



Reed Research  
Reactor

# Control Rods

SOP  
**34**

Standard  
Operating  
Procedure

## Revision History

### December 17, 2020

- Clarified where to find Multitrend password.
- Updated where BNC cable for period timer cal is located.
- Updated where rodcal.py program is located.
- Clarified what to do with banked rod height tables.
- Added clarifying steps in the calibrating auto demand section.
- Minor clarifications.

### July 29, 2019

- Clarified instructions for limit switch adjustment.
- Clarified where BNC-banana plug is located.
- Changed rod calibration so that Safe and Shim are done separately.
- Clarified how to run the rodcal.py program.

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### 34.1 Scope

34.1.1 This procedure covers the calibration and maintenance of the control rods.

### 34.2 Schedule

34.2.1 Each of the three control rods shall be visually inspected at least once every two years, usually during the January annual maintenance. [TS 4.2b]

34.2.2 The control rod drives shall be visually inspected at least once every year, usually during the January annual maintenance. [TS 4.2a]

34.2.3 Control rod worth measurement shall be done semiannually, following any inspection or handling of fuel elements or control rods (SOP 34 or SOP 35), and following any core configuration change. Worth measurements may be done at other times at the discretion of the Operations Supervisor. [Required annually by TS 4.2d]

34.2.4 Control rod drop times shall be measured semiannually. [Required annually by TS 4.2c]

34.2.5 Adjusting the rod position indication may be necessary following maintenance on the limit switches or the position indication.

34.2.6 The console buttons are cleaned as part of the Annual Checklist.

34.2.7 Auto Demand is calibrated as part of the Semiannual Checklist.

### 34.3 Personnel

34.3.1 During control rod operation, removal, or calibration the reactor is not secured; therefore:

- A licensed operator must be at the console.
- A second person, who can summon help, must be in the facility.
- An SRO must be on duty.

34.3.2 During control rod maintenance the SRO of Record must be present in the facility.

34.3.3 Before working with radioactive material, individuals must be RAM Handling Certified.

- In this procedure, RAM Handling Certification is required to handle control rods for control rod inspection.
- Non-certified individuals may perform all parts of the procedure up to the physical removal of the control rod from the core.

### 34.4 Precautions

34.4.1 The circuit boards on the control rod motors are exposed and energized. Some maintenance requires the use of metal tools, so be careful to avoid electric shock.

**34.5 OPERATION**

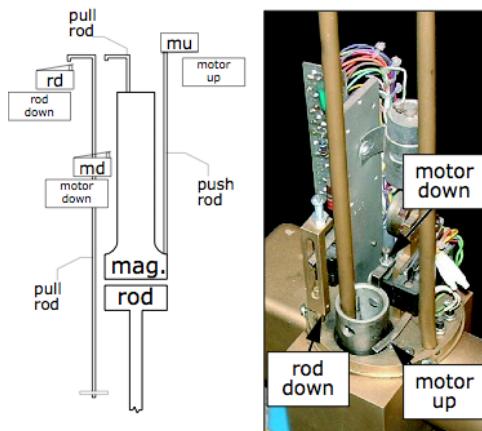
See SOP 1 (Reactor Operation) and SOP 20 (Startup Checklist).

## 34.6 MAINTENANCE

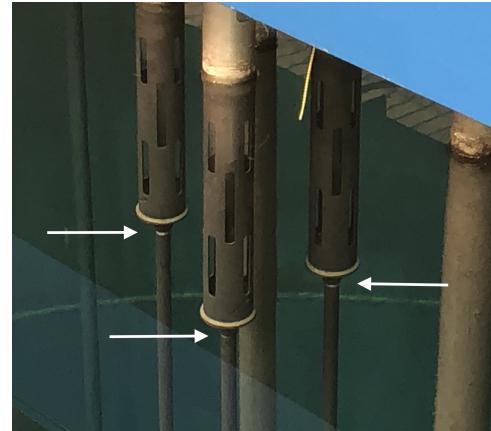
### 34.6.1 Adjusting the Limit Switches

34.6.1.1 This procedure requires at least two people: the Operator of Record at the console and someone in the Reactor Bay to diagnose the problem and make adjustments. The reactor is not shutdown during this procedure, so also follow the staffing requirements in SOP 1. The SRO of Record must be present for this control rod maintenance.

34.6.1.2 Walkie-talkies are useful for communication.



*Limit Switches*



*Rings on Control Rods*

34.6.1.3 First ensure the motor moves in far enough to contact the control rod armature; if there's a gap between the electromagnet and the armature, the motor won't be able to raise the control rod.

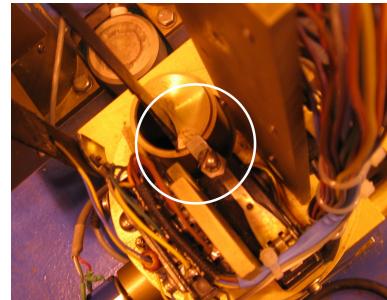
34.6.1.4 Manually raise the rod. Watch the control rod in the Reactor Bay to see if the light-colored ring under the water disappears as it moves up into the shroud. If the rod withdraws normally, go to §34.6.1.6.

34.6.1.5 If the rod does not withdraw, lower the motor until it stops. Turn the screw on the motor down limit switch (pictured below) counterclockwise until the motor down limit switch clears. You will hear a click.

- Raise the rod. If the rod does not withdraw, drive the motor down until it stops.
- Repeat from §34.6.1.4 until the rod withdraws freely.



*Motor Down Limit Switch*



*Motor Down Limit Switch*

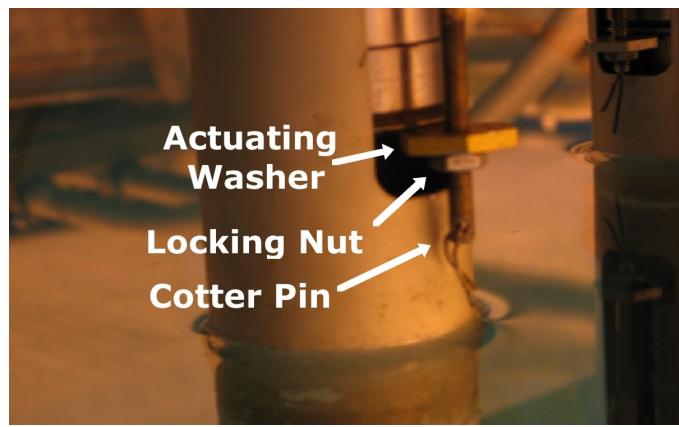
34.6.1.6 Now ensure that the rod down limit switch works on a scram.

- Raise and scram the rod. Ensure the motor drives in automatically after the scram.
- If it does not drive in, use a 3/8" wrench to loosen the locking nut on the rod down limit switch. Be careful because the circuit board on the rod is exposed and is energized.



Rod Down Limit Switch

- Turn the screw on the rod down limit switch clockwise a quarter turn.
- Raise the rod and scram it again.
- Repeat as necessary.
- If you run out of room on the screw on the rod down limit switch, you may have to reach under the bridge and adjust the washers at the bottom of the pull rod. Loosen the nut and actuating washer (located a few inches above the water) on the pull rod. You will have to lean over the pull to do this. It may be necessary to tighten the actuating washer a bit in order to get at the nut. You should be able to do it all with your fingers. Adjust the height of the washers to provide more room on the rod down limit switch screw.



