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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

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FIG. 3.

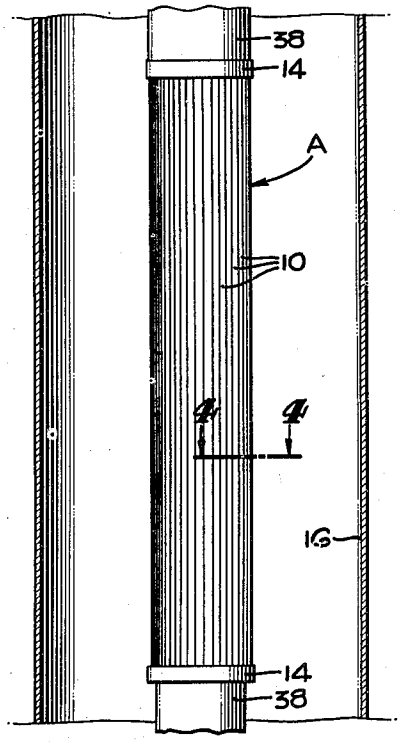
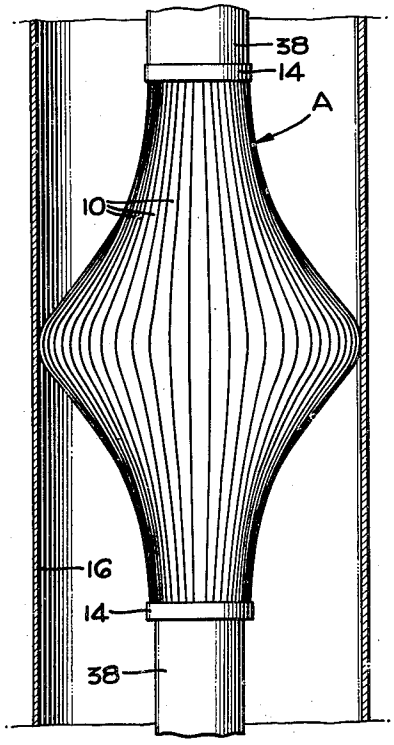


FIG. 5.



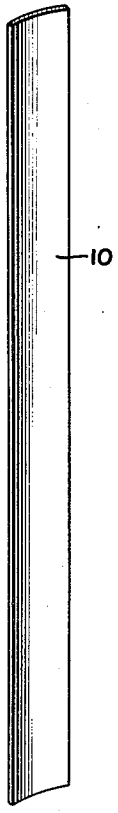


FIG. 1.

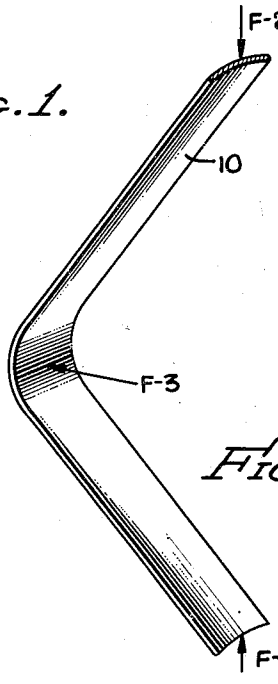
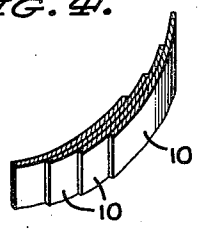


FIG. 2.

FIG. 4.



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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

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FIG. 6.

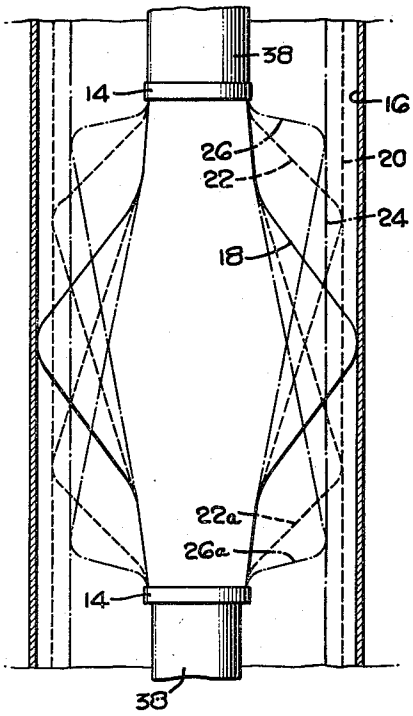


FIG. 7.

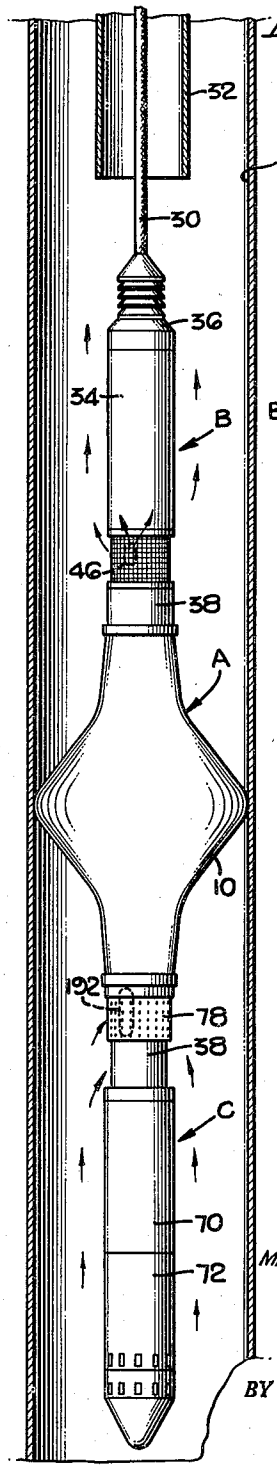
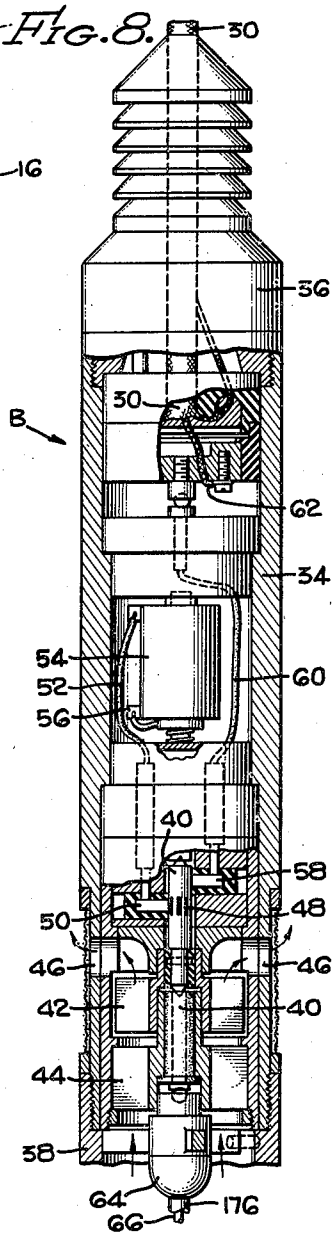


FIG. 8.



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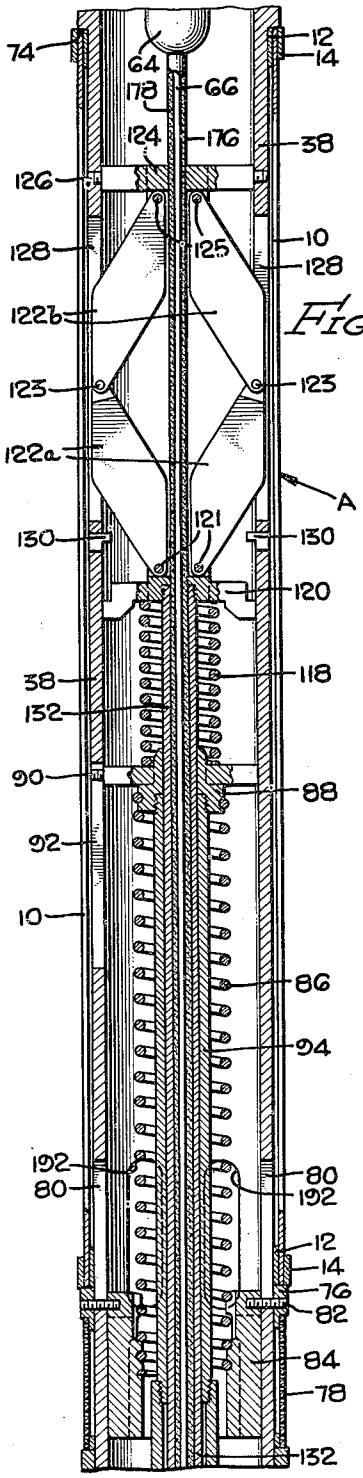


FIG. 9a.

