 preferably are solid in construction though they may be hollow conduits provided they have a closure member in them against which pressure within the well bore above and below the packer may be exerted, as hereinafter explained.

Referring back to FIGURE 3, a lower slip carrier 190 is secured on the mandrels by split rings 191 and 192 around the mandrel 122. The split ring 193 and an upper split ring, not shown, corresponding to ring 192, secure the lower carrier to the mandrel 121. A plurality of slips 194 are engaged on the lower carrier and secured around the carrier and the lower cone by a retaining band 195.

The multiple string packer is set with a suitable running tool, not shown. One portion of the running tool has J-slots in which the lugs 135 and 140 in the packer head are received while another portion of the running tool in the form of a sleeve fits around the head with the lower end of the sleeve engaged with the shoulder 141*a* on the upper slip carrier. The running tool is manipulated so that the portion engaging the lugs 135 and 140 is withdrawn upwardly while the sleeve fitting around the packer head is restrained from upward movement so that the net effect is an upward movement of the packer head and the mandrels 121 and 122 with the upper slip carrier 141 being held from upward movement by the sleeve portion of the running tool bearing down against the shoulder 141*a*. The shear pin 142 is thus severed due to the forces tending to move the mandrels relative to the upper carrier allowing the mandrels to be drawn in an upward direction. With the shear pin 142 severed and the mandrels moving in an upward direction while the upper slip carrier and upper slips are restrained from upward movement, the upper cone 145 moves upwardly relative to the slips expanding the slips into engagement with the inner wall of the well casing. When the upper slips are fully engaged with the casing the upper slip cone will become wedged between the mandrels and the upper slips so that the cone may be not move farther upwardly resulting in the severing of the shear pin 150 to allow the mandrels to continue to be withdrawn in an upward direction. With the upper cone restrained from further upward movement the mandrels continue in an upward direction with a resulting expanding of the seal element into sealing relationship with the well casing and a subsequent setting of the lower slips. Since the lower slip carrier 190 is locked to the mandrels by the split ring, upward movement of the mandrels carries the slip carrier with them to force the lower slips and the lower cone upwardly. The upper end of the lower cone through the pressure plate presses against the lower backup shoe causing a stressing of the seal element expanding the seal element outwardly into contact with the casing wall. As the seal element engages the casing wall the lower slips are pushed upwardly along the surface of the lower cone expanding the slips into engagement with the inner wall of the casing. Since the split ring 160, which is locked around the mandrels, may slide in the annular space 162 within the lower cone, the mandrels may thus move upwardly relative to the cone to effect the expanding of the slips. The final force exerted on the mandrels by the setting tool results in the full expansion of the lower slips and the final stressing of the seal element to obtain maximum expansion of the seal element with the force available from setting tool. The setting tool then disengages from the packer and is withdrawn from the well.

Under average operating conditions, the final setting of the packer results in stressing the seal element sufficiently to prevent leakage along the surface of the element between the contact of the element with the wall of the casing. However, in the event that the pressure differential across the packer exceeds the stress thus induced in the seal element there will be a tendency toward leakage between the seal element and the casing. This leakage which will normally occur in a conventional form of packer is, however, prevented by a packer constructed in accordance with the invention. Assuming for purposes of explanation that the pressure differential across the seal element from below to above the seal element exceeds the stress induced in the seal element there will be leakage along the element between it and the well casing in a conventional packer. With the apparatus of the invention, however, this added pressure from below the packer will be exerted within the bores 172 and 173 in the lower cone causing the pressure thus to be imposed on the lower ends of the piston rods or means 174 and 181. Since these rods are exposed through the bores 170 and 171 in the upper cone to a lower pressure on the other side or above the packer element, the rods tend to be displaced in an upward direction. The higher pressure is exerted on the lower ends of the rods and the lower pressure on the upper ends of the rods. The rods will thus move in an upward direction and the split rings 180 and 183 on the lower ends of the rods engage the lower pressure plate 154 causing the plate to be carried upwardly with the rods exerting additional force on the lower end of the seal element. The upper end of the seal element is restrained from upward movement by the action of the upper slips acting through the upper cone and the upper seal plate 151 and the lower end of the seal element is urged upwardly resulting in lateral expansion of the element and more effective sealing. So long as this higher pressure differential across the seal element exists, the lower plate will be urged in an upward direction by the pressure differential across the rods causing the additional stressing of the seal element proportional to the pressure differential. Should the pressure differential be across the seal element from above the packer to below the packer, the apparatus of the invention will be in the same manner stress the seal element proportional to the differential effecting a tighter sealing relationship with the well bore. Under such circumstances, the upper ends of the piston rods are exposed to higher pressure with the lower ends of the rods being exposed to lower pressure and the resultant downward displacement of the rods carrying the upper pressure plate downwardly due to engagement by the split rings 175 and 182. Where the rods are being urged downward the lower end of the seal element is prevented from downward movement by the locking action of the lower slips acting through the lower cone and lower pressure plate. Thus, additional stressing and consequently more effective sealing is achieved in a multiple string packer where pressure differentials are created