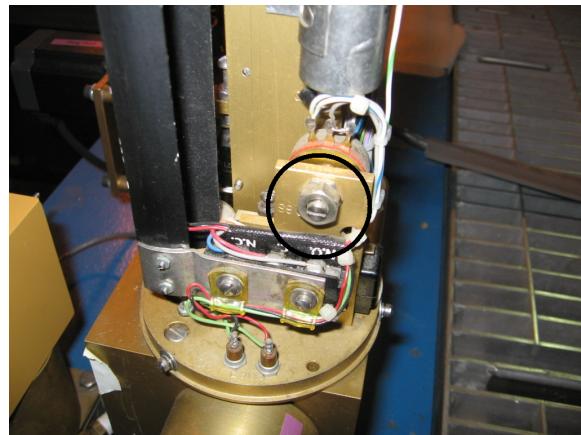
Pull Rod Bottom

34.6.1.7 Now make sure the rod and motor will withdraw properly. Repeat these steps until the rod withdraws and scrams properly.

- 34.6.1.8 Tighten the Rod Down locking nut.
- 34.6.1.9 Log the limit switch adjustment in the Main Logbook and the Maintenance Logbook.

### 34.6.2 Adjusting the Balancing Potentiometer

- 34.6.2.1 The Up Motor and the Down Motor on the Safety and Shim Rods are balanced to hold the rod in place when there is no signal to move it. Sometimes the motor becomes unbalanced. This is indicated by the motor creeping up or down when there is no demand signal. This procedure will explain how to rebalance the motors.
- 34.6.2.2 An SRO must be present for any control rod maintenance.
- 34.6.2.3 The balancing potentiometer is on the top of the control rod motor. The Reg Rod does not have a balancing potentiometer since it has been replaced with a stepping motor.



*Rod Balancing Potentiometer*

- 34.6.2.4 Partially withdraw the rod needing adjustment. You must have the scamps reset and the control rod attached to the motor to correctly adjust the rod since the weight on the motor is different without the control rod attached.
- 34.6.2.5 With the rod and motor partially withdrawn, observe which way the motor is creeping. Loosen the locking nut on the potentiometer. Turn the balancing potentiometer clockwise to stop downward motion or turn it counterclockwise to stop upward motion.
- 34.6.2.6 When the rod no longer creeps, scram the rod to make sure it behaves properly on a scram. Repeat these steps as necessary.
- 34.6.2.7 Log the balancing potentiometer adjustment in the Main Logbook and the Maintenance Logbook.

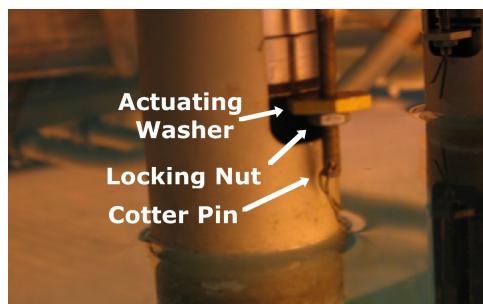
### 34.6.3 Replacing a Control Rod Motor

- 34.6.3.1 Before replacing a control rod motor, perform SOP 62 (Changes, Tests, and Experiments) to see if a safety evaluation is necessary.
- 34.6.3.2 While removing the control rod motor, the reactor is not shutdown so a licensed operator must be at the console and a second person in the facility.
- 34.6.3.3 An SRO must be present for any control rod maintenance.
- 34.6.3.4 Unplug all three console-to-rod-drive motor plugs inside the console: J-7 (Reg Rod), J-8 (Shim Rod), and J-10 (Safety Rod). The rod UP and DOWN lights will come on when this is done.
- 34.6.3.5 For the Reg Rod, also unplug the 36-pin Centronics parallel connector behind the north panel of the console.



*Rod Plugs J-7, J-8, J-10*

- 34.6.3.6 Remove the rod-down actuator cotter pin, nut, and actuating washer (located a few inches above the water) from the pull rod. You will have to lean over the pool to do this. Be careful not to drop them. The cotter pin is really a paper clip that has to be unbent before removing it from the small hole at the bottom of the pull rod. The nut and actuating washer unscrew as normal. It may be necessary to tighten the actuating washer a bit in order to loosen and get at the nut. You should be able to do it all with your fingers.



*Pull Rod Bottom*

- 34.6.3.7 Unplug the position indication for the rod being removed. It is at the potentiometer at the side of the motor.



*Rod Position Connection*

- 34.6.3.8 For the regulating rod only, unplug the motor power supply next to the motor.



*Reg Rod Power Connection*

- 34.6.3.9 Remove the small Allen head 3/32-inch screws from the upper edge of each base mount. There are screws on four locations around the rod motor, approximately 90° apart. Two locations have two screws; two have only one screw. Note that you only have to remove the top screw of the pair. The bottom one holds the control rod housing (which is not being removed).



*Two Allen-Head Screws*

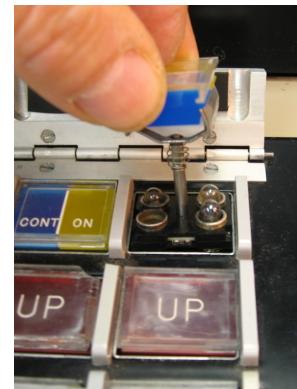
- 34.6.3.10 Lift the rod motor off. The control rod and barrel should not move. The pull rod will come up through its opening.
- 34.6.3.11 Install the new rod motor on the rod motor mount. You'll need to guide the pull rod into its opening. (You may also have to transfer the pull rod from the old motor to the new motor if the new one doesn't have a pull rod.)
- 34.6.3.12 Install the small Allen head 3/32-inch screws in the upper edge of each base mount.
- 34.6.3.13 Reinstall the rod-down actuator cotter pin, nut, and actuating washer (located a few inches above the water) from the pull rod. You will have to lean over the pool to do this; be careful not to drop them.
- 34.6.3.14 Plug in the position indication for the rod.
- 34.6.3.15 For the regulating rod only, plug in the motor power supply.
- 34.6.3.16 Reconnect all three console to rod drive motor plugs inside the console: J-7, J-8, and J-10.
- 34.6.3.17 Adjust the screws on the limit switches per §34.6.1 until the micro-switches work properly when scamming the rod.
- 34.6.3.18 Check the rod by raising it a short distance and then releasing it by a scram.
- 34.6.3.19 Check the top and bottom position indications per §34.7.2.
- 34.6.3.20 Check the rod travel time by raising and lowering the control rod full travel.
- 34.6.3.21 Log the control rod motor replacement in the Main Logbook and the Maintenance Logbook. Include the model and serial number of both the old motor and the new motor in the Maintenance Logbook entry.

#### **34.6.4 Replacing a Console Light Bulb**

- 34.6.4.1 Anyone designated by the Operations Supervisor may perform this procedure.
  - This does not count as maintenance of a reactor control system, so the presence of an SRO is not required.
- 34.6.4.2 Turn console power off and record this in the Main Logbook.
- 34.6.4.3 To replace a light bulb, start by lifting straight up on the console button. It comes out partway and then stops.

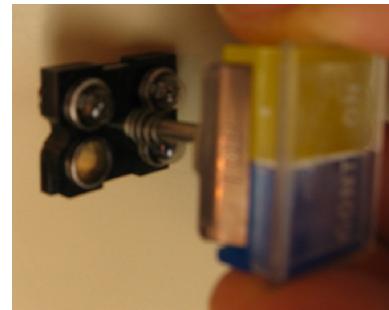


Button up partway



Button fully out

- 34.6.4.4 Turn the top of the button 90° clockwise to release it, and then pull it the rest of the way out.
- 34.6.4.5 Remove the burnt out bulb and replace it with a 381 bulb, normally kept in the classroom.
- 34.6.4.6 With the button top still at 90° to the base, reinsert it in the opening. Note that the small notch on the base must be on the left side to fit in.



