Recommended Practice on Application and Testing of Electric Submersible Pump Seal Chamber Sections

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SECTION 1 GENERAL

1.1 Introduction

This recommended practice applies to the seal chamber section used in support of an electric submersible motor. Seal chamber sections are assemblies connected in tandem with oil filled motors to provide several supporting functions to the ESP system. They are also referred to as protectors, equalizers, or seal sections.

1.2 Scope

This RP contains tutorial, testing, and failure evaluation information. It provides a general understanding of construction and functioning of seal chamber sections and identification of well conditions, system requirements and characteristics that influence component selection and application. Also included is information needed to evaluate causes of seal chamber section failures. Testing sections establish acceptable test procedures and criteria to help verify seal chamber section functionality. General shipping and handling information is also included.

SECTION 2
DEFINITIONS

Bag — The bladder.

Barrier Fluid — Blocking Fluid.

Bladder — An elastomeric membrane within the seal chamber section that separates the filling fluid from the well fluid.

Blocking Fluid — A heavy fluid occasionally used to separate well fluid and filling fluid.

Chamber — The enclosed compartment which houses the labyrinth or bladder(s).

Check Valve — Mechanical devices that allow one-directional flow of fluid when a differential pressure exists across the valve. It may not seal against positive pressure.

Communication Hole — A passage to allow flow of fluid between chambers and from the top chamber to the wellbore.

Coupling — The splined concentric mechanical connection between the seal chamber section shaft and adjacent shafts.

Drain Port — A port to allow draining of fluid from a chamber.

Equalizer — Seal chamber section.

ESP — Electric submersible pump.

Filling Fluid — Motor oil.

FIM — Full Indicator Movement: the total movement of an indicator when appropriately applied to a surface to measure its variation (per ANSI Y14.5M).

Housing — A cylindrical casing that contains the components of the seal chambers.

Labyrinth Chamber — A labyrinth chamber provides a fluid interface between the well fluid and motor oil. Separation is maintained by the difference in specific gravity of the fluids.

Motor Oil — A dielectric oil used to insulate, lubricate, and cool the motor and seal chamber section.

Motor Seal Section — An obsolete term for seal chamber section.

Operating Temperature — Temperature of the component during operation.

Protector — Seal chamber section.

Relief Valves — Mechanical devices that allow one-directional flow of fluid when a pre-set differential pressure is exceeded across the valve.

Seal Section — Seal chamber section.

Shaft Seal — A device used to seal the interface between the shaft and a stationary component.

Thrust — Axial force transmitted from the pump shaft to the top of the seal section shaft.

Thrust Chamber — An assembly or a section of the seal chamber section which houses the thrust bearing assembly.

Vent Port — A port to allow venting of air during the filling process.

SECTION 3
FUNCTIONS OF THE SEAL CHAMBER SECTION

3.1 General

The seal chamber section has several functions that support operation of the liquid filled submersible motor and the centrifugal pump. These supporting functions must be addressed in any ESP configuration.

3.2 Provide Oil Expansion Volume

The motor and seal chamber section are filled with a dielectric oil that lubricates the bearings and cools the motor. During system installation, operation, and pulling, the motor oil will expand or contract. This change in the motor oil volume is accommodated by the seal chamber section.

3.3 Pressure Equalization

The seal chamber section equalizes the pressure inside the motor with the well bore pressure and thus eliminates pressure differences across the shaft seals.

3.4 Exclude Well Fluids

The seal chamber section prevents entry of well fluid into the motor.

3.5 Thrust Compensation

The seal chamber section carries downthrust transmitted from the pump to prevent loading the motor thrust system. An upthrust system is usually included to protect the seal chamber section should an unusual operating condition cause the pump to develop upthrust.

3.6 Torque Transmittal

The seal chamber section transmits torque from the motor shaft to the pump shaft. This function includes the reaction torque transmitted through the housings.

SECTION 4
COMPONENTS

See Figures 4.1A, 4.1B, and 4.1C for a general depiction of the seal chamber section.

4.1 Shaft: The shaft transmits torque from the motor to the pump. It also transmits the axial thrust generated by the pump to the thrust bearing. Shaft straightness is fundamentally important in the reduction of vibration and assuring proper function of shaft seals and bearings. Shaft runout of 0.002" FIM or more between bearing locations is likely to result in unacceptable vibration levels.

4.2 Shaft Seals: Shaft seals are used to seal the interface between the shaft and a stationary component. The most commonly used types are elastomeric bellows and metal bellows mechanical face seals. Radial lip seals are sometimes used.

4.2.1 Mechanical Face Seal: The sealing function of the face seal is accomplished by a stationary, primary seal ring bearing against the face of a mating ring mounted on a shaft. Axial pressure maintains the contact between the stationary and rotating mating rings. See Figures 4.2 and 4.3 for a description of components.

4.2.2 Radial Lip Seals: Sometimes used to provide the same function as Mechanical Face Seals. Composed of a "U" shaped stationary elastomeric or plastic ring sealing against the shaft or a shaft sleeve. See Figure 4.4 for a description of components.

4.3 Static seals are installed between surfaces where no relative motion exists.

4.3.1 O-Rings are elastomeric ring type seals used to keep well fluids from entering the seal chamber through housing joints, mechanical seals and flanges.

Elastomeric O-rings have become widely used in static sealing applications because of their flexibility and resistance to compression set.

O-rings are prone to damage during installation. Care must be taken to insure that the O-ring sealing area is clean and free of scratches across the grooves in order to insure proper sealing. A small amount of lubrication on the O-ring aids in assembly, but excessive lubrication can defeat sealing ability. The O-ring should never be forced over sharp corners, threads, keyways, slots, or splines nor should its ID be stretched more than 100% upon installation. The O-ring should be placed in the groove so that it is not damaged as the components are assembled. It is good practice to not reuse O-rings.

4.3.2 Lead gaskets are commonly used to seal vent plugs and drain and fill valves. Never re-use lead gaskets.

4.3.3 Fiber gaskets may be used under shipping caps during shipping but must not be used during unit installation.

4.4 Bearings: Both radial and thrust bearings are used in seal chamber sections. Sleeve and roller bearings are common examples of radial bearings. Typical thrust bearings are fixed and pivot shoe types.

4.5 Bladder: The bladder forms a flexible barrier between the motor oil and the well fluid thus preventing comingling of the two fluids. (See 4.9)

4.6 Housings (See Figures 4.1A, 4.1B, and 4.1C): Housings are tubular threaded sections that connect the inner body(s), head, and base. Housings must be able to support the weight of the motor and withstand the reactive torque between the pump and the motor and the reactive thrust from the pump. They must also provide appropriate sealing surfaces where required.

4.7 Labyrinth Chamber (See Figures 4.1A, 4.1B, and 4.1C): The labyrinth chamber provides a fluid interface between the well fluid and motor oil. Typical designs are the annular and breather tube configurations, as shown in Figures 4.5A and 4.5B. Normally there is a mechanical face seal located at the top of this chamber and mounted on the shaft. Its function is to prevent the well fluid from traveling directly down the shaft and through the chamber. For pressure equalization to the well bore, a passageway is provided in the seal assembly head connecting the area just above the mechanical face seal to the outside annular section (Fig. 4.1A) or a breather tube (Fig. 4.1B) of the labyrinth chamber. The fluid flow paths through each chamber design are shown in Figures 4.5A and 4.5B.

For the annular design, as the temperature of the unit increases, the fluid expands up the inner annulus tube section formed by the shaft and the shaft tube. At the top of this annulus, the fluid migrates over to the middle annular section formed by the shaft tube and the middle tube. It then travels down this section and up the outer annular section formed by the middle tube and the outer housing. The fluid then travels through the passageway connecting the area above the mechanical face seal. Upon contraction, the fluid follows the reverse path through the chamber.

For the breather tube configuration, as the temperature of the unit increases, fluid expands up the lower breather tube from the bottom of the lower chamber to the top of the upper chamber. It then settles to the bottom of the labyrinth chamber and travels up the upper breather tube to the well bore. Upon contraction, the well fluid travels the reverse direction.

During the expansion mode in the annular design, motor oil is being vented through the chamber to the well bore. As the unit cools down and the motor oil inside the unit contracts, fluid outside of the chamber (well fluid) is pulled back along the flow path into the outer annulus (upper chamber) of the chamber. As well fluid usually has a significant percentage of water, it will have a higher specific gravity than the motor oil, it will settle to the bottom of that annular section (upper chamber) and separate the well fluid from the motor oil.

Thereafter, as the unit goes through further thermal cycling, the well fluid in this chamber will transfer between the middle and outer annular sections (upper chamber and well bore). If there is a severe expansion cycle, then the well fluid can be displaced out of the middle annulus and additional motor oil can be displaced by the well fluid. If there is a severe contraction, well fluid could be pulled high enough into the middle annulus to flow over into the inner annulus and down into the cavity below the chamber.

The breather tube design functions in a similar manner (See Fig. 4.5B).

When well fluid and filling fluid have a common interface, the filling fluid will degrade because of water saturation or wetting from the well fluid. The effectiveness of a Labyrinth seal chamber section decreases if operated in other than a vertical orientation.

