Feb. 7, 1967 D. W. EDWARDS 3,302,698

HEAT EXCHANGE APPARATUS

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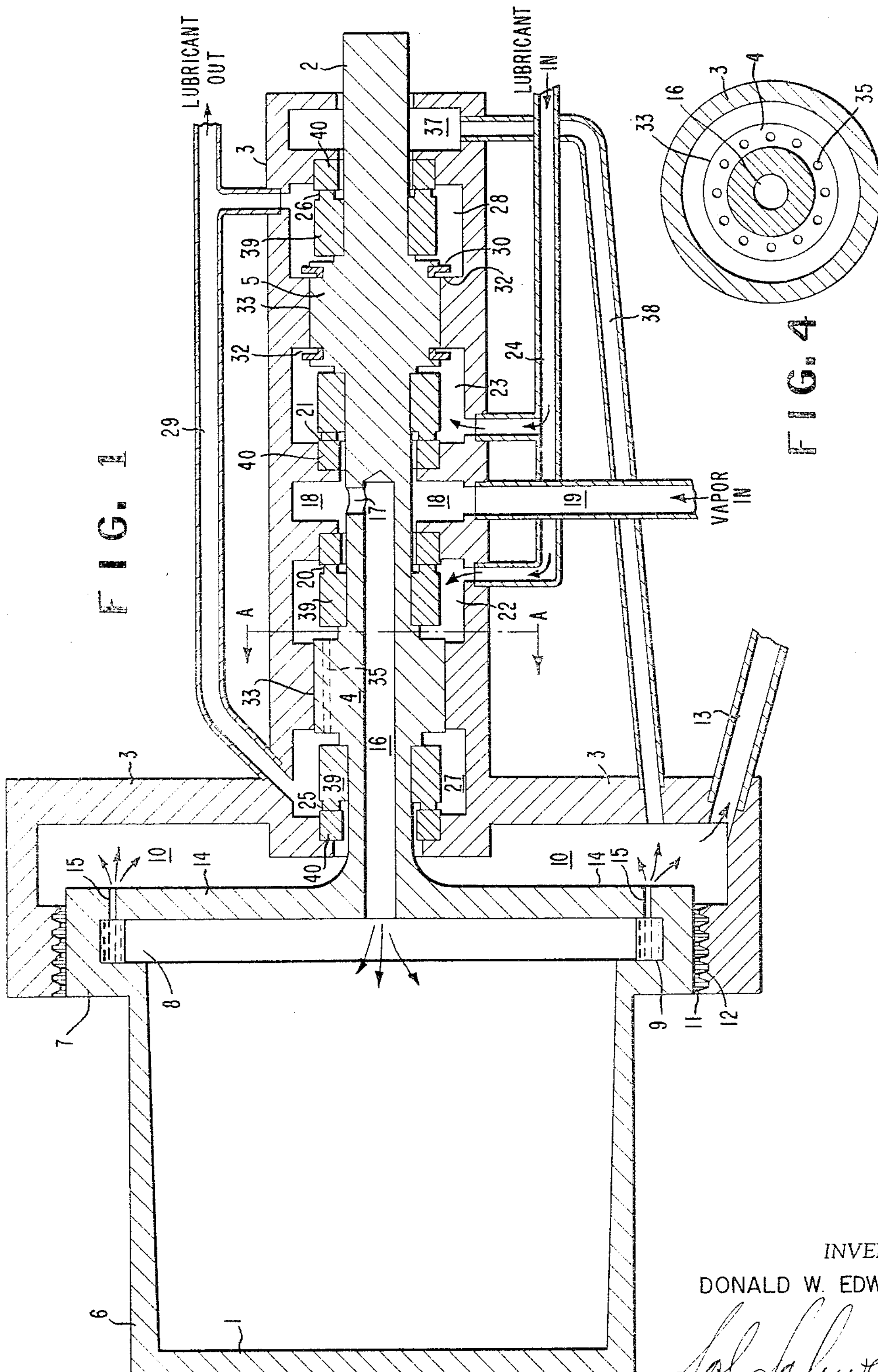