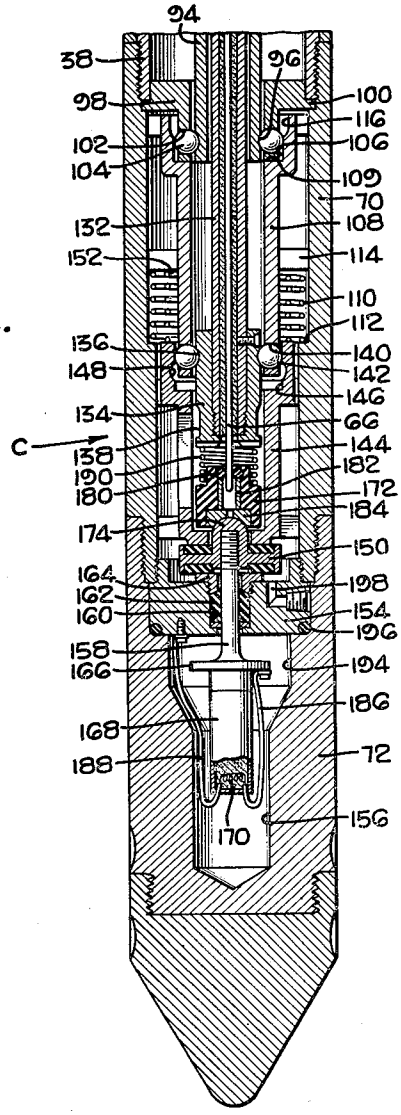


FIG. 9b.

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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

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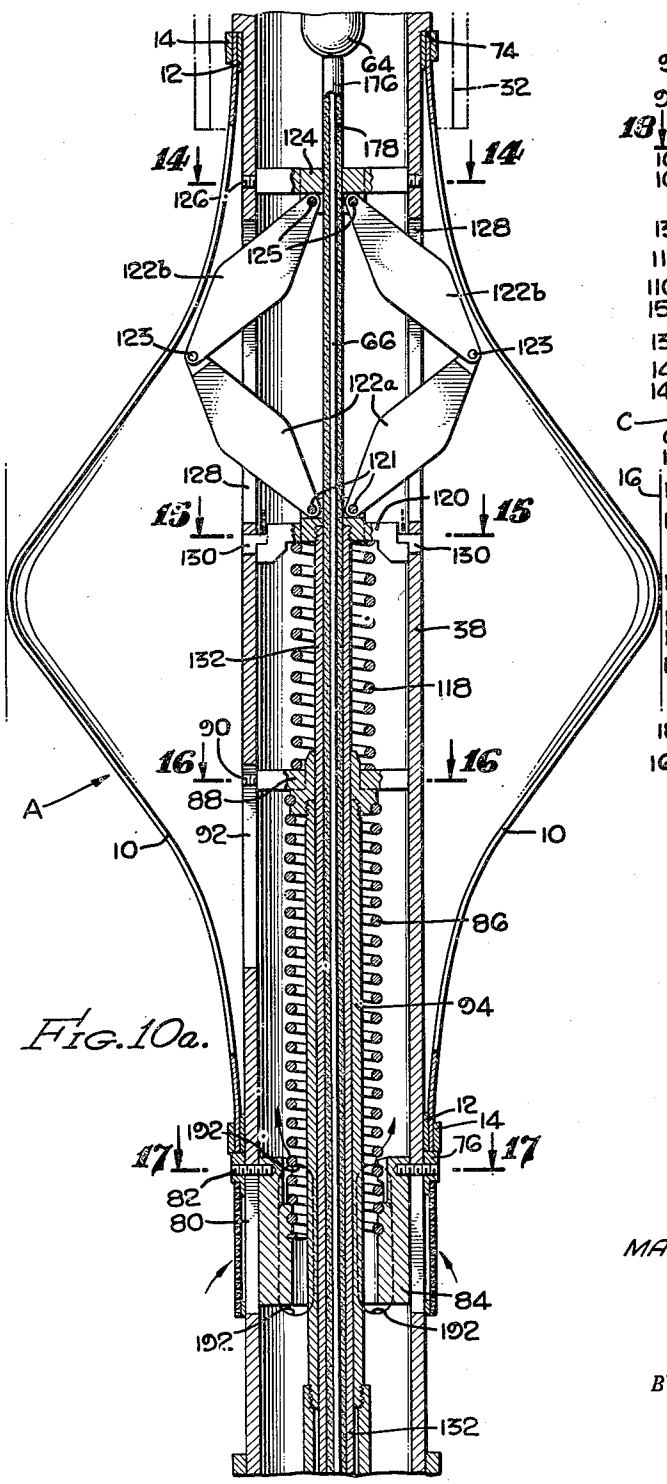


FIG. 10a.

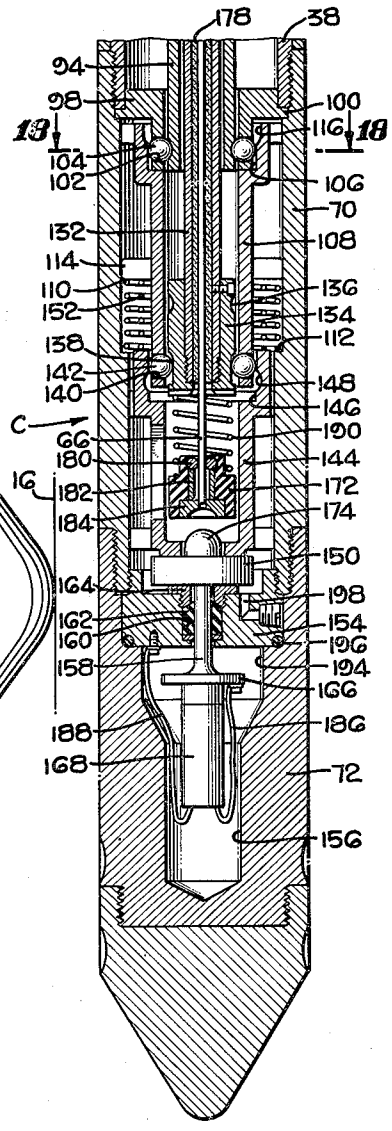


FIG. 10b.

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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

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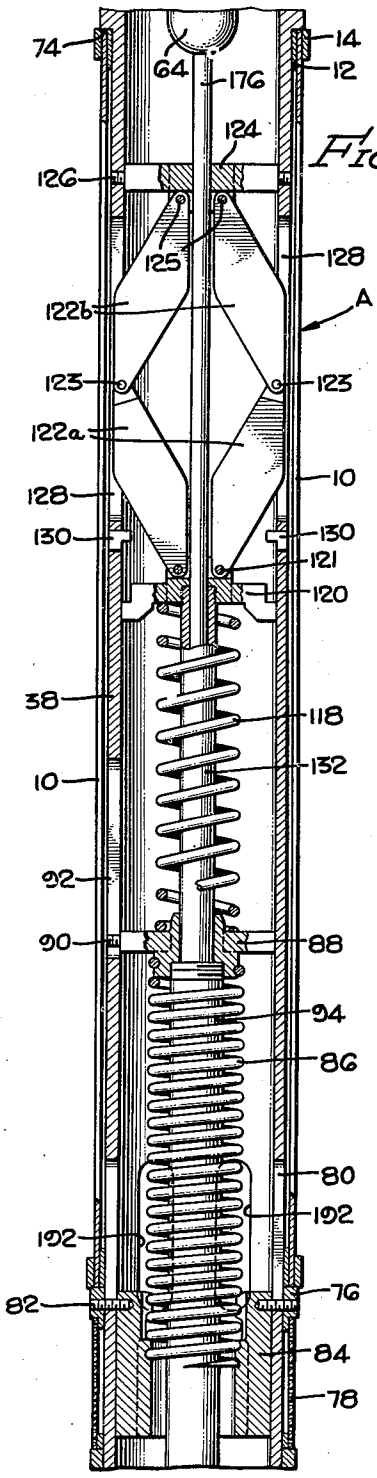


FIG. 11a.

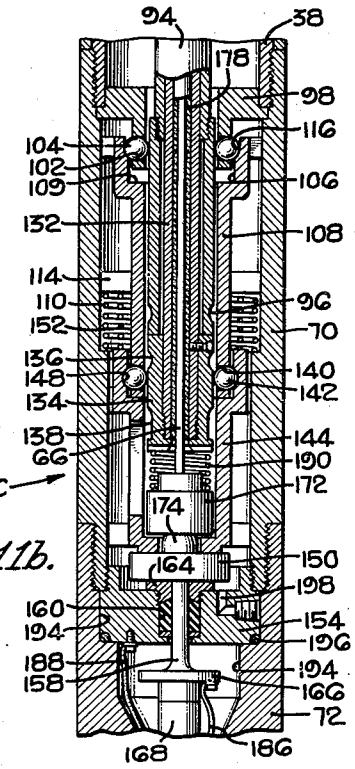


FIG. 11b.

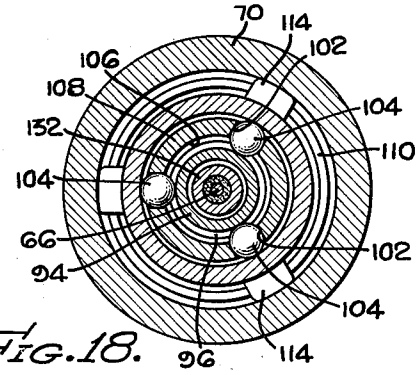


FIG. 18.

