BABCOCK & WILCOX CROSS TRAINING COURSE LESSON PLAN		
Lesson Number: 326-6.1	Title: Control Rod Drive Mechanism - Construction	
Written By: Bobby R. Eaton	Approved By:	Date: 10/15/1998

3.0 Learning Objectives

3.1 List the two types of control rod drive mechanisms.
3.2 Explain the functions of the following:
- 3.2.1 Rotor assembly,
- 3.2.2 Leadscrew,
- 3.2.3 Torque taker,
- 3.2.4 Snubber assembly, and
- 3.2.5 Leadscrew guide assembly.

3.3 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.

4.0 Presentation

Figure 1-1 and Figure 1-2

4.1 Major Components

- 4.1.1 Motor tube assembly
- 4.1.2 Leadscrew assembly
- 4.1.3 Torque tube assembly
- 4.1.4 Rotor assembly
- 4.1.5 Stator cooling water jacket assembly

4.2 Motor Tube Assembly

- 4.2.1 Part of the RCS pressure boundary and is designed for 2500 psig and 670°F. It is hydro tested to 3125 psig.
- 4.2.2 Motor tube assembly can be divided into four sections:
  - 4.2.2.1 Motor tube base
  - 4.2.2.2 Motor tube center section
  - 4.2.2.3 Motor tube extension
  - 4.2.2.4 Motor tube extension cap
- 4.2.3 The bottom of the motor tube base is bolted to the control rod drive flange on the top of the reactor vessel using 8 bolts and a locating pin to ensure alignment.
- 4.2.4 Two concentric flexitallic gaskets are used to seal the mating flanges.
- 4.2.5 The motor tube is constructed of 304 stainless steel with the exception of the motor tube center section, where the control rod drive stator is mounted, and this area is constructed of 403 magnetic stainless steel.

4.2.6 The motor tube center section provides mounting for the control rod drive stator.
- 4.2.6.1 The control rod drive stator is a 4-pole, six phase, reluctance stepping motor.
- 4.2.6.2 Electrical rating is 125 Vdc, 8 amps per coil in the holding mode of operation.

4.2.7 The control rod drive motor stator is surrounded by a cooling water jacket that cools the stator.
- 4.2.7.1 Control rod drive cooling water system
- 4.2.7.2 Minimum of 2 gpm per stator
- 4.2.7.3 CRD stator temperature alarms on the PMIS
- 4.2.7.4 If stator temperature exceeds 180°F, the control rod drive must be de-energized.

4.2.8 Motor tube extension provides for leadscrew travel

4.2.9 Motor tube extension cap closes the motor tube
- 4.2.9.1 Cap is threaded into the top of the motor tube
- 4.2.9.2 Jacking screws and an o-ring are used to seal the assembly
- 4.2.9.3 Vent plug allows the venting of the control rod drives. Tygon tubing from the vent assembly to waste gas system or poly bottle.

4.3 Leadscrew

4.3.1 The leadscrew assembly is the connecting link between the control rod spider and the motor rotor assembly.

4.3.2 The leadscrew passes through the torque tube, the rotor assembly, and the thermal barrier assembly.

4.3.3 The leadscrew assembly is comprised of:
- 4.3.3.1 Male coupling
- 4.3.3.2 Lower extension
- 4.3.3.3 Leadscrew
- 4.3.3.4 Upper extension
- 4.3.3.5 Three locking sleeves

4.3.4 Male coupling
- 4.3.4.1 Inserted into the control rod drive hub and turned 45° to ensure engagement.
- 4.3.4.2 Male coupling length of the APSR (6.08") is shorter than the male coupling length of a control rod (6.21") to ensure that an APSR is not coupled to a control rod and vice versa.

4.3.5 Lower extension - an unthreaded section of the leadscrew that runs from the male coupling to the leadscrew section

4.3.6 Leadscrew - contains threads that mate with the roller nuts on the rotor segment arms

4.3.7 Upper extension - an unthreaded section of the leadscrew that runs from the leadscrew section to the top of the leadscrew assembly. The upper extension contains:

- 4.3.7.1 Torque taker
- 4.3.7.2 Position indication magnet
- 4.3.7.3 "Buffer" piston

4.3.8 Torque taker - coupled directly to the leadscrew upper extension and rides on the torque tube key preventing rotary motion of the leadscrew.