FIG. 1

FIG. 4

INVENTOR
DONALD W. EDWARDS

ATTORNEY

Feb. 7, 1967 **D. W. EDWARDS** **3,302,698**

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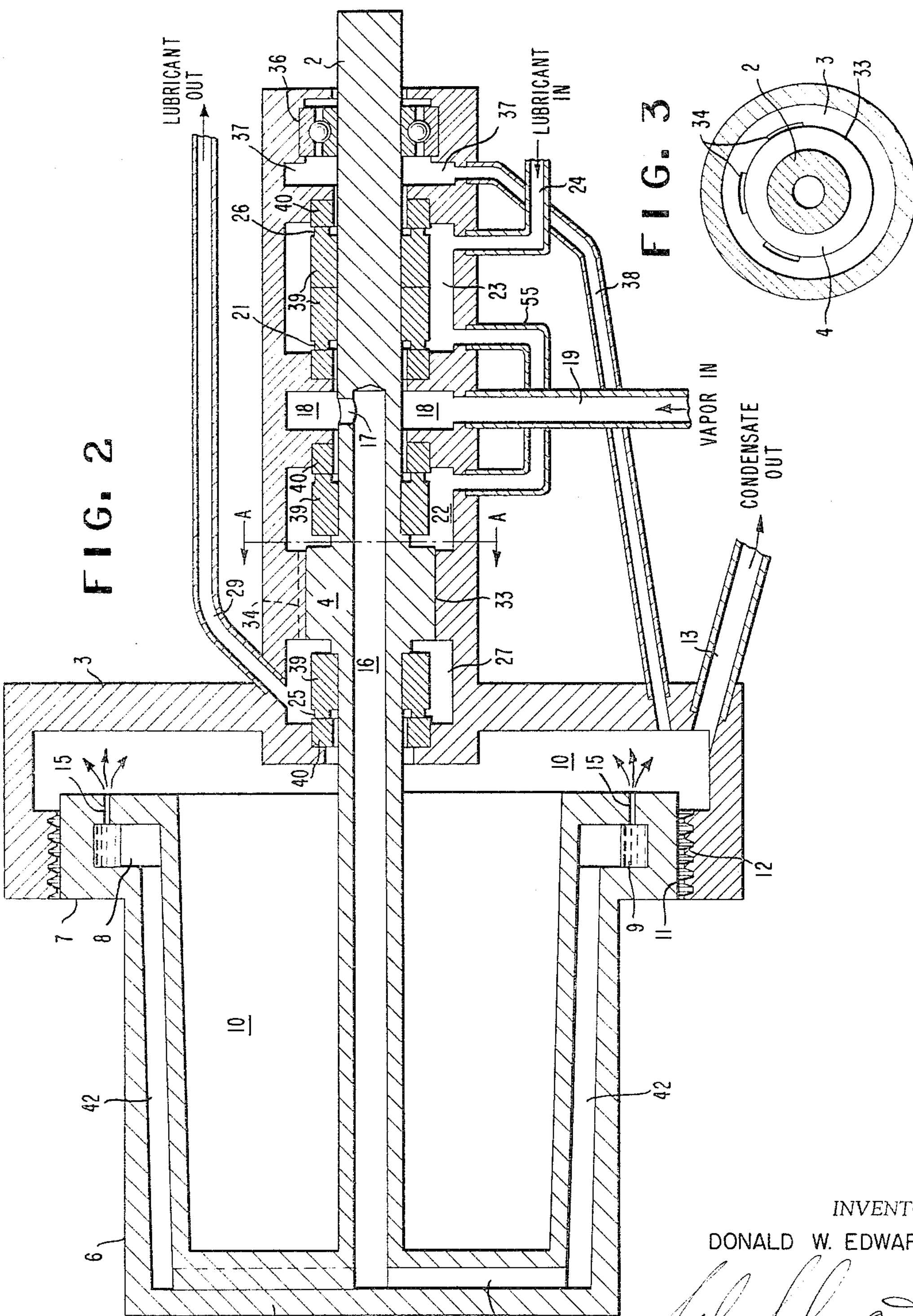

FIG. 2

FIG. 3

INVENTOR
DONALD W. EDWARDS

BY Sol Schwartz

ATTORNEY

3,302,698
HEAT EXCHANGE APPARATUS

Donald W. Edwards, Wilmington, Del., assignor to E. I. du Pont de Nemours and Company, Wilmington, Del., a corporation of Delaware
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This invention pertains to a heated, high-speed, leak-free roll suitable for treatment of textiles.