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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

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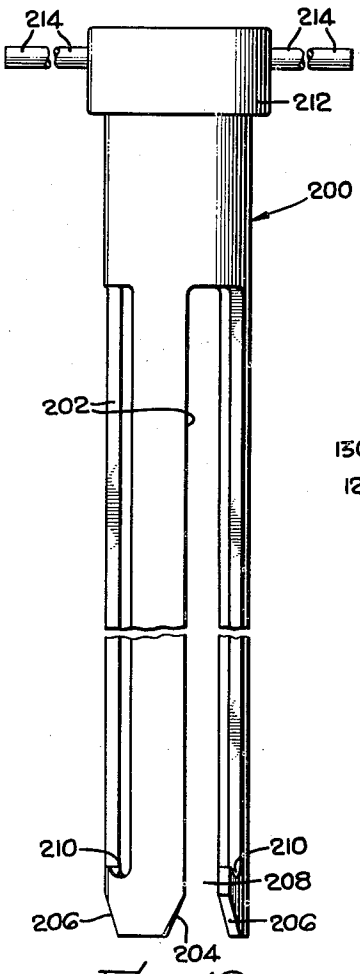


FIG. 12.

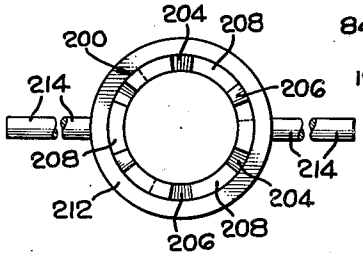


FIG. 13.

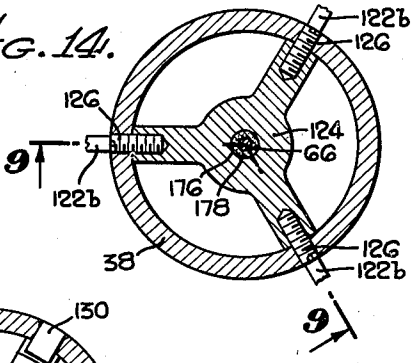


FIG. 14.

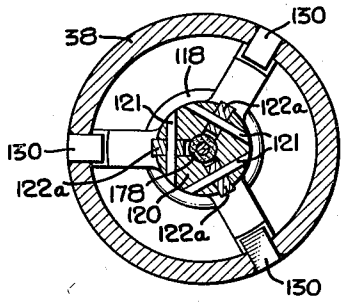


FIG. 15.

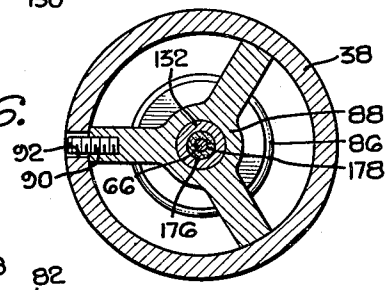


FIG. 16.

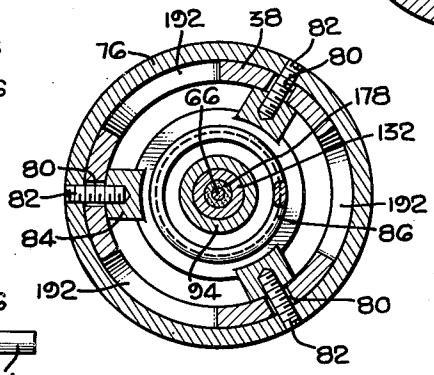


FIG. 17.

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United States Patent Office 2,701,615 Patented Feb. 8, 1955

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WELL BORE PACKER AND ACTUATING MEANS THEREFOR

Matthew B. Riordan, Jr., La Habra, Harry B. Boller, Alhambra, and Allen E. Hambly, South Gate, Calif., assignors to Byron Jackson Co., Vernon, Calif., a corporation of Delaware

Application March 16, 1951, Serial No. 216,038

16 Claims. (Cl. 166—63)

This invention relates generally to well packers, and particularly to a novel expansible packer especially designed for use as a by-pass packer in conjunction with a flow meter or other instrumentality necessitating the diversion of fluid flow from a large diameter flow passage into a relatively small diameter flow passage.

Valuable information as to the production characteristics of an oil, gas or water well could be obtained if it were possible to make accurate flow measurements at various levels in the well while it is producing. Thus the relative contributions from various zones of a producing formation to the total production from the formation could be determined. However, inasmuch as oil and gas wells are commonly produced through well tubing, it is apparent that in order to obtain flow measurements while the well is producing, the flow measuring instrument must be introduced into the well either through the well tubing or through the annulus between the tubing and the casing. The tubing is usually of an outside diameter on the order of 2" to 3", and hence an instrument insertible through the tubing must have an outside diameter not exceeding 1½". On the other hand, the well casing in which the flow measurements are to be taken is most commonly 7" in diameter. It is obvious that with a 1½" instrument in a 7" flow passage, it is impossible to obtain accurate measurements of low flow rates or of small changes in flow rate.

This problem can be solved by providing means bridging the annular space between the relatively small flow measuring instrument and the well casing and capable of diverting all or substantially all of the fluid flow through the instrument. A general object of this invention is to provide such means.

Another object of the invention is to provide such means in the form of an expansible and collapsible by-pass packer capable of being contracted to a diameter which will permit its being passed through the usual well tubing, and capable of being expanded to a diameter at least equal to the inner diameter of usual well casing.

In making flow measurements in a well the instrument is moved to different levels to obtain readings of flow rates from or into various zones. Accordingly a by-pass packer associated with the instrument must be capable of being moved upwardly or downwardly while in expanded condition. The well casing frequently varies in diameter at different elevations, it often has inward projections such as burrs around gun perforator holes, and is frequently encrusted with rust, paraffin or sludge. Hence the packer must be capable of accommodating itself to such anomalies while being moved through the well. It is still another object of this invention to provide a packer of the above character which possesses sufficient inherent flexibility, when expanded, to permit it to pass readily through sections of casing of sub-normal diameter, and to permit it to pass over inward projections on the wall of the casing, all while maintaining a substantially complete and effective sealing off between the associated instrument and the wall of the casing.

It is still a further object of the invention to provide, in combination with a packer having the foregoing characteristics, means controllable from the surface of the well for expanding the packer after it has passed through the small diameter tubing and into the relatively large diameter flow passage defined by the well casing.

Yet another object of the invention is to provide packer expanding means actuated by means controlled electrically from the surface of the well, thereby rendering it possible to employ the packer in conjunction with an instrument suspended from a conductor cable.

A still further object of the invention is to provide means whereby a packer of the foregoing type may be collapsed after being expanded in the well, to permit its retraction from the well through small diameter tubing.

A still further object of the invention is to provide a novel packer of all-metal construction, thus avoiding the use of rubber-like material or fabric and their inherent susceptibility to high well temperatures, abrasion, and deterioration when exposed to certain well fluids.

Other objects and advantages of the present invention will be apparent from the following detailed description of a presently preferred embodiment of the invention, reference being had to the accompanying drawings wherein:

Figures 1 and 2 are perspective views of a crowned spring metal strip forming an element of the packer element of the present invention;

Figure 3 is a view in side elevation of the packer element in collapsed condition;

Figure 4 is a fragmentary perspective view on an enlarged scale, taken substantially on line **4—4** of Figure 3, showing the overlapping arrangement of the crowned metal strips;

Figure 5 is a view similar to Figure 3 but showing the packer element in expanded condition;

Figure 6 is a view generally similar to Figure 5 but showing in broken lines various profiles of the packer element when moved through bores of varying diameters;

Figure 7 is a view in side elevation of an assembly of flow meter, packer element and packer actuator in operative position in a well;

Figure 8 is a view, partly in longitudinal section, of a typical flow meter with which the packer of the present invention is adapted to be associated;

Figures 9*a* and 9*b* are longitudinal sectional views of the upper and lower portions, respectively, of a preferred form of packer and packer actuator embodying the invention, these views being taken on the broken section line **9—9** of Figure 14 and illustrating the packer element in collapsed condition and the actuator mechanism cocked for actuation by remote control;

Figures 10*a* and 10*b* are views corresponding to Figures 9*a* and 9*b* but showing the packer element in expanded condition and showing the parts of the actuator mechanism in the positions they assume after expanding the packer element;

Figures 11*a* and 11*b* are views corresponding to Figures 9*a* and 9*b* but showing the packer element in collapsed condition and showing the actuator mechanism in fully deenergized condition, this being the condition as the assembly is retrieved from the well after completing a flow survey;

Figure 12 is a view in side elevation of a special tool employed in cocking or re-setting the actuator mechanism;

Figure 13 is an end view of the tool shown in Figure 12;

Figures 14, 15, 16, 17 and 18 are transverse sectional views taken respectively on lines **14—14, 15—15, 16—16, 17—17** and **18—18** of Figures 10*a* and 10*b*.

Referring to Figures 1 to 6 inclusive, an important feature of the invention is a packer element, generally designated A, of novel construction and possessing unique and distinctive characteristics. This packer element comprises essentially a circumferential series of longitudinally extending crowned spring metal strips assembled in overlapping relation so as to form a cylindrical structure when in contracted condition, as shown in Figure 3. The term "crowned spring metal strip," as used in this description and in the appended claims, is intended to mean and include a strip of any metal such as steel, copper-beryllium alloy or the like, having good spring qualities and of relatively thin, transversely curved cross-section. A typical example of this material which is readily available commercially is that used in steel measuring tapes. Figure 1 illustrates a piece of such material, designated **10**.

