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PROGRESSIVELY EXPANDED PACKING ELEMENT FOR A BRIDGE PLUG

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*Fig. 1*

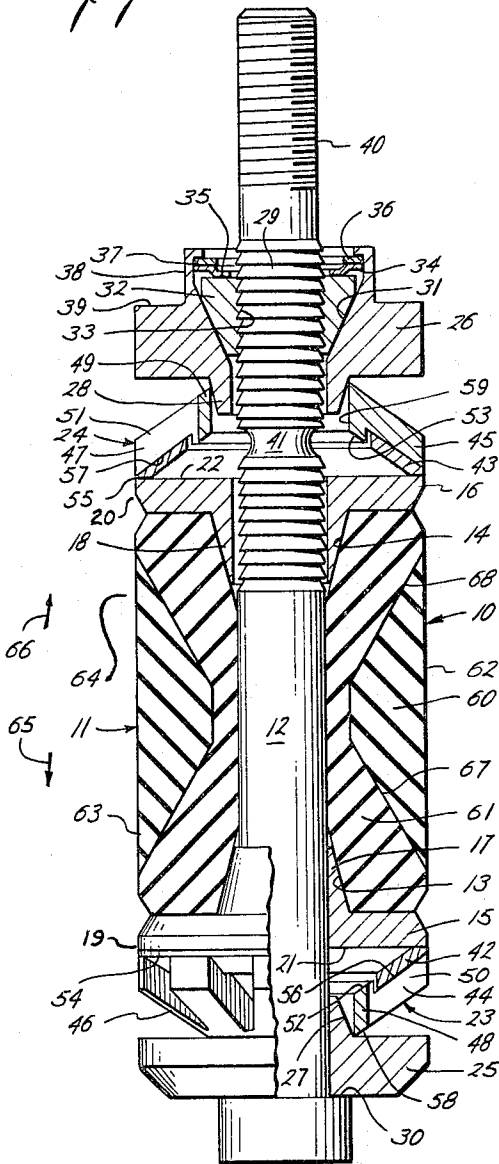
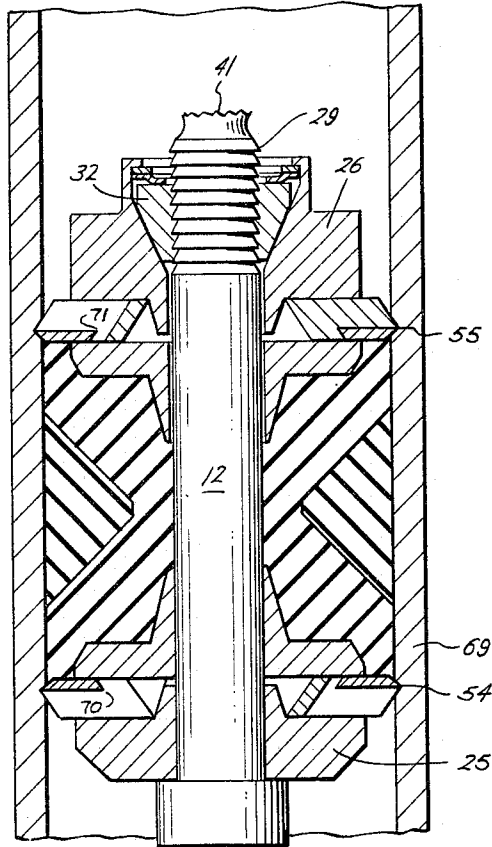


*Fig. 2*



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## PROGRESSIVELY EXPANDED PACKING ELEMENT FOR A BRIDGE PLUG

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5 Claims. (Cl. 166—192)

This invention relates to a bridge plug for use in a well bore, and, more particularly, to a bridge plug with packing means arranged for progressive expansion into sealing engagement with a well tubing or casing.

A bridge plug typically consists of a mandrel on which a packing element is mounted between reversely directed sets of extendible slip elements carried on tapered expander elements, with the slip elements being releasably held by shear pins in an inoperative first position on the expander elements. A body lock is provided to hold these elements in an operative second position in anchoring engagement with a casing. Setting of such a bridge plug is conventionally accomplished by a setting tool which applies oppositely directed forces in such a manner that the packing element is expanded into sealing engagement and the slip elements are extended into anchoring engagement to hold the bridge plug set in place.