With the increasing trend toward more widespread use of synthetic, polymeric fibers, there are growing demands for better quality and uniformity of the fiber product. To meet these demands, severe criteria on processes and apparatus used in the manufacture of the fibers have been imposed. For instance, it is well known that when certain synthetic fibers such as polyamides, polyesters, polypropylene and the like are subjected to special heat treatment within a narrow temperature range, they acquire optimum physical and chemical properties. In continuous treatment of synthetic fibers, it is generally convenient and economical to treat such fibers over heated rolls driven at a proper speed. Depending on the kind of fiber properties desired and degree of heat treatment required, a single fiber end may either be wrapped several times in a nonoverlapping manner around the circumference of a roll or, as in multi-end operation, a plurality of fiber ends generally in warp for mmay be brought into contact partly around two or more heated rolls.

When processing a plurality of fiber ends over a hot roll, uniformity of treatment of the individual ends in contact with the roll surface is largely dependent on each end obtaining identical and even heating. This quite naturally requires that strict control of roll surface temperature be maintained such that the desired temperature is held constant within narrow limits.

Previously in most textile operations temperature limits were not excessively strict, hence heating a roll by electrical or hot air convection means provided satisfactory results. With the recent advances in synthetic fiber manufacture, particularly with the increased emphasis on product uniformity and higher productivity, stringent control of the roll temperature must now be exercised. It has been found that the necessary temperature control now required is not only difficult to attain by electrical or hot air means, but that both heating techniques tend to be rather insensitive and inherently too slow in responding to slight thermal load changes. As a result of this thermal inertia, valuable production time is lost and considerable quantities of product are misprocessed.

In many instances, some of these drawbacks have been partially overcome by utilization of higher capacity heating and more sensitive temperature controls. These alternatives, however, have in many processes reached a practical limit wherein the size of the heating equipment necessary to perform with satisfactory response, far exceeds available machine space and the complexity of the controls is prohibitively expensive.

On the other hand, precise temperature control of a roll surface can be readily obtained by heating the roll with a condensing vapor. In U.S. 2,643,099 to W. T. R. Kinraide, such a roll is heated by introducing saturated steam at relatively low pressure internally. The steam releases its thermal energy into the roll as it condenses on the inner peripheral wall. Since condensation occurs at a precise temperature for a given pressure, the surface temperature of the roll can be easily maintained within 4° C. even under varying thermal load. A desired temperature may be obtained by merely adjusting the pressure of the vapor.

Notwithstanding these excellent heat-transfer charac-

teristics, rolls of this kind have not gained widespread acceptance in high-speed textile fiber processing. This is mainly due to the difficulties involved in condensate removal and in providing adequate mechanical shaft-sealing to withstand prolonged high-speed operation.

In accordance with one method in the prior art a heated vapor is supplied to the roll chamber at super-atmospheric pressure through an internal passage in the shaft or axle supporting the roll. In doing so, shaft seals must be provided across the rotary and stationary portions of the passage so as to prevent leakage. More importantly, the seals serve to isolate the vapor from the shaft bearing members which due to the limitations of bearing materials and lubricants cannot operate at excessively elevated temperatures.