either above or below the packer in excess of the differentials under which the packer was initially set.

It will thus be seen that there has been illustrated and described a new and improved form of well packer having a resilient seal element which, after initial setting of the packer in a well bore, is stressed in proportion to the pressure differential imposed across it.

It will also be seen that the packer of the invention forms a tighter sealing relationship with the wall of the well bore in which it is installed as the pressure within the well bore above or below the packer increases.

It will additionally be seen that the well packer includes a resilient seal element in which the sealing relationship with the well bore is improved in response to the pressure differential across the element whether such pressure differential is in an upward or a downward direction.

It will also be evident from the foregoing description that the well packer may be initially set in the well bore with a predetermined stress imposed on the seal element of the packer and subsequently the seal element will respond to higher pressure differentials and be additionally stressed in proportion to such higher pressure differentials to effectively prevent leakage around the seal element.

It will also be seen that there has been provided an improvement in a well packer which is applicable to either a single string packer or a multiple string packer for effectively preventing leakage around the packer due to pressure differentials across the packer setting up stress conditions in the seal element of the packer greater than initially induced in the packer when set in the well bore.

It will be further seen that the well packer includes structure through the seal element which is exposed to the pressure both above and below the seal element and is slidable relative to both the seal element and the mandrel of the packer for providing additional stressing and resultant lateral expansion of the seal element in response to increased pressure differentials across the packer for effectively preventing leakage around the packer subsequent to initial setting.

The foregoing description of the invention is explanatory only, and changes in the details of the construction illustrated may be made by those skilled in the art, within the scope of the appended claims, without departing from the spirit of the invention.

What is claimed and desired to be secured by Letters Patent is:

1. A well packer comprising in combination: body means; resilient seal means around said body means and adapted to be expanded into sealing relationship with the wall of the well bore; means on said body associated with said seal means for imposing an initial stress on said seal means to expand the same into such sealing relationship with the wall of the well bore; and pressure means associated with said seal means and said body and exposed to fluid pressures above and below said seal means and movable longitudinally in either direction with respect to said body and independently of said means imposing said initial stress on said seal means by fluid pressure differentials acting on said pressure means for imposing an additional stress on said seal means in response to such pressure differentials acting on said pressure means.

2. A well packer comprising in combination: a mandrel; upper and lower slips movably secured around said mandrel and adapted to be expanded into engagement with the wall of the well bore; a resilient seal element secured around said mandrel between said upper and said lower slips and adapted to be initially stressed to expanded sealing position in engagement with said wall of said well bore between said slips; and means associated with said seal element and exposed to fluid pressures above and below said seal element and movable independently of said slips longitudinally in either direction with respect to said element and said mandrel by fluid pressures differentials acting on said means for increasing the stress imposed upon said seal element in response to and proportional to the pressure differential exerted across said element.

3. A well packer comprising in combination: a mandrel; an upper slip assembly secured on said mandrel; a lower slip assembly secured on said mandrel; a resilient seal element secured around said mandrel between said upper and said lower slip assemblies and adapted to be initially stressed to expanded sealing position between said slip assemblies; pressure means positioned through said seal element and in sealing relationship with the exterior of said mandrel exposed to the pressure around said seal element above and below said element and movable longitudinally independently of said slip assemblies relative to said mandrel and said seal element in response to fluid pressure differentials acting on the opposite ends of said pressure means; and engaging means operatively engaging said pressure means with the upper and lower ends of said seal element whereby longitudinal displacement of said pressure means by a pressure differential across said seal element in either direction will effect increased stress in said seal element in response to and in proportion to said pressure differential.

