

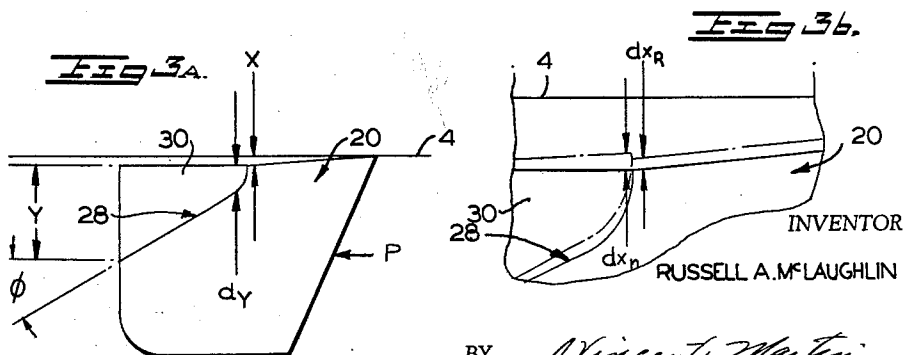
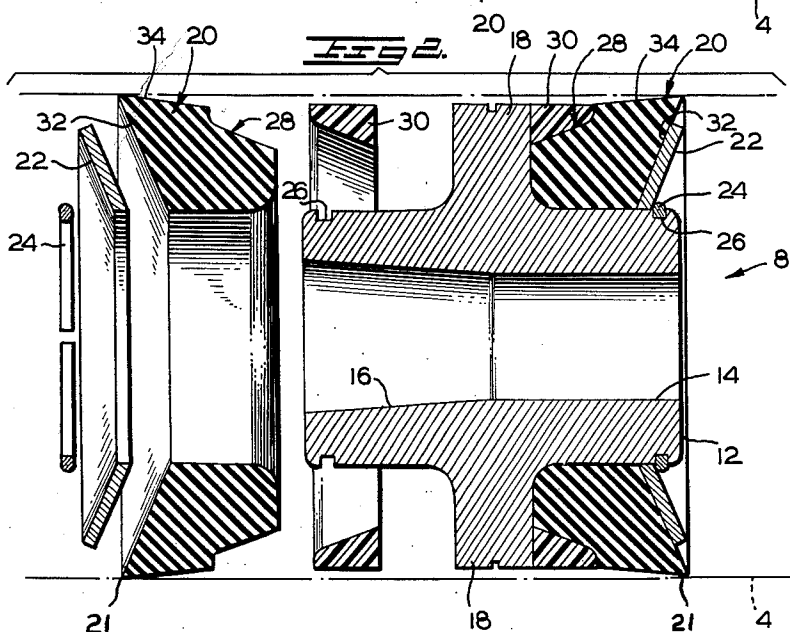
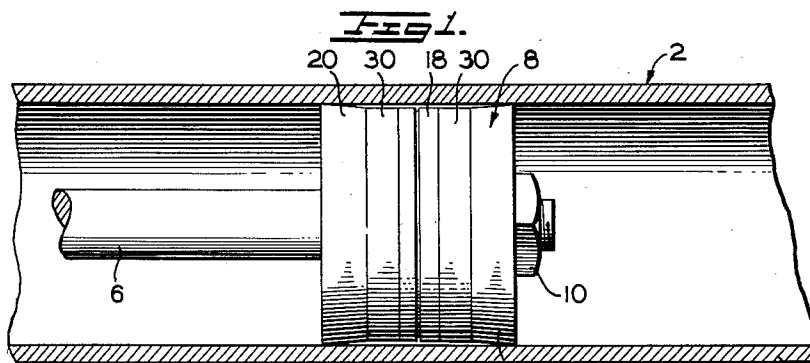
May 5, 1964

R. A. McLAUGHLIN
TAPER CUP BACK PISTON

3,131,611

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2 Sheets-Sheet 1



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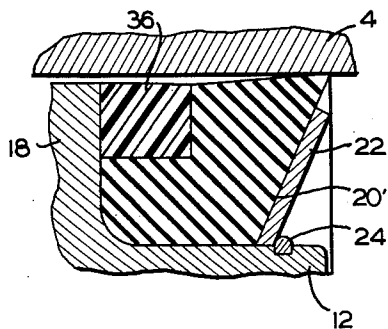
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(PRIOR ART)

FIG 4A



(PRIOR ART)

FIG 4b.

