

Pressurized Water Reactor
B&W Technology
Crosstraining Course Manual

Chapter 6.1

Control Rod Drive Mechanism - Construction

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6.1 CONTROL ROD DRIVE MECHANISM—CONSTRUCTION

Learning Objectives:

1. List the two types of control rod drive mechanisms.
2. Explain the functions of the following:
 - (a) rotor assembly
 - (b) leadscrew
 - (c) torque taker
 - (d) snubber assembly
 - (e) leadscrew guide assembly
3. Describe the operation of the control rod drive mechanism following a reactor trip signal, including the action of the leadscrew guide assembly and hydraulic dampening.

6.1.1 Introduction

The most recent B&W design control rod drive mechanism (CRDM) is designated as type C. This type of mechanism is currently being used at Oconee Nuclear Station Unit II. It is similar in design to the type A and B mechanisms in use at other B&W facilities.

The CRDM (Figure 6.1-1) consists of an electrically driven, roller nut assembly (rotor) within a pressure vessel; a four-pole, six-winding stator; and a leadscrew that converts the rotary motion of the roller nut assembly to the linear travel of the leadscrew and control rod assembly.

The rotor assembly is split so that when power is applied to the stator, the rotor assembly segment arms pivot to mechanically engage the roller nuts with the leadscrew threads. As the power to the stator coils is sequenced, the rotor rotates to a new position. One rotor revolution results in a linear leadscrew translation of 0.75 in.

The drive is designed to trip whenever stator power is interrupted. The power loss causes the rotor assembly segment arms to pivot, disengaging the roller nut assembly from the leadscrew and allowing the leadscrew and control rod assembly to fall into the reactor core. Each axial power shaping rod is modified so that the roller nut assembly cannot disengage from the leadscrew when power is interrupted to the stator.

6.1.2 Component Description

The CRDM includes a motor tube that acts as the primary pressure boundary and houses the leadscrew, the leadscrew rotor assembly, and a snubber assembly (Figure 6.1-

2). The top end of the motor tube is sealed by a closure and vent assembly. The motor stator is mounted externally and surrounds the motor tube. The rotational motion of the rotor assembly is translated to the non-rotating leadscrew coupled to the control rod. The leadscrew is driven by separating roller nut assemblies attached to segment arms, which are rotated magnetically by the motor stator outside the motor tube. Current flow through the stator windings establishes a magnetic field, which causes the separating roller nut assembly arms to close and engage the leadscrew. When current is removed from the stator, the loss of the magnetic field allows mechanical springs to force the segment arms apart, disengaging the roller nut halves from the leadscrew.

An anti-rotation device, the torque taker, prevents rotation of the leadscrew while the control rod drive mechanism is in service.

Subassemblies of the CRDM are described in the following sections.

6.1.2.1 Motor Tube

The motor tube is a four-piece welded assembly. The wall of the motor tube between the rotor assembly and the stator is constructed of magnetic material to present a small air gap to the motor. This increases the magnetic coupling to the rotor assembly. The material used is martensitic stainless steel. The upper extension of the motor tube functions as a pressurized enclosure for the withdrawn leadscrew. The extension is constructed of austenitic stainless steel and is welded to the upper end of the magnetic motor tube section. The lower end of the magnetic motor tube is welded to an austenitic stainless steel forging, which is flanged to connect to a reactor vessel CRDM head penetration.

6.1.2.2 Motor

The CRDM motor is a synchronous reluctance stator with an integral cooling water jacket in the outer area of the casing. The stator windings are varnish impregnated to provide better heat transfer and to increase electrical insulation properties. The stator assembly is mounted over the motor tube housing. Stator winding temperature is monitored by two copper-constantan thermocouples. An alarm is actuated in the control room should the winding temperature exceed predetermined limits.

6.1.2.3 Closure and Vent Assembly

The upper end of the motor tube is closed by a closure insert assembly containing a vapor bleed port and vent valve. The vent valve and the closure insert have double seals. The closure insert is retained by a closure nut threaded to the inside of the motor tube. The sealing force for the closure insert is applied by jackscrews threaded through the closure nut and pressing the closure insert against an internal shoulder in the motor tube.