4.3.9 The position indication magnet is incorporated in one side of the torque taker to operate the reed switches

4.3.10 The buffer piston or snubber assembly is designed to decelerate the leadscrew near the full in position during a trip condition.

4.3.11 There are three locking sleeves installed on the leadscrew assembly

- 4.3.11.1 One between the male coupling and the lower extension
- 4.3.11.2 One between the lower extension and the leadscrew
- 4.3.11.3 One between the leadscrew and the upper extension
- 4.3.11.4 The leadscrew assembly is about 303" long.

4.4 Rotor Assembly

4.4.1 Rotor assembly components

- 4.4.1.1 Rotor tube
- 4.4.1.2 Segment arms
- 4.4.1.3 Roller nuts
- 4.4.1.4 Radial bearing
- 4.4.1.5 Synchronizing bearing
- 4.4.1.6 Thrust bearing
- 4.4.1.7 Segment arm springs
- 4.4.1.8 Pivot pins

4.4.2 Rotor tube

4.4.2.1 The whole rotor assembly is called the rotor tube

4.4.2.2 A journal bearing is located at the top of the rotor tube

4.4.2.3 A journal bearing is located at the bottom of the rotor tube

4.4.2.4 The thrust bearing is also located at the bottom of the rotor tube

4.4.2.5 The upper end of the rotor tube incorporates a segment arm stop (lipped flange). The stop ensures proper clearance between the segment arms and the motor tube wall.

4.4.3 Segment arms

4.4.3.1 Mounted on rotor tube by four pivot pins - allowing them to rotate with and pivot on the rotor tube

4.4.3.2 The upper portion of the segment arms forms a 4-pole collapsible motor rotor

4.4.3.3 The lower portion of the segment arms is a collapsible split nut designed to latch, drive, and unlatch the leadscrew

4.4.3.4 Buttons on the bottom of the APSR's segment arms prevent disengagement when the reactor is tripped.

4.4.4 Four compression springs hold the roller nuts disengaged from the leadscrew. To engage the leadscrew, a force greater than the spring force must be applied to the segment arms by the motor's magnetic field.

4.5 Torque Tube

4.5.1 The torque tube is a cylinder approximately 151 inches long and 3-3/8" in diameter located on the inside of the motor tube.

4.5.2 A key runs the entire length of the torque tube and mates with the key way of the leadscrew assembly

4.5.3 Belleville springs located at the bottom of the torque tube cushions the leadscrew on a trip

4.5.4 The torque tube also plays a part in the uncoupling of the rod during refueling

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4.6 Thermal Barrier

Four spring check valves that will restrict the flow of coolant from the RCS into the drive housing and relieve the pressure drop created within the drive during a trip condition.

5.0 Operations

5.1 Latching

- 5.1.1 All trip signals are cleared
- 5.1.2 Trip breakers are closed
- 5.1.3 Control rod drives are inserted in JOG speed to ensure that the lands of the roller nuts are properly engaged

5.2 Reactor trip

- 5.2.1 Control rod drive motor is de-energized by the opening of the trip circuit breakers
- 5.2.2 Springs in segment arms overcome the collapsing magnetic field - the roller nuts disengage from the leadscrew and the leadscrew is free to drop
- 5.2.3 The leadscrew is decelerated by the action of the snubber and comes to rest on the Belleville springs
- 5.2.4 The hydraulic lock of the leadscrew is relieved by the spring check valves in the thermal barrier

BABCOCK & WILCOX CROSS TRAINING COURSE LESSON PLAN		
Lesson Number: 326-6.2	Title: Control Rod Drive Control System	
Written By: Bobby R. Eaton	Approved By:	Date: 10/19/1998

Figure 1-1
and
Figure 1-2

3.0 Learning Objectives

3.1 State the purpose of the control rod drive control system.
3.2 State the functions of the following:
- 3.2.1 Safety rods,
- 3.2.2 Regulating rods,
- 3.2.3 Axial power shaping rods,,
- 3.2.4 Group power supply, and
- 3.2.5 Auxiliary power supply.