A crowned spring metal strip, when straight, is characterized by high columnar strength or resistance to bending

or buckling when subjected to longitudinal compression. This high columnar strength is attributable to the transverse curvature of the strip, and is proportional to the degree of curvature. Hence upon the application of a transverse force, such as indicated at F–3 in Figure 2, at any point on the strip intermediate its ends, the resulting bending of the strip is accompanied by a reduction of its transverse curvature and a corresponding reduction in the columnar strength of the strip. It requires only slight bending of the strip to transform the transversely curved section into a straight section at the point of application of maximum bending stress. This occurs abruptly with a snap-action, and is accompanied by a sharp reduction in bending strength at the transversely straightened section. Thus upon initially bending a strip as indicated in Figure 2, the magnitude of the oppositely directed forces F–1 and F–2 applied to the ends of the strip to further bend the strip is only a small fraction of the longitudinally applied force required to buckle the strip when straight. Because of the inherent resiliency of the strip, it tends to straighten out upon release of the longitudinally applied force.

The aforementioned characteristics of a crowned spring metal strip are availed of to maximum advantage in the packer element A of the present invention. As shown in Figures 3 and 4, a plurality of strips **10** are arranged longitudinally in circumferentially overlapping relation about a common axis with their concave sides facing radially inwardly, thus forming a generally cylindrical structure. As shown most clearly in Figure 9*a*, the strips are secured in assembled relation by clamping their adjacent ends between inner and outer rings **12** and **14**. The assembly operation may be performed simply and inexpensively by arranging the strips on a suitable mandrel and pressing the end rings onto the respective ends.

The extent of overlapping of the strips should be such that when the intermediate portion of each strip is bulged radially outwardly a distance sufficient to cause it to contact the well casing, the strips still maintain their overlapping relationship even at the point of maximum diameter, as indicated in Figure 5. The required extent of overlap depends on the width of the individual strips and should be commensurate with the ratio of expanded diameter to collapsed diameter of the packer element.

When the packer element A is expanded into the position shown in Figure 5, by mechanism to be described hereinafter, its maximum diameter will lie in a transverse plane midway between the ends of the packer element if the unrestricted maximum diameter does not exceed the diameter of the bore in which the packer element is positioned. However, because of the low bending strength of the strips at the bent region, the plane of maximum diameter may be shifted in either direction by the application of a relatively small axial force at the bent region. This movement of the plane of maximum diameter results in a reduction in maximum diameter, such reduction being proportioned to the extent of displacement from the median transverse plane. This characteristic is important in connection with the intended primary use of the packer element, inasmuch as it allows the packer element to accommodate itself to variations in the diameter of the well casing through which it is moved while in expanded condition.

Thus, as illustrated in Figure 6, the normal diameter of the well casing may be that indicated by the solid lines **16**, the normal profile of the expanded packer element being indicated by the solid line **18**. Assuming that the packer element is being moved downwardly and encounters a section of casing of slightly reduced diameter, as indicated by dotted lines at **20**. The upward and inward pressure exerted on the leading side of the region of maximum diameter of the packer element as it enters the section of casing of reduced diameter displaces the region of maximum diameter upwardly a distance sufficient to reduce the maximum diameter to that of the casing, and causes the packer element to assume the shape indicated by dotted lines at **22**. A still smaller casing diameter, indicated by dot-and-dash lines at **24**, will further deform the packer element into the profile indicated at **26**. Similarly, if the packer element should be moved upwardly in the well and should encounter a section of casing of a diameter indicated at **20** or **24**, its region of maximum diameter will be moved downwardly to produce packer profiles as indicated respectively at **22***a* and **26***a*.

As pointed out hereinafter, a preferred type of packer

actuator applies a predetermined compressive force, as by means of a spring, to the ends of the packer element, the magnitude of this force being such as to tend to expand the packer element to a diameter somewhat in excess of the maximum diameter of the well casing in which it is designed to be operated. In this manner the packer element exerts moderate pressure against the wall of the casing, sufficient to effect a substantial seal but insufficient to offer any substantial resistance to movement of the packer element upwardly or downwardly in the well casing.

It will be observed that the bend in the median portion of each of the metal strips **10** has a substantial radius of curvature, thereby presenting a nicely rounded outer surface for sliding contact with the well casing. This streamlined contour contributes materially to the ease of self-adjustment of the packer element to compensate for variations in casing diameter and to permit it to pass over projections on the casing wall without damage to the packer element.

It should be understood that the intended function and purpose of a packer element constructed as described herein is merely to divert the flow of fluid in the well casing into the relatively small diameter central passage defined by the confined ends of the strips **10**, and thence through a correspondingly small diameter flowmeter, so that substantially all of the fluid passes through the flowmeter. Under these circumstances the only pressure differential prevailing across the packer element is that resulting from the pressure drop caused by friction losses in the small diameter passages through the packer element and the flowmeter. It is not intended that the packer element should be capable of withstanding any substantial pressure differential. In fact, the aforementioned characteristic of low resistance to axial displacement of its region of maximum diameter upon application thereto of a relatively small axial force renders it inherently incapable of establishing or maintaining a substantial pressure differential. Furthermore, although the metal-to-metal contact betwen the overlapping faces of the strips **10** is adequate to effect a substantial seal against leakage of fluid between these faces, it will be obvious that such leakage would occur if it were attempted to establish a substantial pressure differential across the packer element.

With respect to leakage of fluid between the strips **10**, it has been ascertained in actual practice that in the case of liquids such as oil or water and with rates of flow other than extremely low rates, this leakage is of such minor nature as not to materially affect the accuracy of the flow measurements. However, when measuring extremely low rates of flow of liquids or when measuring gas flow rates it has been found desirable to augment the sealing effect of the metal-to-metal contact between the faces of the strips **10** by coating such faces with a suitable plastic sealing compound. In order to be effective for this purpose the sealing compound should have the property of good adhesion to the metal strips and should be of such viscosity as to cause it to yield or flow as the extent of overlapping of the strips **10** changes during expansion and contraction of the packer element. It should also be chemically and physically stable at all well temperatures commonly encountered, and it should be insoluble in hydrocarbons. We have found that a well-known valve lubricant marketed under the name "Nordcoseal No. 54–S" is typical of various compounds which meet these specifications. In applying the sealing compound, it should be inserted by any suitable means between the overlapping faces of the strips **10** while the packer element is in collapsed condition, to deposit a film of the compound between those faces.

Referring now to Figures 7, 8, 9*a* and 9*b*, the packer element A is shown assembled with a flowmeter unit B and a packer actuator assembly C, the entire assembly being shown in Figure 7 as being suspended from a conductor cable **30** in the well casing **16** with the packer element A expanded after the assembly has been lowered through the string of production tubing **32**. As shown in Figure 8, the flowmeter is of the rotating impeller type and comprises primarily a housing **34** threadedly connected at its upper end to a cable socket **36** and threadedly connected at its lower end to the upper housing section **38** of the actuator assembly C. An impeller shaft **40** is journaled in the housing **34** and has an impeller **42** affixed thereto. A series of stationary deflector vanes **44** is mounted in the housing below the impeller, these vanes being inclined oppositely to the inclination of the vanes

of the impeller 42 so as to deflect the upwardly flowing fluid against the impeller vanes. Below the stationary vanes 44 the interior of the housing 34 communicates with the interior of the actuator housing section 38, which serves as a fluid by-pass conduit through the packer element A. Fluid outlet ports 46 are formed in the wall of the housing 34 above the impeller 42, through which the fluid is discharged into the well casing after acting on the impeller.

The flowmeter B is of the type in which rotation of the impeller and its shaft produces interruptions in an electrical circuit, the frequency of the interruptions being proportional to the speed of rotation of the impeller shaft and therefore constituting a measure of the rate of flow of the fluid through the instrument. As shown, the impeller shaft 40 is provided with a short commutator section 48 consisting of alternating conducting and non-conducting surfaces. A brush 50 engages the commutator section and is connected by a conductor 52 through a resistor 54 to a ground connection 56 on the housing 34. A second brush 58 contacts an uninterrupted portion of the surface of the shaft 40 and is connected through a conductor 60 to the conductor core of the cable 30. One of the strands of the outer steel armor of the cable 30 is grounded to the housing 34 at 62, thus completing an electrical circuit from a voltage source at the ground surface, such as a battery or generator (not shown), through the insulated conductor core of the cable 30, conductor 60, brush 58, shaft 40, brush 50, conductor 52, resistor 54, housing 34, the steel armor of the cable 30, to the ground side of the voltage source at the surface. Upon impressing a voltage on this circuit, rotation of the impeller shaft 40 by the fluid flowing past the impeller causes the commutator 48 to alternately open and close the circuit, thus producing a variable frequency signal at the surface which may be translated into rate of flow of the fluid. With this arrangement it is obvious that the shaft 40 must be insulated from the housing 34, suitable insulation being provided as indicated at the shaft bearings and at other necessary points.

As described in detail hereinafter, the operation of the packer actuator assembly C to expand the packer element A is initiated electrically, upon initial closing of the above-described electrical circuit by manipulation of a switch (not shown) at the surface. The electrical impulse for initiating operation of the actuator assembly C may be transmitted thereto by a branch circuit including the insulated shaft 40. As shown at the lower extremity of Figure 8 and at the upper extremity of Figure 9*a*, a plug-and-socket connector 64 provides a detachable electrical connection between the shaft 40 and a conductor 66 which extends downwardly through the actuator assembly as described hereinafter.