4. A well packer comprising in combination: a mandrel; an upper slip assembly engaged around said mandrel and having slips adapted to be expanded into the wall of a well; a lower slip assembly spaced apart from said upper slip assembly and secured around said mandrel including slips adapted to be expanded into engagement with said wall of said well; a resilient seal element positioned around said mandrel between said upper slip assembly and said lower slip assembly, said seal element being initially expandable into sealing relationship with said wall of said well bore between said slip assemblies; means extending through said seal element slidable longitudinally relative to both said mandrel and said seal element, said means having means sealing with the exterior of said mandrel, said means being exposed at opposite ends to the pressure above and below said seal element to be moved longitudinally relative to said mandrel and seal element in response to fluid pressure differentials acting on said means; means operatively engaged between the upper end of said slidable means and the upper end of said seal element for imposing added stressing force to said seal element as said slidable means moves downwardly in response to fluid pressure differential; and means operatively engaging the lower end of said seal element and the lower end of said slidable means for increasing the stress in said seal element as said slidable means moves upwardly in response to fluid pressure differential.

5. A well packer comprising in combination: a mandrel having a bore extending therethrough; an upper slip assembly engaged around said mandrel and provided with slips adapted to be expanded into the wall of a well bore; a lower slip assembly engaged around said mandrel and provided with slips adapted to be expanded into the wall of a well bore; a lower slip assembly engaged around said mandrel and spaced apart from said upper slip assembly including slips adapted to be expanded into the wall of a well bore; a resilient seal element positioned around said mandrel between said upper slip assembly and said lower slip assembly; stress means slidably engaged through said seal element and in sealing relationship with the exterior of said mandrel, said slidable stress means being movable longitudinally relative to said seal element and said mandrel; the upper end of said slidable stress means being exposed to the pressure above said seal element and operatively engageable with the upper end of said seal element; and the lower end of said slidable stress means being operatively engageable with the lower end of said seal element; said slidable stress means being movable longitudinally relative to said seal element and said mandrel in response to fluid pressure differentials acting on the opposite ends thereof to impose added stress on said seal element in response to pressure differentials acting in either direction.

6. In a well packer the combination which comprises: a mandrel having a bore extending therethrough; a head secured to the upper end of said mandrel; a resilient seal element positioned around said mandrel and adapted to be expanded into sealing relationship with the wall of the well bore; a pressure responsive member extending through said seal element and in sealing relationship with said mandrel, said pressure responsive member being exposed at its opposite ends to fluid pressures above and below said seal element and slidable relative to said seal element and said mandrel in response to fluid pressure differentials acting on the opposite ends of said member; means for operatively engaging said pressure responsive member with the upper end of said seal element whereby downward movement of said member will impose added stress on said seal element as a result of such movement to further laterally stress said seal element; means for operatively engaging said pressure responsive member with the lower end of said seal element whereby upward movement of said member will impose added stress on said seal element as a result of such movement to further laterally stress said seal element; an upper slip assembly operatively engaged around said mandrel above said seal element; and a lower slip assembly operatively engaged around said mandrel below said seal element.

7. A well packer comprising in combination: a mandrel having a bore extending therethrough; a head secured to the upper end of said mandrel; a resilient seal element engaged around said mandrel and adapted to be laterally stressed to effect sealing relationship in the annulus between said mandrel and the wall of a well bore; a sleeve positioned through said seal element around and in sealing relationship with said mandrel, said sleeve being slidable relative to said seal element and said mandrel in response to fluid pressure differentials acting on the opposite ends of said sleeve; means around said mandrel above said seal element for operatively engaging said sleeve and the upper end of said seal element when said sleeve is moved downwardly to impose added stress on said seal element as a result of such movement; means around said mandrel below said seal element for operatively engaging said sleeve with the lower end of said seal element when said sleeve is moved upwardly to impose added stress on said seal element as a result of such movement; an upper slip assembly on said mandrel above said seal element; and a lower slip assembly on said mandrel below said seal element.