3.3 Explain how rotating motion of the control rod drive mechanism is achieved.
3.4 Explain the following terms:
- 3.4.1 Latching and
- 3.4.2 Clamping

3.5 Explain how individual rod motion is achieved.
3.6 Describe how power is supplied to the control rod drive mechanism.

4.0 Presentation

4.1 Description

- 4.1.1 Function is to provide for withdrawal/insertion of control rods to achieve the desired reactor power output.
  - 4.1.1.1 In auto, controlled by the ICS
  - 4.1.1.2 Can be controlled manually by the operator.
- 4.1.2 68 control rod assemblies and 8 axial power shaping rods
  - 4.1.2.1 Groups 1 - 4 are the safety rods
  - 4.1.2.2 Groups 5 - 7 are the control rods
  - 4.1.2.3 Group 8 is the APSR
- 4.1.3 The control rod drive control system consists of three subsystems:
  - 4.1.3.1 The drive mechanism,
  - 4.1.3.2 The motor control system, and
  - 4.1.3.3 The system logic equipment.

BABCOCK & WILCOX CROSS TRAINING COURSE LESSON PLAN		
Lesson Number: 326-6.2	Title: Control Rod Drive Control System	
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	4.2 The Drive Mechanism
	4.2.1 4-pole (2 north and 2 south when power is supplied to the mechanism), 6-phase (A, B, C, AA, BB, & CC make up 12 poles with the A & AA, B & BB, and C & CC in same location but electrically wired opposite so that if they are both energized, they cancel each other's magnetic fields out) reluctance type motor
	4.2.2 Power supplied to each winding is 100 Vdc (rectified from 120 Vac)
	4.2.2.1 For latching, 2 phases are used even though only one is required
	4.2.2.2 For holding rods stationary, a maximum of two phases are used due to potential heat damage to the stator
Leadscrew moves 3/4 " for each revolution Leadscrew travels 30 inches per minute or at 40 mechanical revolutions per minute	4.2.3 Rotation is accomplished by energized the phases in a 2 then 3 then 2 then 3, etc. sequence. Each shift is equal to 15° shift of the magnetic pole and a 15° rotation of the mechanism. Need 2 electrical rotations for 1 mechanical rotation.
	4.2.4 Removing power from the windings results in the segment arms disengaging the leadscrew dropping the rod into the core
	4.2.4.1 Loss of one phase during rod motion can also cause a dropped rod, for example the loss of C phase
	4.3 Motor Control System
Differential changes program motors from 60 to 40 rpm and from 6 to 4 rpm. Slotted disk rotates at 40 and 4 rpm	4.3.1 The programmed power supply uses two drive motors, one 60 rpm (30 inches per minute for run) and one 6 rpm (3 inches per minute for jog) which are coupled to an optical disk
	4.3.2 The optical disk has redundant light sources and redundant photo-detectors. Each set of photo-detectors has one detector for each phase and one for the 3-2 hold circuit. Output of photo-detector drives a relay that closes a contact in a 12 Vdc gate drive circuit. This turns on the SCRs to rectify the 120 Vac to 100 Vdc.
	4.3.3 If rotation stops on 3 phases energized, the 7th photo-detector will jog in to 2 phases energized

4.3.4 Power is supplied from two plant sources through ac trip breakers (A & B). UV coils powered from RPS channels A & B.

4.3.5 DC power is supplied to A & CC phases of the safety rods. Only one needs to be energized to hold the rods. DC breakers are tripped by RPS channels C & D.

4.3.6 AC power is also supplied to the regulating rod power supplies and the auxiliary power supply.

4.3.6.1 Aux power supply can be used to move any individual rod or any group of rods.

4.3.6.2 Removing power from programming lamps will remove power from the rods. Power is supplied through contactors E & F, which are controlled by RPS channels C & D.