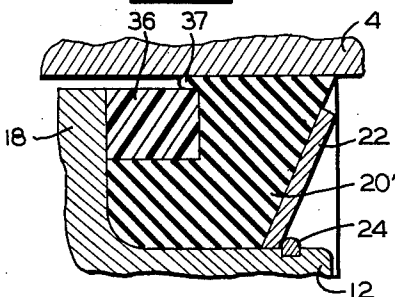


FIG 5A.

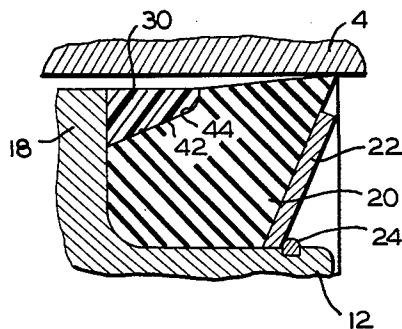


FIG 5b.

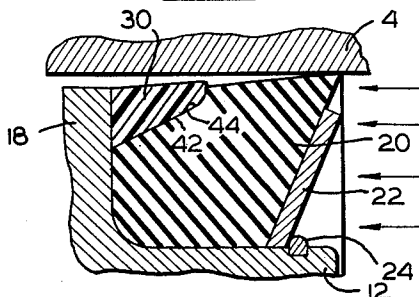


FIG 5c.

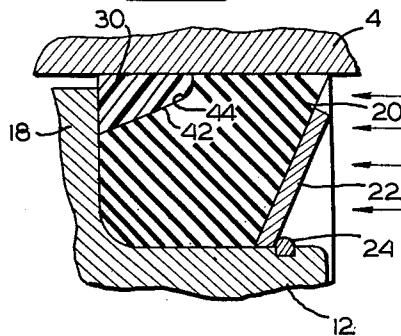
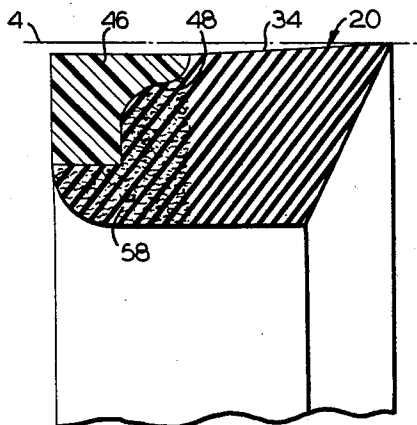


FIG 6.



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3,131,611

TAPER CUP BACK PISTON

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8 Claims. (Cl. 92—244)

This invention relates generally to improvements in slush pumps and more particularly to new and improved seals for use with slush pump pistons.

Slush pumps are used in connection with oil well drilling and are employed to pump drilling mud used in the oil well drilling operation. The fluid pumped is of high specific gravity and has a high proportion of suspended gritty and abrasive solids. For these reasons, the design of slush pumps and especially the slush pump seals is critical. The high pressure abrasive environment in which the pumps must operate is especially deleterious to resilient sealing elements.

Slush pump pistons are generally characterized by a hollow metal body through which a piston rod is connected, the body having a radially extending medial flange, a pair of resilient sealing elements sleeved over either end of the body in abutting relationship with the flange, and suitable seal-retaining means attached to either end of the body. The sealing means must have a configuration and resiliency to provide seal expansion against the bore of the cylinder for increased sealing as pressure is applied to the face of the piston. This is generally accomplished through the use of a flexible synthetic or natural rubber seal having an outwardly tapering face thereon. Since the backing flange supporting the seal is of slightly smaller diameter than the bore of the cylinder in which the piston is operating to avoid contact therebetween and the piston is operating under a relatively high pressure, a problem generally encountered in operation of slush pumps is that of extrusion of the seal over the flange at the outer circumferential flange abutting edge. This is caused by high pressure flow of the sealing material and results in a tearing or pulling off of the edge material between the circumferential surface of the flange and the wall of the cylinder. This creates rapid deterioration of the sealing elements of the piston.