A typical roll of the type contemplated herein must operate at speeds in excess of 6,000 r.p.m. and must be capable of maintaining a constant surface temperature upwards of 200° C. within ±1° C. For mechanical type seals, operation under the above conditions constitutes severe service. The seals are generally single-face rotary devices in which one component or annular member is affixed to the rotary shaft and the other to the stationary housing. Both members are modified by optically flat, smooth end faces which are perpendicuar to the shaft axis and are urged against each other by spring loading. A seal is effected when the end faces are in close contact with each other, separated only by a thin film of the medium being confined. It has been demonstrated that the thickness of the film separating the seal face is a function of the viscosity of the material being sealed. Thus, if a medium has low viscosity, the corresponding film thickness will be small and actual rubbing contact of the seal face members will occur accompanied by rapid wear, overheating, and subsequent leakage along the faces. Unfortunately, most vapors such as steam have a very low viscosity hence cannot establish a sufficiently thick lubricating film between seal faces; consequently, expected service life of the seals is exceedingly short. Furthermore, because of rapid wear, the vapor tends to leak into operating areas, thereby creating a safety hazard to operating personnel and various additional maintenance problems. Vapor leakage may also adversely affect the shaft bearings by attacking and decomposing the vital lubricants. Because of these difficulties, vapor-heated rolls have limited use in low-pressure and/or low-speed applications.

The other major problem associated with these rolls is obtaining a simple, troublefree condensate-removal means. Although there are known a great variety of condensate-removal schemes for vapor-heated rolls, most are intended for slow speed applications. By way of example, an often used scheme involves a siphon tube or scoop to withdraw the liquid from a circumferential trough in the inner periphery of the roll. Like most schemes of this type, the tube is stationary and is journalled and supported in suitable bearings within the rotary shaft. One end of the tube including a bearing resides completely in the hot vapor, while the other end is usually external of the roll and suitably affixed with rotary seals. The bearing immersed in the hot vapor must of necessity be operated without lubrication; consequently, it wears out rapidly, especially at high roll speeds. When this occurs, the siphon tube for all practical purposes, becomes unsupported and is subjected to spurious vibration and deflection as the roll is driven. The tube may even be wrenched off at start-up if the roll is full of condensate. In any event, the impact of the condensate further aggravates the fatigue problem and hastens failure.

An apparatus which avoids the bearing problem associated with the siphon tube, utilizes spring-loaded actuable poppet valves as shown in Crowell U.S. Patent 1,642,-

361. These valves are affixed to the roll periphery and are actuated by a stationary cam that is attached to rigid support and located at the lowest point of the roll. As the valves move past the cam, they are momentarily opened and slugs of condensate are discharged. Obviously, the arrangement is best suited for slow speed operation; for at high speeds, centrifugal force and high frequency opening and closing causes the spring mechanisms in the valves to jam and completely fail.

Lastly, grease pre-lubricated ball bearings have been used on high-speed rotating components including heated rolls. When on heated rolls, these bearings usually have to operate at temperatures well above what is considered ideal for long bearing and lubricant life even with special high-temperature-resistant greases. As a result from a practical standpoint, ball-bearing failure is frequent and is a prime source of trouble on high-speed heated rolls.

Accordingly, a principal object of this invention is to provide a high speed, heated textile-treatment roll.

Another object is to provide a heated, textile-treatment roll capable of maintaining a uniform, constant, surface temperature under varying thermal load conditions.

Another object of this invention is to provide a heated, textile-treatment roll capable of operating at high speed for prolonged durations.

Still another object of this invention is to provide a high-speed, vapor-heated roll adapted with relatively simple, trouble-free, condensate-removal means.

A further object of this invention is a high-speed vapor-heated roll having a mechanical seal arrangement capable of prolonged operation at high temperatures and vapor pressures.

Yet a further object of this invention is a vapor-heated roll having a pressure-balanced, rotary-seal arrangement which effectively isolates the hot medium from the shaft bearings and which absorbs minimum driving torque.

To attain these objects, the present invention provides a novel yarn-handling apparatus comprising (1) a shaft attached to a hollow roll, over which roll, yarn is heated and advanced; (2) a tubular support housing having spaced bearings located therein which carry the shaft while in the passageway of the support housing; (3) a steam inlet extending into the support housing between the bearings and a pair of seals surrounding the shaft, each between the steam inlet and a bearing; (4) a pair of lubricant inlets extending into the support housing for delivering a lubricant under pressure to the bearings, and the aforementioned shaft having a longitudinal passage communicating with the steam inlet and discharging to the interior of the roll. Where the interior of the hollow roll defines a frusto-conical chamber as in FIGURE 1, or coupled with an interior wall as in FIGURE 2, constitutes an annular chamber, condensate, as it forms, is directed to a circumferential groove and through orifices communicating therewith into a housing defining a collector chamber for condensate removal. Also the presence of a second set of seals surrounding the shaft but located exteriorly to the bearings prevents escape of lubricant while permitting withdrawal and recirculation of the spent lubricant through an exit means located between each bearing and said second set of seals.