Removal of the closure and vent assembly permits access to couple and release the leadscrew assembly from the control rod. The vapor bleed port is capable of bleeding all non-condensable gases accumulated in the top of the reactor vessel before the reactor vessel closure head is removed, as well as during reactor coolant system (RCS) fill and heatup. During the draining of the RCS, the vent ports also allow air inflow to replace the drained coolant. Because the leadscrew and control rod assembly depend on hydraulic buffering to absorb the initial force on a control rod trip, it is very important that all non-condensable gases are vented from the CRDM extension housing.

6.1.2.4 Rotor Assembly

The rotor assembly consists of a pair of segment arms supported by a pivot ring and ball-bearing assembly. The upper end of the assembly has a radial ball-bearing and a synchronizing ring assembly that centers the segment arms in the motor tube and minimizes the motion required for engagement to ensure proper radial clearance. The synchronizing ring is pinned to each segment arm to synchronize engagement and disengagement motions. The lower end of each segment arm contains a pair of ball-bearing supported roller nut assemblies, which are skewed at the leadscrew helix angle to facilitate easy engagement with the leadscrew.

Energizing the motor stator causes the portion of the segment arms above the pivot ring to move outward toward the motor tube wall, causing the lower portion of the arms to move inward to the leadscrew and engaging the roller nuts. Four springs mounted in the segment arms keep the rollers disengaged when power is removed from the stator windings.

6.1.2.5 Leadscrew

The leadscrew is connected to the control rod assembly by a bayonet-type coupling and extends up through the motor section of the CRDM. The leadscrew has a lead of 0.750 in. (length of travel of leadscrew for one mechanical revolution of the rotor assembly). The thread on the leadscrew is double lead in that the spacing between adjacent threads is 0.375 in. The thread form is in a modified acme (square) with a relief angle that facilitates roller nut disengagement from the leadscrew. An antirotation device (torque taker) is provided at the top of the leadscrew to prevent the leadscrew from rotating and uncoupling the control rod assembly when the CRDM is in service. In addition, the torque taker and its guides provide alignment for the leadscrew during its travel.

6.1.2.6 Torque Tube and Torque Taker

The torque tube is a separate tubular assembly located inside, and attached to, the motor tube and extending the full length of leadscrew travel. The torque tube contains a key that, in conjunction with the torque taker, prevents rotation of the leadscrew. The torque tube is secured from vertical or rotational movement at the lower end of the motor

tube closure assembly by a retaining ring, keys, and closure insert. The lower end of the torque tube houses a hydraulic snubber assembly that also acts as the down motion stop. The leadscrew contacts the motor tube closure insert assembly for the out-motion stop.

The torque taker assembly (Figure 6.1-3) consists of the permanent magnet for position indication, the snubber piston, and a positioning keyway. It is attached to the top of the leadscrew and has a keyway that mates with a key in the torque tube to provide both radial and rotational support of the leadscrew.

6.1.2.7 Snubber Assembly

The components of the snubber assembly include a piston that is the lower portion of the torque taker assembly, a hydraulic snubber cylinder, and a belleville spring assembly that is attached to the lower end of the torque tube. The hydraulic snubber cylinder is the area in which the tripped leadscrew control rod assembly is decelerated hydraulically. The dampening characteristics are determined by the size and number of holes in the snubber cylinder wall and the water leakage through the snubber piston and bushing. Any excess kinetic energy remaining at the completion of the hydraulic dampening is absorbed by the belleville spring assembly. This is accomplished by a slight instantaneous over travel past the normal in-motion stop.

6.1.2.8 Leadscrew Guide Assembly

The leadscrew guide assembly (Figure 6.1-4) provides two important functions. First, the bushing acts as a thermal barrier and leadscrew guide. Second, it allows flow of coolant into the upper motor tube area on a leadscrew/control rod assembly trip to replace the volume in the tube formerly occupied by the leadscrew shaft.