Attempts have been made to overcome this "extrusion" difficulty by backing up this edge of the seal to prevent pinching movement of the seal material. In one of the attempted solutions of this problem, a backing ring of hydraulic packing or the like has been provided around the flange-abutting edge, thereby interposing a material less subject to extrusion between the resilient seal element and the flange. One of the disadvantages attendant with this solution is that hydraulic packing and similar materials are vulnerable to the gritty environment of the slush pump and are cut by the sand or grit suspended in the fluid and thereby deteriorate rapidly.

Another solution to the problem has been the use of a back-up ring made of nylon. Nylon has beneficial characteristics in that it is more resistant to flow and extrusion than the resilient seal material and also is compatible with the gritty fluid to which slush pumps are subjected. Furthermore, nylon does not readily tear when subjected to abrasive action in the pump and it also reduces the scratching of the liner, compared to that caused by hydraulic packing and similar commonly used materials. The use of nylon as a back-up ring, however, presents a problem in that nylon is a more rigid material than the resilient seal material and, although the nylon is interposed between the edge of the sealing material and the rigid flange to prevent extrusion of the resilient material over the flange, the resilient sealing material will tend to extrude over the back-up ring and be pinched

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off. Due to its strength, the nylon does not expand under pressure as quickly as the resilient sealing material, and the nylon acts as an anvil, much in the same manner as the metal flange, to cut the seal material.

It is an object of this invention to provide a sealing system for slush pump pistons which is not subject to the above stated disadvantages.

It is another object of this invention to provide a slush pump seal having a greatly increased useful life over seals heretofore used.

It is a further object of this invention to provide a nylon back-up ring to prevent extrusion of a slush pump seal which will expand into contact with the pump cylinder wall, under pressure, at a faster rate than the seal to prevent extrusion of the seal thereover and which will recover, when pressure is terminated, to a relaxed position out of contact with the pump cylinder wall to minimize wear of the ring.

It is another object of this invention to provide a simple and inexpensive slush pump sealing system which is compatible with the environment of the slush pump system.

It is still another object of this invention to provide a seal system which can be incorporated into existing slush pump pistons without modification thereto.

Other objects and many of the attendant advantages of this invention will be better understood by reference to the detailed specification and drawings in which like numerals indicate like parts thereof and wherein;

FIG. 1 is a longitudinal view, partly in section, of a slush pump piston, in accordance with the invention, mounted in a pump liner;

FIG. 2 is a partly exploded and enlarged longitudinal sectional view of the piston;

FIG. 3a is an enlarged schematic view of the outer surface of the sealing system of the present invention;

FIG. 3b is a still further enlarged view of a portion of the schematic of FIG. 3a with the relaxed no-pressure condition of the sealing system shown in solid lines and an intermediate initial pressure condition shown in broken lines;

FIG. 4a is an enlarged sectional view of the outer portion of a slush pump piston as typified by the prior art and showing the sealing member in an unloaded relaxed condition;

FIG. 4b is the view of 4a showing the piston in an intermediate pressurized condition;

FIG. 5a is an enlarged sectional view of the outer portion of the piston and a portion of the liner with the piston in a relaxed unpressurized condition and exaggerated to illustrate the operation of the invention;

FIG. 5b is the view of 5a with the piston in an intermediate condition immediately after pressure is applied thereto;

FIG. 5c is the view of 5a showing the piston in a final pressurized condition; and

FIG. 6 is a cross sectional view of a portion of the sealing system of a slush pump showing an alternate configuration of the ring and seal embodying the present invention.

Referring now to FIG. 1, there is shown a slush pump liner or cylinder and piston assembly indicated generally at 2. The assembly includes a cylinder or liner 4, piston rod 6, piston 8 and piston retaining nut 10.

Piston 8 is shown enlarged in FIG. 2 in a partially exploded condition. The piston consists of metal cylindrical body 12 having a cylindrical bore 14 and a tapered counterbore 16 therethrough. The bore serves to receive a tapered portion of piston rod 6 therethrough for connection by nut 10 (FIG. 1). Radial flange 18 is disposed around the midportion of body 12 and is of slightly smaller diameter than the inner bore of cylinder 4 (FIG.

