Peggy Shuttleworth

Department of Energy
Washington, D.C. 20545

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Docket No. 50-537
HQ:S:82:086

AUG 24 1982

Mr. Paul S. Check, Director
CRBR Program Office
Office of Nuclear Reactor Regulation
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Check:

RESPONSES TO REQUEST FOR ADDITIONAL INFORMATION

Reference: Letters, P. S. Check to J. R. Longenecker, "CRBRP Request for Additional Information," dated April 9, May 14 and June 9, 1982.

This letter formally responds to your request for additional information contained in the reference letters.

Enclosed are responses to Questions CS 421.26, 43, 51, and 53 and CS 760.162, 164, and 176 which will also be incorporated into a future PSAR Amendment.

Sincerely,

Joseph C. Barrett for
John R. Longenecker
Acting Director, Office of the
Clinch River Breeder Reactor
Plant Project
Office of Nuclear Energy

Enclosures

cc: Service List
Standard Distribution
Licensing Distribution

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bcc: D. Goeser, WLLCO
P. Gross, CRBRP PO

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	Murphie
DATE	8/24/82
RTG SYMBOL	NE-52
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Question 421.26

In the PSAR, Section 7.4.1.1.2 discusses the Protected Air-Cooled Condenser (PACC) and how air flow through it is controlled by a combination of fan blade pitch and inlet louver position. The staff requires a detailed discussion of this instrumentation and in particular the method used for fan blade pitch indications.

Response:

The outlet louvers have discrete open and closed position sensors. These provide indication at both the local control panel and main control panel in the control room.

The inlet louvers have both discrete open and closed position sensors and a continuous position sensor. The continuous position sensor provides feedback to the louver control. Both types provide indication at the local control panel and the main control panel in the control room.

The fan blade pitch uses continuous position sensors for both control and indication. The indication is provided at the local control panel and the main control panel in the control room.

Both the discrete and continuous sensors are integral to the actuator. The discrete sensors are roller switches activated by a cam and the continuous is a potentiometer.

Question 421.43

Section 7.7.1.3.2 of the PSAR deals with the Rod Position Indication System. Discuss the design criteria for this system.

Response:

The basic criteria for the Rod Position Indication System are 1) to provide redundant indication of primary control rod position over the full range of possible rod movement and 2) provide position information necessary to insure that maximum control rod misalignments are limited to a value less than ±1.5 inches.

To meet the first criterion two diverse and independent measuring systems are provided. Each system is capable of measuring the position of the primary rods throughout their range of motion. The Absolute Rod Position Indication System (ARPI) determines the position of the control rod absorber through the position of the mechanism lead screw relative to the control rod drive mechanism. As the ARPI provides a direct measurement of rod position, it does not lose its reference after a scram or temporary loss of power.

The Relative Rod Position Indication system (RRPI) determines the position of the control rod absorber by monitoring the rotation of the roller nut which operates the lead screw. Because the roller nut opens to allow the lead screw to drop during a scram, the RRPI loses its reference and must be rezeroed after such an event.

To insure that the second design criterion is met, it is necessary to provide system accuracy such that event when readout, accuracy and position uncertainty associated with the position of the absorber assembly relative to the reactor core are considered, rod misalignments are limited to a value less than 1.5 inches. The accuracy of the RRPI and ARPI, each being better than ±0.3 inches, insures that the second criterion is met.

Question 421.51

Using drawings (schematics, P&ID's), describe the automatic and manual operation and control of the atmospheric relief valves (superheater). Describe how the design complies with the requirements of IEEE-279 (i.e., testability, single failure, redundancy, indication of operability, direct valve position indication in control room, etc.).

Response:

The atmospheric relief valves on the superheater outlet line, valves 53SGV106, 107, & 108 in Figure 5.1-4, provide overpressure protection for the superheater and also provide superheater blowdown capability in the event of a sodium/water reaction event.

The overpressure protection is provided when the steam pressure reaches the valve set pressure. The steam pressure overcomes the force exerted by a spring on the pilot valve and opens the pilot valve. This action then causes the main valve to go to the full open position, where it remains until the pressure in the steam line is reduced below the set pressure. Both the pilot valve and the main valve then close. This valve is designed to meet all requirements of the ASME Code, Section III, Class 3, for overpressure protection devices.

An electro-pneumatic actuator is installed on the pilot valve of each superheater and evaporator relief valve, which can open, but not close the valve. For evaporator and superheater blowdown following a SWRPRS event, the relief function is actuated automatically when the SWRPRS is activated (See PSAR Section 7.5.6.1.2 and Figure 7.5-6 for SWRPRS trip logic). SWRPRS actuation of these valves is not safety related.