4.8 Blocking Fluid: Blocking fluids are used to prevent well fluid from contacting the motor oil. The blocking fluid has a high specific gravity and is usually inert. This fluid is placed at the bottom of the outer and middle annular sections so that it remains between the motor oil and well fluid, effectively preventing contamination of the motor oil.

See Figures 4.6A and 4.6B for placement of blocking fluids in the annular tube and breather tube type seal chamber sections. Note that in the breather tube type, two chambers are required, with the tubes removed from the upper chamber.

4.9 Bladder Chamber: The bladder chamber incorporates a positive barrier (bladder) between the well fluid and the motor oil. The bladder chamber functions similarly to the annular type labyrinth chamber except that the middle tube is replaced by a flexible bladder which seals around the shaft tube, see Figures 4.1C and 4.7.

Pressure equalization to the well annulus is provided during period of motor oil expansion or contraction (heating or cooling) as well as the stabilized running condition. During motor oil expansion, the bladder expands in the bladder chamber until internal pressure reaches the opening pressure of the relief valve. Motor oil expands through a flow passageway communicating from the interior section of the bladder to the outer section, then through the seal chamber section head to the wellbore area. A flow diagram is shown in Fig. 4.7. When motor oil expansion stops, i.e. the temperature stabilizes, the check valve reseats. While the motor oil is at constant temperature (no motor oil expansion or contraction), pressure equalization is maintained by the flexible bladder.

When the motor oil contracts, the check valve remains seated and the flexible bladder compensates for the volume reduction by collapsing inward. The pressure outside the bladder is equalized by the flow of well fluid back into the outer section of the chamber from the upper cavity of the seal chamber section head. Upon further thermal cycling, the bladder will expand as the fluid heats up and contract as the fluid cools down. Unless the maximum temperature of the initial thermal cycle is exceeded, there should be no further expulsion of motor oil out of the bladder interior section.

4.10 Relief Valves: Relief valves are used in bag-type seal chamber sections to prevent over-pressure damage to the bag or other components. Over-pressure would be caused by expansion of the oil in the motor and seal chamber section beyond bag capacity as a result of increasing temperature during down-hole installation, system cycling, etc.

Relief valves can be located in a number of places in the seal chamber section and still perform its primary function. The location and number of valves will vary from design to design.

The seal chamber section is designed to operate with a near-zero pressure differential across the bag and thus across the relief valve.

4.11 Check Valves: Check valves, as opposed to relief valves, are incorporated into the "drain and fill" valves to aid in servicing.

4.12 Couplings: The couplings mechanically link the shafts of the motor, seal chamber section(s), and pump. The primary function of the seal chamber section to pump coupling is to transmit torque and thrust load between shafts. The seal chamber section to motor coupling must transfer only torque.