Usually, a packing element for such bridge plugs is composed of an elastomeric material which will readily expand outwardly into engagement with the well casing and conform to the configuration of the casing wall at that point. It has been found, however, that such elastomeric packing elements generally expand faster at their ends than in their central portions. This is not desirable since, in addition to requiring a greater force to complete the expansion of the central portion than if the ends were not yet expanded, well fluids are often trapped in the annular space around the element when the end portions are first to seal against the casing. It will be appreciated that whenever well fluids are so trapped, the effectiveness of the sealing engagement of the element is reduced.

It is, therefore, an object of the present invention to provide a new and improved bridge plug and packing element combination where the packing element is arranged to be progressively expanded against a well tubing or casing.

The bridge plug of the present invention includes a packing element comprised of a plurality of elastomeric elongated annular members proportioned and arranged to form a composite tubular member. Each of the annular members or plies are of an elastomeric material having a modulus of elasticity different than that of one or more of the other members. Each ply also varies in thickness from a first thickness at the ends of the tubular element to at least a second thickness at the central portion or middle of the packing element.

The modulus of elasticity of the individual plies, as well as the thickness of each ply at any particular transverse section, are so chosen that the modulus of elasticity of the composite tubular element will increase in a predetermined order from the central portion outwardly toward each end of the element.

Accordingly, by properly proportioning the relative thicknesses and moduli of elasticity of each of the plies, the composite tubular packing element is arranged to expand initially at its central portion and then, as the setting forces increase, progressively expand in a longitudinal direction toward each end of the element. By proportioning these variables at intermediate longitudinally spaced sections along the remainder of the element as well, the end portions of the element can also be made to expand at a desired rate over a particular range of setting forces.

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In the bridge plug of the present invention, means are provided for expanding the packing element and anchoring the bridge plug to a casing wall.

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

FIG. 1 illustrates a bridge plug, partly in section, employing a packing element constructed in accordance with the principles of the present invention; and

FIG. 2 is a view showing the bridge plug of FIG. 1 expanded into sealing and anchoring engagement with a well casing.

Turning now to FIG. 1, a bridge plug 10 is shown with one embodiment of an elastomeric packing element 11 slidably mounted around an elongated cylindrical member or mandrel 12. Elastomeric packing sleeve or element 11 is provided with tapered annular recesses 13, 14 in its lower and upper ends, respectively. Oppositely directed lower and upper expander members 15, 16 are slidably mounted around mandrel 12 at opposite ends of packing element 11, with each expander having a tapered hub portion 17, 18 complementarily received within packing element recesses 13, 14 and an enlarged-diameter base portion 19, 20. Tapered hub portions 17, 18 are provided to stabilize the expander members 15, 16 against tipping relative to the mandrel. The rearward faces 21, 22 of expanders 15, 16 are flat and respectively engaged with oppositely directed, hollowed, frusto-conical lower and upper anchor elements 23, 24.

Lower and upper anchor members 23, 24 are initially disposed with their outermost edges engaged around the enlarged base portions of the expander members 15, 16 and their innermost edges engaged with oppositely directed lower and upper abutment members 25, 26, respectively.

Abutment members 25, 26 are generally cylindrical with each having reduced-diameter and inwardly converging tapered hub portions 27, 28 received within the inner edges of anchor elements 23, 24. The tapered hubs 27, 28 ensure that anchor elements 23, 24 remain engaged against the abutment members rather than riding loosely on the mandrel 12. Accordingly, it will be appreciated that should an anchor member be longitudinally displaced as the bridge plug is being positioned in a well casing, the tapered hubs will recenter the displaced member when it returns to its original position. Furthermore, as the mandrel travels upwardly during the setting operation, the upper hub 28 prevents mandrel ratchet teeth 29 from catching on the inner edge of upper anchor member 24.