Each evaporator and superheater outlet relief valve can also be opened individually by means of a control button on the main control panel. This control, along with other valve controls, permits the operator to isolate and blow down a single module in the event that a small leak is identified in an evaporator or the superheater module and the plant is being shut down before a rupture disk bursts.

The requirements of IEEE-279 do not apply to the superheater outlet safety/relief valves, since these valves perform their overpressure protection function independent of the electro-pneumatic actuator. Overpressure protection is discussed in Section 5.5.2.4 of the PSAR.

Valve position is indicated in two ways:

(1) An electromagnetic switch senses the position of the electro-pneumatic actuator on the pilot valve stem and actuates position lights in the main control to verify the pilot valve has been opened electrically.

(2) Acoustic sensors are attached to the valve discharge pipes near the valve outlet to verify the presence of flow through the valve and actuates a group alarm in the main control room. The acoustic sensors are capable of detecting small leaks from a valve which has closed, but not fully re-seated itself and thus, provide direct indication of valve position.

Question 421.53

Section 7.2.1.1, paragraph 2, of the PSAR states the Primary RSS is comprised of 24 subsystems and the Secondary RSS is comprised of 16 subsystems. Each of these subsystems consists of three physically separate redundant instrument channels. This information contradicts the information in Table 7.2-1 and Figure 7.2-2B and 7.2-2D, which shows there are 8 subsystems in the Primary RSS and 7 subsystems in the Secondary RSS. Shouldn't it be that the Primary RSS allows 24 inputs, the Secondary RSS allows 16 inputs? There are 8 subsystems in the Primary RSS providing 17 inputs to the Primary RSS logic and the Secondary RSS consists of 7 subsystems providing 16 inputs to the Secondary RSS logic as follows:

PLANT PROTECTION SYSTEM PROTECTIVE FUNCTIONS

Primary Reactor Shutdown System	# of Inputs
1. Flux-Delayed Flux (Positive and Negative)	2
2. Flux-Pressure	1
3. High Flux	1
4. Primary to Intermediate Speed Mismatch	3
5. Pump Electrics	3
6. Reactor Vessel Level	1
7. Steam-Feedwater Flow Mismatch	3
8. IHX Primary Outlet Temperature	3
9.	7 Spare

Secondary Reactor Shutdown System	
1. Modified Nuclear Rate (Positive and Negative)	2
2. Flux-Total Flow	2
3. Startup Nuclear	1
4. Primary to Intermediate Flow Ratio	2
5. Steam Drum Level	3
6. Evaporator Outlet Sodium Temperature	3
7. Sodium Water Reaction	3
	0 Spare

Response:

The Primary RSS coincidence logic allows 24 comparator inputs, the Secondary RSS coincidence logic allows 16 comparator inputs. Not all of the potential inputs are presently utilized. Table 7.2-1 has been revised to indicate the number of inputs.

TABLE 7.2-1

PLANT PROTECTION SYSTEM PROTECTIVE FUNCTIONS

Primary Reactor Shutdown System	Number of Inputs[1]
o Flux-Delayed Flux (Positive and Negative)	2
o Flux-Pressure	1
o High Flux	1
o Primary to Intermediate Speed Mismatch	3
o HTS Pump Frequency	1
o Pump Electrics	1
o Reactor Vessel Level	1
o Steam-Feedwater Flow Mismatch	3
o IHX Primary Outlet Temperature	3

Secondary Reactor Shutdown System	Number of Inputs
o Modified Nuclear Rate (Positive and Negative)	2
o Flux-Total Flow	1
o Startup Nuclear Flux	1
o Primary to Intermediate Flow Mismatch	2
o Steam Drum Level	3
o Evaporator Outlet Sodium Temperature	3
o HTS Pump Voltage	1
o Sodium Water Reaction	3

[1] The Primary RSS can accept a total of 24 inputs and the Secondary RSS can accept 16 inputs. There are 9 spare Primary inputs.

Question CS760.162

In CRBRP-3, Vol. 1, Rev. 2 the applicant describes a method for evaluating certain components loaded during an HCDA wherein component response is evaluated using linear static calculations with "appropriate" dynamic amplification factors. The reactor vessel nozzles, head mounted components, and vessel appurtenances will be evaluated with this method.

The first step is to evaluate the complete reactor vessel system with a dynamic inelastic model. Components then will be evaluated using the system response at their specific location as input. Each component will be analyzed first by applying loads and/or displacements to a static model using what is called an "appropriate" dynamic amplification factor. If the component in question fails this test, it is evaluated using a dynamic elastic model. Finally, if the component fails this test, a more complex inelastic dynamic analysis is performed. The procedure of using a static analysis with dynamic amplification factors is common in linear systems where the appropriate amplification factors are easily obtained. Results are usually conservative because dynamic phasing of different load components is neglected. The appropriate amplification factors for a nonlinear system are not easy to obtain and may not even be unique definable quantities since the vibration frequencies and damping of the component change as it plastically deforms.