More specifically the invention contemplates a condensable-vapor-heated, textile-treatment roll comprising a cylindrical shell providing an exterior surface for contact with fibers and composed internally of an expanded frusto-conical chamber having a circumferential groove at the large diameter end, a plurality of condensate orifices located about the periphery of the shell, each orifice extending through the shell wall and communicating with the groove, a collector chamber external of the shell and co-operating with the orifices for receiving and carrying away condensate, an elongated supporting axle connected to the shell and rotatably journalled in spaced bearings, an internal passageway within said axle communicating with both said shell and a first inlet means located between bearings for introducing a condensable vapor into the passageway, a first set of rotary seals interposed between the first inlet means and the adjacent bearings, a second set of rotary seals located along the axle exteriorly to the bearings and in opposed relationship to the first set of seals to enclose each of said bearings therebetween, a second inlet means between the bearings and the first set of rotary seals for supplying a pressurized lubricant-coolant to the bearing surface, and exit means located between the bearings and said second set of seals for removing spent coolant-lubricant.

The structural and functional features of the improved roll are best understood with reference to the accompanying drawings in which:

FIGURE 1 shows a sectional view of the roll and its supporting shaft equipped with a symmetrical rotary seal arrangement.

FIGURE 2 shows a sectional view of an alternative embodiment equipped with a pre-lubricated ball bearing.

FIGURE 3 shows a sectional view along the A—A of FIGURE 2 wherein longitudinal passageways are employed for increasing the circulation rate of the coolant-lubricant.

FIGURE 4 shows a sectional view taken along line A—A of FIGURE 1 wherein a plurality of capillary-like passageways are employed.

The term roll as used herein describes a complete self-contained assembly to be mounted to a spinning machine frame, connected to the various service lines and placed into operation in short order.

Reference is now made to FIGURE 1 of the drawing which illustrates a preferred embodiment of the invention. In this figure, and in the other figures, similar reference numerals refer to similar parts throughout the several figures. In FIGURE 1, the roll comprises a rotatable shell **1** which is modified and supported at one end by an elongated extension that serves as an axle **2**. This axle **2** is preferably fabricated of stainless steel alloy and is journalled in sleeve bearings **4** and **5** that are suitably retained in a stationary housing **3**. The external end of axle **2** is connected to a conventional coupling (not shown) and thence to the output shaft of an electric motor (not shown) whereby it is rotatably driven at proper speed. Shell **1** is cylindrical in shape externally and is composed of tempered aluminum alloy or ordinary carbon steel or other suitable material. Its circumferential surface serves as the yarn contact surface which hereinafter is referred to as surface **6**. Near the axle **2** end, shell **1** is additionally modified by a raised shoulder **7**. Shoulder **7** serves as a convenient stop that prevents the yarn from inadvertently slipping off the contact surface **6** and entangling around the axle **2**. It also accommodates an internal circumferential groove **8** which is described in more detail later. Internally shell **1** has a frusto-conical peripheral surface which slopes gradually from a small diameter at the outboard end toward a larger diameter terminating in the groove **8**. The sloping surface cooperates with the centrifugal force as the roll is driven such that condensate forming thereon is urged toward and into the groove **8** as shown by reference numeral **9**.

Set into face **14** are one or more orifices **15** (only two are shown in the figure). These orifices **15** extend through the shell **1** wall, communicate with the groove **8** and function as constricted outlets through which condensate **9** is expelled. The aperture size of the individual orifices **15** is fixed to remove condensate under maximum heat transfer loads. However, the combined aperture area is sufficiently small to prevent excessive leakage and pressure loss of the heated vapor. In the preferred embodiment, one orifice **15** having an aperture opening approximately .020 inch in diameter is sufficient to meet maximum operating conditions. More than one orifice, however is used to insure that the roll will function in the event that the other becomes plugged. It is also understood that in certain processes, thermal loads and condensate formation rates may be significantly different, hence a different size orifice may be required.