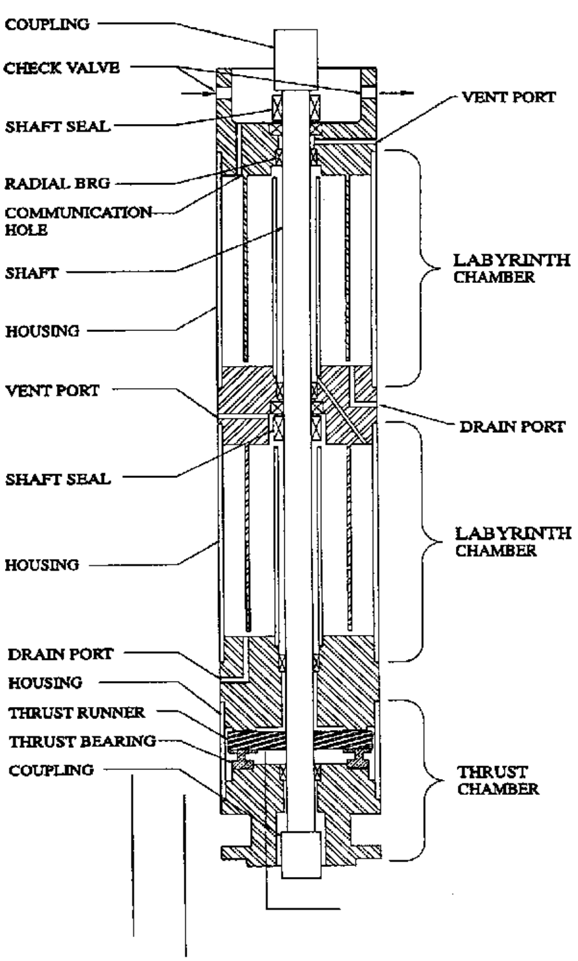


FIG. 4.1A
LABYRINTH SEAL CHAMBER SECTION ANNULAR CONFIGURATION

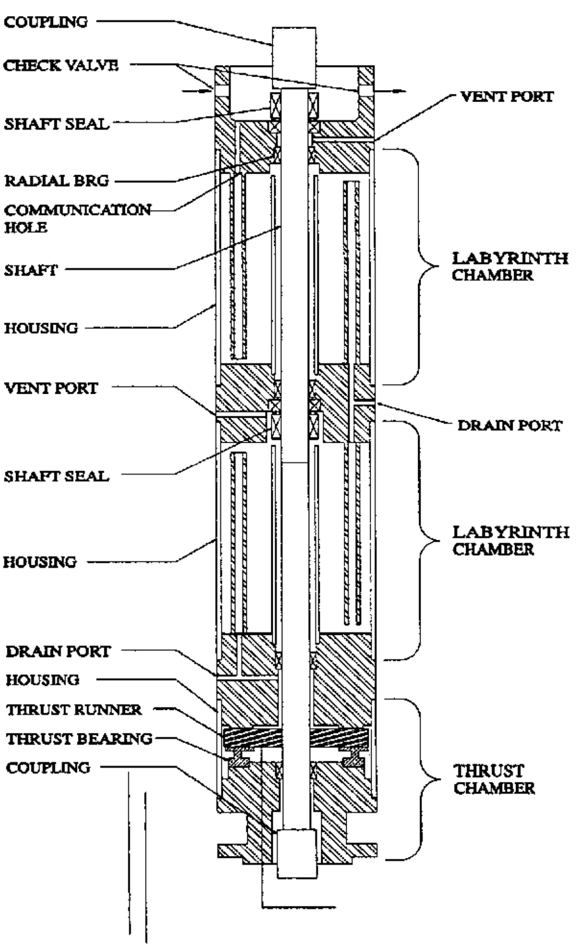


FIG. 4.1B
LABYRINTH SEAL CHAMBER SECTION BREATHER TUBE CONFIGURATION

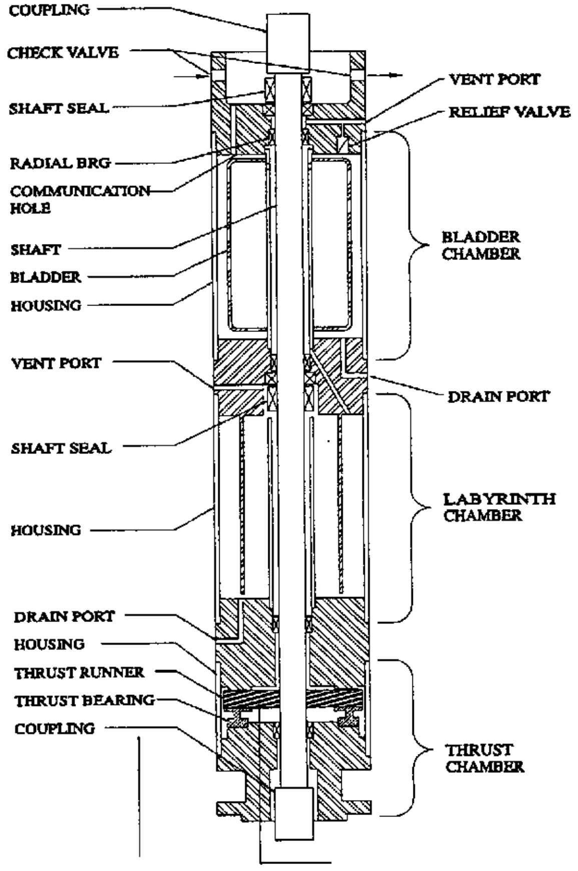


FIG. 4.1C
BLADDER SEAL CHAMBER SECTION

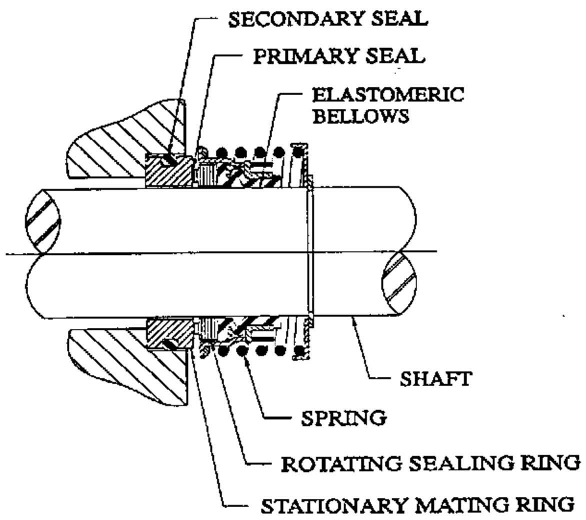


FIG. 4.2
MECHANICAL FACE SEAL COMPONENTS
ELASTOMERIC BELLOWS TYPE

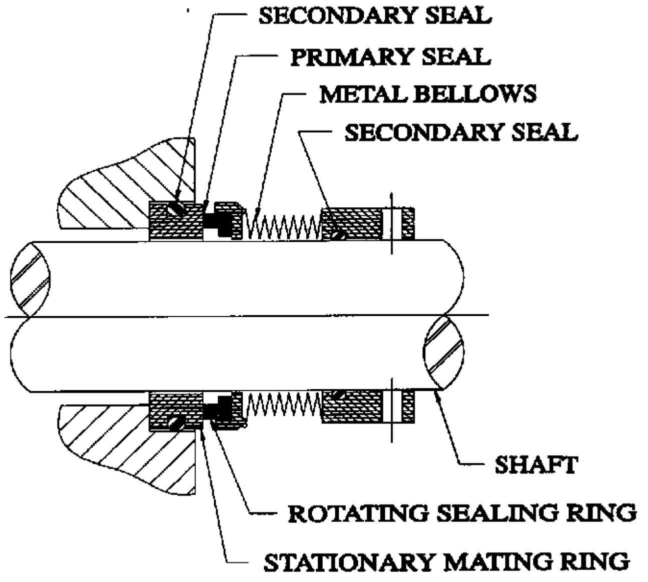


FIG. 4.3
MECHANICAL FACE SEAL COMPONENTS
METAL BELLOWS TYPE

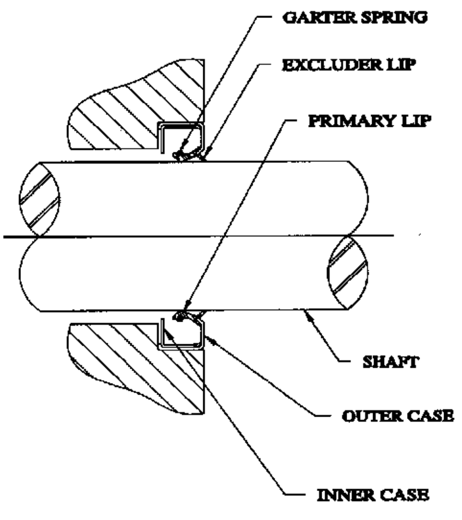


FIG. 4.4
LIP SEAL

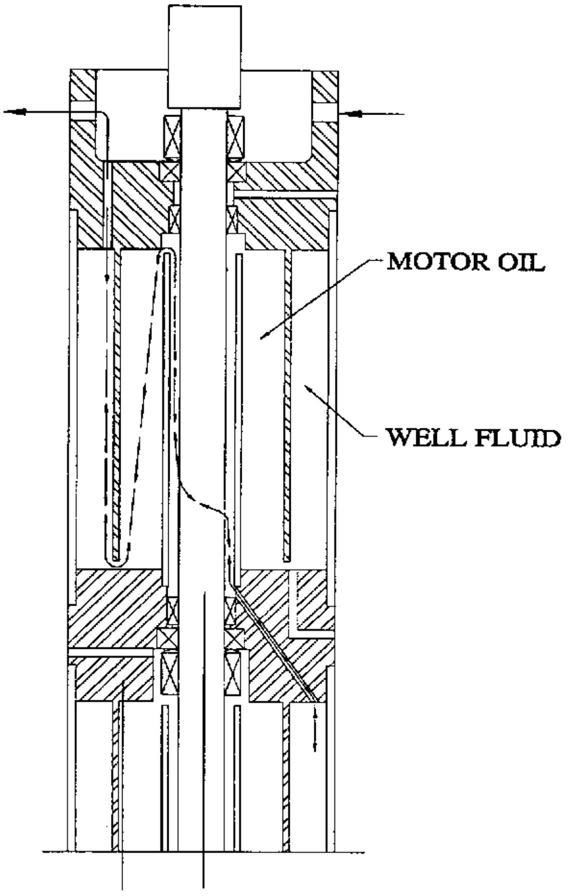


FIG. 4.5A
ANNULAR TYPE LABYRINTH CHAMBER FLUID FLOW PATH

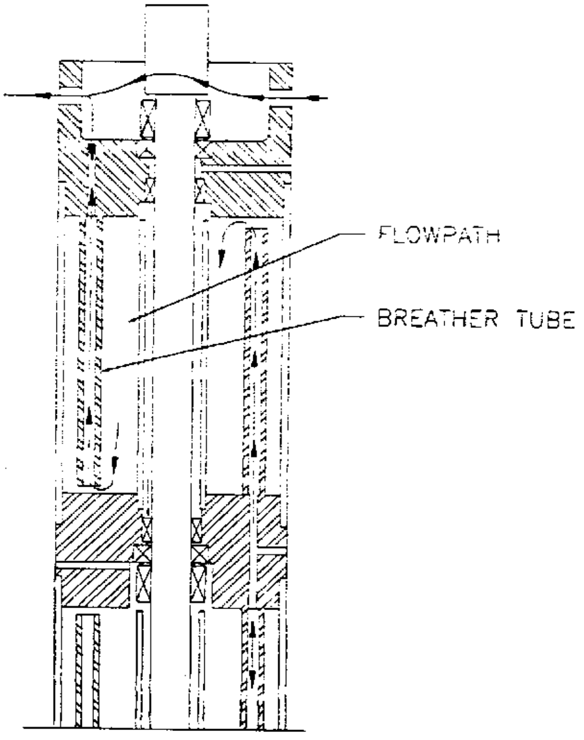


FIG. 4.5B
BREATHER TUBE LABYRINTH CHAMBER FLUID FLOW PATH

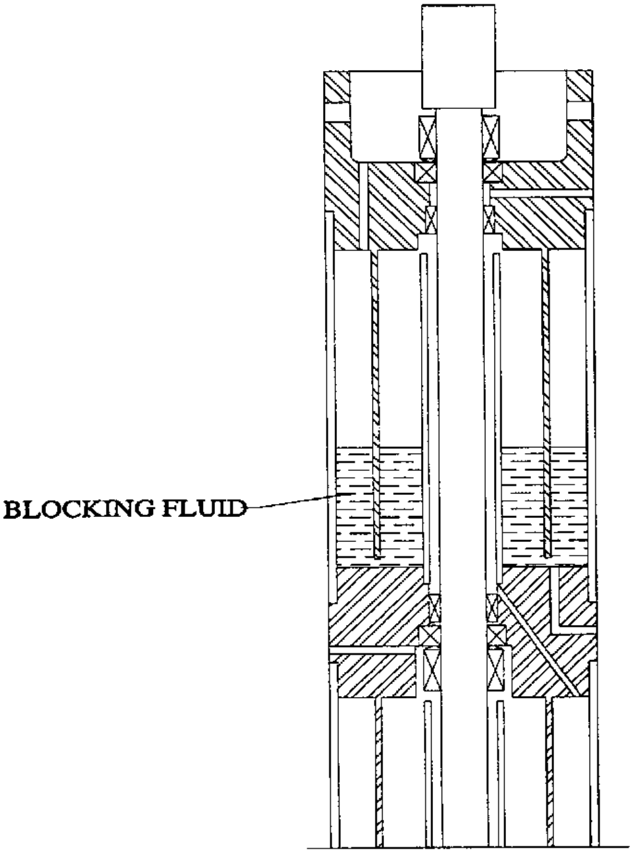


FIG. 4.6A
ANNULAR TYPE LABYRINTH CHAMBER
BLOCKING FLUID

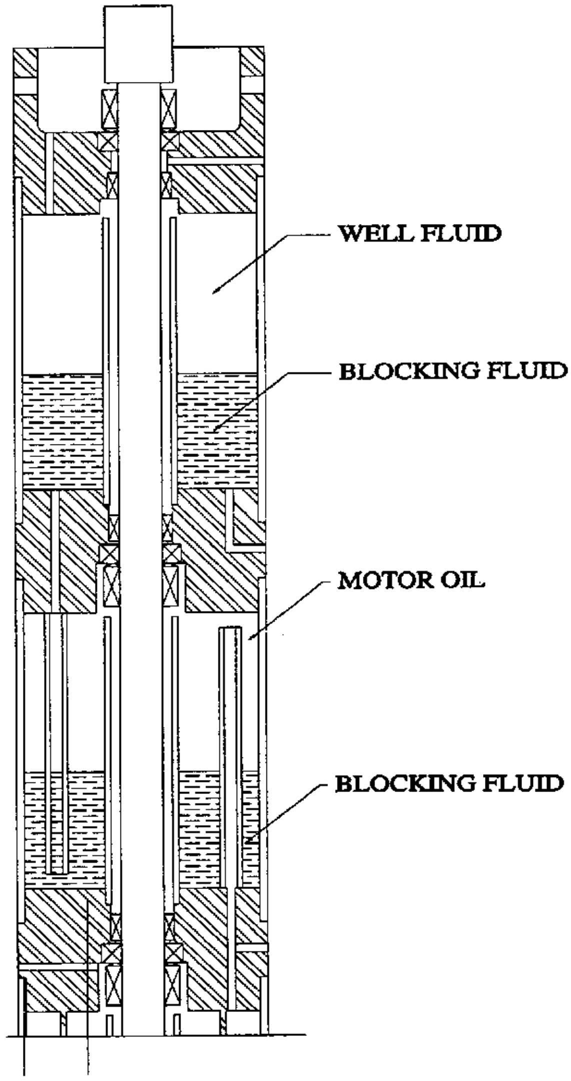


FIG. 4.6B
BREATHER TUBE WITH
BLOCKING FLUID

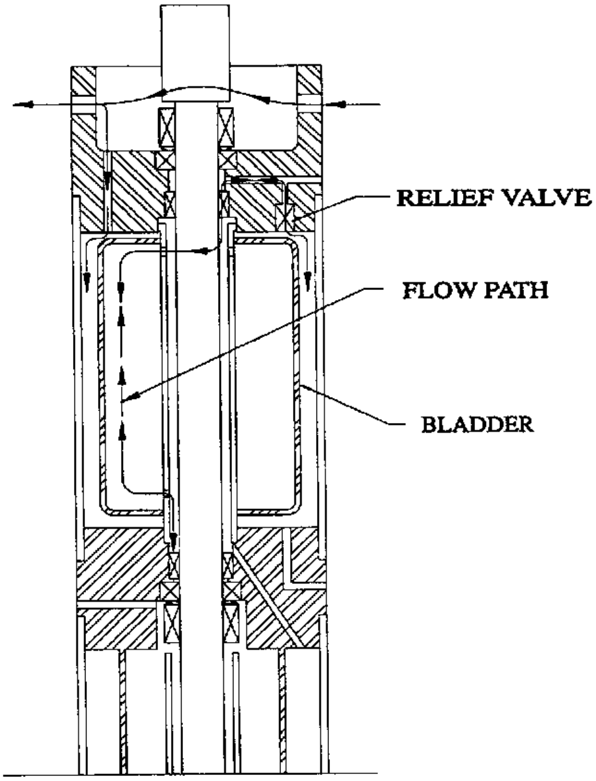


FIG. 4.7
BLADDER SEAL CHAMBER
FLUID FLOW PATH

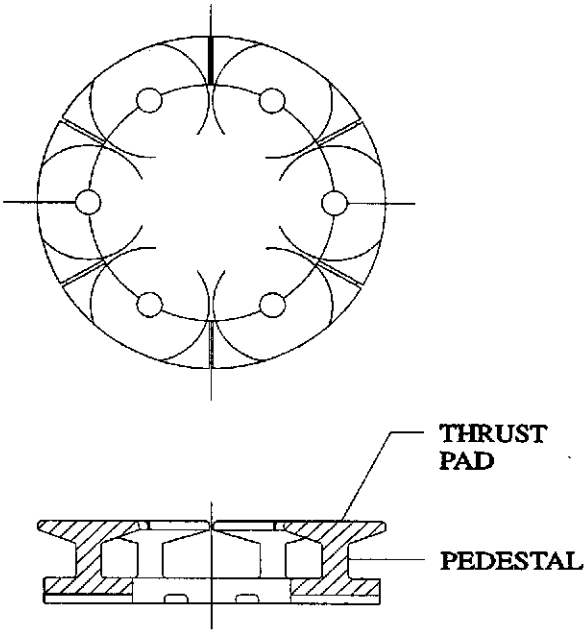


FIG. 5.1A
SOLID SHOE THRUST BEARING

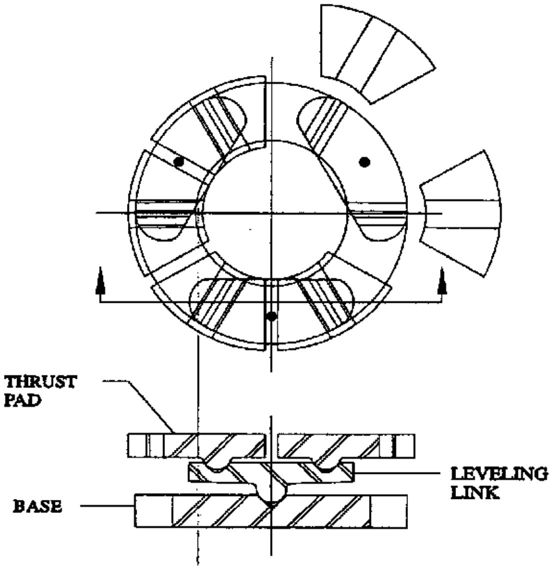


FIG. 5.1B
SELF-ALIGNING THRUST BEARING

SECTION 5
APPLICATION AND SELECTION CONSIDERATIONS

5.1 Temperature

5.1.1 Operating temperature is an important consideration; the material should be matched to its intended operating temperature. Consider all temperatures (high and low) that the material will see in all other conditions of unit life, i.e. storage, shipping, testing, and installation. Also be aware that a "high temperature" elastomer may not be the best selection for a low temperature application.

There are many different formulations with widely divergent properties and performance. Generally, ESP manufacturers specify the elastomer formulation used in various components and offer several choices for varying well conditions. Typical maximum service temperatures for several elastomers are shown below:

Nitrile: 250 °F (121 °C)

Highly Saturated Nitrile (HSN): 275 °F (135 °C)

Fluoroelastomer compounds: 325 °F (163 °C)

Tetrafluoroethylene/propylene copolymer (TFE/P): 350 °F (177 °C)

It is important to ensure that the specific formulations selected are compatible with the operating environment. Each application should be reviewed with the ESP manufacturer for specific recommendations.

5.1.2 Operating temperature should be considered when selecting motor oil. In general, motor oil viscosity decreases as temperature increases. At operating temperature the motor oil viscosity must be sufficient to provide lubrication for the seal chamber section bearings. ESP manufacturers typically offer several types of motor oil to accommodate a range of operating temperatures. Motor oil should be selected based on the manufacturer's recommendation to ensure proper bearing operation.

5.1.3 The motor oil used in the seal chamber section must be compatible with the motor oil used in the motor. If the seal chamber section is to be serviced (filled) in a cold climate, the pour point of the motor oil should be considered to ensure proper filling of the unit.

5.2 Fluid Characteristics