The applicants must describe how the dynamic amplification factors are to be derived.

Response:

The applicant agrees with the NRC regarding the use of dynamic amplification factors for static analysis of linear elastic systems. The current CRBRP-3 analyses do not use dynamic amplification factors for analysis of non-linear systems. CRBRP-3, Volume 1, Section 5 will be amended to clarify this.

Question CS760.164

In Sec. 5.4 of CRBRP-3, Vol. 1, Rev. 2, the applicant states that results of both analyses and experiments indicate that the closure head will withstand SMBDB loads without structural failure. This conclusion is based in part on the results of scale model tests SM-4 and SM-5 where the head model showed no visible plastic deformation. A problem exists in using these test results to demonstrate the capability of the head in that the design of the scale model heads was non-prototypic. The shielding plates were bolted directly to the bottom of the head, possibly overstiffening it considerably and, therefore, not allowing deformations that lead to the most probable head failure mode (disengagement of the intermediate rotating plug). Because of the design of the model head, we are not convinced that the applicants conclusions regarding the acceptability of the head design can be made based on the experiments done to date.

The analysis presented does indicate that, under SMBDB leading, the head only displaces 23% of its predicted failure displacement. This analysis is acceptable if the applicant can benchmark the analytical model with experimental data. Benchmarking with other analyses is not acceptable, especially because many analytical techniques, in particular the finite element method, overpredict the stiffness of structures being modeled by several percent.

To resolve this issue of vessel head capability the applicant should benchmark the analytical model being used and show that it predicts a comfortable margin to head failure. The required margin will be less if the model is benchmarked with both static and dynamic test data.

Response:

The analytical model used to predict strains and displacements of the CRBRP Reactor System under SMBDB loading will be benchmarked against static (SM-1) and dynamic (SM-5) test data. These analyses will be completed by October 30, 1982, and the documentation will be provided to NRC by November 30, 1982.

Question CS760.176

In preparation for writing those sections of the SER dealing with PCRDM, we have found it necessary to secure additional documentation on the D. C. stepper motor used in the system. Specifically, we would like to obtain the following information:

1. Complete description of the motor

2. Equipment specification for the motor, and

3. Test information or data establishing that the specifications are met, including the maximum withdrawal speed in the event an over-speed signal is sent to the controller.

We would also like to know the maximum slew rate of the motor and what power input conditions, however improbable, that would be required to obtain it.

Response:

ITEM 1

Description of PCRDM Motor

The PCRDM utilizes a collapsible roller nut design which has been successfully used in the past on pressurized water reactors. This type of drive has a non-rotating leadscrew which is driven up or down by a fixed elevation roller nut formed by four ball bearing mounted rollers, equally spaced around the leadscrew. The rollers are inclined from vertical at the leadscrew helix angle and have teeth which engage the leadscrew threads to provide a positive connection to the translating assembly. Two rollers are mounted in each segment arm which are attached by pivot pins to a rotor carried on ball bearings in the motor tube. The complete assembly is shown in PSAR Figure 4.2-101. The motor tube is shown in Figure QCS760.176-1, the segment arms and roller nuts in Figure QCS760.176-2, and the stator in Figure QCS760.176-3.

The roller nut is actuated by a six-phase, four pole stator mounted outside the motor tube. The stator and segment arms together form a reluctance type synchronous stepping motor. The stator windings are energized by direct current which can be swirched in a programmed sequence among the six-phase to produce a stepwise rotating magnetic field in the armature region (see Fig. QCS760.176-4). The two segment arms, which make up the motor armature are fabricated from permeable stainless steel and tend to align themselves with the rotor field so as to minimize the magnetic circuit reluctance between adjacent stator poles. The motor armature is, therefore rotated in synchronism with the rotating stator field.

The segment arms pivot in a vertical plane through the leadscrew centerline and are constrained to move through the same angle by means of a synchronizer bearing mounted at the top of the rotor. The armature region of each segment arm is located above the pivot pin, while the rollers are mounted below the pivot pin. When the stator is not energized, the segment arms are held in the collapsed position by springs acting outward below the pivot pin. In this position, the rollers are disengaged from the leadscrew, and the armature section of the segment arms are displaced inward toward the mechanism centerline. When the stator is energized, the armature section of the segment arms are magnetically attracted toward the stator with a force sufficient

to overcome the segment arm spring force and engage the rollers with the leadscrew.