The upper abutment member is of hardened steel to ensure that as the bridge plug is being set, the tapered hub portion 28 will not deform under the substantial radial load applied thereon by the upper anchor member 24 as it is flattened and extended against the casing. It will be appreciated, of course, that should this hub 28 deform, the mandrel could not travel smoothly through the upper abutment member 26.

Lower abutment member 25 is slidably disposed around mandrel 12 and engaged with an upwardly facing shoulder 30 at the lower end thereof. Upper abutment member 26 has an upwardly directed and outwardly diverging tapered recess 31 which receives a complementary tapered split-nut 32. Split-nut 32 has upwardly facing ratchet teeth 33 around its axial bore which are cooperatively engaged with downwardly facing ratchet teeth 29 cut around the upper end of mandrel 12. A spring member 34 is operatively engaged between the upper end 35 of split-nut 32 and a snap-ring 36, which is in turn held

against a downwardly facing circumferential shoulder 37 around the upper end of recess 31. Spring member 34 is preferably an assembly of two opposed springs with each spring consisting of a flat ring having resilient projecting tabs which are interlocked with the tabs of the other spring. These springs, when nested together, make a compactly arranged spring member with oppositely directed flattened annular end surfaces.

The upper end of upper abutment member 26 has a reduced outer-diameter portion 38 providing an upwardly facing shoulder 39 which is sized and arranged for receiving the lower end of the outer sleeve or pushing member of a conventional setting tool (not shown). If desired, the sleeve of the setting tool may be releasibly connected to the upper abutment member 26 by means of a shear pin (not shown). External threads 40 around the upper end of mandrel 12 are provided for coupling to the inner mandrel or pulling member of the setting tool. A reduced-diameter or necked portion 41 near the upper end of mandrel 12 is sized to fail whenever oppositely directed forces of a predetermined magnitude are applied in the well-known manner by the setting tool.

Each of the anchor elements 23, 24 are identical and include an annular yieldable restraining member 42, 43 mounted around the outer circumference of multi-fingered wall-engaging members 44, 45.

Wall-engaging members 44, 45 are integrally formed of steel and have a plurality of uniformly spaced fingers 46, 47 extending radially outwardly around a weakened and deformable annular base portion 48, 49. Fingers 46, 47 are initially disposed at an acute angle to the central axes of the wall-engaging members and mandrel to form a frusto-conical configuration. The outer ends 50, 51 of the fingers 46, 47 are cut at an acute angle to the inner faces 52, 53 of the fingers to provide a sharp corner, as at 54, 55, and are selectively hardened for anchoring engagement against the wall of the casing. Peripheral grooves for receiving annular restraining members 42, 43 are formed by cutting recesses 56, 57 in the inner faces 52, 53 and at the outer end of each of the fingers 46, 47. The inner edges 58, 59 of the annular base portions are beveled to weaken the base portions and are sized for engagement around the inwardly converging hub portions 27, 28 of abutment members 25, 26.

The yieldable annular restraining members 42, 43 of the anchor elements 23, 24 are frusto-conically shaped members, preferably of steel, and are sized for reception within the peripheral recesses 56, 57 of wall-engaging members 44, 45. It will be appreciated that by varying the dimensions and material of the annular restraining members 42, 43, the strength of these members can be regulated to require a predetermined force for stretching them sufficiently to allow the anchor elements to completely flatten. Accordingly, the restraining members can be sized where they will not stretch until the setting forces reach a predetermined magnitude which may be less than, equal to, or greater than the magnitude of force required to completely expand a particular packing element. Thus, by regulating the strength of the restraining members the degree of expansion of the packing element may be controlled.

Annular restraining members 42, 43, however, are preferably sized and proportioned to restrain the outward extension of fingers 46, 47 until such time that packing element 11 has at least been substantially expanded against the casing. Thus, by properly correlating the amount of force required to displace the packing element to the amount of force required to stretch the restraining members, the anchor elements can be delayed from flattening and engaging the casing until the bridge plug has been shifted to substantially its minimum longitudinal displacement, which delay will prevent the finger ends 50, 51 from being dragged along the casing during the setting operation.