5.2.1 Water, oil, gas and brine are among the many fluids to be considered when selecting materials for the "wetted" (in contact with well fluid) components of the seal chamber section. The wetted parts of the seal chamber section include housings, head, base, shaft, and shaft seal. Generally, housings, heads, and bases are available in carbon steel or high chrome alloys for added corrosion resistance. Special coatings can also be applied to these components for additional corrosion protection. Corrosion resistant materials such as monel, stainless steel, and inconel are commonly used for shafts. Metallic components of mechanical face seals are typically stainless and bronze with monel available for additional corrosion resistance.

Generally, stainless steel is used for ancillary components like bladder clamps and relief valves. Inconel provides good corrosion resistance and is often used for actuating springs of relief/check valves or rotating seals.

5.2.2 It is important to consider the effect of produced and treatment fluids, such as corrosion inhibitors and acids, when selecting materials. For example, amines will greatly accelerate the deterioration of some elastomers.

5.2.3 The metal components of the seal chamber section should be selected so that destructive galvanic cells are not formed between adjacent components.

5.2.4 If solids are present in the well fluid, hard mechanical seal faces may be required to avoid excessive face wear. Tungsten carbide and silicon carbide seal faces are generally used in more abrasive well conditions.

5.2.5 When the internal oil has a higher specific gravity than the well fluid, a bladder or a labyrinth chamber with blocking fluid is required.

5.3 Well Geometry

5.3.1 The resultant diameter of the seal chamber section with the motor flat cable on one side should be smaller than the casing drift diameter to avoid damage when installing the equipment. Refer to API RP 11S4, Recommended Practice for Sizing and Selection of Electric Submersible Pump Installations.

5.3.2 In deviated wells the effective oil expansion capacity of a labyrinth seal chamber section will be reduced. Bladder type seal chamber sections should be considered for wells with any deviated section over 30 degrees from vertical.

5.4 Equipment

5.4.1 When sizing a seal chamber section for an application, the following features must be considered:

— shaft torque capacity

— thrust bearing capacity

— oil expansion capacity

Consider all phases of operation when evaluating the required shaft torque capacity. Maximum torque may occur during start-up or when pumping heavy fluids.

The required thrust bearing capacity will be determined primarily from the thrust characteristics of the pump which is unique to each application. All phases of operation should be considered; including the pumping of heavy fluids which directly impacts thrust. Thrust bearings are typically available in several configurations (see Figures 5.1A and 5.1B) and materials. Bearing surfaces are made from a wide range of materials. Babbitt is commonly used and is rated for operating temperatures up to 300 °F (149 °C). Bronze alloys may be used for high temperature applications. A number of plastic formulations have been developed for use in thrust bearings and are rated for high loads and high temperatures. The capacity of a given thrust bearing may be reduced at elevated temperatures or by rotating opposite to the design direction; refer to manufacturer for recommendations.