Notch on the left

- 34.6.4.7 Push down until the button stops, then turn it 90° counterclockwise and push it the rest of the way in.
- 34.6.4.8 Log the light bulb replacement in the Main Logbook and the Maintenance Logbook.

#### **34.6.5 Cleaning Console Buttons and Switches**

- 34.6.5.1 Anyone designated by the Operations Supervisor may perform this procedure.
  - This does not count as maintenance of a reactor control system, so the presence of an SRO is not required.
  - A licensed operator, SRO of record, and second person in the facility will be needed to insert the console key.
- 34.6.5.2 Open CB-1 inside the back of the console and log it in the Main Logbook.

- 34.6.5.3 Gently pry up the console POWER button until it comes out, and then rotate it by 90° counterclockwise so that the linkage to which it is attached, can also be withdrawn.
- 34.6.5.4 Use cotton swab or equivalent to clean the button housing of all oil and debris. The cotton swab may be dipped in alcohol, but the housing must be left dry.
- 34.6.5.5 Use a dry lubricant on the linkage shaft where it passes through the bushing.
- 34.6.5.6 Inspect the spring for integrity.
- 34.6.5.7 Lock the shaft into the light-socket assembly, and re-install the entire mechanical linkage into its housing. Note that it will insert in only one orientation.
- 34.6.5.8 Test to see that the button depresses and returns easily.
- 34.6.5.9 Repeat §34.6.5.3 through §34.6.5.8 for the following buttons:
  - Safety CONT/ON
  - Safety UP
  - Safety DOWN
  - Shim CONT/ON
  - Shim UP, Shim DOWN
  - Reg CONT/ON
  - Reg UP
  - Reg DOWN.
- 34.6.5.10 Add a small amount of dry lubricant to the console key switch and rotate the key through all its positions a few times to ensure easy operation. Log this in the Main Logbook.
- 34.6.5.11 If the key does not rotate easily, remove the two screws that hold the control console in place and lubricate the internal workings of the key switch. Rotate the key through all its positions a few times to ensure easy operation. Screw the control console back into place.
- 34.6.5.12 Close CB-1 inside the back of the console and log it in the Main Logbook.
- 34.6.5.13 If this procedure was done for the Annual Checklist, record the date on the Checklist form. Otherwise, log this maintenance in the Main Logbook and the Maintenance Logbook.

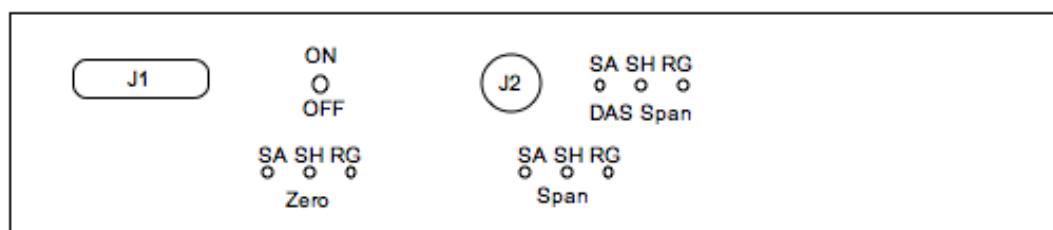
**34.7 CALIBRATION AND INSPECTION****34.7.1 Control Rod Calibration**

- 34.7.1.1 This procedure describes how to perform the semiannual control rod calibration. The calibration includes:
- Adjusting the control rod position indications on the console and Multitrend.
  - Measuring control rod drop times, withdrawal times and insertion times.
  - Measuring control rod reactivity worth.
- 34.7.1.2 Use the date stamp (or print very neatly) to enter the date on SOP 34A, Control Rod Calibration Form.
- 34.7.1.3 Record the names of the checkers. It will take several hours to complete the calibration, and the different parts may be spread over multiple days. Each person who participates in any part of the calibration should add his or her name to the list at the beginning of the form.
- 34.7.1.4 Adjust the rod position indications per §34.7.2. This must be done before the reactivity worth measurement. Record the “as found” and “as left” data on SOP 34A.
- 34.7.1.5 Use a stopwatch to measure the time it takes each rod to travel from bottom to top, and from top to bottom (this is measured using the motor UP and motor DOWN lights). Record each value on SOP 34A. It may be convenient to perform these measurements while adjusting the rod position indications.
- 34.7.1.6 Measure the control rod drop times per §34.7.3 and record the values on SOP 34A. This may be done before or after the worth measurement.
- 34.7.1.7 Measure the control rod reactivity worth per §34.7.4.
- 34.7.1.8 Leave the completed form on the hanging Supervisor’s Clipboard for the Operations Supervisor to review.
- 34.7.1.9 If the calibration is being performed for the Semiannual Checklist, initial and date the appropriate line of the checklist.
- 34.7.1.10 After review, the Operations Supervisor will file the Control Rod Calibration Form in the Other Checklists binder in the Control Room.

**34.7.2 Adjusting the Rod Position Indication**

- 34.7.2.1 This procedure describes how to calibrate the control rod position indications on the console and Multitrend. This must be done before performing a control rod reactivity worth measurement per §34.7.4, and may be done at other times at the discretion of the Operations Supervisor.

- 34.7.2.2 The limit switches on the bridge control the rod motion. They must be correct before adjusting the position indication. If the limit switches need adjustment, see §34.6.1.
- 34.7.2.3 The position indications are adjusted with a small slot screw driver on the potentiometers in back of the rod position indication inside the console. Clockwise increases the value, counter-clockwise decreases it. There are three adjustments for each rod: zero, span, and DAS Span (Multitrend). The rods are abbreviated SA (safety), SH (shim), and RG (reg).



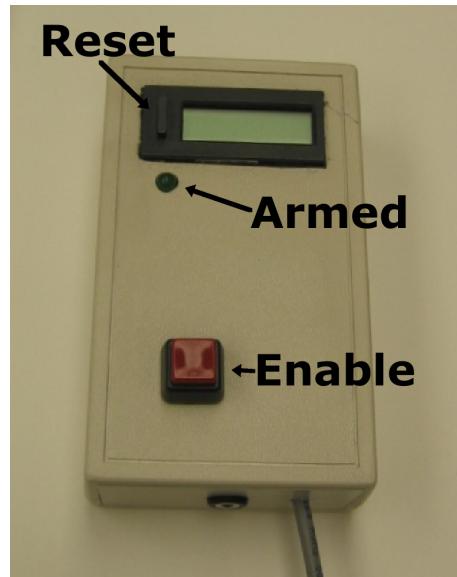
- 34.7.2.4 If this is part of a control rod calibration, record the information on SOP 34A. Otherwise record it in the Main Logbook and Maintenance Logbook.
- 34.7.2.5 Leave two control rods on the bottom at all times during this adjustment.
- 34.7.2.6 Drive the control rods all way down (the DOWN light on).
- 34.7.2.7 Record the “as found” bottom position indication for each rod from the position indication and the Multitrend indication.
- 34.7.2.8 Drive ONE control rod all way up (the UP light on).
- 34.7.2.9 Record the “as found” top position indication for the rod from the rod position indication and the Multitrend indication.
- 34.7.2.10 Adjust the span position indication for the rod to indicate between 99.5% and 100.5% (exactly 100.0% is best).