Referring now to the packer actuator assembly C, it has been stated previously that each individual strip 10 of the packer element A possesses an appreciable columnar strength when straight, but when initially bent by application of a transverse force at any point along its length, the resultant straightening of the transverse section at the point of bending produces a sharp decrease in bending strength at that point. Thereafter the strip may be bent further by moving the ends thereof toward each other by application of a force very materially less than the longitudinally applied force required to buckle the strip when straight. When a plurality of such strips are assembled as shown in Figure 3 and described hereinabove, each strip is reinforced against buckling by several adjacent overlapping strips thereby producing a structure having a columnar strength, when in the collapsed condition shown in Figure 3, which is appreciably greater than the aggregate of the columnar strengths of the individual strips. However, upon application of a radially outward force to certain of the strips at points in a transverse plane intermediate the ends of the packer element, and upon the subsequent slight outward bulging of the structure in the region of such plane, the columnar strength of the structure is reduced sharply.

This characteristic of the assembly of strips is fully availed of in the actuator assembly described herein by pre-loading the packer element, in its collapsed or "running-in" condition, with an axial compressive force which is of insufficient magnitude to buckle the column when it is straight, but which is of sufficient magnitude to continue the buckling and consequent expansion of the packer element once it has been initially buckled by application of a radially outwardly applied force. To expand the packer element, it therefore becomes necessary only to apply the radially outward force by means controllable from the well surface, and thereafter the axial compressive force automatically becomes effective to complete the expansion and to maintain the packer element expanded.

Generally speaking, both the axial compressive force and the radially outwardly directed force are preferably supplied by springs in which the required energy is stored by initial "cocking" of the actuator mechanism prior to running the device into a well. The release of the energy stored in the spring which furnishes the axial compressive force is initially prevented by the columnar strength of the collapsed packer element against which one end of the spring acts, part of this energy being released upon expansion of the packer element. The remaining energy stored in this spring to maintain the packer in its expanded condition may subsequently be released, to permit the packer element to return to its collapsed condition by its inherent resiliency, by releasing a latch which releasably retains in fixed position an abutment engaging the other end of the spring. The energy stored in the spring which supplies the radially outwardly directed force is released by the release of latch mechanism associated with an abutment engaging one end of the spring, the latch mechanism being releasable upon actuation of electrically controlled means under the control of the operator at the ground surface. This spring is normally completely de-energized during its operating cycle, so that upon de-energization of the first-mentioned spring and consequent self-collapsing of the packer element, the device may be withdrawn from the well through the tubing 32 with all initially stored energy released.

A specific embodiment of an actuator mechanism incorporating the above-mentioned principles of operation will now be described, reference being had first to Figures 9*a* and 9*b*, the latter figure being a downward extension of the former. In these figures the packer element A is collapsed and the acuator mechanism is shown in "cocked" condition in readiness for lowering the assembly into a well.

The actuator mechanism is enclosed within a three-section housing comprising the upper section 38, an intermediate section 70 and a lower section 72, threadedly interconnected to each other and the upper section 38 being adapted for threaded connection to the flowmeter housing 34. The packer element A is mounted on the upper housing section 38, with its upper extremity abutting a downwardly facing external shoulder 74 formed on the housing section. The lower extremity of the packer element is engaged by the upper end ring 76 of a screen 78. The housing section 38 is provided, adjacent the screen 78, with a plurality of longitudinal slots 80 which, as shown in Figure 17, are in this embodiment three in number and spaced 120° apart. Retaining screws 82 extend from the screen end ring 76 through the respective slots 80 and are threaded into the upper headed portions of three equally spaced webs formed integral with the hub of a floating spider 84 slidably mounted within the housing section 38 and guided by the inner wall thereof. The retaining screws serve to interconnect the spider 84 and the screen end ring 76 to constrain the later to move vertically with the spider. The slots 80 also guide the screws 82 and thus restrain the spider against rotation relative to the housing.

The upper portion of the hub of the spider 84 is internally threaded to receive the lowermost coils of an extension spring 86 and thus anchor the spring to the spider. The upper extremity of the spring 86 is similarly threadedly connected to the hub of a second spider 88 guided within the housing. A guide screw 90 is threaded into the outer end of one of the three webs of the spider 88, as shown most clearly in Figure 16, and projects into a longitudinal slot 92 formed in the housing to restrain the spider against rotation relative to the housing.

A latch sleeve 94 is threadedly connected at its upper extremity to the spider 88 and extends downwardly therefrom through the floating spider 84 and into the upper portion of the intermediate housing section 70 (Figure 9*b*). Adjacent the lower extremity of the latch sleeve 94 a circumferential arcuate groove 96 is formed in its outer surface. A stationary spider 98 is clamped between the lower extremity of the upper housing section 38 and an internal shoulder 100 formed on the

intermediate housing section 70, the hub of the spider 98 having a plurality of radial bores 102 in each of which is disposed a ball detent 104. In the cocked position of the mechanism as shown in Figures 9a and 9b, the groove 96 in the latch sleeve 94 is aligned with the bores 102 and the ball detents 104 project partially from their bores into the groove 96 to thereby lock the sleeve 94 in fixed relation to the stationary spider. In this position of the latch sleeve, the spring 86 is extended materially beyond its free or relaxed length and hence it is energized and exerts an upward force on the floating spider 84. This upward force is transmitted by the retaining screws 82 to the screen end ring 76 and thence to the lower extremity of the packer element A, thus exerting an axial compressive force on the metal strips 10 of the packer element. This force is less than that required to overcome the columnar strength of the packer element when it is fully collapsed, but it is sufficient to fully expand the packer element into the condition shown in Figure 7 or Figure 10a once the strips 10 have been initially buckled.

The ball detents 104 are releasably retained in their interlocking position shown in Figure 9b by engagement thereof with the inner wall of an enlarged recess 106 formed in the upper portion of a latch cage 108. The cage 108 is yieldably urged upwardly to bring the shoulder 109 into abutting engagement with the lower end of the stationary spider 98 by a compression spring 110 interposed between an internal shoulder 112 in the housing section 70 and a plurality of bosses 114 formed on the cage. It will be observed that the upper portion of the recess 106 is counterbored at 116 to a larger diameter, whereby upon slight downward movement of the cage 108 against the force of the spring 110, the ball detents may move radially outwardly into the counterbore 116 and out of the groove 96, thus releasing the latch sleeve from the stationary spider. The arrangement whereby this downward movement of the latch cage 108 is effected will be described hereinafter.

Referring again to Figure 9a, a compression spring 118 is interposed between the spider 88 and a third movable spider 120. To the upper surface of the hub of the spider 120 there are pivotally secured, as by pivot pins 121, three expander arms 122a, to the upper extremity of each of which there is pivotally connected by a pivot pin 123 an identical but inverted expander arm 122b. The upper extremities of the arms 122b are pivotally connected by pivot pins 125 to the hub of a stationary spider 124 which is secured by set screws 126 to the housing (Figure 14). The arms 122a and 122b are disposed in radial planes and, as shown in Figure 15, the axes of the pivot pins 121, 123 and 125 all extend perpendicular to the planes of the respective arms so that the arms may move radially outwardly and inwardly. The housing section 38 is provided with three longitudinal slots 128 each aligned with a respective pair of arms 122a, 122b and of such width as to permit the arms to move outwardly through their respective slots and into engagement with the packer element A. It will be observed that the pivotal connections 123 between the adjacent ends of the two sets of arms are disposed radially outwardly with respect to the location of the pivot pins 121 and 125, whereby upon upward movement of the spider 12 the arms will be pivoted outwardly. A short distance above the spider 120 in its position as shown in Figure 9a, there are provided three inward projections 130 formed on the inner wall of the housing, each projection being disposed in axial alignment with a respective web of the spider 120 and serving as abutments limiting the upward movement of the spider and hence limiting the outward pivotal movement of the arms 122a and 122b.

It has been previously stated that in the cocked condition of the actuator mechanism as shown in Figures 9a and 9b the spider 88 is latched in fixed position. With the spiders 88 and 120 in the relative positions shown in these figures, the spring 118 interposed therebetween is under compression and hence tends to move the spider 120 upwardly and thus pivot the arms 122a, 122b outwardly. However, in this "running-in" condition the spider 120 is also releasably latched in fixed position. A trigger sleeve 132 is secured at its upper extremity to the spider 120 and extends downwardly therefrom within the latch sleeve 94 and concentric therewith. As seen in Figure 9b, the trigger sleeve projects downwardly below the lower extremity of the latch sleeve and has secured to its lower extremity a latch head 134 having axially spaced upper and lower circumferential grooves 136 and 138 in its outer surface.

A plurality of radial bores 140 extend through the latch cage 108 adjacent its lower extremity, there being a ball detent 142 in each bore. In the cocked condition of the mechanism the upper groove 136 in the latch head 134 is aligned with the bores 140 and the detents 142 are disposed partly in the groove 136 and partly in the bores to releasably latch the trigger sleeve 132 to the cage 108. The sleeve tends to move upwardly under the influence of the spring 118, but upward movement of cage 108 is prevented by the abutment of its shoulder 109 against the stationary spider 98. Thus so long as the detents 142 engage the groove 136 the spider 120 and the pivoted spreader arms 122a and 122b are held in their retracted or cocked positions.