The direction of leadscrew travel is determined by the direction of rotor rotation which, in turn, is determined by the particular switching sequence applied to the stator phase windings. The speed of rotation is controlled by the switching rate, which is adjustable over a wide range by the controller. The rollers remain engaged to the leadscrew during reversal of rotation direction.

If the switching sequence is stopped and the stator is left energized in any of the twelve (12) possible phase combinations, the segment arms continue to be attracted outward and they will hold the leadscrew indefinitely at the elevation achieved when the rotation was stopped. The windings comprising the six phases are so arranged that when energized in a 3 - 2 sequence, the force-pole magnetic pattern formed by the stator rotates in space in 15-degree steps. If the six phases are designated by the letters, A, B, C, D, E and F the sequence for rotation is shown below.

Rotational Degrees	0	15	30	45	60	75	90	105	120	135	150	165
Phases Energized	AB	ABC	BC	BCD	CD	CDE	DE	DEF	EF	EFA	FA	FAB

As shown above, the motor is energized in either a two phase or three phase mode in the hold condition and switches from two phase-to three phase-to two phase while in the run mode. Since the motor is either in a two phase or three phase condition during hold, the two conditions will produce different magnetic field strengths. Theoretically, the three phase condition should produce 1.5 times the magnetic flux of the two phase mode, but in the real motor, it is less than this ratio due to temperature and saturation effects.

For the motor to produce torque, the induced poles in the rotor must lag the stator poles. The torque is roughly a sinusoidal function of the lag angle, and in actual operation, the lag angle adjusts itself to the value just sufficient to balance the applied torque resisting rotation, up to the pull out or pole slip value. The radial moment on the engaged segment arms, called holding moment, is also a function of the rotor lag angle, and in this type of rotor increases somewhat as the lag angle departs from zero.

The radial moment also varies strongly as a function of the collapse angle of the segment arms (as does the peak torque) because of the large change in air gap and the corresponding change in flux linking the arms. Since the segment arms are held in the collapsed position by eight coil springs, the moment required to overcome the springs and bring the rollers into engagement (latch) plots as a straight line, with force increasing toward the fully engaged position. This relationship is shown in Figure QCS760.176-5.

During steady state operation (run or hold mode) the available torque and moment are determined by the available current. The run - hold voltage is specified to be 175 $\pm$ 5 volts DC, and will be controlled within this range. Therefore the available current is determined by the resistance of the winding, and the resistance is a function of the stator winding temperature. The temperature of the winding is controlled by a constant flow of nitrogen gas. The specified operating parameters of this stator cooling system are:

Inlet temperature	55$\pm$ 5^{o}F
Outlet temperature	140^{o}F maximum
Pressure at inlet	90 psig minimum 100 psig minimum
Flow	157 $\pm$ 10 scfm

During acceptance testing of the PCRDMs at the vendors plant the following typical operating parameters were determined:

Outlet coolant temperature	= 120$\pm$ 5^{o}F
Phase resistance	= 24.6 $\pm$ 4 ohms (hot)
Phase current	= 7.1 $\pm$ .1 amps

ITEM 2

The equipment specification for the PCRDM motor is contained in and is a part of the equipment specification for the Primary Control Rod Drive Mechanism. The following are those sections which apply to the motor.

I. ASME Code Classification

A. The mechanism motor tube, motor tube holddown ring, and position indicator housing act as part of the reactor primary system boundary, and shall be constructed as a Class 1 vessel meeting requirements of the ASME Boiler and Pressure Vessel Code, Section III.

B. The design of the CRDM shall be based on the Fast Flux Test Facility (FFTF) CRDM as defined on component drawings.

II. Environment and Duty Cycle

A. The external surfaces of the CRDM are exposed to the Head Access Area (HAA) air temperature of 85^{+37}_{-30} °F during normal operation and 140°F maximum for loss of HAA cooling. Normal CRDM internal pressure ranges from 0-20 psig. Design condition for ASME Code evaluation are 500°F and 35 psig.

B. Neutron Environment

Neutron dose levels above the closure head in the vicinity of the control rod drive mechanisms may range from 100 mr/hr to <2 mr/hr. A shield system/seismic support will shield areas above 100 inches. The corresponding total neutron flux range is approximately 2×10^4 r/cm^2/sec to $2 \times 10^2 \times 10^2$ n/cm^2 sec.

The above total fluxes correspond to a fast neutron flux $<2 \times 10^2$ n/cm^2/sec.