As a thermal barrier the bushing allows only a small path for free convection of water between the mechanism and the reactor closure head nozzle, resulting in reduced coolant temperatures in the mechanism. To obtain acceptable control rod assembly trip travel times, it is necessary to provide an additional flowpath for coolant around the leadscrew guide bushing. This additional flowpath prevents formation of a low-pressure area above the leadscrew shaft as it leaves the motor tube area. Additional coolant flow passes through the ball check valves, which prevent normal convection flow, but allow coolant flow by opening fully during a trip.

6.1.3 Component Operations

6.1.3.1 Reactor Trip

The control rod drive mechanism is designed to trip whenever power to the stator is interrupted. During such a power loss, the rotor assembly segment arms pivot, releasing the mechanical contact between the roller nut assembly and the leadscrew. The leadscrew

and control rod assembly then free fall into the reactor core to the full-in position by gravity. During the free-fall condition, coolant is allowed to pass from the reactor head area into the motor tube housing, through the ball check valves in the leadscrew guide assembly, to fill the volume vacated by the leadscrew. This prevents the formation of a low-pressure area that could affect rod drop times. The hydraulic snubber assembly, within the motor tube housing, decelerates the moving control rod assembly (CRA) to a low speed just before it reaches the CRA full-in position. The final deceleration energy is absorbed by the belleville spring assembly.

As mentioned in Section 6.1.1, a group of rods known as the axial power shaping rods (APSRs) are modified so that their roller nut assemblies cannot disengage from their leadscrews on a loss of power to their stators. A brake is designed into the APSR drive unit that prevents rotation of the segment arms when power is lost to the stator.

6.1.3.2 Control Rod Assembly Leadscrew Coupling

The leadscrew assembly is connected to the control rod by a bayonet coupling. This coupling design provides easy attachment of the leadscrew to the control rod assembly from a position external to the reactor vessel. The closure and vent assembly at the top of the motor tube housing permits access to couple and release the leadscrew assembly from the control rod.

The leadscrew and control rod assembly are coupled by a leadscrew coupling/uncoupling tool. The leadscrew is lowered downward through the motor tube until the male bayonet coupling is positioned inside the female coupling of the control rod assembly. At the same time, a pin on the upper portion of the leadscrew (Figure 6.1-3) is positioned within the torque taker. The leadscrew is rotated 45° by the coupling/uncoupling tool, and the leadscrew nut on top of the leadscrew assembly is tightened and locked in place. This tightening of the leadscrew nut restricts any movement of the leadscrew relative to the torque taker and the female coupling of the control rod assembly. The reverse procedure is used for uncoupling.

6.1.3.3 Cooling Water

The stator requires cooling water with an inlet temperature of 80°F to 120°F and a 2-gpm minimum flow per drive. The design flow to each drive is 3 gpm with a 50-psi pressure drop across the stator water jacket. Cooling water supply and return is accomplished in the closure head service structure by main headers connected to the CRD cooling water system. Smaller headers branching from the main header provide supply and return to all groups of drives.

Each CRDM's basic requirements for cooling water are:

1. Cooling water must be on and flowing at a rate of 2 gpm minimum before the stator assembly coils are energized.
2. Cooling water quality (chemistry and particulate content) must be maintained within standards approved by Babcock and Wilcox and the utility at all times.

6.1.4 Summary

The two types of rods, control rods and axial power shaping rods (ASPRs), are identical in operation. The only difference is that during a reactor trip the control rods free fall into the reactor core, and the APSRs remain at their position and are prevented from falling by internal brakes.

The leadscrew assembly provides the interconnecting component between the drive mechanism and the control rod assembly. During normal operation the control rod assembly is withdrawn and inserted by the interaction between the drive mechanism and the leadscrew. The rotational motion of the rotor assembly is converted to the linear motion of the leadscrew by the threads on the leadscrew. Rotation of the leadscrew is prevented by the torque taker and torque tube interface. The motor tube assembly provides the primary pressure boundary for the drive mechanism components. It can be opened at the top to allow for leadscrew control rod assembly coupling/uncoupling.

During a reactor trip the force of the free-falling CRA and leadscrew is absorbed first by the hydraulic action of the snubber assembly, then by the belleville spring assembly. Providing sufficient coolant flow into the motor tube during the trip is important to ensure correct rod drop times.