- 34.7.2.11 Adjust the DAS Span (Multitrend position indication) for the rod to indicate between 99.5% and 100.5% on the Multitrend (exactly 100.0% is best). Note that it may take several minutes for the Multitrend display to stabilize.
- 34.7.2.12 Drive the rod to the bottom.
- 34.7.2.13 Adjust the bottom position indication for the rod to indicate between 0.0% and positive 0.5% (exactly 0.0% is best).
- Note that there is no negative sign, so you need to turn the screw back and forth to determine if you are looking at positive or negative numbers.
  - Do not leave the value below 0.0% since the indication is not linear below 0.0%.
- 34.7.2.14 Adjust the Multitrend bottom position indication as follows, so that it indicates between 0.0% and positive 0.5% (exactly 0.0% is best):
- From the main screen of the Multitrend, Press “Menu” → “Configure”
    - If you are asked for name and password, log in using the username and password indicated on the Multitrend. Press “Configure” again after the password has been entered.
  - Press “Setup” → “Edit” → “Field IO” → “Analogue In”
  - Select the rod.
  - To make the rod position higher (more positive) you must make the lower limit number more negative and visa versa.
    - Changing the lower limit number by 0.1 VDC will change the display by 1%.
    - For example, assume the Multitrend rod position indicates 0.1% when the rod is actually at the bottom. You must make the lower limit number more positive by 0.01 VDC to reduce the display to 0.0%. So, if the lower limit reads -0.22 you will have to change it to -0.21.
  - Press “Finish”
  - Press “Commit” to accept the changes.
  - There will be a delay while it updates.
- 34.7.2.15 Drive the control rod all way up (the UP light on).
- 34.7.2.16 Adjust the span position indication for the rod to indicate between 99.5% and 100.5% (exactly 100.0% is best).
- 34.7.2.17 Adjust the DAS Span (Multitrend position indication) for the rod to indicate between 99.5% and 100.5% (exactly 100.0% is best).
- 34.7.2.18 Repeat §34.7.2.12 through §34.7.2.17 until the top and bottom are acceptable on the console position indication and on the Multitrend.

- 34.7.2.19 Record the “as left” bottom position indication for the rod from the position indication and the Multitrend indication.
- 34.7.2.20 Record the “as left” top position indication for the rod from the position indication and the Multitrend indication.
- 34.7.2.21 Repeat steps §34.7.2.8 through §34.7.2.20 for the other two control rods.

### 34.7.3 Control Rod Drop Time Measurement

- 34.7.3.1 Control rod drop times shall be verified to be less than one second semiannually and following removal of any control rod for maintenance or inspection [TS 4.2c]. Drop times may be measured at any time at the discretion of the Director.
- 34.7.3.2 To measure the control rod drop times manually:
  - This section shall be used if the Rod Drop Timer is considered non-operational or it is decided to manually measure the control rod drop times. If the electronic timer is to be used, go to §34.7.3.3.
  - The operator remains at the console as for normal operations with the two timers positioned in a way that they can easily view the control rod indicator lights. The operator will raise a single rod to its maximum height. The other two rods shall remain fully inserted.
  - The operator manually scrams the rod. The timers start their stopwatches when the yellow “on” light (Magnet Power) is extinguished and stop them when the blue “cont” light goes off. The yellow light indicates that the rod has been released and the blue light indicates when the rod-down switch has been closed (rod fully down in core).
  - Repeat for each control rod. Average the two times for each rod to get the final value for the drop time.
  - Go to §34.7.3.13
- 34.7.3.3 Get the Rod Drop Timer (pictured below) from its drawer in the Control Room under the AMS-4s. The Rod Drop Timer power supply is a 6V 200 mA AC adapter; it should be with the timer. Plug in the power supply transformer to the wall outlet and to the small plug at the base of the timer.



Rod Drop Timer

- 34.7.3.4 Connect the Rod Drop Timer to the connection inside the console near CB-1.



Rod Drop Timer Connection



Rod Drop Timer Connected

- 34.7.3.5 You must press the black reset button on the rod drop timer before the next measurement to clear the display.
- 34.7.3.6 Raise the rod to be tested until the red UP light on the rod is lit.
- 34.7.3.7 Press the red enable button on the Rod Drop Timer. The green armed light on the rod drop timer will turn on.
- 34.7.3.8 Manually scram the reactor. This will not work by pressing the individual rod drop button. The SCRAM light must come on.
- 34.7.3.9 The timer will show, in milliseconds, how long between the scram signal and a rod down limit switch being actuated.

- 34.7.3.10 Reset the scram.
- 34.7.3.11 Repeat §34.7.3.5 to §34.7.3.10 for each additional rod to be tested.
- 34.7.3.12 Disconnect the rod drop timer when done.
- 34.7.3.13 If the drop time for any rod is greater than 1 second, notify the Operations Supervisor, ROM, and Director.
- 34.7.3.14 If the drop times are being measured for a control rod calibration, record the values on the Control Rod Calibration Form (SOP 34A); otherwise, record the drop times in the Main Logbook. If the times are being measured for the semiannual checklist, initial and date the appropriate line of the checklist.

#### 34.7.4 Control Rod Reactivity Worth Measurement

- 34.7.4.1 This procedure describes how to measure the differential reactivity worth of the control rods. This is done by incrementally withdrawing a control rod and measuring the resulting reactor period; period and reactivity are related by the In-Hour equation. Control rod worth measurement provides the means to determine the core-excess and shutdown margin of the reactor as well as the reactivity change induced by changes in control rod heights.
- 34.7.4.2 Record all information on SOP 34A. Preliminary steps for filling out the form are described in §34.7.1.
- 34.7.4.3 The reactor should not have been run at powers above 5 watts for 48 hours prior to performing this procedure to minimize the xenon effects.
  - Note: Since the reactor is essentially at 5 watts during this control rod reactivity measurement, it does not preclude activities that require the reactor to have been below 5 watts for a specified time before the activity, e.g., fuel movement, power calibrations, demineralizer changes, and control rod reactivity measurement itself.
- 34.7.4.4 Ensure a Startup Checklist has been completed.
  - Because this procedure is performed at 5 watts, there is no need to perform a separate core excess before beginning the calibration.
- 34.7.4.5 Ensure the rod position indication is correct per §34.7.2.

#### 34.7.4.6 Period Timer Calibration

- 34.7.4.6.1 Find the BNC cable under the console, near the AMS-4s.
- 34.7.4.6.2 If you cannot find the cable, or it is not connected, remove the far north panel on back of the console.
  - At the back of the Multitrend, there is a BNC connection coming off of the cable that carries information from the Linear Channel to the Multitrend. Attach a BNC cable

to this connection (long enough to reach the front of the console where you will be working).



*BNC Connection*

34.7.4.6.3 Attach a BNC-banana plug adaptor to the end of the BNC cable, and plug the adaptor into a digital voltmeter. The adaptor is normally in one of the drawers of the mini shelving unit next to the console.

- The banana plug will have a little bump on one side (see below); make sure the prong below the bump is put into the ground, or “CO,” hole in the digital voltmeter.

34.7.4.6.4 Set the voltmeter for direct current volts ( $\overline{\text{V}}$ ). The voltage is less than 10 VDC.



*BNC-Banana Adapter*



*Voltmeter Setting*

34.7.4.6.5 Insert the console key per SOP 1.

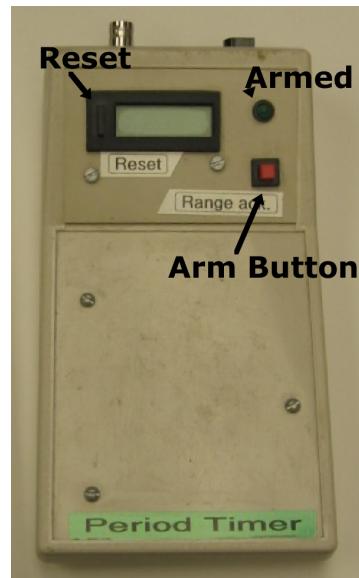
34.7.4.6.6 Withdraw control rods as necessary to reach a subcritical power of exactly 30% of scale on the linear channel module, on the lowest possible range. Record the voltage on SOP 34A.