C. The design life of the CRDM shall be 30 years.

D. Duty Cycle

* Total start-stop cycles	8×10^6
** Total lifetime scrams	732
***Lifetime travel (0.36 to 9.0 ipm)	17,000 feet

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* One motor step equals a start-stop cycle
** Includes 150 isothermal test scrams
***Includes start-stop cycles

III. Loading Conditions

A. Stroke

The CRDM shall provide a minimum withdrawal stroke of 36.00 inches as measured from the nominal position (station -351.025) of the top of the control assembly disconnect coupling to the minimum up position of the CRDM rotational stop. The CRDM insertion stroke shall reach and couple with the control assembly at the lowest position with the top of the control assembly disconnect coupling at -351.750. The CRDM maximum withdrawal stroke shall not exceed 37.80 inches as measured from the lowest position (station -351.750) of the top of the control assembly disconnect coupling to the maximum up position of the CRDM rotational stop. The stroke requirements are referenced to a 70°F temperature environment.

The CRDM shall be capable of providing an incremental motion of 0.025 inches (nominal). The nominal selectable in and out CRDM speed range shall be 0.36 to 9.0 inches per minute. The maximum possible withdrawal speed of the CRDM with a failed controller shall be less than 73 inches per minute.

Amend. 70
Aug. 1982

B. CRDM/CRD Operating Forces

The CRDM shall be designed to exert the following forces:

1. Minimum insertion force on control rod (stuck rod) 1,000 lbs.

2. Minimum withdrawal force sufficient to overcome all worst case forces acting on the control rod assembly is 285 lbs. This force includes control assembly weight (167 lbs), bouyant forces (-30 lbs) and rod friction (148 lbs) acting over the first 8 inches of withdrawal. When the rod is withdrawn above 8 inches and the rod friction force is reduced to 48 pounds and the total force is reduced to 185 lbs.

The CRDM and CRD shall be designed to withstand the following loads. The temperature under which these loads are to be applied is 400oF.

3. Maximum leadscrew driveline tensile load 20,000 lbs

4. Maximum position indicator rod compressive load at refueling temperatures. 1,000 lbs

The CRDM shall resist outward motion of the translating assembly;

5. With the segment arm rollers engaged to the leadscrew (latched), the translating assembly shall not move up when a constant up force of 1800 lbs, or less, is applied to the control rod coupling interface.

6. During a scram operation (stator power interrupt and roller unlatching) the translating assembly outmotion shall be limited when a constant up force of 1800 lbs, or less, is applied to the control rod coupling interface.

7. With the rollers disengaged (unlatched) and the pawl engaged to the leadscrew, the translating assembly outmotion shall be limited when a constant dynamic up force of 1800 lbs, or less, is applied to the control rod coupling interface. Prior to pawl engagement the out-motion velocity is limited (by sodium flow rate) to 25 ips.

4. Since the CRDM employs a pawl design which positively prevents axial outmotion after engagement, the axial outmotion prior to motion arrest shall be limited as follows:

Paragraph (III.B.5) - 0.200 inches
Paragraph (III.B.6) - 0.600 inches
Paragraph (III.B.7) - 3.25 inches

The design shall be capable of resisting outward motion in each of the above operating modes a minimum of two times during plant operation.

The up force is not an ASME Code requirement. Structural integrity of the primary pressure boundary to prevent generation of missiles must be maintained under this loading condition.

The CRDM Scram spring shall meet the following:

1.	Minimum Spring Force	362 lbs at minimum spring compression with the translating assembly in the "full out" position as limited by the rotational stop.
2.	Minimum Spring Stroke	25 inches
3.	**Spring Force at beginning of dashpot operation	0.00 lbs
4.	Design Temperature	400°F

**Defined as elevation (-175.87) where the dashpot piston enters the end of the tapered section of the dashpot cylinder.

IV. Scram

A. Scram Requirements

The overall Primary control Rod System scram requirements are depicted in PSAR Section 4.2.3 and on PSAR Figure 4.2-93 and include the total time from stator power interrupt to reativity insertion. The unlatch time is defined as the time from the start of stator current decay to the initial insertion motion of the leadscrew and shall be 90 msec maximum at normal CRDM and stator operating temperatures.

B. Dashpot

A dashpot shall be included in the CRD for decelerating the translating driveline and control rod during the last nine inches of a scram insertion. The energy of the scrammed assembly shall be absorbed at a deceleration rate which will limit stresses in the driveline components to an acceptable level. The dashpot shall reduce the velocity of the CRD and Control Rod when scrammed from any position between 0 and 37 inches to less than 14 inches/sec at the time of impact on the hard stop at the end of scram insertion.

V. Independence

Each control rod shall be driven and positioned by its own mechanism. Each control rod shall be independent to the extent that protective action is not delayed. The CRDM shall be designed to minimize the probability of simultaneous disability in the scram mode of all CRDMs through systematic, concurrent, undetected failures in the CRDMS resulting from commonality of components or susceptibility to failure due to common environmental conditions, duty cycles, or loads.