8. A well packer comprising in combination: a mandrel having a bore extending therethrough; a head secured to the upper end of said mandrel; an upper slip assembly engaged on said mandrel below said head; a resilient seal element on said mandrel below said upper slip assembly, said resilient seal element being adapted to be stressed to effect lateral expansion of said element to establish a sealing relationship in the annulus between said mandrel and the wall of a well bore; a sleeve extending through said seal element around said mandrel, said sleeve being slidable longitudinally relative to said seal element and said mandrel in response to fluid pressure differentials acting on the opposite ends of said sleeve; an upper pressure ring slidably engaged around said sleeve above said seal element; means for operatively engaging said sleeve above said seal element with said pressure ring to force said pressure ring against the upper end of said seal element with downward movement of said sleeve to impose additional stress on said seal element as a result of such movement of said sleeve; a lower pressure ring around said sleeve below said seal element, said lower pressure ring being slidable relative to said seal element; means for operatively engaging said lower pressure ring with said sleeve below said seal element for forcing said lower pressure ring against the lower end of said seal element upon upward movement of said sleeve to impose additional stress on said seal element as a result of such movement of said sleeve; and a lower slip assembly on said mandrel below said seal element.

9. A well packer comprising in combination: a mandrel having a bore extending therethrough; a head on the upper end of said mandrel; an upper slip assembly on said mandrel below said head; a resilient seal element on said mandrel below said upper slip assembly, said seal element being adapted to be stressed to effect lateral expansion of said element to form a seal in the annular space around said mandrel between said mandrel and the wall of the well bore; a sleeve positioned through said seal element around said mandrel, said sleeve being slidable relative to said seal element and said mandrel in response to fluid pressure differentials acting on the opposite ends of said sleeve and extending above and below said seal element; an upper pressure ring slidably fitted around said sleeve above the upper end of said seal element; means on said sleeve above said upper pressure ring for operatively engaging said pressure ring upon downward movement of said sleeve to force said pressure ring into contact with the upper end of said seal element to impose an additional stress thereon as a result of fluid pressure differential acting downwardly on said sleeve; a lower pressure ring slidably positioned around said sleeve below the lower end of said seal element; means secured to said sleeve below said lower pressure ring for operatively engaging said lower pressure ring upon upward movement of said sleeve to force said pressure ring into contact with the lower end of said seal element to impose an additional stress thereon as a result of an upward fluid pressure differential acting on said sleeve; and a lower slip assembly on said mandrel below said seal element.

10. A well packer comprising in combination: a mandrel having a longitudinal bore extending therethrough; a head secured to the upper end of said mandrel; an upper slip assembly engaged on said mandrel below said head; a resilient seal element around said mandrel below said upper slip assembly, said seal assembly being adapted to be stressed to effect lateral expansion of said element to form a seal in the annulus around said mandrel between said mandrel and the wall of a well bore; a sleeve extending through said seal element around said mandrel above and below said seal element; an internal seal ring within said sleeve around said mandrel for effecting a sealing relationship between said sleeve and said mandrel whereby said sleeve is movable longitudinally of said mandrel in either direction by fluid pressures acting on the opposite ends of said sleeve; an upper pressure ring slidably engaged around said sleeve above the upper end of said seal element; a lock ring engaged around said sleeve above said pressure ring for operatively engaging said pressure ring upon downward movement of said sleeve to force said pressure ring into contact with the upper end of said seal element to impose an additional stress on said seal element as a result of a fluid pressure differential acting on the upper end of said sleeve; a lower pressure ring slidably engaged around said sleeve below the lower end of said seal element; a lock ring engaged around said sleeve below said lower pressure ring for operatively engaging said lower pressure ring upon upward movement of said sleeve to force said pressure ring into contact with the lower end of said seal element to impose additional stress on said seal element as a result of a fluid pressure differential acting on the lower end of said sleeve; and a lower slip assembly on said mandrel below said seal element.

11. A well packer comprising in combination: a mandrel having a longitudinal bore extending therethrough; a head secured to the upper end of said mandrel; an upper slip carrier engaged around said mandrel below said head; a plurality of slips secured around said mandrel and operatively engaged with said slip carrier; an upper slip cone slidably engaged around said mandrel below said upper slips for expanding said slips outwardly from said mandrel, said upper cone having an enlarged internal bore along a portion of the length and extending from the lower