34.7.4.6.7 Move control rods as necessary to reach a subcritical power of exactly 81.5% of scale on the linear channel module, on the lowest possible range. Record the voltage on SOP 34A.

34.7.4.6.8 Insert all control rods and secure the console key per SOP 1.

34.7.4.6.9 Remove the banana plug-BNC adaptor from the digital voltmeter and hook up the normal meter probes.

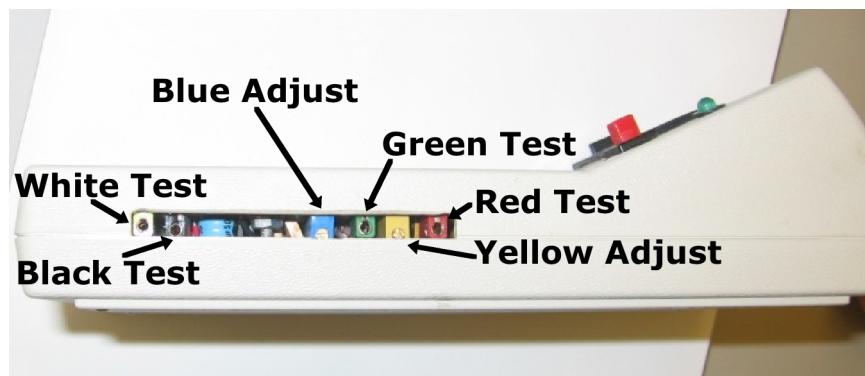
34.7.4.6.10 Get the period timer and adapter from its drawer in the Control Room under the AMS-4s. Plug in the Period Timer's power adaptor.



*Period Timer*

34.7.4.6.11 Use the digital voltmeter probes to measure the voltage between the green test point and the black test point on side of the period timer.

- The red probe goes to green and the black probe goes to black.



*Period Timer Adjustments*

34.7.4.6.12 Adjust the blue potentiometer on side of the period timer as necessary to make it the same voltage as measured above at 30%.

34.7.4.6.13 Use the digital voltmeter probes to measure the voltage between the red test point and the black test point on side of the period timer.

- The red probe goes to red and the black probe goes to black.

34.7.4.6.14 Adjust the yellow potentiometer on side of the period timer as necessary to make it the same voltage as measured above at 81.5%.

34.7.4.6.15 Connect the BNC cable to the top of the period timer, so that the period timer receives information from the Linear Channel.

#### 34.7.4.7 Reg Rod Worth Measurement

34.7.4.7.1 Record in the Main Logbook that the Reg Rod worth measurement is beginning.

34.7.4.7.2 Per SOP 1, establish a critical condition at 5 watts with the Reg Rod on the bottom.

- The Safety and Shim Rods should be withdrawn to approximately the same height.

34.7.4.7.3 Allow power level to stabilize at approximately 5 watts (18% to 22% on the 25 watt scale) for at least two minutes with minimal rod motion.

- It is much more important that the power be stable than that it be at exactly 5 watts. This allows delayed neutrons to reach equilibrium.

34.7.4.7.4 With the reactor stable for at least two minutes with minimal rod motion, withdraw the Reg Rod to approximately the new target height.

- The reactivity change should take place in one continuous pull. When you release the UP button do not adjust the height. Leave it wherever it was when you stopped.

34.7.4.7.5 Allow the power level to increase one full range on the linear channel so that the “prompt jump” is gone.

34.7.4.7.6 When the linear channel auto-ranges to the 250-watt scale, arm the period timer with its red button; the green armed LED will come on.

34.7.4.7.7 When the linear channel crosses 30%, the timer will start.

34.7.4.7.8 When linear channel crosses 81.5%, the timer will stop and indicate the period in milliseconds.

34.7.4.7.9 After power exceeds 82% of 250-watts and the timer stops, return the power level to 5 watts by lowering the Safety and Shim Rods.

- Try to keep the Safety and Shim rod banked at about the same height.
- Do not reposition the Reg Rod during this step!

34.7.4.7.10 Record the period on SOP 34A.

34.7.4.7.11 Record the rod positions after stabilizing at 5 watts on SOP 34A.

34.7.4.7.12 Reset the timer with the black button on the left of the display.

34.7.4.7.13 Remember to complete a Status Stamp every hour.

34.7.4.7.14 Repeat §34.7.4.7.4 to §34.7.4.7.13 until the Reg Rod UP light is lit.

#### 34.7.4.8 Safety Worth Measurement

34.7.4.8.1 Record in the Main Logbook that the Safety Rod worth measurement is beginning.

34.7.4.8.2 Per SOP 1, establish a critical condition at 5 watts with the Shim Rod and Reg Rod all the way out and the Safety Rod as far in as possible while remaining critical.

- It is not possible to be critical with the Safety or Shim on the bottom.

34.7.4.8.3 Allow power level to stabilize at approximately 5 watts (18% to 22% on the 25 watt scale) for at least 2 minutes with minimal rod motion.

- It is much more important that the power be stable than that it be at exactly 5 watts. This allows delayed neutrons to reach equilibrium.

34.7.4.8.4 With the reactor stable for at least two minutes with minimal rod motion, withdraw the Safety Rod to approximately the new target height.

- The reactivity change should take place in one continuous pull. When you release the UP button do not adjust the height. Leave it wherever it was when you stopped.

34.7.4.8.5 Allow the power level to increase one full range on the linear channel so that the “prompt jump” is gone.

34.7.4.8.6 When the linear channel auto-ranges to the 250-watt scale, arm the period timer with its red button; the green armed LED will come on.

34.7.4.8.7 When the linear channel crosses 30%, the timer will start.

34.7.4.8.8 When linear channel crosses 81.5%, the timer will stop and indicate the period in milliseconds.

34.7.4.8.9 After power exceeds 82% of 250-watts and the timer stops, return the power level to 5 watts by lowering Shim Rod.

- Do not reposition the Safety Rod or Reg Rod during this step!

34.7.4.8.10 Record the period on SOP 34A.

34.7.4.8.11 Record the rod positions after stabilizing at 5 watts on SOP 34A.

34.7.4.8.12 Reset the timer with the black button on the left of the display.

34.7.4.8.13 Remember to complete a Status Stamp every hour.

34.7.4.8.14 Repeat §34.7.4.8.4 to §34.7.4.8.13 until the Safety Rod UP light is lit.

34.7.4.8.15 Return the reactor to 5 watts to record the critical rod height on the Shim Rod. This is essential for the Shim Rod worth measurement.

34.7.4.8.16 Record in the Main Logbook that rod worth measurement is complete.

#### 34.7.4.9 Shim Worth Measurement

34.7.4.9.1 Record in the Main Logbook that the Shim Rod worth measurement is beginning.

34.7.4.9.2 Per SOP 1, establish a critical condition at 5 watts with the Safety Rod and Reg Rod all the way out and the Shim Rod as far in as possible while remaining critical.

- It is not possible to be critical with the Safety or Shim on the bottom.

34.7.4.9.3 Allow power level to stabilize at approximately 5 watts (18% to 22% on the 25 watt scale) for at least 2 minutes with minimal rod motion.

- It is much more important that the power be stable than that it be at exactly 5 watts. This allows delayed neutrons to reach equilibrium.

34.7.4.9.4 With the reactor stable for at least two minutes with minimal rod motion, withdraw the Shim Rod to approximately the new target height.

- The reactivity change should take place in one continuous pull. When you release the UP button do not adjust the height. Leave it wherever it was when you stopped.

34.7.4.9.5 Allow the power level to increase one full range on the linear channel so that the “prompt jump” is gone.

34.7.4.9.6 When the linear channel auto-ranges to the 250-watt scale, arm the period timer with its red button; the green armed LED will come on.