Enclosing and cooperating with these orifices **15** is a stationary plenum **10** which extends partly over the shell **1** and receives the expelled condensate. Plenum **10** is an annular projection of housing **3** and is separated from the shoulder **7** by a narrow clearance gap **11**. Within gap **11** there is preferably a labyrinth composed of modified screw threads **12** that are machined into the plenum **10** wall. The lead or direction of these threads **12** corresponds with the rotational direction of the shell **1** so that when the shell **1** is rotated, the threads **12** act as vanes and pump air into the plenum **10**. The inward movement of air checks any seepage of condensate or vapor (at atmospheric pressure) that may occur through gap **11**. A drain **13** located at the lowest part of the plenum **10** carries away liquid accumulating therein to a remote tank (not shown). In special situations, as for instance, when toxic or corrosive vapors are used, it may be necessary to augment the pumping action of the threads **12** to prevent even minute quantities of vapor escapage. In such situations, drain **13** can be connected to a suction tube and the plenum **10** partly evacuated and operated at sub-atmospheric pressure. Thus with this arrangement, virtually any kind of condensate vapor can be used which satisfies the desired temperature requirements. In the present case, saturated steam is preferred because of its ready availability and low cost. Accordingly, the steam is conveyed into the shell **1** through an internal passageway **16** within the axle **2**. Passageway **16** extends longitudinally to a midpoint on the axle **2** between bearings **4** and **5**, at which point it terminates into ports **17** and an annular inlet **18**. Inlet **18** is recessed in the housing **3** and is connected by means of supply conduit **19** to a remote steam manifold (not shown). Adjacent and on either side of inlet **18** are rotary seals **20** and **21**. Both are commercial type, single-face mechanical seals consisting of an annular rotary member that is affixed to the axle **2** for the rotation therewith and a stationary member which is suitably retained in the housing **3**. The rotary member is adapted with a spring-loaded carbon ring **39** that is urged axially against a durable metal ring **40** on the stationary member. The seal assemblies reside in recesses **22** and **23** which are flooded with a pressurized coolant-lubricant. The fluid is introduced into the recesses through a branched inlet **24** which is connected to a remote resorvoir (not shown). At the extremities of axle **2**; that is, outboard of bearings **4** and **5**, there is provided a second set of rotary mechanical seals **25** and **26** that are identical in structure to the aforementioned seals and likewise reside in recesses **27** and **28** which are flooded with the coolant-lubricant. These seals serve to confine the coolant-lubricant within the axle **2** housing. Recesses **27** and **28** are connected to a branched outlet **29** which serves to carry away spent quantities of coolant-lubricant to a remote storage container (not shown).

Any suitable liquid preferably of sufficient viscosity, resistant to degradation at elevated temperatures, miscible with the heated medium and possessing good heat transfer and lubricating properties can be used as a coolant-lubricant. In the instant case, a polyalkylene glycol synthetic oil which is sold by the Union Carbide Corporation under the trade name of Ucon, Grade 50HB170 provides satisfactory results. The oil is particularly well suited for use in the present case for if overheated its products of decomposition are a gas and a water-soluble liquid.

This coolant-lubricant is introduced into the cavities **22** and **23** at a slightly greater pressure than the steam, it being the purpose to force the fluid to flow along the seal interfaces into the inlet **18**. In doing so, the liquid cools and lubricates the rubbing surfaces. More importantly, the liquid forms a film-thick barrier that prevents steam escapage. The negligible quantity of the coolant-lubricant that seeps into inlet **18** combines with the condensate that forms thereat and passes downward within inlet conduit **19** into a trap (not shown) from which it is expelled into a branch (not shown) of drain **13**. Because the coolant-lubricant is miscible in the steam condensate, there is no noticeable effect in the heat transfer rate or accumulation of gummy residue in the condensate orifices **15**. Placement of the pressurized seals **20** and **21** in opposed relationship; that is, on either side of the inlet **18**, and applying pressurized fluid against the steam counteracts uneven thrust forces on the axle **2**. More importantly, applying a fluid in the seal interfaces at a slightly higher pressure than the steam (about 30 p.s.i.g.) effectively prevents steam leakage and insures adequate lubrication of the moving surfaces. Notwithstading the high pressures of both fluid masses (steam and coolant-lubricant), either seal senses only a relatively low differential thrust pressure. At these low differential thrust pressures, frictional torque is correspondingly low and expected seal life greatly extended due to lubricating properties of the film barrier.