end thereof forming an annulus within said cone around said mandrel, said upper cone having a port through the wall thereof leading to said annulus around said mandrel, the lower end of said upper cone having a shoulder formed thereon; a sleeve slidably engaged around said mandrel below said upper cone; the upper portion of said sleeve being slidable into the annulus within said upper cone around said mandrel; an internal seal within the upper end of said sleeve around said mandrel to effect a sealing relationship between said mandrel and said sleeve; a resilient seal element positioned around said sleeve, said seal element being adapted to be stressed to effect lateral expansion for forming a seal between the annulus around said mandrel within a well bore; an upper pressure ring slidably engaged around said sleeve above the upper end of said seal element; the upper face of said upper pressure ring being engageable by the lower end of said upper cone; a lock ring secured around said sleeve above said upper pressure ring for engaging said pressure ring to force said ring into contact with the upper end of said seal element upon downward movement of said sleeve relative to said seal element; a lower pressure ring slidably engaged around said sleeve below the lower end of said seal element; a lock ring secured around said sleeve below said lower pressure ring for engaging said lower pressure ring to force said ring into contact with the lower end of said seal element upon upward movement of said sleeve; a lower slip cone positioned around said mandrel below said seal element and adapted to slide relative to said mandrel, said lower cone having an enlarged longitudinal bore over a portion of the length thereof forming an annulus extending from the upper end thereof between said cone and said mandrel, said lower cone being provided with a port extending through the wall thereof into the annulus around said mandrel, the upper end of said cone being engageable with the lower face of said lower pressure ring, said lower cone having a downwardly inwardly sloping surface along the lower portion thereof; a lower slip carrier engaged on the lower end of said mandrel; a plurality of slips operatively secured around said lower slip carrier and adapted to slide along the surface of said lower cone into engagement with the wall of a well bore.

12. A well packer comprising in combination: at least two mandrels oriented substantially parallel to each other; means at the upper end of said mandrels for securing said mandrels to a setting tool and drill string; an upper slip assembly engaged on said mandrels on the upper end thereof; a resilient seal element on said mandrels below said upper slip assembly, said seal assembly being adapted to be stressed to effect initial lateral expansion to form a seal between said mandrels and the wall of a well bore; slidable pressure responsive means positioned through said seal element exterior of said mandrels, said pressure responsive means being exposed at opposite ends to the pressure on opposite sides of said seal element; means at the upper end of said seal element for operatively engaging said pressure responsive means with the upper end of said seal element whereby downward movement of said pressure responsive means will impose an additional stress on said seal element to effect further lateral expansion thereof; means below said seal element for operatively engaging said pressure responsive means with the lower end of said seal element whereby upward movement of said pressure responsive means will impose an additional stress on said seal element to effect further lateral expansion thereof; and a lower slip assembly engaged on said mandrels below said seal element.

13. A well packer comprising in combination: at least two mandrels having longitudinal bores therethrough and oriented substantially parallel to each other; head means engaged on the upper ends of said mandrels for securing said packer to a setting tool and tubing strings; an upper slip assembly engaged on said mandrels below said head means; a resilient seal element positioned around said mandrels, said seal element being adapted to be initially mechanically stressed laterally to effect a sealing relationship around said mandrels with the wall of a well bore; pressure responsive means extending through said seal element exterior of said mandrels, said pressure responsive means being exposed at the upper end thereof to the pressure above said seal element and at the lower end thereof to the pressure below said seal element; means above the upper end of said seal element for operatively engaging said pressure responsive means above said seal element with the upper end of said seal element whereby downward movement of said pressure responsive means will impose an additional stress on said seal element; means below said seal element for operatively engaging said pressure responsive means with the lower end of said seal element whereby upward movement of said pressure responsive means will impose an additional stress on said seal element; and a lower slip assembly engaged on said mandrels below said seal element.

14. A well packer comprising in combination: at least two mandrels each having a longitudinal bore extending therethrough and oriented substantially parallel to each other; a head member engaged on the upper ends of said mandrels for securing said packer to a running tool and tubing string; an upper slip assembly engaged on said mandrels below said head member; a resilient seal element around said mandrels below said upper slip assembly, said seal element being adapted to be stressed to effect lateral expansion for forming a sealing relationship with the wall of a well bore around said mandrel; a slidable member positioned through said seal element exterior of said mandrels; an upper pressure plate slidably positioned around said mandrels above said seal element; means for operatively engaging the upper end of said slidable member and said upper pressure plate for forcing said pressure plate against the upper end of said seal element upon downward movement of said slidable member; a lower pressure plate slidably positioned around said mandrels below said seal element; means for operatively engaging said slidable member with said lower pressure plate below said seal element whereby upward movement of said slidable member will force said lower pressure plate into contact with the lower end of said seal element; and a lower slip assembly on said mandrels below said seal element.