Moreover, by disposing annular members 42, 43 around the outer edges of wall-engaging members 44, 45, when the wall-engaging members are fully extended against the casing wall, annular members 42, 43 will substantially close all openings between the fingers and around the outer periphery of expander members 15, 16. Thus, it will be appreciated that annular members 42, 43 also effectively prevent the extrusion or cold-flow of the elastomeric packing element 11 after it has been sealingly engaged with the casing wall.

It has been found, furthermore, that the restraint provided by the yieldable restraining members 42, 43 guides each finger 46, 47 and ensures that it moves radially outwardly in unison with the other fingers. Thus, no one finger can extend further than the others and become lodged between the casing and bridge plug to prevent the bridge plug from being centralized in a casing.

Turning now to the particular configuration and arrangement of the packing element 11, it has been found that a packing element fabricated in accordance with the principles of the present invention will initially expand at its central portion and thereafter progressively expand from this central portion in a longitudinal direction toward each end of the element as the setting forces increase.

The basic principle of the invention is to arrange a packing element or sleeve in such a manner that as the bridge plug is being set, the central portion of the packing element will always expand radially at a faster rate than at its ends. Thus, a packing device with a packing element employing this principle will always seal uniformly against the casing without corrugating.

It has been found that to accomplish this, the central portion of the packing element must have a composite modulus of elasticity less than the composite modulus of elasticity of the end portions. Accordingly, the new and improved packing element of the present invention is fabricated from two or more plies of different elastomeric materials, which materials are preferably bonded together to maintain the alignment of the plies.

These plies are respectively arranged so that at those portions where it is desired to have a relatively fast rate of radial expansion, the composite modulus of elasticity of a transverse segment through that portion is relatively lower than the composite modulus at those portions where the expansion is to be at a retarded rate.

This composite modulus of elasticity is appropriately adjusted by providing thick plies of elastomeric materials having a low modulus in the rapidly expanding sections and thinner plies of such materials in the slowly expanding sections. Since it is usually preferred to maintain a substantially uniform wall thickness along the length of a packing element, the composite packing element of the present invention is completed by bonding one or more plies of high-modulus elastomeric material to the lower-modulus material. It will be realized, of course, that this will result in the high-modulus material being thinner in the rapidly expanding sections than in the slowly expanding sections.

It will be appreciated that by appropriately varying the number of plies, by selecting elastomeric materials with relatively different moduli of elasticity, and by proportioning the thickness of each ply at any particular transverse segment, an infinite number of expansion rates can be provided or "programmed" along the length of a particular packing element in response to a particular range of setting forces. It should be further appreciated that these parameters can be selected to make a packing element expand progressively toward each end thereof in a predetermined manner. For example, by arranging a packing element as shown in FIG. 1 with the outer ply 60 having a lower modulus of elasticity than that of the inner ply 61, the central portion 62 will be the first to expand against the casing. Thereafter, as the setting forces continue to increase, intermediate portions 63, 64 will pro-

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gressively expand in the direction shown by arrows 65, 66. Since the complementarily engaged surfaces of the plies forming the element are uniformly tapered, as at 67, 68, through intermediate portions 63, 64, this expansion will progress longitudinally and uniformly in direct relationship to the magnitude of the setting forces at any particular moment.

Similarly, the rate of expansion of these intermediate portions 63, 64 could be accelerated or retarded by respectively curving surfaces 67, 68 inwardly or outwardly. Other variations in expansion rates could also be achieved by stepping surfaces 67, 68 at one or more longitudinally spaced points.

It should be further realized that the higher-modulus material can also be placed on the outside of the element, with the lower-modulus material being around the mandrel. This would naturally require that the direction of slope of the surfaces 67, 68 be reversed from that shown in FIG. 1 to maintain the composite modulus of the central portion 62 at a lower level than that of the intermediate portions 63, 64. This reversal of slope would leave the action of the element as discussed above.