Bearings **4** and **5** are ordinary sleeve-type bearings which are adapted with thrust washers **30**. These washers **30** are fixedly attached to the bearings in a suitable manner such as by threaded fasteners or snap locks and act against the housing **3** to restrain the axle **2** from longitudinal displacement. The washers **30** are modified by a plurality of radial clearances or grooves **32** that allow unrestricted passage of the coolant-lubricant into the annular running clearance **33** between the bearings and the journals. The size of clearance **33**; that is, the gap width and the flow path length are closely controlled so as to establish a predetermined flow rate while, at the same time, being proportioned to properly carry the imposed bearing loads. Besides functioning as a passage for cooling and lubricating the bearings, clearance **33** serves as a convenient means for reducing the pressure of the liquid to near atmospheric levels before entering the recesses **27** and **28**. In the preferred embodiment, clearance **33** is adjusted to reduce the coolant-lubricant pressure to about 30 p.s.i.g. in recesses **27** and **28**. Thus both sets of rotary seals operate under substantially the same differential thrust pressures.

It is recognized that in some high-temperature applications, additional cooling capacity may be required to maintain the bearings and seals at safe operating temperatures. The coolant-lubricant can be either supercooled before being introduced into the roll or the flow rate can be increased by enlargement of the clearance **33**. There is, of course, a practical limit to which clearance **33** can be increased beyond which the bearings will no longer properly carry the imposed loads. The flow rate can be increased across the bearings **4** and **5**, without compromising on proper running fits, by alternate passages. As shown in FIGURE 3, open longitudinal grooves **34** can be added along the nonload carrying portions of the bearing housing or as shown in FIGURE 4, a plurality of longitudinal capillary-like conduits **35** can be arranged about the periphery.

As previously mentioned, the concept is ideally suited for confinement of vapors at high pressures in rapidly rotating rolls; however, it also can be utilized for either low pressure and/or slow speed rolls. In FIGURE 2, an alternate embodiment of the roll is shown for low vapor pressure service. The roll is essentially the same as in FIGURE 1, except for minor modifications which have been incorporated to provide a more simplified structure.

Bearing **5** is replaced by a pre-lubricated sealed ball bearing **36** eliminating thrust washers **30**, and seals **21** and **26** are housed in an opposed relationship in an enlarged recess **23** which is serially connected to recess **22** by a duct **55**. In this embodiment, vapor pressures may range anywhere up to 100 p.s.i.g., thus the resulting coolant-lubricant pressure is well within the range considered light-duty service for mechanical rotary shaft seals. The coolant-lubricant is introduced into recess **23** at slightly greater pressure (30 p.s.i.g. greater) than the steam and circulated through duct **55** to recess **22**. In this embodiment, the coolant-lubricant functions primarily to confine the steam to inlet **18** and prevents overheating of ball bearing **36**. Upon entering recess **22**, the coolant-lubricant circulates through bearing **4** into recess **27** through grooves **34**. The fluid is then returned through outlet **29** to a remote storage container. Seepage past seal **25** discharges directly into plenum **10** while seepage past seal **26** is collected in recess **37** and then carried by tube **38** into the plenum **10**.

In the figure, shell **1** contains a narrow-annular steam chamber **42**. The peripheral sides of the chamber **42** slope gradually toward a larger diameter and terminate into condensate groove **8**. At the small diameter end, the chamber **42** is connected to passageway **16** of the axle **2** by a plurality of radial distributors **41**.