1) to avoid metal-to-metal contact between the moving parts. Annular resilient seals 20 are sleeved over either end of body 12 and abut flange 18 at their inner surfaces. Frusto-conical metal seal retainers 22 are disposed over body 12 at the outer sides of the seals and are held in place by snap rings 24 in grooves 26. The outer circumferential, flange abutting edge of seals 20 has an annular groove-like recess 28 there-around to receive back-up ring 30.

The general over-all configuration of seals 20 consists of an outwardly tapering pressure face 32 which is formed to increase sealing pressure between cylinder 4 and outer sliding surfaces 34 as pressure is increased against the face of the piston. The material of the sealing elements may be of any resilient natural or synthetic elastomeric material known in the art, and may incorporate imbedded fibrous material as a back-up or strengthening material near the rear portions of the seal.

It is essential that the back-up rings be made of nylon or material having substantially equivalent characteristics, in that it has been found that nylon, because of its physical properties, is very resistant to the suspended gritty particles present in the fluid with which the slush pump works. Nylon is resistant to tearing from abrasive material and also will imbed abrasive particles in such a way that the imbedded particles will scratch the liner of the pump cylinder substantially less than hydraulic packing or similar commonly used materials will. The nylon is also resistant to flow under pressure, thereby preventing extrusion of the seal system between the circumferential surface of flange 18 and cylinder 4.

The cross-sectional configuration of ring 30 may vary. It has been found that use of a rigid nylon back-up ring, while preventing extrusion of the resilient seal member over the piston flange, can permit extrusion of the seal member over the nylon back-up ring due to the rigidity of the nylon itself as compared to the resilient seal.

This problem is solved in this invention by supplying a back-up ring which, due to its cross-sectional properties, will expand at a rate at least equal to and preferably greater than the rate of expansion of the resilient seal member under pressure, and at the same time, provide constraint for the adjacent seal material, thereby preventing extrusion of the seal member over the back-up ring surface.

Since a single sealing element of the slush pump piston only provides sealing for the system in one direction of the piston stroke, the seals are generally designed to recover when pressure is relieved therefrom to a relaxed configuration in wiping contact with the cylinder wall of the piston as shown in FIG. 2. This wiping contact of the lip 21 provides a means to clean the cylinder walls of abrasive particles on the return, non-pressure portion of the pump stroke. The recovery of the remainder of the system decreases unnecessary wear on the seals. This factor also makes it imperative that ring 30 be designed to recover with the sealing element to a relaxed position out of contact with cylinder 4. In summary, ring 30 must radially expand into contact with cylinder wall 4 under pressure at a faster rate than the adjacent edge of seal 20 and must recover, when pressure thereon is terminated, to a position out of contact with cylinder wall 4. The desired configuration and the pertinent features thereof are dictated by factors as presented in the following analysis.

In FIG. 3a of the drawings a schematic, adapted to better illustrate the analysis, is shown. FIG. 3b is an enlargement of the schematic of FIG. 3a showing the pertinent surfaces of the nylon ring and the seal, the relaxed condition of the members being shown in the unbroken lines of the drawing. The transitional position of the same surfaces with incremental displacement from rest are shown in the drawing in broken lines.

dx_n as shown in the drawing denotes the incremental distance of outward movement of the nylon ring near the

outer circumferential interface between the ring and the seal.

dx_r denotes the incremental distance of outward movement of the resilient seal near the same interface.

5 dt represents an incremental period of time.

P is pressure.

R is restraining force.

$F''Ndy$ is the hoop strength of the ring 30.

Y is the maximum thickness of ring 30.

10 X is the initial distance between the inner wall surface of cylinder 4 and the outer circumferential surface of the seal system of the interface between ring 30 and seal 20.

15 ϕ is the angle of the inclined portion of the interface between ring 30 and seal 20 with respect to the centerline of piston 8.

The success of the present invention in providing a unique solution to the problems associated with slush pumps by use of a specially constructed nylon ring is discussed below.