TABLE 6.1-1 CONTROL ROD DRIVE DATA

Item	Control Rod	Axial Power Shaping Rod
Number of drives	68	8
Type	Roller nut	Roller nut
Location	Top mounted	Top mounted
Direction of trip	Down	Does not trip
Maximum travel time for trip at full-flow 3/4 insertion, sec.	1.86 sec.	Does not trip
Length of stroke, in.	138.5 in.	138.5 in.
Design pressure, psig	2500 psig	2500 psig
Design temperature, °F	670 °F	670 °F
Weight of mechanism (approximate), lb.	935 lb.	935 lb.

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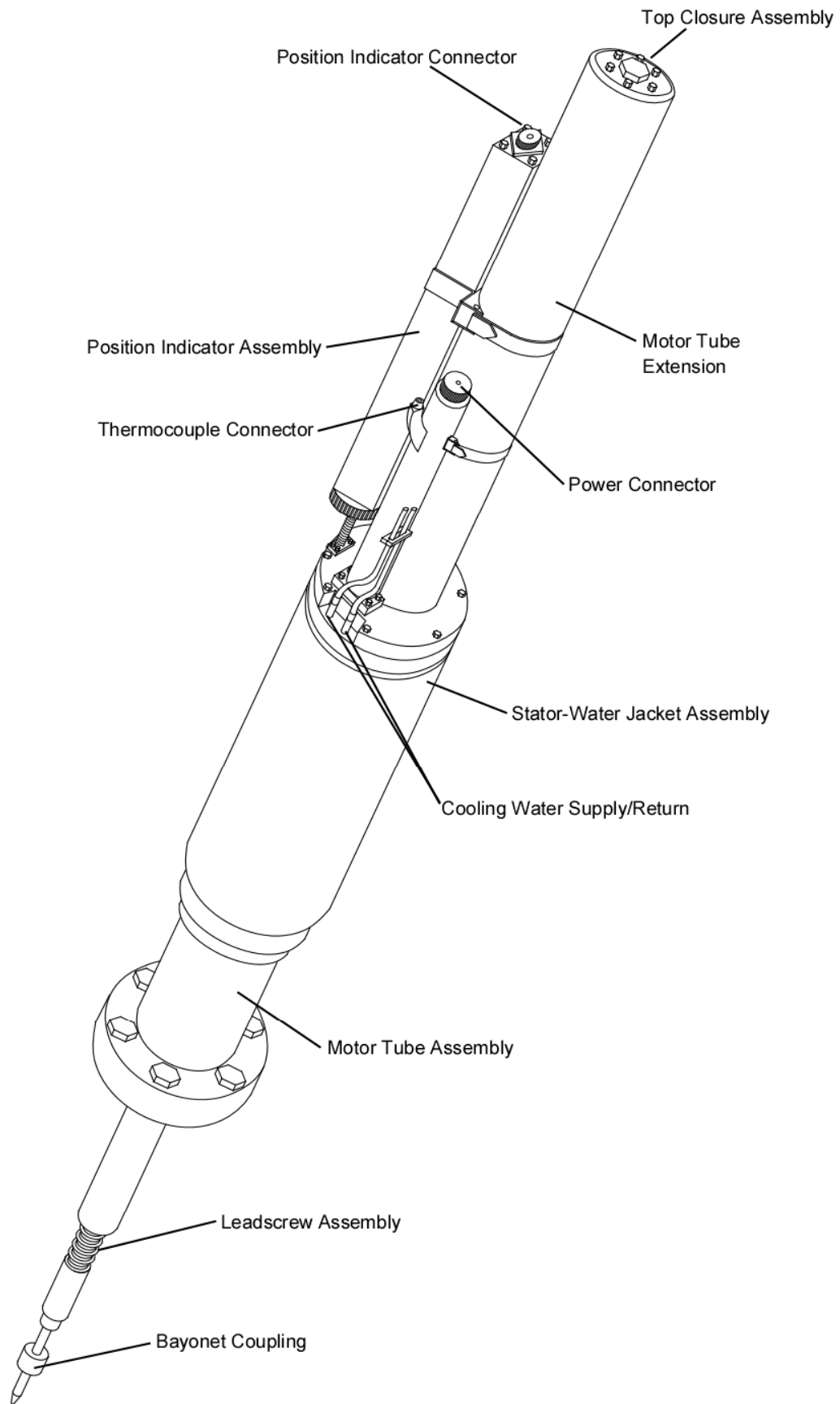