VI. CRDM Position Indicators

Two independent CRDM position indicator systems shall sense the position of the leadscrew and thus produce two separate signals indicating the relative position of the control rod in the core.

The rotary (relative) position indicating system shall consist of an electromagnetic sensor that counts the revolutions of salient poles of an indicating disc attached to the drive mechanism rotor. The axial resolution of the rotary position indication system shall be 0.10 inches (nominal).

The absolute position indication system shall measure the position of the leadscrew through a sensor located in a housing that projects into the inside diameter of the leadscrew. This system shall not lose its reference position because of mechanism scram. The resolution of the

absolute position indication system shall be 0.50 inches. The system position accuracy over full stroke shall be ± 3.5%, of the full stroke. The accuracy of the position indication sensor over the range of environmental conditions shall be ± 1.62% of the full stroke. the accuracy refers to the ability to measure the true position of the top of the leadscrew.

VII. Cooling

A stator cooling system shall be provided. This system shall not act as part of the reactor primary system boundary. The design shall incorporate thermocouples into the stator cooling system and provide the corresponding electrical interface information.

VIII. Reactor Refueling

The mechanism design shall permit refueling and fuel transfer operations inside the reactor vessel in the space above the core without disassembly and removal of the mechanism. The design shall permit access to the actuating shaft interlock ring and disconnect actuating shaft so that the disconnect coupling between the driveline and control assembly can be manually operated

The design shall have provisions for the operation of a manual disconnect tool (not provided as part of this specification) for disconnecting the control rod from the driveline and for holding the leadscrew in a withdrawn position for refueling operations.

IX. Out-Motion Limited Pawl

An OML pawl shall be provided to limit outward motion of the translating assembly. Structural integrity of the pawl system (pawl and mounting brackets and hardware) shall be maintained for a static up force of 4000 lbs acting on the control rod coupling interface. During a scram the pawl shall not produce a drag force on the leadscrew in excess of 19 lbs. (average) based on worst case dimensions with a friction coefficient of 0.8.

X. Internal Seal Requirements

The Seal Requirements listed here are for Internal Seals and not the CRDM pressure boundary.

(a) Each CRDM shall be equipped with seal arrangements which consist of a Main Bellows Seal, Position Indicator Rod Bellows, Disconnect Actuating Shaft Bellows, and Lower CRDM to Nozzle Extension Conoseal.

(b) The Seals shall separate the CRDM rotor assembly and leadscrew from the reactor environment.

(c) All bellows parameters (length of stroke, etc.) shall be compatible with the CRDM parameters.

(d) The Main Bellows shall collapse upon withdrawal of a control rod and extend upon insertion of a control rod.

(e) The Disconnect Actuating Shaft Bellows and the Position Indicator Rod Bellows expand and collapse only during operation of the manual disconnect.

(f) Maximum helium leak rate for each of the four seals listed in (a) above is 1 x 10^{-5} cm^3/sec at standard temperature and pressure.

(g) Bellows seal environment

- Temperature - 400°F (maximum)

- CRDM - argon gas

The internal fluid in the mechanism above the bellows is normally reactor grade argon gas at 0 to 20 psig. The composition of this gas is as follows:

Argon	-99.996% pure
Oxygen	- 5 ppm maximum (volume)
Hydrogen	- 2 ppm maximum (volume)
Nitrogen	-15 ppm maximum (volume)
Carbonaceous Gases	- 5 ppm maximum (volume)
Water (D.P. -84°F)	- 6 ppm maximum (volume)
Other	- 7 ppm maximum (volume)

An environment of Argon saturated with sodium vapor is to be considered an abnormal condition. The mechanism shall be designed to operate throughout a reactor operating cycle (1 year) when exposed to this abnormal environment. In order to assure that the mechanism continues to operate with a failed bellows, the design shall make provision to prevent sodium from depositing on the rotor assembly parts.

After repair and/or replacement of a failed bellows and cleaning of the CRDM to return it to its normal condition, the mechanism shall continue to function for the remainder of its design life.

o Reactor cover gas side - Argon gas saturated with sodium vapor (external to bellows).

The environment external to the bellows is reactor grade Argon cover gas saturated with sodium vapor. Normal operating pressure is 6 $\pm$ 2 in. w.g. Maximum operating pressure is 7 psig. during shutdown maximum pressure is 11 psig. The composition of the gas is identical to 3.5.2S except as follows:

Oxygen	10 ppm maximum
Hydrogen	50 ppm maximum
Nitrogen	2000 ppm maximum

o Pressure - Normal operating pressure differential is 0 to +20 psig. Maximum operating pressure differential is -7 to +20 psig. During shutdown, maximum pressure differential is -11 psig. During CRDM fill with Argon gas, maximum over pressure is 35 psig (not an operating condition).