34.7.4.9.7 When the linear channel crosses 30%, the timer will start.

34.7.4.9.8 When linear channel crosses 81.5%, the timer will stop and indicate the period in milliseconds.

34.7.4.9.9 After power exceeds 82% of 250-watts and the timer stops, return the power level to 5 watts by lowering the Safety Rod.

- Do not reposition the Shim Rod or Reg Rod during this step!

34.7.4.9.10 Record the period on SOP 34A.

34.7.4.9.11 Record the rod positions after stabilizing at 5 watts on SOP 34A.

34.7.4.9.12 Reset the timer with the black button on the left of the display.

34.7.4.9.13 Remember to complete a Status Stamp every hour.

34.7.4.9.14 Repeat §34.7.4.9.4 to §34.7.4.9.13 until the Shim Rod UP light is lit.

34.7.4.9.15 Return the reactor to 5 watts to record the critical rod height on the Safety Rod. This is essential for the Shim Rod worth measurement.

34.7.4.9.16 Record in the Main Logbook that rod worth measurement is complete.

#### 34.7.4.10 Calculations

34.7.4.10.1 Run the Python program (“rodcal.py”) on the West iMac in the classroom.

- If the folder “rodcal” is not on the computer, download it from the Reactor General Google Drive. It is located in Data → rodcal → rodcal.
- Search for the Terminal application on the computer and open it.
- Type “cd Desktop” and hit “enter.” This command means “change directory” and opens the desktop directory.
- Type “cd rodcal” and hit “enter.” This opens the rodcal folder on the desktop.
- Type “python3 rodcal.py” to run the Python program. Typing ”python3” tells terminal to use the Python software (version 3), and “rodcal.py” is the name of the file you are running.

34.7.4.10.2 Enter the data into the Python program used to calculate rod worths.

- Type in each number carefully, and when you are done hit “enter.” The program will prompt you to look over the numbers for that section. If the section is correct, type “y” and hit “enter” to continue. If there was a mistake, type “n” and hit “enter” to retype the section.
- The program will not generate rod worth tables or a report if the TeX files called “template-report.tex” and “template-worthtables.tex” are not in the same folder as the Python program.

34.7.4.10.3 Print the rod worth tables generated by the Python program. Remove the old rod worth charts and tape the new ones into the back of the Main Logbook. Old rod worth charts should be filed in Chem 102.

34.7.4.10.4 Print the report generated by the Python program. Record the values on SOP 34A and verify that each is within the Tech Spec requirement.

34.7.4.10.5 Record in the Main Logbook that banked rod height measurement is beginning.

34.7.4.10.6 Per SOP 1, operate the reactor at each power listed on SOP 34A. For each power, record the banked rod height and core excess (using the new rod worth charts). Enter the data into the Python program used to calculate banked rod heights (“rodbank.py”).

34.7.4.10.7 Record in the Main Logbook that banked rod height measurement is complete.

34.7.4.10.8 Print the generated table of banked rod heights. Remove the old banked rod height table and tape the new one into the back of the Main Logbook. The old banked rod height table should be filed in Chem 102.

34.7.4.10.9 Write the current Log Channel Wide Range calibration potentiometer value on the banked rod heights table.

34.7.4.10.10 Save all the generated PDFs in the Drop Folder on the Reactor Drop Google Drive.

34.7.4.10.11 Finish the Control Rod Calibration Form (SOP 34A) per §34.7.1.

### 34.7.5 Control Rod Drive Inspection

34.7.5.1 Each of the three control rod drives shall be visually inspected for damage or deterioration annually. [TS 4.2a]

34.7.5.2 Since this is maintenance on a control mechanism, the responsible SRO must be present in the facility.

34.7.5.3 When console power is on and the rod drives are connected, the circuit boards on the rod drives are energized. Use caution to avoid electric shock.

34.7.5.4 For each of the Safe, Shim and Reg rod drives, visually inspect the circuit board, limit switches, motor housing, potentiometer, and other components for any damage, loose connections, degradation, or other indication that a component has failed or could fail soon.

34.7.5.5 It may be convenient to complete the following steps while calibrating the rod position indications.

34.7.5.6 Insert the console key per SOP 1. Since the reactor is not shut down, staffing requirements are as listed in SOP 1.

34.7.5.7 Raise and lower each control rod completely while observing the rod drive.

- Watch for any scraping of components, and pay attention to sounds or smells from the rod drive that may indicate electrical or mechanical problems.
- Check that the three limit switches are opened and closed at the correct times. If necessary, adjust them per §34.6.1.
- To ensure the reactor remains subcritical, lower each control rod before raising the next.

34.7.5.8 Remove the key from the console.

34.7.5.9 If this procedure was done for the Annual Checklist, record the date on the Checklist form. Otherwise, log this maintenance in the Main Logbook and the Maintenance Logbook.

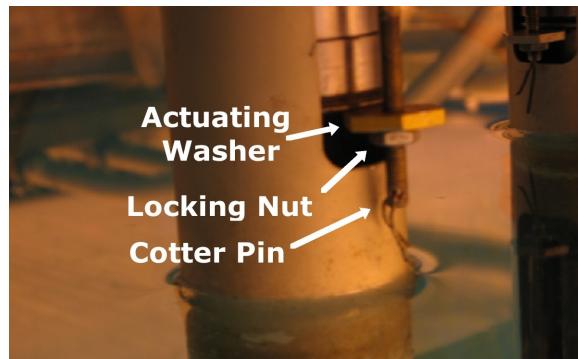
### 34.7.6 Control Rod Inspection

- 34.7.6.1 Each of the three control rods shall be visually inspected at least once every two years, usually during the January annual maintenance. [TS 4.2b]
- 34.7.6.2 Staffing is required per SOP 35 for fuel inspection since it is necessary to move fuel first.
- 34.7.6.3 The reactor is not shutdown while control rods are being removed or inserted into the reactor, so a licensed operator must be at the console and a second person must be in the facility. Since this is maintenance on a control mechanism, the SRO must be present in the facility.
- 34.7.6.4 Inspect one control rod at a time and replace it into the core before going on to the next one.
- 34.7.6.5 Wear full body water resistant coveralls and gloves when handling the control rods. Monitor anything that comes out of the pool for radioactivity.
- 34.7.6.6 Only aluminum clad control rods are in the core, but if stainless-steel clad control rods are being inspected, there may be a significant radiation field present. In that case, the reactor shall be shutdown 48 hours before control rod removal and a Radiation Work Permit (SOP 53) shall be used.
- 34.7.6.7 Complete the Control Rod Inspection Checklist (Appendix B) while doing this procedure.
- 34.7.6.8 Perform a Startup Checklist per SOP 20. Do not perform a core excess.
- 34.7.6.9 Using SOP 35, move any two elements from the B-ring or three elements of the C-ring to the fuel storage racks.
- 34.7.6.10 Unplug all three console-to-rod-drive motor plugs inside the console: J-7 (Reg Rod), J-8 (Shim Rod), and J-10 (Safety Rod). The rod UP and DOWN lights will come on when this is done.
- 34.7.6.11 Unplug the 36-pin Centronics parallel connector behind the north panel of the console.



Rod Plugs J-7, J-8, J-10

- 34.7.6.12 Remove the rod-down actuator cotter pin, nut, and actuating washer (located a few inches above the water) from the pull rod. You will have to lean over the pool to do this; be careful not to drop them. The cotter pin is really a paper clip that has to be unbent before removing it from the small hole at the bottom of the pull rod. The nut and actuating washer unscrew as normal. It may be necessary to tighten the actuating washer (the top one) a little bit in order to get at the nut. You should be able to do it all with your fingers.