20 In order to prevent extrusion of the elastomeric seal material around the nylon back-up ring, the outward velocity of the resilient material from pressure on the piston face should be equal to or less than the velocity of the nylon ring in the vicinity of the outer circumferential interface. This can be mathematically expressed as:

$$\frac{dx_r}{dt} \leq \frac{dx_n}{dt}$$

30 where dx_r is directly proportional to a function of the pressure, and to the negative of the restraining force. That is:

$$dx_r = dfP - df'R$$

35 where $df'R$ is the force restraining outward movement of the rubber at the interface region; assuming negligible resistance to outward movement by the resilient material itself, it consists of the force in the radial direction times the coefficient of friction between the two materials times the cosine of the angle ϕ . Hence, dx_n is directly proportional to pressure, to the negative of the thickness of the nylon in the region of the outer circumferential interface and to the reaction of the restraining force, i.e.,

$$dx_n = dfP + df'R - f''Ndy$$

40 Therefore:

$$dfP - df'R \leq dfP + df'R - f''Ndy$$

Thus:

$$-2df'R \leq -f''Ndy$$

or

$$2df'R \geq f''Ndy$$

The last inequality states that, for the concept to be true, the function of the nylon material which resists radial motion, times the thickness of the ring at x_n , should be equal to, or less than, twice the value of the restraining force at the outer circumferential interface. If the above condition exists, then the rate of motion of the nylon at the interface is at least equal to the rate of motion of the resilient material at the interface.

60 If the thickness of the nylon at the interface is kept small enough and the interface angle is kept below an angle dependent upon the thickness of the nylon, the resilient seal at that area will not move faster than the nylon ring and protection against extrusion of the resilient material over the nylon will be afforded. As an example, it has been found that a nylon ring having a maximum thickness of 1/4 inch at the outer circumferential interface and an interface angle of 60° or less will afford suitable extrusion preventive protection for the resilient seal member.

70 Referring now to FIGS. 4a and 4b, the outer portion of the slush pump piston comprising flange 18 and seal 20 is shown with a portion of the pump cylindrical wall 4 and a back-up ring 36 typifying that of the prior art. FIG. 4a shows the seal elements in their configuration prior to

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deformation under load or pump pressure. FIG. 4b is a view showing the expansion of seal 20 and resulting extrusion 37 between back-up ring 36 and cylinder 4 caused by the seal expanding faster than the nylon ring 36. This primarily results from too great a hoop strength of the ring 36 and lack of sufficient restraining force at the interface between the ring and seal. These combine to allow expansion of seal 20 before expansion of ring 36.

Referring now to FIGS. 5a, 5b, and 5c, the operation of the invention as depicted in the above-mathematical analysis is shown. As in FIGS. 4a and 4b, an outer portion of the piston consisting of flange 18 and seal member 20 with a portion of cylinder 4 is shown. Nylon back-up ring 30 embodying the features of this invention is shown disposed around resilient seal 20 as in FIG. 2. FIG. 5a shows a configuration of the resilient elements of the piston prior to pump pressure being applied thereto, FIG. 5b illustrates the intermediate, dynamic configuration of the resilient elements immediately after pump pressure is applied to the face of seal 20. The outer circumferential interface end of back-up ring 30 is shown expanded outwardly toward contact with cylinder 4 since, because of the designed strength of ring 30 at this point, axial force transmitted through the resilient member 20 expands the ring at a faster rate than the resilient material at the interface. The restraining force imposed on the elastomeric member by the frictional resistance to movement of surfaces 42 and 44, of the nylon ring and elastomeric seal respectively, constrains the outward expansion of the seal member at this point so that rate of expansion is equal to or less than that of ring 30. In the drawing, the ring is shown moving outward at a much greater rate than seal 20 for purposes of illustration. FIG. 5c illustrates the final static configuration of the seal system at a time after the application of pressure to the pump piston showing the extrusion preventative interposition of ring 30 between flange 18 and seal 20.

The sequence also demonstrates the motion of ring 30, afforded by its design, which prevents extrusion of seal 20 over the ring itself.