Disposed below the latch cage 108 is a trigger cage 144 having an enlarged central recess 146 in its upper portion into which the lower end of the latch cage extends, the bore of the upper portion of the recess having only a working clearance with the detents 142 so as to retain them firmly and securely in the groove 136. An internal arcuate groove 148 is formed in the wall of the recess 146 slightly below the median transverse plane of the recess. In the cocked condition the groove 148 is offset downwardly from the plane of the detent bores 140. The trigger cage rests on an actuator head 150, being yieldingly urged downwardly thereagainst by a compression spring 152 interposed between the upper end surface of the trigger cage and the bosses 114 formed on the latch cage 108. The trigger cage is adapted to be moved upwardly a short distance, by electrically controlled means to be described presently, to bring the groove 148 into alignment with the detent bores 140 and thus permit the detents to be cammed out of the groove 136. When this occurs, the trigger sleeve 132 and its associated spider 120 are free to move upwardly under the influence of the spring 118 and thus expand the arms 122a, 122b.

The lower housing section 72 (Figure 9b) is of heavy-walled construction and, in conjunction with a thick-walled cylinder head 154, defines a blast chamber 156. A plunger rod 158 is secured to the actuator head 150 and extends downwardly through a central opening 160 in the cylinder head. The opening is pressure-sealed by suitable packing 162 which is adapted to be tightly compressed by a follower 164 threaded into the opening 160. The plunger rod 158 is provided with a head 166 on its lower end, to which is attached a small electric blasting cap 168 containing a charge of explosive in which is embedded a wire filament 170 by which the explosive is ignited upon passing an electric current through the filament. Upon ignition of the explosive, the blast drives the plunger rod 158 and its associated actuator head 150 upwardly.

As previously mentioned, the conductor 66 is electrically connected to the insulated impeller shaft 40 of the flowmeter (Figure 8) and extends downwardly along the axis of the actuator housing sections 38 and 70, through a central passage in the trigger sleeve 132, and terminating within a socket 172 disposed between the lower end of the trigger sleeve and the domed head 174 of the actuator head 150. The conductor 66 is enclosed within a thin metal sleeve 176 and is insulated therefrom by insulation 178.

The conductor 66 and its protective sleeve 176 remain stationary during actuation of the various parts of the mechanism, and therefore a sliding clearance is provided between the sleeve 176 and the bore in the trigger sleeve 132. Also, inasmuch as the socket 172 moves vertically with the plunger rod 158 and the actuator head 150, a sliding electrical contact is provided between the lower end of the conductor 66 and the current-conducting elements of the socket 172. As shown, the conductor projects snugly through a split spring ring 180 of conducting material seated in a groove in the upper portion of the socket and in contact with a conductor sleeve 182 resting on a conductor bushing 184 having a spherical recess fitting the domed head 174. The actuator head 150 and the plunger rod 158 serve as conductors and are suitably insulated from the housing as shown. A current impulse may thus be transmitted from the flowmeter impeller shaft 40 through the conductor 66, con-

ductor elements **180**, **182** and **184** of the socket **172**, actuator head **150**, plunger rod **158** and conductor **186** to the filament **170** and thence to ground through conductor **188**. The housing sections **72**, **70** and **38**, being tightly screw-threaded together and to the flowmeter housing **34**, constitute a ground connection.

With the parts in the positions shown in Figures *9a* and *9b*, the assembly of Figures 8, *9a* and *9b* is cocked and ready for lowering into a well on a conductor cable. With the packer element collapsed, the maximum diameter of the entire assembly is less than the inner diameter of commonly used production tubing and hence the assembly may be lowered through the tubing. It is usually desirable to obtain a flow measurement immediately below the lower end of the tubing, and hence when the assembly reaches this point its descent is stopped and the operator closes a switch at the control station to close the circuit including the blasting cap **168** and also the flowmeter signalling circuit.

Upon firing of the blasting cap **168** the plunger rod **158** and its associated actuator head **150** are driven upwardly a short distance, which causes the trigger cage **144** to move upwardly. This results in the internal groove **148** in the trigger cage becoming aligned with the detent bores **140** in the lower portion of the latch cage **108**, thus permitting the detents **142** to move outwardly partially into the groove **148** and out of the groove **136** in the latch head **134** attached to the trigger sleeve **132**. The latter is thereby free to move upwardly into the position shown in Figures 10*a* and 10*b* under the influence of the compressed spring **118**, causing the spider **120** to move upwardly and move the expander arms **122***a*, **122***b* outwardly against the inner wall of the packer element A. The resulting outward buckling of the strips **10** of the packer element reduces the aggregate columnar strength of the packer element to such an extent that the upward force exerted by the extension spring **86** against the lower end of the packer element, through the spider **84**, screws **82** and screen end ring **76**, becomes effective to move the lower end of the packer element upwardly and thus expand the median portion thereof outwardly into sealing engagement with the well casing **16**, as shown in Figure 10*a*. Upward movement of the trigger sleeve **132** and of the spider **120**, and the consequent outward pivotal movement of the spreader arms **122***a*, **122***b*, are limited by engagement of the webs of the spider **120** with the projections **130** on the inner wall of the housing.

After firing the blasting cap **168** the pressure developed in the blast chamber **156** holds the plunger rod **158** and the actuator head **150** in raised position until the gaseous products of the explosion have cooled and contracted sufficiently to reduce the pressure in the blast chamber to less than that of the well fluid in the immediate vicinity of the device, whereupon the plunger rod is returned to its initial position by the higher external pressures. It will be understood that the entire interior of the actuator housing sections **38** and **70** become filled with well fluid at the prevailing submergence pressure, only the blast chamber **156** being sealed off from the well pressure. Upon downward movement of the actuator head **150**, the socket **172** is urged downwardly by a compression spring **190** interposed between the socket and the lower end of the trigger sleeve **132**.

During the abovementioned upward movement of the trigger sleeve **132** the detents **142** are maintained in their outer positions, partially within the groove **148**, by the cylindrical portion of the latch head **134** between the upper and lower external grooves **136** and **138**. Hence during this portion of the cycle the latch cage **108** and the trigger cage **144** are interlocked and the latter is temporarily held in slightly raised position. Upon completion of the upward stroke of the trigger sleeve, however, the lower groove **138** in the latch head **134** is brought into alignment with the detent bores **140** whereupon, assuming that the plunger rod **158** and actuator head **150** have returned to their initial positions, the detents **142** are free to move into the groove **138** and are cammed out of the groove **148** in the trigger cage **144** by the downward force exerted on the cage by the spring **152**. Thereupon the trigger cage is released from the latch cage **108** and moves downwardly into the position shown in Figure 10*b*, in which position the wall of the recess **146** locks the detents partially within the groove **148** to interlock the trigger sleeve **132** and the latch cage **108**. As described hereinafter, this interlocking of the trigger sleeve and the latch cage against downward movement of the trigger sleeve relative to the latch cage is an essential step in conditioning the mechanism for subsequent collapsing of the packer element.

Attention is directed to the fact that during the above-described actuation of the mechanism to expand the packer element, the position of the latch cage **108** has not changed and hence the latch sleeve **94** and its associated spider **88** remain locked in fixed relation to the stationary spider **98** by the detents **94**. The extension spring **86** is therefore still partially energized and exerts sufficient upward force on the packer element to maintain it expanded against the wall of the well casing.

With the parts in the position shown in Figures 10*a* and 10*b*, the assembly is conditioned for making a flow survey in the well by moving the assembly through the interval to be surveyed and making flow rate measurements either continuously or at selected stations. As shown in Figures *9a*, 10*a* and 17, the actuator housing section **38** is provided with three fluid inlet openings **192** in the region of the guide slots **80** but angularly offset from these slots so as not to be obstructed by the webs of the floating spider **84**. While the packer element A is in collapsed condition it extends downwardly below these inlet ports, but upon expansion of the packer element its lower extremity moves upwardly a distance sufficient to uncover these ports. The screen **78** simultaneously moves upwardly to surround the inlet ports and thus exclude any solid matter in the well fluid of a size such that, if allowed to enter the instrument, it might clog the passages or foul the flowmeter impeller **40**. The fluid flowing upwardly in the well thus enters the housing through the inlet ports **192**, flows upwardly in the housing to the flowmeter housing **34**, past the stationary vanes **44**, impinging on the impeller to rotate it, and emerges from the housing **34** through the outlet ports **46**. It will be noted from the transverse sectional views, Figures 14, 15, 16 and 17, that all elements extending transversely across the path of flow of fluid through the housing, such as the webs of the spiders **84**, **88**, **120** and **124**, and the expander arms **122***a*, **122***b*, are of small cross-sectional area and hence do not materially reduce the flow passage area. Furthermore, these elements are all disposed in axial alignment with each other, whereby the three segmental flow passages are continuous and uninterrupted from the inlet ports **192** to the stationary vanes **44**.

It should also be pointed out that it is immaterial to the functioning of the packer whether the fluid flow is upwardly or downwardly. In the case of downward flow the fluid enters the ports **46** and flows downwardly and emerges from the ports **192**. In that case the flowmeter may be altered slightly by substituting a different impeller and stationary vane subassembly wherein the relative positions of these elements are reversed.