4.4 Reactor Trip

4.4.1 In order to cause a reactor trip, must open one of the two breakers in each power supply (for example, A & D, A & B, C & D, or C & B). The contactors are considered as opening when the associated C & D breakers open.

4.5 Rod Operation

Rods are divided into 8 groups, 4 safety rods, 3 regulating rods, and one APSRs. Regulating rods are operated with 25% overlap.

4.6 Control Panel

4.6.1 Discuss the basics of the control panel and Table 6.2-2

4.7 Latching Operations

Latching is accomplished by selecting a group of rods to be moved, bypassing the in limit, and inserting at jog speed for 30 seconds.

4.8 Power supply transfer

BABCOCK & WILCOX CROSS TRAINING COURSE LESSON PLAN		
Lesson Number: 326-6.3	Title: Control Rod Position Indication	
Written By: Bobby R. Eaton	Approved By:	Date: 10/20/1998

3.0 Learning Objectives

3.1 State the purposes of the control rod position indication systems.
3.2 Explain the two methods used to determine control rod position.
3.3 Explain how the two rod position indication systems are used in the following:
- 3.3.1 Asymmetric rod determination,
- 3.3.2 In, out limits,
- 3.3.3 Regulating group sequence enabling,
- 3.3.4 Inhibit circuits, and
- 3.3.5 Sequence monitoring.

4.0 Presentation

4.1 General Description

Two methods of rod position indication are absolute position and relative position.

4.2 Absolute Position Indication

- 4.2.1 Absolute position uses 72 high differential reed switches located 2" apart and the signal goes through a voltage divider network. The reed switches are operated by a permanent magnet on the torque taker.
- 4.2.2 Two channel averaging used 48 switches. They operated in a 2-1-2-1 open-close sequence. Failed reed switch when in the 1 close condition would cause an asymmetric rod runback to 60% power because it looked like a dropped rod, and there was no bypass capability.
- 4.2.3 Four channel averaging uses the 72 switches on 2 pc boards of 36 switches each divided into the 4 channels. The output of the 4 channels are average for indication. The channels are isolable, so can operate on 3 channels. With all channels, switches close in a 3-2-3-2 sequence. Normal accuracy is 2.62 inches, with a switch failed open the accuracy is 3.56 inches, and with one channel in bypass the accuracy is 3.69 inches.
- 4.2.4 Reference switches are at IN LIMIT, 0%, 25%, 50%, 75%, 100%, and OUT LIMIT. First rod in a group to reach in or out limit stops all rods in the group.

4.3.4 Power is supplied from two plant sources through ac trip breakers (A & B). UV coils powered from RPS channels A & B.

4.3.5 DC power is supplied to A & CC phases of the safety rods. Only one needs to be energized to hold the rods. DC breakers are tripped by RPS channels C & D.

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4.3 Relative Position Indication

Pulse stepping motor connected in parallel with the A, C, & BB phases of power to each mechanism. As the phases are energized, the motor drives a potentiometer which provides indication of rod position. Shows demanded rod position and does not show dropped or misaligned rods. A method of manually adjusting the relative position is provided.

4.4 Position Indication Panel

Discuss the indications and controls on the position indication panel.

4.5 Group Meters

Provides indication of the average of the groups API on four meters. Selected by the pushbutton on the diamond station for regulating rods or for safety rods.

5.0 Operations

5.1 Uses of API

5.1.1 Asymmetric Rod - Each rod position is compared to the average for the group. If more than 5% apart, get asymmetric alarm, if more than 6.5% apart, get fault light on diamond and runback to 60%. Show how a dropped rod gives asymmetric light on all rods in the group.

5.1.2 Group out limits - comes from out reference switch and prevents any further out motion for the group.

5.1.3 Group in limits - comes from in reference switch and prevents any further in motion for the group. Can be bypassed by in limit bypass switch on diamond station for latching.

5.1.4 Inhibit circuits

5.1.5 Sequence enable logic

5.1.6 Feed and bleed permit

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	5.2 Applications of Relative Position Indication Sequence monitor looks for too much overlap.	