Within the limits of the requirements of configuration, as outlined above, back-up ring 30 can have various cross-sectional configurations. Referring now to FIG. 6, a variation of the configuration of the back-up ring embodying this invention 46 is shown. As before noted, the configurational requirements of thickness and angle of inclination of the ring must be carefully considered near the outer surface interface of the ring and seal member. As long as the ring can expand at a faster rate than the seal member at this interface, extrusion of the seal member over the ring is effectively prevented. The configuration of the ring at a point removed from this interface therefore does not substantially effect the extrusion preventative characteristics of the ring. The cross section near the flange abutting surface may therefore be of various shapes such as that shown in FIG. 6. The critical interface surface 48 has a substantially tapering configuration similar to that of the configuration of FIGS. 2, 3 and 5a through 5c. The remaining portion of the ring cross sectional configuration is, in this example, rectangular as shown in the drawings.

The seal material may also be of any type standard in the art and may consist of two materials such as an elastomer and a reinforcing fiber imbedded therein. Referring again to FIG. 6, the configuration of a typical seal having reinforcing fiber imbedded therein is shown with the fibrous area shown at 58.

This invention therefore provides a back-up ring for slush pump seals which is resistant to the abrasive environment of the slush pump which insures longer seal life by preventing extrusion of the resilient seals between the rigid portions of the pump piston and the pump cylinder wall and is so designed to further prevent extrusion of the resilient seal between the more rigid back-up ring and the pump cylinder wall.

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Modifications and variations of the present invention are possible in the light of the above teachings. It is, therefore, to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

What is claimed as new and desired to be protected by Letters Patent of the United States is:

1. In a slush pump, a cylinder, a piston adapted to reciprocate in said cylinder, said piston including a cylindrical metal body having an outwardly extending medial flange therearound of smaller diameter than the inner diameter of said cylinder to avoid contact therebetween, annular resilient seal members sleeved over each end of said body in abutting relationship with said flange, an annular groove in each seal member terminating in the outer circumferential surface and in the flange-abutting surface of each seal member, nylon back-up rings disposed in said grooves to constrain said flange-abutting edge of said seal members from flowing over said flange under pressure, the relaxed outer diameter of said rings being less than the inner diameter of said cylinder, the relaxed outer diameter of said seal members being substantially equal to the outer diameter of said rings beginning at said grooves and tapering outwardly therefrom into wiping contact with said cylinder at the free ends of said seal members, said rings and seal members each having an annular interface at least a portion of which is inclined outwardly with respect to the axis of said piston in a direction away from said flange, the radial thickness of said ring adjacent its end remote from said flange and the angle of said inclined portion of said interface being such that the component of the radial force normal to said interface will cause sufficient frictional restraint to movement between said interface surfaces to provide an outward velocity of said interface surface of said seal under the influence of said radial force equal to or less than the rate of radial expansion of said interface surface of said ring under the same radial force, whereby said nylon ring provides a tear-resistant and grit-embedding back-up ring to prevent flow of said seal around said flange and said radial thickness and the inclination of said interface provides expansion of said ring at least as fast as said seal to prevent flow of said seal around said ring, and removable means on each end of said body to retain said seals thereover.

2. A pump in accordance with claim 1, wherein said ring is formed to expand under radial pressure at a faster rate than the adjacent outer surface of said seal to block flow of said seal thereover.

3. A slush pump piston comprising a cylindrical body, an outwardly extending annular flange on the mid-portion of said body, a resilient annular seal member sleeved over each end of said body in abutting relationship with said flange said seal members having an annular groove in the outer circumferential flange abutting edge thereof, a nylon restraining ring disposed in said groove in constraining relationship with said seal member, the outer diameter of said ring in its relaxed configuration being at least equal to the outer diameter portion of said seal member adjacent said ring but less than the inner diameter of the cylinder in which said piston is to operate, said ring and said seal having an annular interface at least a portion of which is inclined outwardly with respect to the axis of said piston in a direction away from said flange, the radial thickness of said ring adjacent its end remote from said flange and the angle of said inclined portion of said interface being such that the component of the radial force normal to said interface will cause sufficient frictional restraint to movement between said interface surfaces to provide an outward velocity of said interface surface of said seal under the influence of said radial force equal to or less than the rate of radial expansion of said interface surface of said ring under the same radial force, whereby said nylon ring provides a tear-resistant and grit

imbedding back-up ring to prevent flow of said seal around said flange and said radial thickness and the inclination of said interface provides expansion of said ring at least as fast as said seal to prevent flow of said seal around said ring.