In order to withdraw the assembly from the well through the tubing **32**, it is obvious that the packer element A must first be collapsed. The inherent resiliency of the spring metal strips **10** of the packer element causes them to constantly tend to return to a straight condition, and hence this will occur upon release of the upward axial force exerted on the packer element by the extension spring **86**. The actuator mechanism disclosed herein is constructed and arranged to de-energize the spring **86** upon application of slight downward pressure exerted against the upper set of expander arms **122***b* to swing them inwardly a short distance about their pivots **125**. This downwardly directed pressure may be applied to the arms **122***b* by pulling the assembly upwardly into the tubing **32** until the lower end of the tubing engages the outwardly and downwardly flared upper portion of the packer element A. It will be observed by reference to Figure 10*a* that when this occurs the lower end of the tubing, indicated by broken lines at **32**, will engage the packer element in the region of the outer portions of the arms **122***b*. Thereafter continued upward movement of the assembly causes the arms to be rocked inwardly, resulting in downward movement of the spider **120** and the trigger sleeve **132**.

Referring to Figure 10*b*, it will be noted that the ball detents **142** extend partially into the lower groove **138** of the latch head **134** and thus restrain the trigger sleeve **132** against downward movement relative to the latch cage **108**. Hence the initial downward movement of the trigger case **132** caused by inward pivotal movement of

the arms 122*b* moves the latch cage 108 downwardly, compressing the spring 110. A slight downward movement of the cage 108 brings the counterbore 116 in the upper end portion of the cage into alignment with the detent bores 102 in the stationary spider 98 and thus allows the detents 104 to move outwardly. Thereupon the downward force exerted on the latch sleeve 94 by the stressed extension spring 86 cams the detents 104 out of the groove 96 in the lower end of the latch sleeve, thus allowing the latch sleeve and its associated spider 88 to move downwardly into the position shown in Figures 11*a* and 11*b*. In this position of the latch sleeve and spider the spring 86 is fully relaxed and unbiased. Meanwhile during downward movement of the latch sleeve the attendant release of the energy stored in the spring 86 has permitted the floating spider 84 and the screen 78 to move downwardly to its original position, thus releasing the packer element from the previously applied compressive force. The inherent resiliency of the metal strips 10 thereupon causes the packer element to return to its collapsed condition as shown in Figure 11*a*. It will be understood that the latch sleeve 94 is released from the stationary spider 98 upon only slight downward movement of the trigger sleeve 132 and the latch cage 108. Hence it requires only slight inward pivotal movement of the arms 122*b* to effect de-energization of the spring 86 and the consequent self-collapsing of the packer element. This avoids the possibility of damaging the packer element by attempting to pull it upwardly into the tubing 32 while it is in expanded condition. The movements of the various elements from the positions shown in Figures 10*a* and 10*b* to those shown in Figures 11*a* and 11*b* are all influenced by relatively high spring forces and consequently they occur very rapidly, with a snap-action. There is therefore no appreciable time lag between the initial inward pivotal movement of the arms 122*b* by the tubing 32 and the collapsing of the packer element.

It will be observed by reference to Figure 10*b* that the trigger cage 144 rests on the actuator head 150 and hence cannot move downwardly. The initial downward movement of the latch cage 108 with the trigger sleeve 132, resulting from the temporary interlocking of these elements by the detents 142, brings the detent bores 140 in the latch cage into registry with the internal groove 148 in the wall of the recess 146 in the upper portion of the trigger cage 144. This allows the detents 142 to move outwardly partially into the groove 148 and out of the groove 138 in the latch head 134, thus releasing the trigger sleeve 132 and its associated spider 120 for further downward movement into the position shown in Figures 11*a* and 11*b*. In this position the expander arms are fully collapsed. It will be understood that the release of the trigger sleeve 132 from the latch cage 108 occurs substantially simultaneously with the release of the latch sleeve 94 from the stationary spider. Hence the expander arms 122*a*, 122*b* are retracted into the position shown in Figure 11*a* during the self-collapse of the packer element.

It will be noted by reference to Figure 11*b* that in the position of the parts after collapse of the packer element the latch cage 108 is interlocked with the trigger cage 144 by the detents 142. The two cages are held downwardly in the positions shown in Figure 11*b* by the detents 104, which are retained in their outer positions, partially within the counterbore 116, by the latch sleeve 94.

Upon removal of the assembly from the well it may be re-conditioned for a subsequent run by replacing the discharged blasting cap 168 and its wiring 186 and 188, and by re-setting or cocking the spring mechanism. To replace the blasting cap the housing section 72 is unscrewed from the section 70, thus exposing the plunger rod 158 and its head 166. It will be noted that the cylinder head 154 is threadedly connected to the intermediate housing section 70 and is seated in a counterbore 194 (Figure 11*b*) in the wall of the blast chamber 156. A packing ring 196 is compressed to provide a pressure-tight joint upon screwing the housing section 72 onto the section 70. The cylinder head 154 is provided with a normally plugged drain port 198 communicating with the interior of the housing sections 70 and 38, the drain plug being accessible for removal upon breaking the joint between the sections 70 and 72, to permit draining off any fluid trapped in the sections 70 and 38.

To re-set or cock the actuator mechanism from the condition shown in Figures 11*a* and 11*b* to the "running-in" condition shown in Figures 9*a* and 9*b*, the flowmeter housing 34 is unscrewed from the upper actuator housing section 38. Cocking is effected by inserting a special tool into the open upper end of the housing section 38 to engage the spider 88 and move it upwardly from the position shown in Figure 11*a* to that shown in Figure 9*a*. The corresponding upward movement of the latch sleeve 94 causes the groove 96 at the lower end of the latch sleeve to register with the detent bores 102 in the stationary spider. Thereupon the detents 104 are free to move inwardly into the groove 96, and they are cammed into this position by the curved shoulder joining the recess 106 and the counterbore 116 in the upper portion of the latch cage 108, as the latch cage moves upwardly under the influence of the spring 110. The latch sleeve 94 and its associated spider 88 become locked in fixed position by the detents 104, which are retained in the groove 96 by the wall of the recess 106.

During this upward movement of the latch cage 108 the trigger cage 144 is also constrained to move upwardly by reason of its being interlocked with the latch cage by the detents 142. However, the upward movement of the latch cage causes the detent bores 140 therein to register with the upper groove 136 in the latch head 134, thus permitting the detents 142 to move inwardly into the groove 136. The trigger cage is biased downwardly by the spring 152, and hence the detents are cammed out of the groove 148 in the trigger cage and into the groove 136. Subsequent downward movement of the trigger cage brings the upper cylindrical portion of the wall of the recess 146 into registry with the detents 142, thereby retaining them in the groove 136.

The above-described upward movement of the spider 88 and the latch sleeve 94 extends the spring 86 and compresses the spring 118, it being understood that the floating spider 84, to which the lower end of the spring 86 is secured, is restrained against upward movement by the collapsed packer element. The compressing of the spring 118 tends to cause the spider 120 to move upwardly, and hence during the cocking operation it is necessary to temporarily confine the expander arms 122*a*, 122*b*, as by gripping the packer element in the region of the expander arms, until the detents 142 have engaged the groove 136 to lock the trigger sleeve 132 and spider 120 against axial movement.

In order to permit inserting of a cocking tool into the housing section 38 a distance sufficient to enable it to engage the spider 88 in its position as shown in Figure 11*a*, the elements disposed in the housing between the spider 88 and the open upper end of the housing are arranged in a particular manner. Thus each of the spiders 88, 120 and 124 has the same number of webs, with corresponding webs being disposed in axial alignment, as indicated by a comparison of Figures 14, 15 and 16. Each pair of expander arms 122*a*, 122*b* is also axially aligned with a web of each spider. There are thus formed three uninterrupted segmental passages extending from the open end of the housing to a point beyond the spider 88.

A special cocking tool suitable for this purpose is shown in Figures 12 and 13, and comprises an elongated tubular body 200 having an outer diameter somewhat less than the inner diameter of the housing section 38 so as to clear the projections 130, and having an inner diameter greater than the outer diameter of the springs 86 and 118 and of the hubs of the spiders 88, 120 and 124. The body 200 is provided with three longitudinal slots 202 extending from one end thereof for a distance somewhat greater than the axial spacing between the spiders 124 and 88. The slots are angularly offset 120° apart, to correspond to the arrangement of the webs of the spiders. The entrance end of each slot is flared as at 204 and 206 and merges into a short length of slot 208 slightly wider than the widest spider web. The main portion of each slot is of a width approximately twice that of the slot length 208, the juncture of the wide and narrow portions providing a shoulder 210 which, as shown, is concave. The opposite end of the body 200 is provided with an enlarged head 212 having a pair of grip rods 214 extending therefrom.

The tool is inserted into the housing through its open upper end, a web of each spider 124, 120 and 88 and a pair of expander arms 122*a*, 122*b* progressively entering each slot 202 as the tool is inserted. When the shoulders 210 have passed beyond the spider 88 the tool is turned

clockwise, as viewed from above, to cause the shoulders **210** to underlie the respective webs of the spider **88**. Thereupon the tool is pulled upwardly to cause the shoulders **210** to engage the webs of the spider **88** and pull the spider up to the position shown in Figure 9*a*. During this operation the operator grasps the packer element A in the region of the expander arms to prevent their moving outwardly prior to latching of the trigger sleeve **132** and spider **120** in fixed position, as described hereinabove. The automatic latching of the latch sleeve **94** and spider **88** in fixed position, as described above, permits the tool to be lowered slightly, turned counterclockwise and withdrawn. Upon re-assembly of the housing sections the device is ready to be run in a well.