The required oil expansion capacity of the seal chamber section is a function of the total oil volume in the motor and seal chamber section and the maximum thermal cycle the unit experiences during installation and operation. Usually, the motor/seal chamber section assembly is at the lowest temperature during installation. The highest temperature will typically occur when the motor has reached operating temperature downhole. Provided with the thermal cycle, the manufacturer can select a seal chamber section with adequate oil expansion capacity.

5.4.2 Generally the seal chamber section will be selected in the same nominal diameter as the motor and pump. An alternate diameter seal chamber section may be used if the shaft, thrust, and oil expansion capacity are adequate.

5.4.3 Interchangeability of equipment offered by various manufacturers may be limited by flange and coupling incompatibility which may be overcome by adapters. However, consideration should also be given to thrust requirements of the pump (both magnitude and direction) and oil volume support requirements of the motor.

5.4.4 Tandem seal chamber sections are units where two or more seal chamber sections are stacked in series for the purpose of increasing the number of protection chambers, thereby increasing the motor protection. These units have been used in very hostile environments or in applications with expensive installation and pulling costs. In most cases, if each section has a thrust bearing, the upper unit will carry the pump thrust unless special consideration is given to shaft spacing or shimming.

In some applications bladder and labyrinth seal chamber sections are used in tandem. In deviated wells, the bladder seal chamber section should be installed on top to prevent contamination of the labyrinth seal chamber motor oil. In vertical wells, the bladder seal chamber section may be installed on the bottom for increased protection of the bladder from chemical attack by the well fluid.

Seal chamber section designs are available that use multiple chambers in a single unit to achieve the functions of tandem seal chamber sections. In these designs, the criteria for arrangement of labyrinth and bladder chambers is the same as for tandem seal chamber sections.

5.4.5 In a conventional ESP configuration, where the motor is located below the assembly, the seal chamber section is mounted between the motor and pump. The pressure equalization and volume change accommodation may be located elsewhere if desired, for instance at the bottom of the motor as in a "water well" type motor.

5.4.6 In an inverted ESP system with the motor on top, it is still necessary for the seal section to be located between the motor and pump. However, it may be more desirable to accommodate volume change and pressure equalization with a device located above the motor. These types of systems require special installation procedures to prevent loss of motor oil during installation.

5.5 Operating Conditions

5.5.1 Operating an ESP system on a variable speed drive may cause increased motor temperature rise which results in additional oil expansion. The seal chamber section must have adequate capacity to accommodate motor oil expansion at the highest anticipated operating speed. Shaft torque and thrust bearing capacity should also be checked at the highest operating speed since pump torque and thrust increase with speed.

5.5.2 The number of starts and stops (cycles) during operation of an ESP determines the number of thermal cycles the seal chamber section must support. Bladder type seal chamber sections should be considered for applications where frequent cycling is anticipated.

5.5.3 Actual motor loading should be considered when evaluating the required oil expansion capacity in the seal chamber section. The seal chamber section should be selected with sufficient oil capacity to accommodate the maximum probable motor load condition.

5.5.4 Other operating conditions that cause increased motor temperature rise include: restricted fluid flow past the motor; voltage imbalance; low voltage conditions: specific heat of the well fluid; etc.

SECTION 6
ACCEPTANCE TESTING

The following acceptance tests are recommended to assure that seal chamber sections have been properly manufactured and assembled.

6.1 Shafts

6.1.1 Shaft End Play: Shaft end play is the maximum allowed axial displacement as measured from the top flange face of the seal chamber to the end of the shaft. The first measurement from the flange face to the end of the shaft is made with the shaft down such that the thrust runner is firmly against the down thrust bearing. The second measurement from the flange face to the end of the shaft is made with the shaft fully up such that the runner is firmly against the up thrust bearing. As shown in Fig. 6.1, the difference in these two measurements is the shaft end play. Shaft end play and extension measurements are usually made and set during the thrust bearing assembly procedure. Shaft extensions and total movement in both the up and down directions can then be adjusted according to manufacturers specification.

6.1.2 Top Shaft Extension — Shaft extension at the top of the seal chamber is measured from the top flange face to the end of the shaft with the shaft in the down position. This measured extension should be within the tolerances specified by the seal chamber's manufacturer.

6.1.3 Bottom Shaft Extension — Shaft extension at the bottom of the seal chamber section is measured from the bottom flange face to the end of the shaft. The shaft should be in the down position . This measured extension should be within the tolerances specified by the seal chamber section's manufacturer.

6.2 Shaft Seals, Joints and Vents

Manufacturers should perform air pressure checks on shaft seals, joints and vents either during assembly or as a part of final unit acceptance test.

6.2.1 Air pressure test — A low pressure (0 to 15 psig) (0 to 103 kPa (ga)) air source is connected to the motor side of the shaft seal. A leak detection fluid is placed over the exposed section of the shaft seal, at joints and at vents. Fixtures or plugs may be required to seal off other vents or prevent actuation of a relief/check valve.

Slowly begin applying pressure up to the manufacturer's specified maximum while rotating the shaft by hand. The shaft may also be moved axially while being rotated. Hold pressure for a period of time that insure leaks are detectable. If air is seen bubbling past the seal, then the seal is leaking. Air bubbles at joints or vents also indicates a leak.

6.2.2 Oil pressure test of seals — The above test may be performed with oil instead of air. No oil should be present over the top of the seal when pressurized oil is placed below the seal. If oil begins to appear on the top of the seal when the manufacturer's recommended pressure is placed below the seal then the seal is leaking.

6.2.3 Internal seals — Seals internal to the seal chamber may or may not be accessible for testing on a completed seal chamber section. They should be checked during assembly by a low pressure air/fluid test. Appropriate vents, tubes and other openings are plugged, seals flooded with oil, and air is introduced at low pressure to the seal area. The shaft is turned and moved up and down. Bubbles indicate a faulty seal.

6.3 Idle Power Loss

The power consumed by an unloaded seal chamber section can be used to determine if the thrust bearing is functioning properly and if any radial bearings are misaligned. The manufacturer should determine allowable power consumption.

6.3.1 Calibrated Motor Method — A motor which has known operating characteristics can be used to measure the power consumed by an unloaded seal chamber section. The seal chamber section can be driven from either the top or bottom, depending upon the motor or test stand design. The rating of the motor should be appropriate for the loads being measured.

The power consumed by oil flooded bearings is very dependent upon their temperatures, making this an important measurement during testing. Since temperatures will vary throughout the seal chamber section, it is best to monitor one location, such as the thrust bearing housing which is typically the hottest location readily accessible. For the best consistency, both operating temperature and ambient temperature should be controlled as much as possible. See also 5.1.2.

6.3.2 Speed/Torque Cell Method — A speed/torque cell placed between the motor and seal chamber section can measure the horsepower that the seal chamber draws with no thrust loading. The no load losses of the support bearings of the speed/torque cell should first be measured so these losses can be subtracted from the measured losses.

The rating of the speed/torque cell should be in a range appropriate for the loads being measured. The seal chamber section should be brought up to operational speed and the temperature of the oil in the bearing area should be monitored. No load losses should be measured at the oil temperature specified by the manufacturer and compared to the rated no load losses.

6.4 Relief Valves

Check proper functioning of the relief valve in an assembled, filled seal chamber section or during assembly after the relief valve is installed. The openings in the head or body are closed using proper fixtures and the relief valve is pressurized to test for appropriate performance. Generally relief valves open at 5 psi (35 kPa) and reseat at 3 psi (21 kPa) or less. Specific relief valve operating pressures can be provided by the manufacturer.

6.5 Bladder Pressure Test

The air test for checking seal integrity between a bladder and its associated connecting hardware is performed at subassembly stage before insertion into a seal chamber section or at final assembly. Use 5 to 10 psi (35 to 69 kPa) differential across the bag.

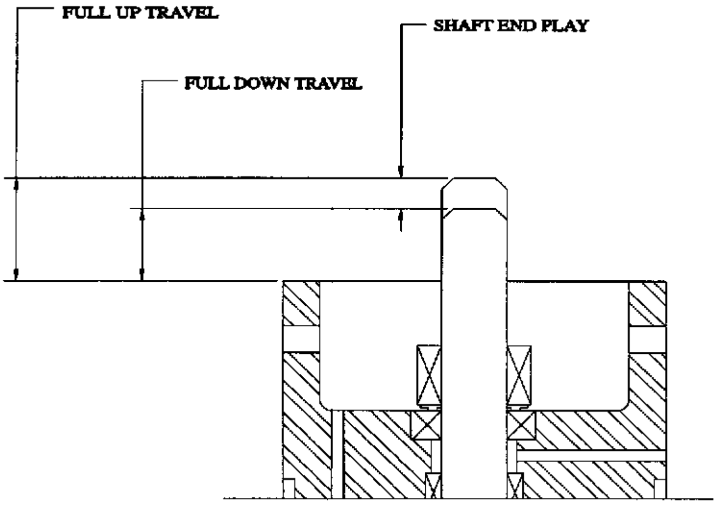


FIG. 6.1
SHAFT END PLAY

SECTION 7
SUPPLEMENTAL VIBRATION TESTING

Vibration testing may further insure the integrity of the seal chamber section. Vibration testing may be performed in conjunction with Idle Power Loss Tests and/or Thrust Load Testing; see API RP 11S8, Recommended Practice on Electric Submersible Pump System Vibrations, (to be issued).