Figure 6.1-1 Control Rod Drive Mechanism – Illustration

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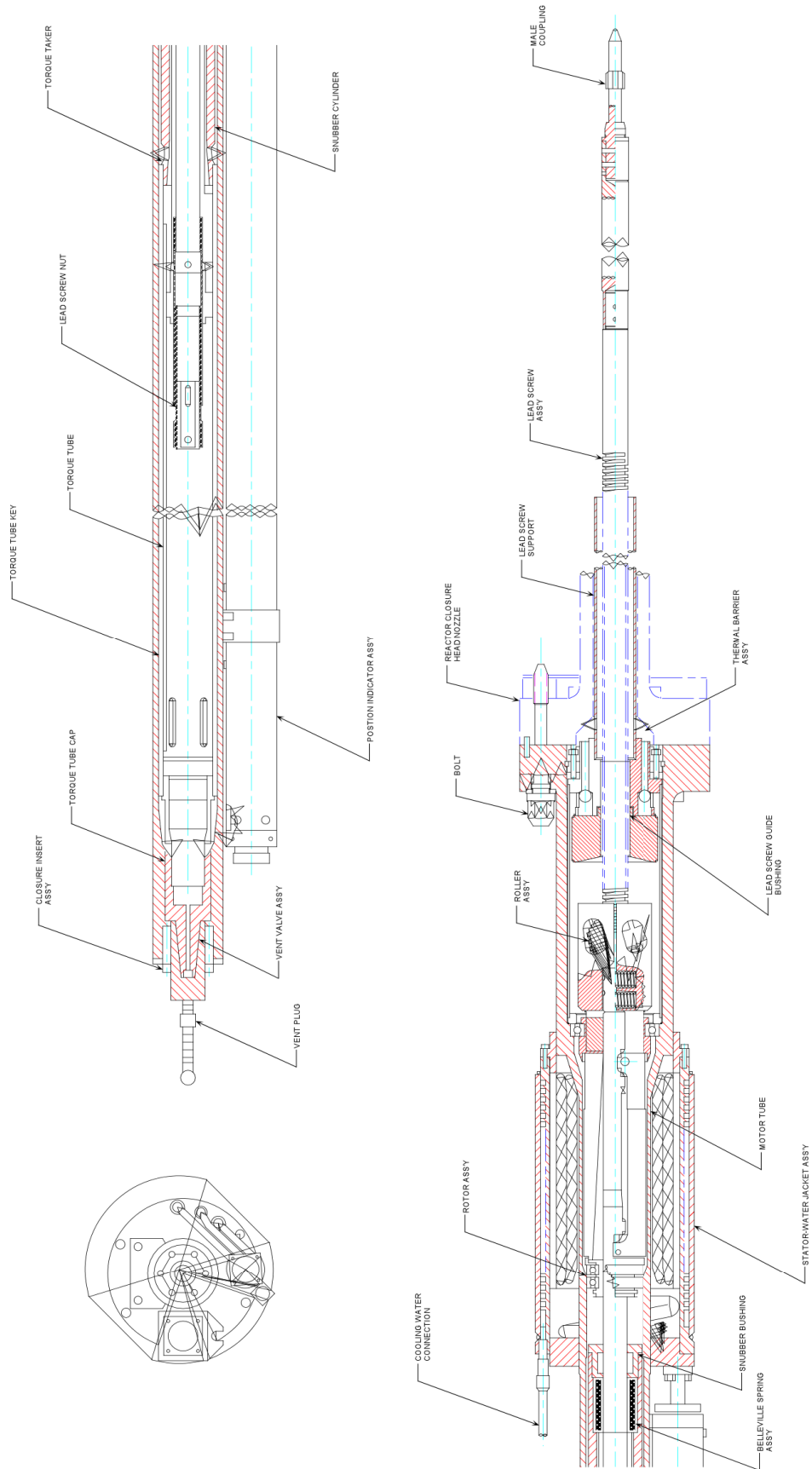