For the leadscrew and position indicator shaft bellows, a positive (+) pressure differential denotes a higher internal bellows pressure with respect to the external pressure and a negative (-) pressure differential denotes a lower internal bellows pressure with respect to the external pressure. For the actuating shaft bellows, a positive (+) pressure differential denotes a lower internal pressure with respect to the external pressure, and a negative (-) pressure differential denotes a higher internal pressure with respect to the external pressure.

(I) A pressure switch will be provided in the CRDM to sense internal pressure and indicate seal failures.

XI. Installation and Removal

The mechanism shall be arranged so that all operations incident to its installation on, and removal from, the reactor can be performed with access only to the head of the reactor vessel. Replacement of the stator assembly shall be possible without penetration of the primary reactor system boundary.

XII. Electrical

Stator Design

A redesign of the FFTF stator which meets the requirements of Section III "Loading conditions" and its subsections shall be provided. The design shall be consistent with a mechanism design which is balanced over all parameters, particularly with respect to load capability, scram reliability and stator cooling requirements. The design basis shall be increased margin over worst case loading allowing higher segment arm spring force for improved scram reliability and possible reduction of electrical and cooling power demand.

The stator shall be designed for a 30-year life. Motor lead wire shall conform to MIL-W-8777C and MS-25471. The stator shall have monofilar windings of the double ML type wire. The cooling jacket for the stator shall also be redesigned to be compatible with the cooling requirement of the redesigned stator configuration. The cooling requirements shall not exceed FFTF values:

Cooling Gas	Nitrogen
Supply Pressure	90 to 100 psig
Inlet Gas Temperature	50 to 60°F
Outlet Gas Temperature	130°F maximum
Pressure Drop Across Stator	1.5 ± .5 psi
Heat Load-Each CRDM	12,000 BTU/hr maximum
Flow Rate	157 ± 10 SCFM
Moisture Content	8 ppm by weight maximum

XIII. Testing Requirements

A. Stator Tests

The stator shall be tested at various points during fabrication as indicated below. The results of these tests shall be recorded and maintained in the record book for each particular stator. If thermocouples are required to be incorporated into the stator, these thermocouples shall conform to ASTM E 230.

The individual coil group resistance shall be checked prior to inserting the coils into the stator. Any coil whose resistance varies by more ± 2% from the nominal design value shall be rejected. After all windings have been inserted into the stator and before the lead connections are permanently made, the stator shall be subjected to a DC Insulatin Test and an AC Dielectric Strength Test as described below:

The following tests shall be made on the stator upon completion of the lead connections and before varnish impregnation.

1. DC Winding Resistance Test

   The resistance of each phase of the stator shall be checked. Resistance which varies by more than ± 2% from the nominal design value, shall be cause for rejection. Also, an unbalance of phase resistance which exceeds ± 1.5% of the average value for all the phases of the stator shall be cause for rejection.

2. DC Insulation Resistance Test

   The insulation resistance from all phases and neutral lead to ground shall be checked. The minimum acceptable phase-to-ground resistance at 25°C is 10 megohms.

3. AC Dielectric Strength Test

   Apply 1500 volts rms 60 Hz between the stator iron and any one of the stator leads. Voltage shall be applied at a rate of

approximately 100 volts per second, maintained at 1500 volts for 15 seconds, then reduced to zero at approximately 100 volts per second. All of the phases of the stator shall be checked. The stator insulation must not exhibit dielectric breakdown when subjected to the above test voltages. All six phases may be tested simultaneously. In addition, measurements of the maximum compensated current leakage between coils and between windings and the core stack will be recorded for the prototype CRDM stator. From these values an acceptance criteria will be established for the plant unit CRDM stators.

4. Surge Comparison Test

Surge testing shall be conducted using 3000 volts DC and shall check the waveform of power thru the stator phases. Any sharp or jagged indication of a trace, regardless of proximity of comparison between traces, shall be cause for rejection of the stator. Stators which include test instrumentation may be tested at lower voltage subject to Purchaser approval.

After successful completion of these tests, the stator shall be varnish vacuum impregnated and baked. During this processing, the stator leadwires must be protected to prevent the varnish for making them inflexible. Upon completion of this processing the tests described above shall be reperformed and the results recorded.

5. Cooling Jacket Leak and Strength Test

The cooling jacket supplied with the CRDM shall be tested for leakage and strength against pre-defined acceptance criteria.