SECTION 8
RE-USE TESTING

The decision to reuse a seal chamber section without disassembly is based upon several factors, some of which are listed below.

- Condition of fluid in the seal chamber section when unit is pulled.
- Reason for pulling unit. (Motor burn, well workover, loss of production, etc.)
- Well conditions, operating history, and length of run.
- Top bushing wear based on degree of shaft side play

Passing the following tests does not assure the integrity of all internal components. However, failure indicates the need for teardown analysis.

8.1 Check for leaks in the bladder, shaft seal and some seal chamber joints. A typical method for checking a bladder type seal chamber section is described below. Other procedures can be used to accomplish the same purpose.

8.1.1 A low pressure gauge (0 to 10 psi) (0 to 69 kPa) should be placed in the vent port that accesses the high pressure side of the relief valve. See Figure 8.1 for an example. This gauge will measure the pressure under the shaft seal and the inside of the bag. The ports on the top of the seal should be open to allow oil to escape out of the check as the unit is filled with oil from the bottom. As oil is pumped into the bottom of the seal chamber, the bag will expand and eventually the check valve will open. When the valve opens pumping should stop, the oil pump line should be shut off with a valve, and the opening pressure for the check/relief should be noted and should be within the tolerance specified by the manufacturer. The pressure that the relief valve sustains after it breaks open should also be recorded and checked against the manufacturer's specifications.

The above procedure may have to be repeated several times to clear air from the seal chamber in order to get good pressure readings. The holding pressure should be monitored for 20 to 30 minutes to guarantee that the valve, bag or shaft seal are not leaking.

8.1.2 A volume check can be performed on a full bag to verify that it is not stuck to the housing or bag frame. Oil should be forced into the area on the outside of the bag and the top of the shaft seal at a pressure no greater than what the shaft seal was tested to in 6.2. The contents of the bag should be allowed to drain until it is completely collapsed. The volume of the drained oil should be equivalent to the bag volume specified by the manufacturer. (If the relief, top shaft seal, and bag are not leaking then no additional oil will drain from the bag.) This also may take several minutes to make sure no small leak exists.

8.2 Thrust Load Testing: A thrust applicator may be bolted to the head of the seal chamber and the horsepower required by the seal chamber versus thrust loading can be recorded. The thrust applied and the associated horsepower used should be specified by the manufacturer. The horsepower (or kilowatts) may be recorded using the methods in 6.3.1 or 6.3.2.

8.3 Tests in Sections 6 and 7 should be applied as appropriate.

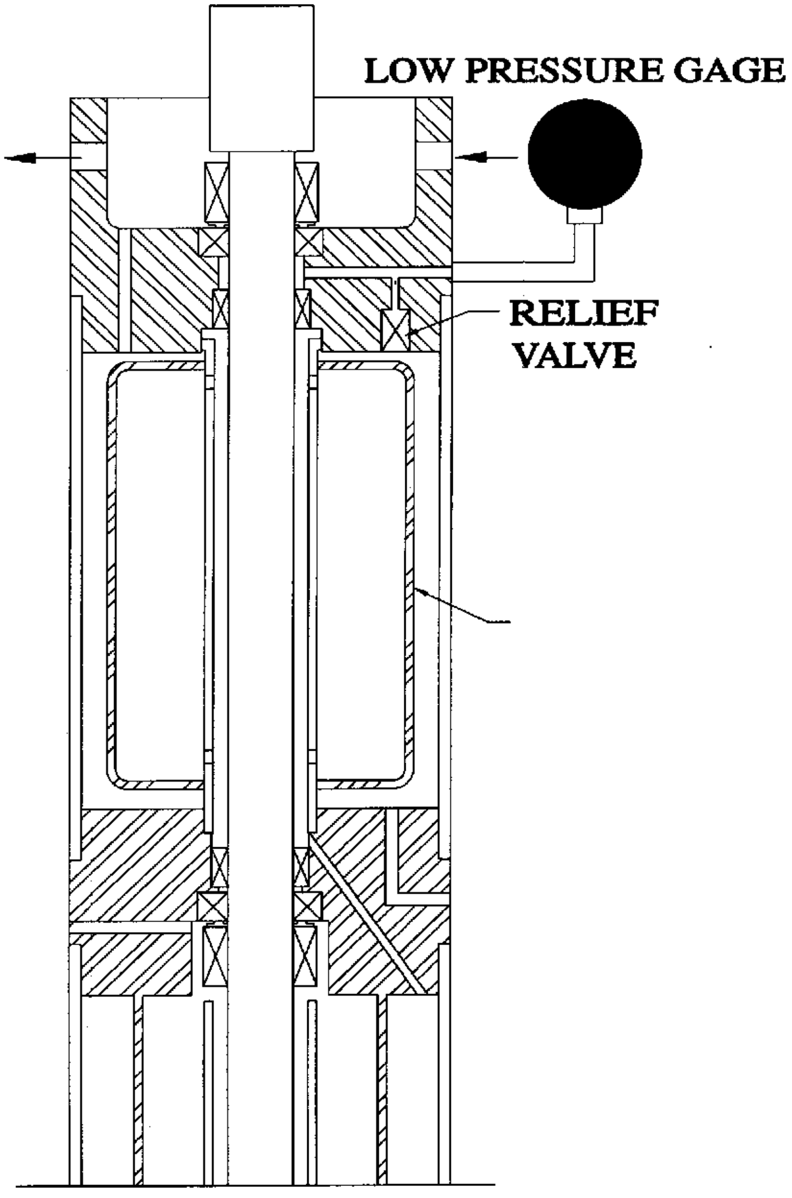


FIG. 8.1
BLADDER SEAL CHAMBER
PRESSURE TEST/GAGE LOCATION

SECTION 9
TEARDOWN ANALYSIS

9.1 The purpose of teardown analysis is to determine if a failure has occurred and probable causes. After probable causes are identified corrective actions can be developed. Analysis of the seal chamber section must be conducted in conjunction with a review of the other components of the ESP system. Before analysis begins the following information should be present:

9.1.1 When the unit is pulled and prior to laying it down, check for presence of emulsion or of free water and note location. (Once the unit is laid down any emulsion may separate and the free water can migrate to other chambers.) If free water is present, it may or may not have entered the unit when it failed. Emulsion indicates water was present while the unit was running. (See Sec. 9.2.8 thrust bearing examination)

9.1.2 Accurate assembly records (pull and run reports)

9.1.3 Prompt completion of teardown inspection report (API RP 11S1).

9.1.4 All records relating to operating and well conditions.

9.2 General Component Analysis

9.2.1 Inspect the outside of the unit.

a. Look for corrosion, pits and scale. How much of surface is affected? If corrosion is only in the thrust bearing area, bearing wear heat could be the cause of accelerated corrosion.

b. Inspect for mechanical damage such as dents, scratches, or bending which could have occurred on installation or pulling.

9.2.2 With the protective end caps in place and with the unit appropriately sealed, pressurize the seal section with compressed air. Use a soap solution to inspect for leaks at the O-ring, solder joints, vent plugs, and flange joints. The pressure required depends on the type of unit and will range from 10 to 20 psi (69 to 138 kPa). Consult manufacturer for proper pressure.

9.2.3 With the head end-cap removed, test the top shaft seal (at 3-4 psi) (21-28 kPa) for leaks by adding pressure to the body while rotating the shaft and looking for leaks around the shaft.

9.2.4 Inspect shaft extensions (Sec. 6.1.3 and 6.1.4) and shaft end play (Sec. 6.1.1).

9.2.5 Inspect the condition of the fluid in each chamber including the thrust chamber for discoloration and contamination. Contaminants can reduce the dielectric strength. The specific gravity and dielectric strength of the fluid can be measured.

a. Possible sources of discoloration include:

- — High temperatures in the seal chamber section or motor were experienced.
- — Contamination by well fluid.
- — Contamination from wear of internal components of the seal chamber section and/or motor. Metal particles will be present if this has happened.
- — The motor has burned.
- — Other, less common causes like chemical attack on the oil.

b. Water, usually evidenced by beads of water either in the fluid or on the components, could indicate that a leak has occurred. Water will reduce the dielectric strength of the oil. Check any information from the unit pull report to see if emulsion or free water was noted. Refer to Section 9.1.1.

9.2.6 Inspect O-rings for cuts, cracks, softening or hardening. Inspect O-ring grooves for leakage tracks.

a. O-rings can be cut when improperly installed or at dismantle.

b. Cracks, softening and hardening result from chemical attack and/or high temperature.

c. Dull streaks (leakage tracks) across the O-ring seat indicate leakage.