4. A slush pump piston in accordance with claim 3, wherein the inclination of said interface is not greater than 60° and said radial thickness of said ring adjacent its end remote from said flange is not larger than 1/4 inch.

5. A slush pump piston comprising: a cylindrical body; an outwardly extending annular flange on the mid-portion of said body; a resilient annular seal member sleeved over each end of said body in abutting relationship with said flange; said seal members having an annular groove in the outer circumferential flange abutting edge thereof; a back-up ring for protection of the outer circumferential flange abutting surface of said seal disposed in said groove; said back-up ring comprising: an annular nylon ring having a cylindrical outer circumferential surface of equal diameter to the adjacent outer surface of said seal but less than the inner diameter of the cylinder in which said piston is to operate, a transverse flange abutting surface and an irregular third surface connecting the inner edge of said transverse surface to the seal abutting edge of said circumferential surface; said third surface having an inclined portion adjacent to the circumferential surface end thereof; the radial thickness of said ring adjacent to the outer circumferential seal abutting surface thereof and the inclination of said inclined portion with respect to the longitudinal axis of said ring being such that the component of radial force caused by pressure on a slush pump seal constrained therein normal to said surface will cause sufficient frictional restraint to movement between the abutting surfaces of said seal and said ring to provide an outward velocity of said abutting seal surface under the influence of said radial force equal to or less than the outward radial velocity of the seal abutting surface of said ring as determined by the hoop strength of said ring under the influence of the same radial force; whereby said nylon ring provides a tear-resistant and grit imbedding back-up ring for a slush pump seal and the configuration of said ring provides a radial expansion of said ring at least as fast as radial expansion of said seal under pressure to prevent flow of said seal around said ring.

6. A slush pump sealing system in accordance with claim 5, wherein the hoop strength of said ring is at most equal to twice the value of said frictional restraint.

7. A slush pump piston comprising a hollow cylindrical body having a medial radial flange thereon, the diameter of said flange being slightly smaller than the diameter of the cylinder in which the piston operates, annular seal members disposed over the ends of said cylindrical body in abutting relationship with said flange, annular retainer plates disposed over the ends of said body in abutting relationship with said seal members, means to retain said

plates on said body, said seal members having an annular groove in the outer circumferential flange abutting edge thereof, a nylon restraining ring disposed in said groove in constraining relationship with said seal member, the relaxed outer diameter of said ring being at least equal to the adjacent outer diameter of said seal but less than the inner diameter of the cylinder in which said piston is to operate, said ring and said seal having an interface inclined with respect to the axis of said piston adjacent to the outer circumferential surfaces thereof, the radial thickness of said ring adjacent to the outer circumferential seal abutting surface thereof and the inclination of said interface being such that the component of the radial force normal to said interface will cause sufficient frictional restraint to movement between said interface surfaces to provide an outward velocity of said interface surface of said seal under the influence of said radial force equal to or less than the rate of radial expansion of said interface surface of said ring under the same radial force, whereby said nylon ring provides a tear-resistant and grit-imbedding back-up ring to prevent flow of said seal around said flange and the radial thickness and the inclination of said interface provides expansion of said ring under radial pressure at least as fast as said seal to prevent flow of said seal around said ring.

8. In a slush pump, a cylinder, a double acting piston adapted to reciprocate in said cylinder, said pump applying pressure to alternate sides of said piston with the alternative direction of the stroke thereof, an outwardly extending medial flange around said piston, a resilient seal element on either end of said piston in abutting relationship with said flange, said seal element adapted to expand into sealing contact with the walls of said cylinder under pressure applied thereto and to relax into wiping contact with said cylinder when pressure is relieved therefrom, said seal further having an annular groove on the outer circumferential flange abutting edge thereof, a nylon back-up ring disposed in said groove, said ring having a relaxed outer diameter at least equal to the diameter of the adjacent outer surface of said seal but less than the inner diameter of said cylinder, said ring adapted to radially expand into contact with said cylinder at a rate faster than the rate of expansion of the adjacent surface of said seal when said seal is under pressure, said ring further being adapted to recover to its relaxed configuration out of contact with said cylinder when pressure is relieved from said seal, whereby expansion of said ring prevents extrusion of said seal and recovery of said ring provides a minimum friction minimum wear unpressurized movement of said ring.

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