Accordingly, when the packing device is being set, the packing element 11 will be progressively expanded from its central portion 62 uniformly toward each end. The periphery of the central portion 62 of the packing element will be the first to engage the casing 69; and as the element is progressively displaced toward its ends, well fluids will be forced out of the constantly diminishing annulus surrounding the packing apparatus. It will be appreciated, therefore, that this progressive longitudinal displacement ensures that the packing element 11 completely seals against the casing 69 without trapping well fluids therebetween.

When the bridge plug of FIG. 1 is to be operated, a conventional setting tool (not shown) is attached to the upper end of bridge plug 10. The pulling member or inner mandrel of the setting tool is threadedly attached to threads 40 at the upper end of mandrel 12 and the pushing member or outer sleeve of the setting tool is co-operatively engaged with upwardly facing shoulder 39 of upper abutment member 26.

When the bridge plug has been positioned for setting within a well bore, the setting tool is operated in the conventional manner to pull mandrel 12 and lower abutment member 25 upwardly as the setting tool sleeve forces upper abutment member 26 downwardly. As the abutment members 25, 26 advance toward each other, it will be appreciated that gradually increasing and oppositely directed setting forces will be applied through the anchor elements 23, 24 and expander members 15, 16 against the opposite ends of packing element 11, which forces will begin progressively foreshortening and displacing the central portion 62 of the packing element 11 radially outwardly toward the casing wall 69.

When the packing element 11 has been substantially displaced, the setting forces will have then increased sufficiently to cause the yieldable restraining members 42, 43 to gradually yield and begin to stretch. When the restraining members begin to stretch, the inner faces 52, 53 of the fingers 46, 47 slide outwardly in unison over the adjacent edges of the enlarged portions 19, 20 of expander members 15, 16 as the base portions 48, 49 of the anchor members are concurrently deformed and forced toward the expander members.

When restraining members 42, 43 have stretched sufficiently, the hardened tips 54, 55 of the fingers will contact the casing and the continued travel of the abutment members 25, 26 will subsequently flatten the conically formed anchor members again the flat end surfaces 21, 22 of the opposing expander members to drive the hardened finger tips into the casing 69. When the hardened tips are driven into the casing, the peripheral edges of the annular restraining members 42, 43 will be flattened against the casing 69 to substantially fill any slight irregu-

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larities in the casing wall at that point. Furthermore, as seen in FIG. 2, it will be noted that expander members 15, 16 are so portioned that when the bridge plug is fully set, the enlarged portions 19, 20 of the expander members project radially to a point intermediate the casing wall and the shoulders 70, 71 of the fingers 46, 47. Thus, it will be appreciated that annular restraining members 42, 43 completely close any sectorial space remaining between the fingers which would otherwise exist between the outer periphery of the expander members 15, 16 and the casing wall 69.

When the setting tool is actuated and as the mandrel 12 first begins to travel upwardly, ratchet teeth 29 on the mandrel 12 will slide under ratchet teeth 33 on split-nut 32 to expand the split-nut. Accordingly, split-nut 32 is free to alternately expand and contract, and each time it expands, it will begin sliding relatively upwardly and outwardly along the tapered surface 31 of upper abutment member 26. A split-nut 32 begins to slide upwardly, however, spring member 34 is compressed and then expands to drive the split-nut inwardly and downwardly to force ratchet teeth 33 into engagement with the next group of ratchet teeth 29 around the mandrel. This alternate compression and expansion of spring member 34 tends to drive split-nut 32 downwardly while preventing any "backlash" or retrograde movement of the packing element. It will be appreciated, therefore, that split-nut 32 will be continuously driven over the lowermost ratchet teeth of the mandrel that the nut can engage.

After the bridge plug has been completely set into anchoring and sealing engagement with the casing, the setting tool forces continue to increase until weakened portion 41 of mandrel 12 fails, which failure will release the mandrel 12 from the setting tool and allow the setting tool to be retrieved in the conventional manner. When bridge plug 10 is finally anchored and the setting tool disengaged, it will be appreciated that the bridge plug will effectively resist either upwardly or downwardly directed forces.

Although a particularly arranged bridge plug has been illustrated and disclosed, it will be understood that the new and improved packing element of the present invention can be employed with any packer device which utilizes an elastomeric annular packing element arranged to be foreshortened by applying longitudinally directed forces thereon.