15. A well packer comprising in combination: at least two mandrels having longitudinal bores extending therethrough and oriented substantially parallel to each other; a head engaged on the upper ends of said mandrels for securing a setting tool and tubing string to said packer; an upper slip assembly engaged on said mandrels below said head; a resilient seal element around said mandrels below said upper slip assembly, said seal element being adapted to be stressed to effect lateral expansion for forming a seal with the wall of a well bore around said mandrels; at least one bar member positioned longitudinally through said seal element exterior of said mandrels, the upper end of said bar being exposed to the pressure above said seal element and the lower end of said bar being exposed to the pressure below said seal element, said bar being slidable relative to said seal element; an upper pressure plate slidably engaged around said mandrels above said seal element, the lower face of said pressure plate being adapted to apply force over the upper end of said seal element; means for operatively engaging the upper end of said bar and said upper pressure plate whereby downward movement of said bar will force said pressure plate into engagement with the upper end of said seal element; a lower pressure plate slidably engaged around said mandrels below said seal element, said lower pressure plate being adapted to engage the lower end of said seal element to apply a force over said lower end; means secured for operatively engaging said bar with said lower pressure plate for forcing said lower pressure plate into contact with the lower end of said seal element upon up-

ward movement of said bar; and a lower slip assembly on said mandrels below said seal element.

16. A well packer comprising in combination: at least two mandrels each having a longitudinal bore extending therethrough secured substantially parallel to each other; a head engaged on the upper ends of said mandrels for securing a setting tool and tubing strings to said packer; an upper slip assembly engaged on said mandrels below said head; a resilient seal element positioned on said mandrels below said upper slip assembly, said slip assembly being adapted to be initially mechanically stressed to effect lateral expansion for forming a seal in a well bore across the annulus between said mandrels and the wall of said well bore; a pressure responsive member slidably positioned through said seal element exterior of said mandrels and adapted to be displaced longitudinally in either direction by a pressure differential across said seal element; means operatively engaged between the upper end of said seal element and said pressure responsive means above said seal element for further stressing said element upon downward movement of said pressure responsive means; means operatively engaged between the lower end of said seal element and said pressure responsive means below said element for further stressing said element upon upward movement of said pressure responsive means; and a lower slip assembly engaged on said mandrels below said seal element.

17. A well packer comprising in combination: at least two mandrels having longitudinal bores therethrough oriented substantially parallel to each other and secured to a packer head engaged on the upper ends of said mandrels for securing a setting tool and tubing strings to said packer; an upper slip assembly on said mandrels below said head; a resilient seal element engaged around said mandrels below said upper seal assembly, said seal element being adapted to be stressed to effect lateral expansion for forming a seal between said mandrels and the wall of a well bore; an upper pressure plate around said mandrels and engageable with the upper end of said seal element; a lower pressure plate around said mandrels and engageable with the lower end of said seal element; a pressure responsive member positioned longitudinally through said seal element exterior of said mandrels, said pressure responsive member being slidable relative to said seal element and said mandrels; means for operatively engaging said pressure responsive member with said upper pressure plate whereby downward movement of said pressure responsive member forces said pressure plate against the upper end of said seal element; means for operatively engaging said pressure responsive member with said lower pressure plate whereby upward movement of said pressure responsive member forces said lower pressure plate against the lower end of said seal element; and a lower slip assembly engaged on said mandrels below said lower pressure plate.

18. A well packer comprising in combination: at least two mandrels having bores extending therethrough engaged substantially parallel to each other; a head secured on the upper ends of said mandrels for securing a setting tool and tubing strings to said packer; an upper slip assembly engaged on said mandrels below said head; a resilient seal element positioned on said mandrels below said upper slip assembly, said seal element being adapted to be stressed to effect lateral expansion for forming a seal in the annulus between said mandrels and the wall of a well bore; an upper pressure plate around said mandrels and operatively engageable with the upper end of said seal element; a lower pressure plate around said mandrels and operatively engageable with the lower end of said seal element; at least one bar engaged longitudinally through said seal element and adapted to slide relative to said seal element and said mandrels, said bar being responsive to the pressure above and below said seal element and displaceable longitudinally by a pressure differential across said seal element; means secured on said bar for operatively engaging said upper pressure plate upon downward movement of said bar for forcing said upper pressure plate against the upper end of said seal element; means engaged on said bar below said lower pressure plate for operatively engaging said lower pressure plate upon upward movement of said bar for forcing said pressure plate against the lower end of said seal element; and a lower slip assembly engaged on said mandrels below said lower pressure plate.