9.2.7 Inspect shaft seals for proper installation and functioning:

a. Inspect the snap ring at the top of the spring assembly on each Mechanical Face Seal. Leakage across the seal will result if the snap ring is missing or not properly seated in the groove on the shaft.

b. Inspect mechanical seal faces for good tracking (see Figures 9.1A, 9.1B, 9.1C, 9.1D, and 9.1E). Under normal operation, the marks left on the stationary half are concentric and the same width as the rotating half. Improper tracking would result in a non-concentric or uneven wear pattern. Some causes of improper seal face tracking include:

- — Vibration from any source.
- — Bent shaft or other alignment problem within the seal chamber section.
- — Improperly seated seal faces.
- — Deformed seal spring or improper spring force.
- — Build up of scale on seal faces or under seal components.
- — Wear of bushings allows excessive movement of seal faces.

c. Inspect rubber bellows inside spring assembly:

- — It should be adhered to the shaft.
- — Inspect for softening, hardening, cracks, or cuts which would indicate chemical attack or heat.
- — Inspect for bellows distortion which would indicate excessive shaft movement.

d. Scoring on the seal face or the runner can indicate abrasives were present.

e. Inspect for leakage tracking on seal interfaces.

- — Look for tracking on shaft under seal bellows locations.
- — Look for leakage tracks at each o-ring location at stationary faces.
- — Rotating face not properly seated in bellows.