*Pull Rod Bottom*

- 34.7.6.13 Unplug the position indication for the rod being removed. It is at the potentiometer at the side of the motor.



*Rod Position Connection*

- 34.7.6.14 For the regulating rod only, unplug the motor power supply next to the motor.



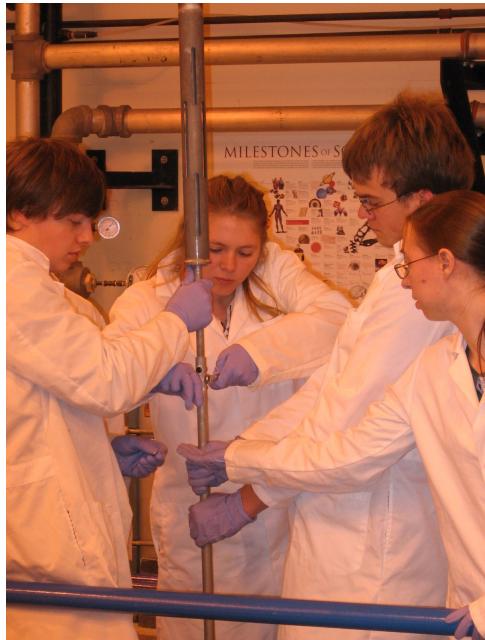
*Reg Rod Power Connection*

- 34.7.6.15 Remove the small Allen head 3/32-inch screws from the upper edge of each base mount. There are locations for six screws, but normally only five are used. Do not removed the large bolts that hold the motor housing to the bridge.



*Two Allen-Head Screws*

- 34.7.6.16 Lift the rod motor off and place it on the floor.
- 34.7.6.17 An operator must be at the console for the next steps.
- 34.7.6.18 Lift the guide barrel up through the base mount, thereby lifting the connecting rod. This is done by reaching inside the barrel from the top and lifting up. As the rod is raised, be sure that someone watches the UPPER part of the rod as it approaches the region of the ceiling lights. Have someone watch the LOWER part of the rod to ensure it doesn't hit other control rods or the central thimble.
- 34.7.6.19 The operator shall log the control rod removed from the core in black and underline in red ink in the Main Logbook.
- 34.7.6.20 Lift the rod high enough to permit removal of the first set of three 7/16-inch bolts and nuts; this will allow the top of the rod extension to be removed. Ensure someone is holding the lower part of the control rod when the three sets of bolts and nuts are removed, otherwise the control rod will fall onto the core.



*Unbolting Rod Extension*



*Unbolting Rod Extension*

- 34.7.6.21 While holding onto the control rod, pass it down through the control rod opening on the bridge and hand it out under the bridge. This will allow removal of the control rod from the pool (the ceiling is too low to pull it straight out the opening in the bridge). Be very careful not to drop the control rod. This is probably best done by one person lying on the bridge with one hand in the control rod opening and one hand around the side of the bridge.



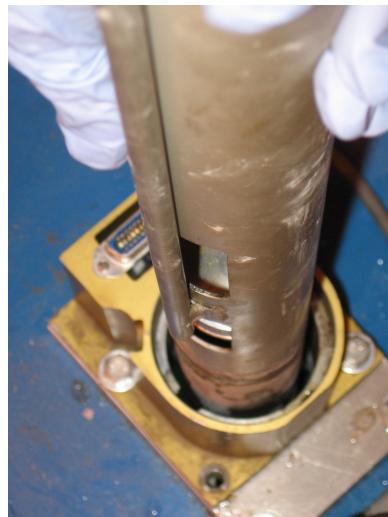
*Handing the Rod Extension Under the Bridge*

- 34.7.6.22 With an ion chamber monitoring the immediate area, remove the control rod and lay it on a piece of absorbent paper.
- 34.7.6.23 Inspect the control rod for scratches, wear, etc. Use a caliper to measure the rod diameter at the top, center, and bottom. Carefully measure the extent of any wear and compare it to previous measurements. Record observations on the Control Rod Inspection Form (Appendix C).
  - A standard control rod is 20 inches long and 1.25 inches in diameter.
- 34.7.6.24 Take photographs of the rod with a ruler and a sign in the picture saying what rod it is and the year. Store the photographs with the Control Rod Inspection Form.



*Control Rod Inspection*

- 34.7.6.25 If indication of significant distortion or deterioration is found, the rod shall be replaced. [TS 3.2.1a]
- 34.7.6.26 Reinstall the rod by reversing the order of removal. First put the control rod back in the pool. While holding onto the control rod, hand it down under the bridge and pass it up through the control rod opening. Be very careful not to drop the control rod or to hit anything with it.
- 34.7.6.27 Lift the rod through the opening high enough to permit reinstallation of the first set of three 7/16-inch bolts and nuts. Ensure someone is holding the lower part of the control rod and the upper part. If the bolts and nuts on the control rod drive shaft don't seem to fit, try rotating one of the shafts by 180°.
- 34.7.6.28 Lower the rod and barrel down into the rod housing. Align the pull rod with the hole in the motor housing when returning it.



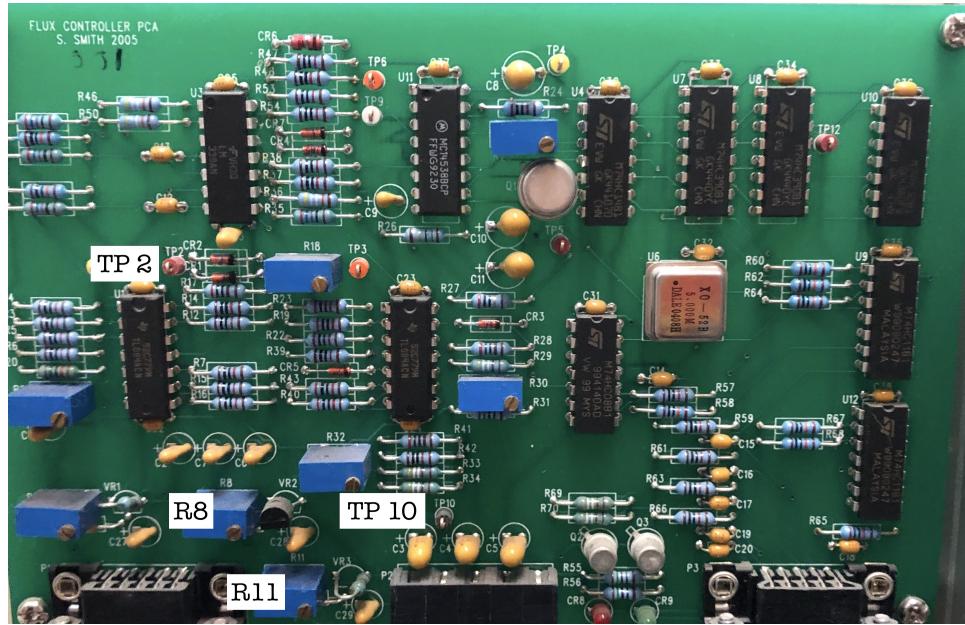
*Aligning Pull Rod*

- 34.7.6.29 The operator shall log the control rod installed in the core in black and underline in red ink in the Main Logbook.
- 34.7.6.30 Reinstall the rod motor on the rod motor mount. Make sure the spring on the rod down limit switch is still there.
- 34.7.6.31 Install the small Allen head 3/32-inch screws in the upper edge of each base mount.
- 34.7.6.32 Reinstall the rod-down actuator cotter pin, nut, and actuating washer (located a few inches above the water) from the pull rod. You will have to lean over the pool to do this; be careful not to drop them.
- 34.7.6.33 Plug in the position indication for the rod.
- 34.7.6.34 For the regulating rod only, plug in the motor power supply.