19. A well packer comprising in combination: at least two mandrels having longitudinal bores and engaged substantially parallel to each other; a head secured on the upper ends of said mandrels for connecting said packer to a setting tool and tubing strings; an upper slip assembly on said mandrels below said head; a resilient seal element on said mandrels below said supper slip assembly, said seal element being adapted to be stressed to effect lateral expansion for forming a seal in the annulus between said mandrels and the wall of a well bore; an upper pressure plate slidably engaged on said mandrels and adapted to contact the upper end of said seal element; a lower pressure plate slidably engaged on said mandrels and adapted to contact the lower end of said seal element; a bar extending through said seal element exterior of said mandrels, the upper and lower ends of said bar being exposed to the pressure above and below said seal element; said bar extending through both said upper and said lower pressure plates; a snap ring around said bar above said upper pressure plate for engaging said pressure plate upon downward movement of said bar; a snap ring engaged on said bar below said lower pressure plate for engaging said lower pressure plate upon upward movement of said bar; and a lower slip assembly engaged on said mandrels below said lower pressure plate.

20. A well packer comprising in combination: a pair of mandrels positioned substantially parallel to each other and each having a longitudinal bore extending therethrough; a head member engaged on the upper ends of said mandrels, said head member having bores coinciding with the bores through said mandrels; means secured to said head for engaging a packer setting tool; an upper slip carrier slidably engaged around said mandrels below said head; a plurality of upper slips operatively engaged on said upper slip carrier; an upper slip cone slidably secured around said mandrels below said upper slips, said cone being adapted to expand said slips laterally, said cone having two bores extending longitudinally exterior of said mandrels, one of said bores being on one side of said mandrels and the other of said bores being on the other side of said mandrels, said bores being open at the upper end of said cone whereby the pressure around said packer above said cone is exerted within said bores; a resilient seal element engaged around said mandrels and adapted to be mechanically stressed to effect lateral expansion for forming a seal in the annulus around said mandrels within a well bore; an upper pressure plate slidably engaged around said mandrels and operatively engageable with the upper end of said seal element, said upper pressure plate having openings therethrough on opposite sides of said mandrels coinciding with said bores in said upper slip cone; a lower pressure plate slidably engaged around said mandrels below said seal element and adapted to operatively engage the lower end of said seal element, said lower pressure plate having openings therethrough coinciding with the openings in said upper pressure plate; a lower slip cone slidably engaged on said mandrels below said lower pressure plate, said lower slip cone having longitudinal bores extending exterior of said mandrels, said bores being on opposite sides of said mandrels and coinciding with said bores in upper slip cone; a pair of pressure responsive rods oriented longitudinally and slidably positioned through said seal element, one of said rods being on one side of said mandrels and the other of said rods being on the other side of said mandrels, the upper end of each of said rods extending through said upper pressure plate into one of said bores in said upper cone and the lower end of each of said rods ex-

tending through said lower pressure plate into one of said bores in said lower cone; a snap ring engaged around each of said rods above said upper pressure plate whereby downward movement of said rods in response to fluid pressure differentials acting thereon effects operative engagement of said rods with said upper pressure plate forcing said plate against the upper end of said seal element to impose added stress on said seal element to effect lateral expansion of said element in response to a pressure differential across said seal element when the higher pressure exists above said seal element; a snap ring around each of said rods below said lower pressure plate for operatively engaging said rods with said lower pressure plate upon upward movement of said rods in response to a pressure differential across said seal element with the higher pressure existing below said seal element for forcing said lower pressure plate into engagement with the lower end of said seal element to impose additional stress on said seal element to effect lateral expansion of said seal element; a plurality of lower slips supported around said lower slip cone and adapted to be moved relative to said cone to

effect lateral expansion of said slips; and a lower slip carrier secured to said mandrels below said lower slips and operatively engaged with said lower slips for moving said lower slips upwardly relative to said lower slip cone.

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