Figure 6.1-2 Control Rod Drive Mechanism Cross Section

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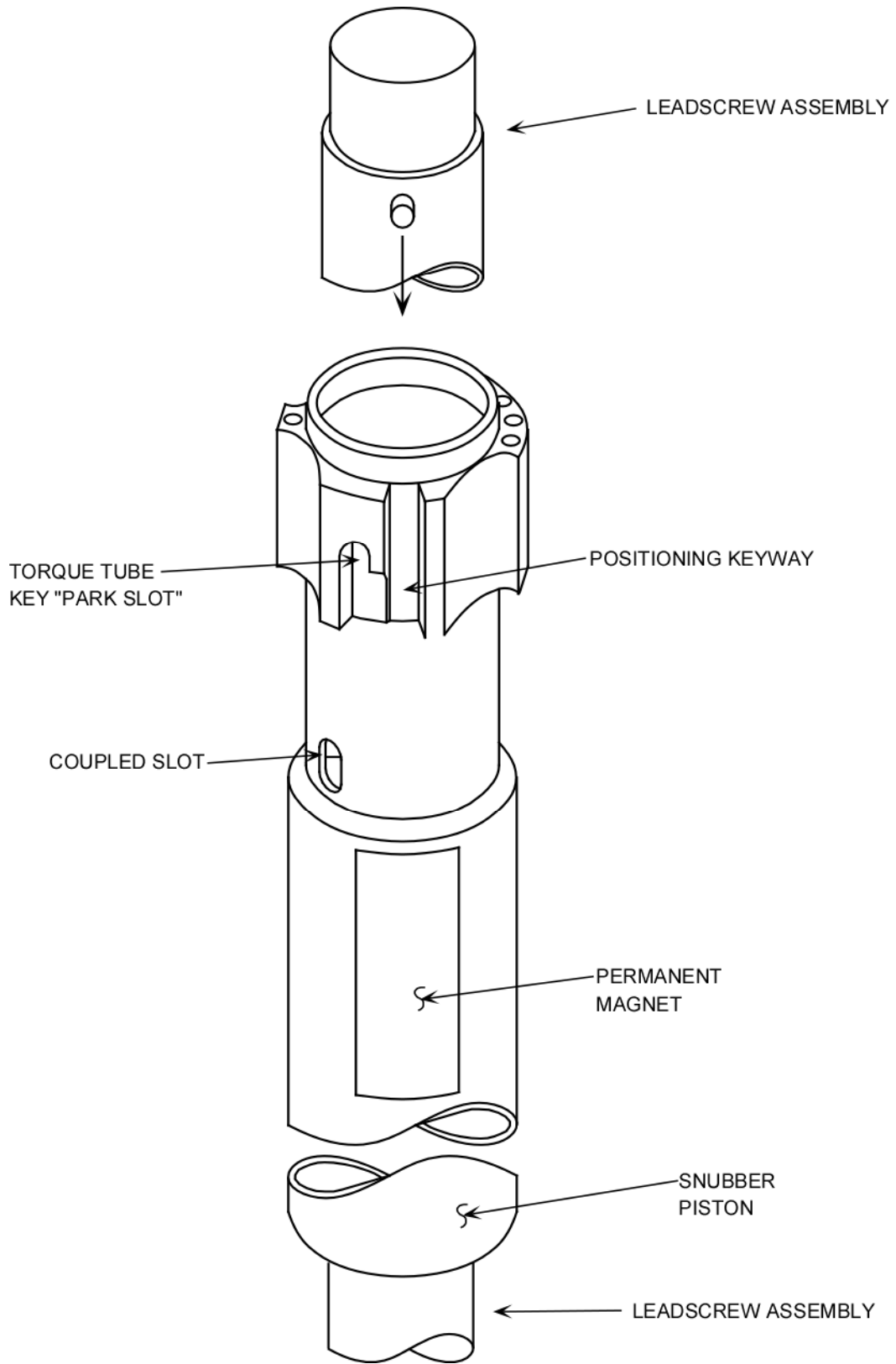