Accordingly, it will be appreciated that a packing element constructed in accordance with the principles of the present invention will permit a wide latitude of control over the rate of expansion as well as the relative order of expansion of the various portions of the packing element. Furthermore, by following the principles of the present invention, a packing element can be constructed which will initially expand into sealing engagement at its central portion and thereafter progressively expand therefrom toward each end thereof at a desired rate.

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

What is claimed is:

1. A packer adapted for packing off a well bore comprising: a cylindrical elastomeric packing element adapted for expansion into sealing engagement with a well bore, said packing element having a circular axial passageway varying from a first diameter at each end thereof to a second diameter at the central portion thereof to provide a substantially greater portion with a low modulus of elasticity in said central portion; a mandrel disposed within and extending through said axial bore; and means for initially expanding the central portion of said packing element into such engagement and thereafter ex-

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panding the remainder of said element into such engagement including an annular sleeve member operatively mounted around said mandrel and complementarily received within and engaged along said axial passageway, said annular sleeve member being of an elastomeric material having a greater modulus of elasticity than that of said packing element.

2. A packer adapted for packing off a well bore comprising: a cylindrical elastomeric packing element adapted for expansion into sealing engagement with a well bore, said packing element having a circular axial passageway tapering uniformly from a first diameter at each end thereof to a second smaller diameter at the central portion thereof; a mandrel disposed within and extending through said axial bore; and means for initially expanding the central portion of said packing element into such engagement and thereafter progressively expanding the remainder of said element into such engagement from said central portion toward said element ends including an annular sleeve member operatively mounted around said mandrel and complementarily received within and bonded to said packing element along said axial passageway, said annular sleeve member being of an elastomeric material having a greater modulus of elasticity than that of said packing element.

3. As a sub-combination, a packing element adapted for mounting around a packer mandrel for expansion into sealing engagement with a well bore, said packing element including: an annular first elastomeric member having an axial bore sized and adapted for receiving a packer mandrel, said first member having end portions of a first diameter and a central portion of a second smaller diameter; and a second elastomeric tubular member complementary fitted and engaged around said first member and longitudinally extending from said central portion along said first member toward said end portions, said second member being of an elastomeric material having a lower modulus of elasticity than that of said first member.

4. As a sub-combination, a packing element adapted for mounting around a packer mandrel for expansion into

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sealing engagement with a well bore, said packing element including: an annular first elastomeric member having an axial bore sized and adapted for receiving a packer mandrel, said first member having conical end portions with ends of a first diameter and tapering uniformly to a central portion of a second smaller diameter, and a second elastomeric tubular member complementarily fitted and engaged around said first member and longitudinally extending from said central portion along said first member toward said end portions, said second member being of an elastomeric material having a lower modulus of elasticity than that of said first member.

5. As a sub-combination, a packing element adapted for expansion into sealing engagement with a well bore, said packing element consisting of: a plurality of elastomeric elongated annular plies bonded together to form a unitary tubular member having a wall of uniform thickness, each of said plies being of an elastomeric material having at least a different modulus of elasticity than that of at least another one of said plies with each being uniformly tapered from a first thickness at each end thereof to a second thickness at the central portion thereof, said plies being cooperatively proportioned and arranged in such a manner that the composite modulus of elasticity at any transverse section of said tubular member progressively increases from the central portion thereof toward each end of said tubular member.

#### References Cited by the Examiner

##### UNITED STATES PATENTS

|           |         |                |             |
|-----------|---------|----------------|-------------|
| 1,050,557 | 1/1913  | McLaughlin     | 166—192 X   |
| 2,449,514 | 9/1948  | Scoville       | 166—196 X   |
| 2,602,513 | 7/1952  | Conrad et al.  | 166—179     |
| 2,612,953 | 10/1952 | Morgan et al.  | 277—116.4   |
| 2,624,603 | 1/1953  | Sweet          | 166—179 X   |
| 2,738,015 | 3/1956  | Lynes          | 277—116.6 X |
| 3,083,775 | 4/1963  | Nielson et al. | 277—9.5     |

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