Although in the foregoing description reference has been made to running the assembly into a well and withdrawing it therefrom through the well tubing, it should be understood that it is equally possible and occasionally desirable to run it in the annular space between the tubing and the well casing. This is especially the case if the well is equipped with a pump, the operation of which it is desired to continue while conducting the survey. It is not necessary, in order to effect collapse of the packer element, that the downward pressure for de-energizing the spring **86** be applied to all three of the expander arms by a tubular member concentric with the device; on the contrary, downward pressure applied at a single point on the periphery of the packer element is effective for this purpose. Hence it is possible to effect collapse of the packer element by drawing it upwardly into the annular space between the tubing and the casing until the lower end of the tubing engages the packer element tangentially at one point.

In the event it is desired to operate the assembly in liquid which is a good electric conductor, such as salt water for example, it may be desirable to initially fill the actuator housing sections **38** and **70** with a non-conducting liquid, of greater specific gravity than the conducting liquid, up to the level of the inlet ports **192** and the slots **80**. This will obviate any possibility of shorting out through the liquid the current impulse transmitted to the blasting cap filament. It will be noted that whereas in the lower portion of the intermediate housing section **70** there are a number of elements of the electrical circuit which are exposed to the fluid in the housing, this is not the case above the fluid inlet ports **192**.

It will be apparent from the foregoing description that we have provided a packer element of unique construction and embodying novel characteristics which have proven in actual practice to be extremely useful and advantageous in connection with the primary intended use of the packer element. Also, considering the fact that operating conditions limit the overall diameter of the assembly to a maximum of about 1½", and considering the complete cycle of operations performed by the actuator mechanism, it will be apparent that this mechanism is of relatively simple and foolproof design and of sturdy, durable construction.

It is to be understood that the single embodiment disclosed herein is merely by way of illustration of the invention and that it is susceptible of various modifications and other embodiments within the spirit of the invention and the scope of the appended claims.

We claim:

1. A well packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges circumferentially overlapping throughout their entire length, and means at each end of the packer element engaging the ends of said strips and retaining said strips in fixed overlapping relation.

2. A well packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges circumferentially overlapping throughout their entire length, and a ring at each end of the packer element engaging the adjacent ends of said strips.

3. A well packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges circumferentially overlapping, and inner and outer rings at the ends of said packer element, the end portions of said strips being confined in fixed overlapping relationship between the respective pairs of rings.

4. A well packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis, one edge of each strip circumferentially overlapping one edge of the next adjacent strip, said strips being secured only at their ends, and being adapted to be bowed radially outwardly upon movement of the ends thereof toward each other, and means for engaging and interconnecting adjacent ends of the strips to maintain said overlapping relationship when bowed outwardly.

5. A well packer comprising: a packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis, one edge of each strip circumferentially overlapping one edge of the next adjacent strip, said strips being secured only at their ends; means for engaging and interconnecting adjacent ends of the strips to secure them and maintain said overlapping relation; and means associated with said first mentioned means for effecting relative movement of the ends of the strips toward each other to bow the intermediate portions of said strips radially outwardly.

6. A well packer comprising: a packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges circumferentially overlapping and secured only at their ends; means for engaging and interconnecting adjacent ends of the strips to secure them and maintain said overlapping relation; means for applying a radially outwardly directed force to said strips at a point intermediate their ends to effect initial outward buckling of said strips; and means operable upon said initial buckling for effecting relative axial movement of the first mentioned means toward each other to continue said buckling.

7. A well packer comprising: a packer element comprising a fluid tight chamber formed by a coextensive plurality of normally straight, crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges circumferentially overlapping and secured only at their ends; means for engaging and interconnecting adjacent ends of the strips to secure them and maintain said overlapping relation; means for applying axially compressive force between said means tending to effect outward buckling of the strips, the magnitude of said axial force being less than the aggregate columnar strength of the strips; and means for initially buckling said strips outwardly by the application thereto of transverse outward force at a point intermediate the ends thereof whereby the aggregate columnar strength of the strips is reduced below the magnitude of said axial compressive force, thereby rendering said axial compressive force effective to continue the outward buckling of said strips.

8. A well packer comprising, in combination: a packer element comprising a fluid tight chamber formed by an annular series of coextensive normally straight, longitudinally extending crowned spring metal strips disposed in circumferentially overlapping relation; end members interconnecting the respective ends of said strips; means for applying to said end members an axial compressive force less than the aggregate columnar strength of said series of strips when said strips are straight; and radially expansible means disposed within said packer element and operable to apply radially outwardly directed force to said strips intermediate the ends thereof to initially buckle said strips outwardly and thereby reduce their aggregate columnar strength to less than said axial compressive force, whereby said axial compressive force is rendered effective to continue the outward buckling of said strips.

9. A well packer comprising, in combination: a packer element comprising a fluid tight chamber formed by an annular series of coextensive normally straight, longitudinally extending crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges in circumferentially overlapping relation throughout their entire length; end members interconnecting the respective adjacent ends of said strips; spring means normally urging

one of said end members toward the other end member in a direction biasing said end members towards outward bowing of said strips, the force of said spring means being less than the aggregate columnar strength of said series of strips when said strips are straight; radially expansible means disposed within said packer element and operable when expanded to initially buckle said strips outwardly at a point intermediate their ends, said initial buckling being effective to reduce the aggregate columnar strength of said strips to less than the force exerted by said spring means, whereby said one end member may be moved by said spring means toward said other end member to bow said strips outwardly against the wall of the well; and an actuator extending within said element and engaging said expansible means for expanding the same.

10. Apparatus as set forth in claim 9, wherein said expansible means comprises at least one pair of arms pivotally connected at their distal ends respectively to one of a pair of members, one of which is axially fixed and the other is axially movable with respect to said other end member, the adjacent ends of said arms being pivotally interconnected on an axis spaced radially outwardly of the axes of pivotal connection of their distal ends to said fixed and movable members, whereby upon movement of said movable member toward said fixed member the pivotally interconnected ends of said arms are moved outwardly to buckle said strips outwardly.

11. A well packer comprising, in combination: a packer element comprising a fluid tight chamber formed by an annular series of coextensive normally straight, longitudinally extending crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges in circumferentially overlapping relation throughout their entire length; end members interconnecting the respective adjacent ends of said said strips; spring means normally urging one of said end members toward the other end member in a direction biasing said end members toward outward bowing of said strips, the force of said spring means being less than the aggregate columnar strength of said series of strips when said strips are straight; radially expansible means within said packer element and operable when expanded to initially buckle said strips outwardly; actuating means extending into said element and engaging said expansible means for expanding said expansible means; and means controllable from the well surface for initiating the operation of said actuating means.

12. A well packer comprising in combination: a packer element comprising a fluid tight chamber formed by an annular series of coextensive normally straight, longitudinally extending crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges in circumferentially overlapping relation throughout their entire length; end members interconnecting the respective adjacent ends of said strips; spring means normally urging one of said end members toward the other end member in a direction biasing said end members toward outward bowing of said strips, the force of said spring means being less than the aggregate columnar strength of said series of strips when said strips are straight; radially expansible means within said packer element and operable when expanded to initially buckle said strips outwardly, said initial internal buckling being effective to reduce the aggregate columnar strength of said strips to less than the force exerted by said spring means, whereby said one end member may be moved by said spring means toward said other end member to bow said strips outwardly against the wall of the well; actuating means extending into said element and engaging said expansible means for expanding said expansible means; a pressure chamber having pressure responsive means therein operatively connected to said actuating means; and means controllable from the surface for developing fluid pressure in said chamber to actuate said pressure responsive means and thereby initiate operation of said actuating means.

13. Apparatus as set forth in claim 12, wherein said surface-controlled means comprises a body of combustible material in said chamber and electrical means controllable from the surface for igniting said combustible material.

14. A well packer comprising, in combination: a packer element comprising a fluid tight chamber formed by an annular series of coextensive normally straight, longitudinally extending crowned spring metal strips disposed longitudinally in encircling relationship about a common longitudinal axis with their edges in circumferentially overlapping relation throughout their entire length; end members interconnecting the respective adjacent ends of said strips; spring means normally urging one of said end members toward the other end member in a direction biasing said end members toward outward bowing of said strips, the force of said spring means being less than the aggregate columnar strength of said series of strips when said strips are straight; radially expansible and retractible means within said packer element operable when expanded to initially buckle said strips outwardly and thereby enable said spring means to bow said strips outwardly against the wall of the well; actuating means extending into said packer and engaging said expansible means for expanding said expansible means; and means operatively interconnecting said actuating means and said spring means and operable, upon enforced retraction of said expansible means, to de-energize said spring means and thereby permit said strips to resume their normal straight condition.

15. A well packer as set forth in claim 14, wherein said spring means comprises a helical spring, a connecting member interposed between one end of said spring and said packer element, and a first sleeve member having one end thereof engaged by the other end of said spring; and wherein said actuating means for said expansible means comprises a second sleeve member connected at one end to said expansible means; and wherein said interconnecting means comprises a member operatively interconnecting said first and second sleeve members.

16. A well packer as set forth in claim 14, wherein said spring means comprises a helical spring, a connecting member interposed between one end of said spring and said packer element, and a sleeve member engaged at one end by the other end of said spring, the other end of said sleeve member being releasably secured to an anchor member axially fixed with respect to said other end member; and wherein said means operatively interconnecting said actuating means and said spring means comprises a release member operable, upon retraction of said expansible means, to release said other end of said sleeve member from said anchor member to thereby de-energize said spring means.

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