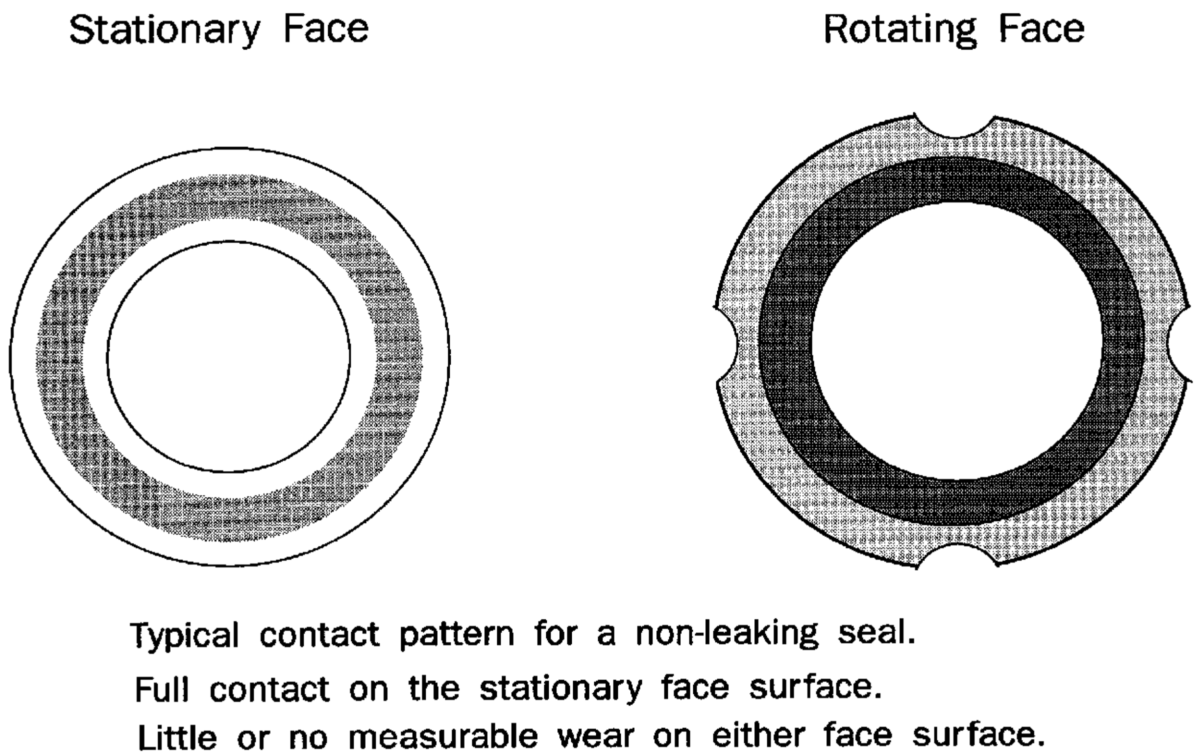


FIG. 9.1A
MECHANICAL FACE SEAL WEAR — NORMAL WEAR

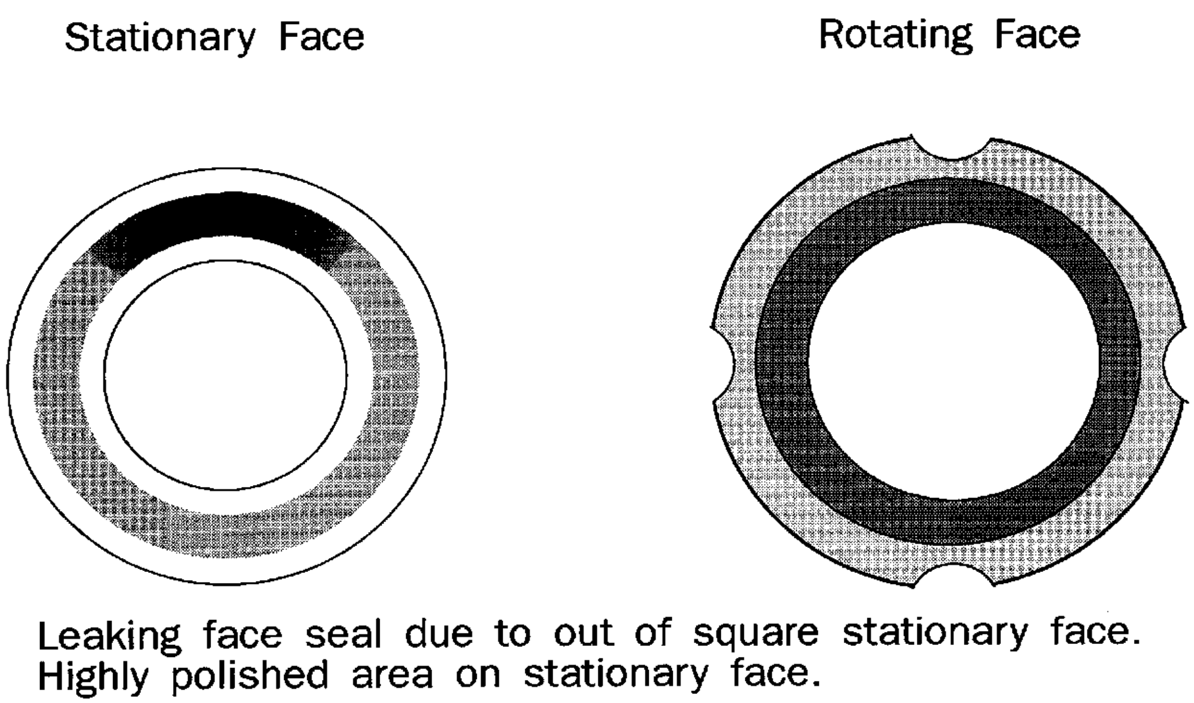


FIG. 9.1B
MECHANICAL FACE SEAL WEAR — OUT-OF-SQUARE STATIONARY FACE

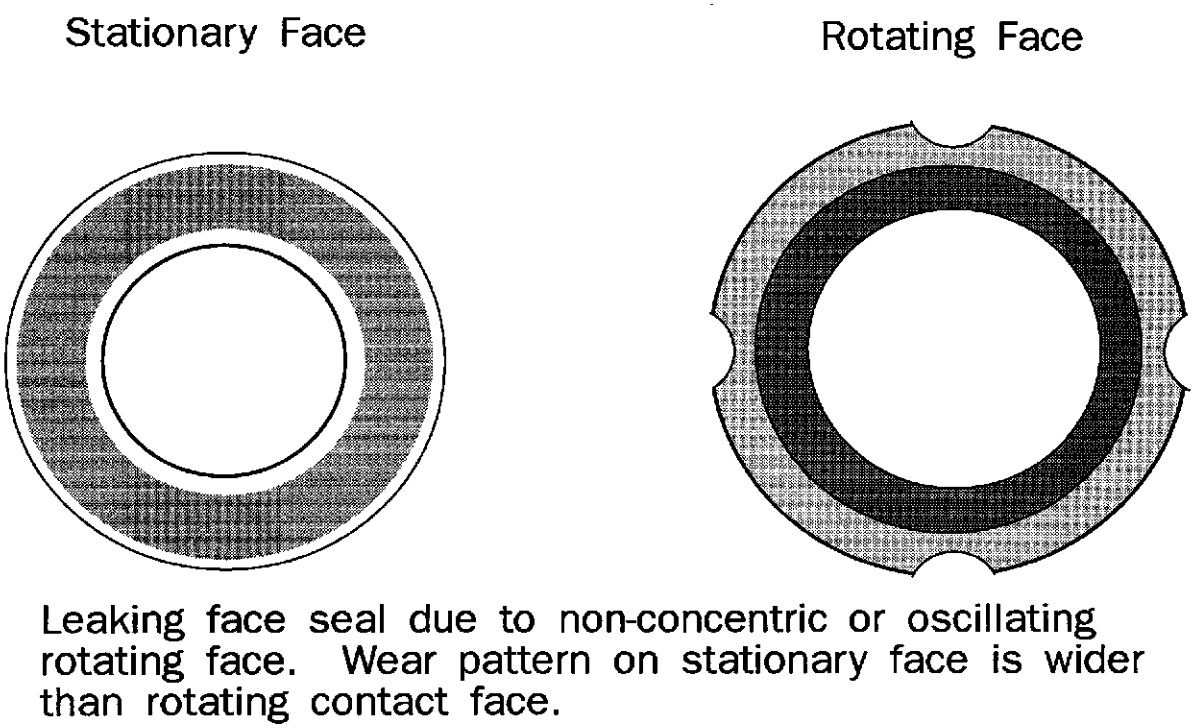


FIG. 9.1C
MECHANICAL FACE SEAL WEAR — NON-CONCENTRIC ROTATING FACE

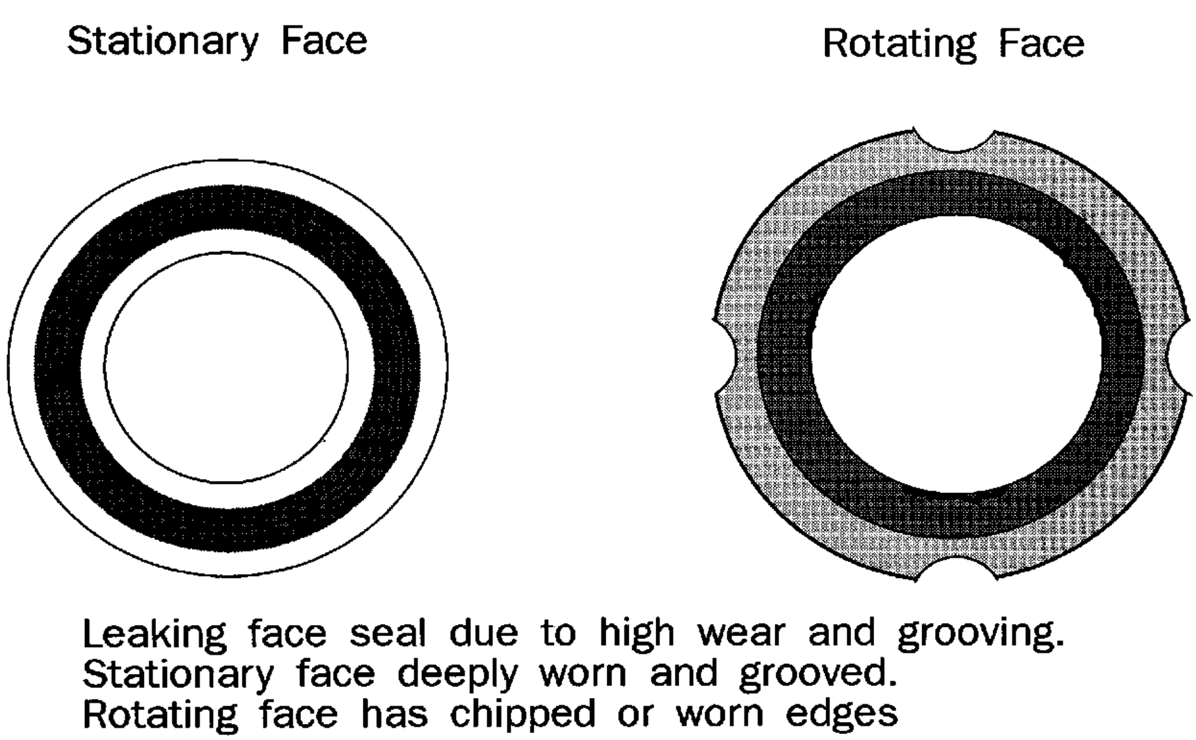
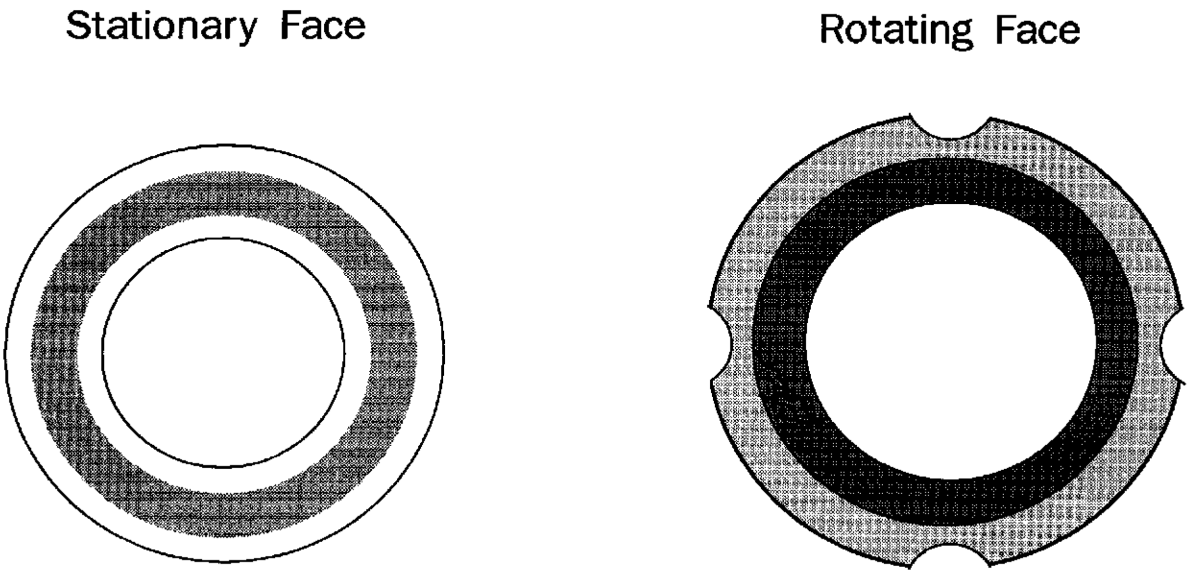


FIG. 9.1D
MECHANICAL FACE SEAL WEAR — HIGH WEAR



Leaking face seal due to thermal cracking or scratching from abrasive contaminates. Rotating face has cracks or scratches.

FIG. 9.1E
MECHANICAL FACE SEAL WEAR — THERMAL CRACKING

f. Check the condition of the seal spring.

— Inspect for breaks or corrosion.

— It should expand when the snap ring is removed.

g. Inspect for proper installation and wear on radial lip seals.

h. Inspect proper installation and condition of bellows on metal bellows seals.

9.2.8 Inspect thrust bearings:

a. Check that upthrust bearing, downthrust bearing and thrust runner retaining mechanisms are intact.

— Look for sign of bearings spinning in housings.

— Runner key is intact.

— Other indications of assembly or loading problems.

b. Inspect thrust bearing faces for the following:

— Upthrust or downthrust wear which should be consistent with operating conditions.

— Discoloration which would indicate contamination by water.

— Scoring which could result from solids contamination.

— Smear or melted thrust face material which could result from:

— Improper lubrication due to the presence of water.

— Severe downthrust.

— Inadequate cooling.

— Improper pump shaft extension.

— Well conditions exceed rated temperature of thrust bearing.

— Separated babbitt which could be caused by chemical attack or poor adhesion.

9.2.9 Inspect shaft bushings and shaft for wear.

a. Wear on top bushing only is an indication of excessive play in the pump shaft.

b. Uneven wear on all bushings indicates misalignment of shaft.

c. Scoring on bronze bushings indicates the unit was running in water or the oil was contaminated with metal fillings.

d. Non-circumferential wear on shaft with circumferential wear of corresponding bushing indicates bent shaft.

e. Circumferential wear on shaft with non-circumferential wear on corresponding bushing indicates misalignment of bushing or seal chamber section assembly.

9.2.10 Inspect for shaft spline damage.

a. A twisted spline indicates that the shaft experienced an overload condition.

b. Wear can indicate the presence of vibration.

9.2.11 If a filter (or screen) is used, check for plugging and determine the cause.

9.3 Additional checks for bladder type seal chamber section.

9.3.1 Check general condition of bladder material.

a. Check for hardening or softening of the bladder material.

b. Check for pinholes, cuts, and cracks.

c. Check condition of bag clamps.

9.3.2 Pressure test the bladder assembly. Consult manufacturer for proper pressure.

9.3.3 After removal of bag from frame:

a. Inspect for leakage tracks between bag and bag frame.

b. Inspect inside of bag for fluid contamination and damage (chemical or mechanical).

9.3.4 If a relief valve is used, check for proper opening and closing pressures per manufacturer's specifications.

a. Inspect valve for presence of scale, sand or other foreign matter that could have prevented proper valve functioning.

b. Look for sign of chemical attack to valve sealing ring and spring.

SECTION 10
HANDLING, SHIPPING, AND STORAGE

10.1 Care should be taken whenever transporting seal chamber sections, both new and used, to insure that precision components are not damaged. Shipping boxes should be used to insure units are not bent. A spreader bar should be used when moving unboxed tandem seal chamber sections or single units over 8 feet (2.44m) long. The manufacturer can suggest the appropriate handling, packaging, and storage instructions. Reference RP 11S3 for other shipping and handling recommendations.

10.2 Proper handling of equipment returned to the manufacturer enhances teardown analysis accuracy.

10.3 Store the unit in the shipping box until removal for installation. Consult the manufacturer for the appropriate storage environment and remaining shelf life for elastomers and other materials.

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