- 34.7.6.35 Repeat §34.7.6.12 through §34.7.6.34 for the other two control rods.
- 34.7.6.36 Reconnect all three console to rod drive motor plugs inside the console: J-7, J-8, and J-10.
- 34.7.6.37 Adjust the limit-switches per §34.6.1.
- 34.7.6.38 Check each rod by raising it a short distance and then releasing it by a scram.
- 34.7.6.39 Check the work area for contamination.
- 34.7.6.40 Water resistant coveralls are single use. Survey coveralls and dispose of them appropriately.
- 34.7.6.41 Perform §34.7.3 to verify that the rod drop time of each control rod is acceptable.
- 34.7.6.42 Using SOP 35, return the fuel elements to the core that were removed in §34.7.6.9.
- 34.7.6.43 Perform a control rod calibration per §34.7.1.
- 34.7.6.44 Complete the “Clean Up” part of the Control Rod Inspection Checklist (SOP 34B).

#### 34.7.7 Calibrating Auto Demand

- 34.7.7.1 This procedure describes how to calibrate Auto Demand so that the setting on the demand potentiometer matches the corresponding reading on the Linear Channel. A startup checklist is not required for this procedure.
- 34.7.7.2 Turn on console power and note this action in the Main Logbook.
- 34.7.7.3 Obtain a digital voltmeter and two test leads. Leads with alligator clips or grabber hooks are ideal.
- 34.7.7.4 Set the voltmeter for direct current volts ( $\overline{\text{V}}$ ). The voltage is less than 10 VDC.
- 34.7.7.5 Remove the north-most back panel of the console (below the Log Channel). While working behind the console, be careful to not touch the large cable connected to the back of the Log Channel.
- 34.7.7.6 Open the inner swinging door.
- 34.7.7.7 On the green “Flux Controller” circuit board, connect the negative lead to TP 10 and the positive lead to TP 2.



- 34.7.7.8 Insert the console key and complete a key in stamp per SOP 1.
- 34.7.7.9 Dial in 20% on the demand potentiometer.
- 34.7.7.10 Withdraw control rods as necessary to reach a subcritical power of exactly 20% of scale on the linear channel module, on the lowest possible range.
- 34.7.7.11 Adjust R11 on the auto rod control circuit board until the voltmeter reads 0 VDC.
- 34.7.7.12 Dial in 96% on the demand potentiometer.
- 34.7.7.13 Turn off auto range by selecting the current range on the Linear Channel.
- 34.7.7.14 Move control rods as necessary to reach a subcritical power of exactly 96% of scale on the linear channel module, on the lowest possible range.
- 34.7.7.15 Adjust R8 on the auto rod control circuit board until the voltmeter reads 0 VDC.
- 34.7.7.16 Repeat §34.7.7 to §34.7.7.15 until both values are less than 0.1 VDC.
- 34.7.7.17 Disconnect the voltmeter.
- 34.7.7.18 Close the swinging door and replace the back console panel.
- 34.7.7.19 Insert all control rods and remove and secure the console key.
- 34.7.7.20 Re-select Auto Range on the Linear Channel.

- 34.7.7.21 If desired, turn off console power and note this action in the Main Logbook.
- 34.7.7.22 If the calibration was done for the Semiannual Checklist, record the date on the checklist. Otherwise, log the calibration in the Main Logbook and Maintenance Logbook.

## 34.8 TROUBLESHOOTING

### 34.8.1 Inoperable Control Rod

#### 34.8.1.1 If the reg rod won't move:

- Ensure that Rod Control is not in Auto.
- Ensure the motor power supply next to the reg motor is plugged in.
- Ensure the 36-pin Centronics parallel connector behind the north panel of the console is plugged in.

#### 34.8.1.2 If a rod moves up a few percent and stops:

- If a rod moves up a few percent and stops when the “DOWN” light turns off, the limit switches are probably misaligned. This can be verified because the blue “CONT” light will also turn off when the white “DOWN” turns off.
- The problem is that the motor down limit switch cleared before the rod down limit switch cleared, so the rod circuitry tried to drive in the motor. When you release the “UP” button, the motor will drive to the bottom and the “DOWN” and “CONT” lights will both turn on.
- To correct this problem, you will have to adjust the limit switches per §34.6.1. Be careful since you will have to use metal tools and the circuit boards on the top of the rod motors are exposed and energized.

#### 34.8.1.3 If a rod moves up or down without input:

- If the rod in question is the reg rod, ensure that Rod Control is not in Auto.
- If the rod in question is the shim or safe rod, the balancing potentiometer will have to be adjusted per §34.6.2.

#### 34.8.1.4 If pressing on the “UP” button does not move the rod:

- For the reg rod, see §34.8.1.1 before moving to this section.
- If the “UP” button for a control rod does not move the rod up but the “DOWN” button functions properly, see if the “UP” light bulb is burnt out by exchanging it with the button for a rod that does work. Instructions for removing console buttons are in §34.6.4. If the light bulb is burnt out, replace it per §34.6.4.

#### 34.8.1.5 If pressing on the “DOWN” button does not move the rod:

- For the reg rod, see §34.8.1.1 before moving to this section.
- Scram the reactor and verify the scram.
- The “DOWN” light may be burnt out if the following are true:
  - the “DOWN” light on the button that did not work earlier does not turn on

- the position indicator reads 0.0%
- the “CONT” light turns on
- See if the “DOWN” light bulb is burnt out by exchanging it with the button for a rod that does work. Instructions for removing console buttons are in §34.6.4. If the light bulb is burnt out, replace it per §34.6.4.
- If the “CONT” light does not turn on, the motor did not drive down. Visually verify the scram, then notify the Director and ROM. If the scram is unable to be verified visually, the reactor is not secured and you may not leave the control room.

#### 34.8.1.6 If the **motor is raising but the rod is not**:

- If a rod seems to be raising normally but the reactor power is not changing, the rod may not be connected to the motor.
- First, scram the reactor and visually verify the scram to be sure the rod is not stuck. If the scram is unable to be verified visually, the reactor is not secured and you may not leave the control room.
- If scram is able to be visually verified, the rod down limit switch for that rod will have to be loosened per §34.6.1.
- If loosening the rod down limit switch does not fix the problem, notify the Director and ROM.

### 34.8.2 Console Lights

#### 34.8.2.1 If the **source interlock light is lit**:

- Ensure the neutron source is in the core by visual observation in the Reactor Bay.
- Reset the log channel trips. To reset the log channel, place it in test at Hi Current, and press the reset button, then return it to operate.

#### 34.8.2.2 If the **yellow magnet power “ON” lights are not lit**:

- Ensure that console power is on.
- Ensure that the key is inserted and fully turned to the “operate” position.
- Ensure that all the scrams are reset, including the red ones on the Linear and Percent Power modules.
- See if the ON light bulb is burnt out by exchanging it with the button for a rod that does work. Instructions for removing console buttons are in §34.6.4. If the light bulb is burnt out, replace it per §34.6.4.

#### 34.8.2.3 If **both “UP” and “DOWN” lights for one or more control rods are lit**:

- Ensure that all three console-to-rod-drive motor plugs inside the console: J-7 (Reg Rod), J-8 (Shim Rod), and J-10 (Safety Rod) are plugged in. A reference picture can be found in §34.6.3.

### 34.8.3 Position Indication

34.8.3.1 If the **position indication is reading 77.7%**:

- Ensure the position indication for that rod is plugged in. This is found at the potentiometer at the side of the motor.

34.8.3.2 If a control rod position indication is **unreliable or out of service**:

- If only one control rod is affected, it is still possible to operate the reactor by withdrawing that control rod all the way. When the UP light is lit, you know the rod is 100% withdrawn.