Axle **2** is rotatably journalled within the housing **3** at the shell **1** end in a bronze sleeve bearing **4** and at the drive end in a ball bearing **36**. The axle **2** is sufficiently long and suitably modified to extend into the casing of a drive motor (not shown) and functions as an armature shaft.

Within condensate groove **8**, there are spaced orifices **15**, generally about .022 inch in diameter

In operation, the contact surface **6** of the roll may be maintained at any temperature between 100° C. and 200° C. within ±1° C. In operation, the roll is driven up to 6,000 r.p.m. with no appreciable wear on the rotary seals and relatively low expenditure of torque for driving the seals.

The textile treatment roll is thus characterized by many advantages which heretofore have not been afforded by prior-art treatment rolls. The roll has greatly extended service life and absorbs a relatively small fraction of the power input for driving. It permits a rotary seal arrangement which affords admittance of very high vapor pressures, while the pressure across the seals is maintained arbitrarily low. The instant apparatus provides a simple, reliable, condensate-removal means which is composed of no moving parts and can be readily adjusted to operate over a wide range of condensate loads.

Condensate and all leakage of coolant-lubricant past the seals is carried away so that no drips appear in the operating area. Lastly, the roll may be operated continuously with relatively high leak rates past the seals without external leakage.

What is claimed is:

1. A yarn handling apparatus comprising a cylindrical shell over which yarn is heated and advanced, a shaft connected to the cylindrical shell and a support housing for the shaft, said shell having a closed end outboard from the shaft and an interior peripheral frusto-conical surface sloping outwardly in a gradual manner from such end and terminating in a groove recessed in the periphery of the shell and a plurality of spaced orifices communicating with the groove and with a collector chamber external of the shell, the said shaft being rotatably journaled in spaced bearings in the support housing and having an internal passageway communicating with the interior peripheral surface of said shell, and the said support housing for the shaft comprising condensible vapor inlet means communicating with the internal passageway of the shaft,

a pair of spaced bearings located on either side of such condensible vapor inlet means, a first set of rotary seals interposed between the condensible vapor inlet means and the adjacent spaced bearings to enclose said condensible vapor inlet means, a second set of rotary seals located along the shaft exteriorly to the pair of spaced bearings and in opposed relationship to the first set of seals to enclose each of said bearings therebetween, pressurized lubricant-coolant inlet means located between the bearings and the first set of rotary seals, and exit means located between the bearings and said second set of seals for removing spent lubricant-coolant.

2. A yarn handling apparatus comprising a cylindrical shell over which yarn is heated and advanced, a shaft connected to the cylindrical shell and a support housing for the shaft, said shell having a closed end outboard from the shaft and said shaft being rotatably journeled in spaced bearings in the support housing and having an internal passageway communicating with the interior peripheral surface of said shell, and the said support housing for the shaft comprising condensible vapor inlet means communicating with the internal passageway of the shaft, a pair of spaced bearings located on either side of such condensible vapor inlet means, a first set of rotary seals interposed between the condensible vapor inlet means and the adjacent spaced bearings to enclose said condensible vapor inlet means, a second set of rotary seals located along the shaft exteriorly to the pair of spaced bearings and in opposed relationship to the first set of seals to enclose each of said bearings therebetween, pressurized lubricant-coolant inlet means located between the bearings and the first set of rotary seals, and exit means located between the bearings and said second set of seals for removing spent lubricant-coolant.

3. An apparatus suitable for the handling of yarn comprising a cylindrical shell over which yarn is heated and advanced, a shaft connected to the cylindrical shell and a support housing for the shaft, said shell having a closed end outboard from the shaft and an interior peripheral frusto-conical surface sloping outwardly in a gradual manner from such end and terminating in a groove recessed in the periphery of the shell and a plurality of spaced orifices communicating with the groove and with a collector chamber external of the shell, the said shaft being rotatably journaled in spaced bearings in the support housing and having an internal passageway communicating with the interior surface of said shell and with condensable vapor inlet means located in the support housing.

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MEYER PERLIN, *Primary Examiner.*

ROBERT A. O'LEARY, *Examiner.*

T. W. STREULE, Jr., *Assistant Examiner.*