Figure 6.1-3 Torque Taker Assembly

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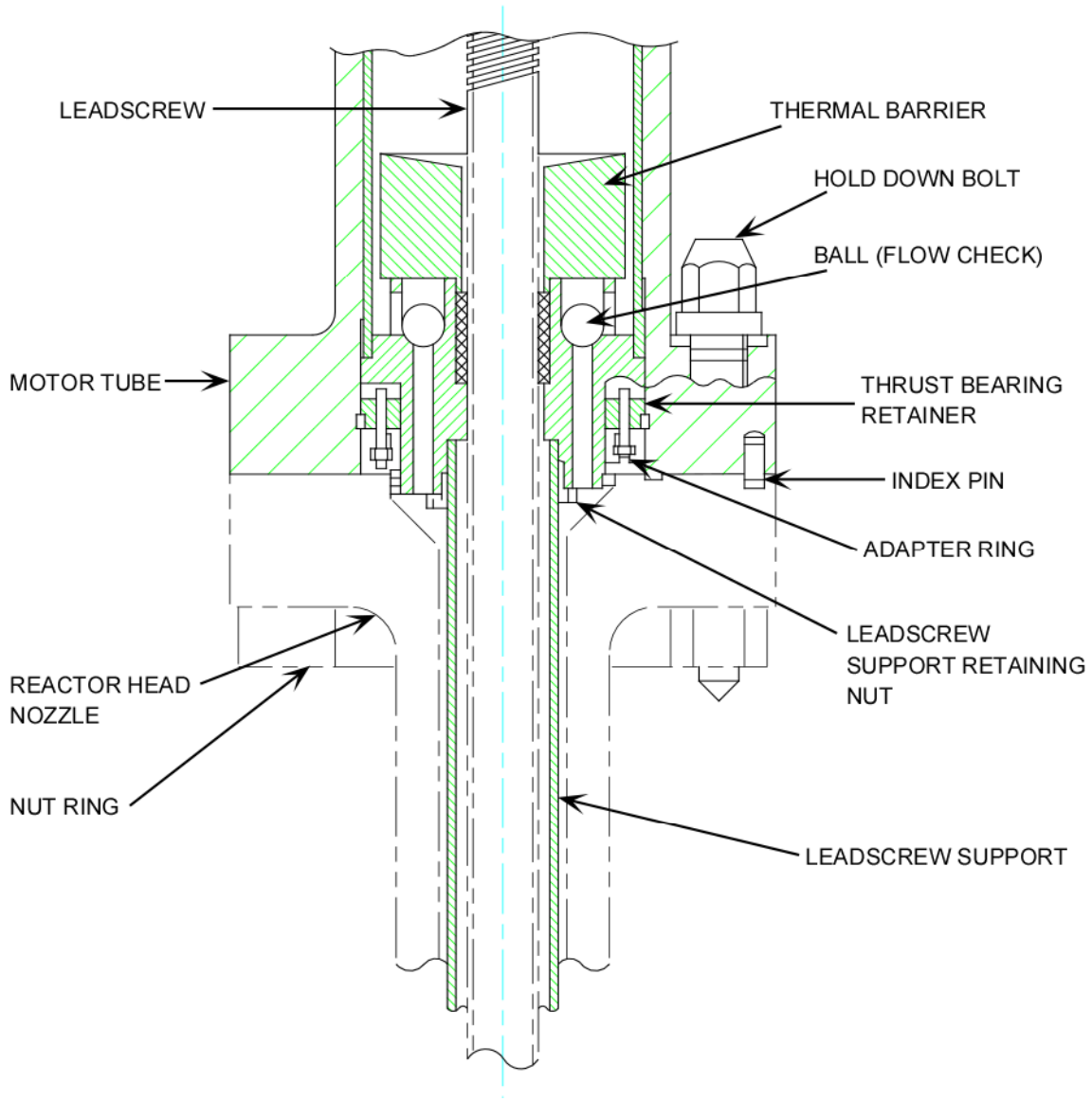


Figure 6.1-4 Leadscrew Guide Assembly

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