B. Helium Leak Test

A helium leak test shall be performed on the completed CRDM components that serve as part of the primary system environmental boundary. The maximum acceptable leak rate for this test shall be 1×10^{-4} scc/sec/CRDM total for all external leak paths.

If it is determined that a dangerous situation would not exist from pressurization of helium gas, the leak test and strength test, as described below, may be combined. However, if they are not combined, the leak test shall be performed after the strength test.

C. Strength Test

A strength test shall be performed on the completed CRDM components that serve as part of the primary system environmental boundary and shall be either pneumatic or hydrostatic.

This test shall be in accordance with NB-6000 of Section III of the ASME Boiler and Pressure Vessel Code. The following general requirements apply to the strength test:

1. Prior to testing, all interior surfaces shall be cleaned. The Supplier shall prepare and submit a detailed cleaning procedure as part of the Fabrication Plan.

2. The component shall be tested at a minimum temperature of 70°F and the test temperature shall be reported in the Fabrication Report.

3. The number of tests above design pressure shall be minimized.

4. Any indication of leakage in the fluid or gas boundary of the components at other than a flanged joint shall be reported. The location and extent of any leak indication and the corrective action taken shall be reported in the Fabrication Report.

5. If a hydrostatic strength test is performed, following this test the mechanism shall be completely drained and internal surfaces shall be completely dried by flushing the still-sealed test assembly with heated dry nitrogen or drawing a vacuum. The pressure component being tested shall be protected from contamination by maintaining the sealed condition and internal environment of dry nitrogen until the helium leak test required by Section XIIB is performed.

D. CRDM Performance Tests

The prototype CRDM shall be tested to show conformance with the design objectives. This testing will be performed in accordance with detailed requirements designated in this specification. For successful completion of the work, this testing will demonstrate compliance with the design objectives with or without any specified additional equipment attached to the mechanism, as applicable. As a minimum, the following parameters will be investigated and reported:

1. Maximum possible lifting force exerted;
2. Normal lifting force exerted;
3. Maximum possible driving-down force exerted;
4. Normal driving-down force exerted;
5. Maximum torque exerted on the leadscrew;
6. Normal torque exerted on the leadscrew;
7. Total travel during the test for maximum, and normally exerted forces;
8. Stator coil amperage and voltage for maximum and normally exerted, forces and driveline speeds;
9. Stator coil amperage, voltage, and resistance as functions of temperature;
10. Stator coil steady-state temperature variation during operation and holding periods;

11. Stator current decay time and total leadscrew release time as a function of temperature, load, stator power, and misalignment. The unit shall be tested for delay time and release time at four different rotor to motor tube (Index) positions and stator to motor tube (Index) positions;

12. The CRDM scram characteristics as functions of the stator power, rod speed, and load;

13. Mechanism internal environment parameters including, but not limited to:

    a. Temperature

    b. Pressure

    c. Contained atmosphere

    d. Lubrication;

14. Dynamic response of the CRDM leadscrew to a single pulse from the controller as well as to travel speeds of 0.36 inches/minute and 9.0 inches/minute;

15. Mechanism cooling system parameters, as applicable;

16. Any other parameters or factors that may have an effect on the mechanism meeting the design objectives.

E. Acceptance Test

1. Acceptance tests shall be performed on each plant unit CRDM/CRD and associated equipment which will establish that the performance of each unit is within acceptable limits established as satisfactory for the CRBRP mechanisms.

2. The translating assembly out-motion requirement shall be verified by testing. Testing shall include the three specified modes of latched, scram and unlatched.

The test article shall include the Upper CRDM and leadscrew as a minimum. A mass equivalent to the mass of the remaining translating assembly components shall be attached to the leadscrew. The specified up force shall be applied to the bottom of the leadscrew and maintained constant for a stroke of 10 inches at 10 $\pm$ 1 inches withdrawn and 25 $\pm$ 1 inches withdrawn for the latched and scram mode. For the unlatched mode the leadscrew shall be a position, with the pawl above the top leadscrew tooth, such that the impact velocity, when the pawl engages the leadscrew top tooth, is equal or greater than 25 ips.

3. The OML pawl maximum drag force requirement shall be verified by test. The system shall meet the requirement during inward motion of the leadscrew with the actual friction coefficient.

ITEM 3 and following request

TEST DATA

I. One of the specifications for the mechanism is that under the most unusual conditions the withdrawal speed shall not exceed 73 ipm. Conformance to this requirement was demonstrated at the vendors facility as part of the performance test.

The maximum withdrawal speed test was run to determine the axial force which could be exerted by the mechanism as a function of current and withdrawal speed before pole slippage occurs. If the speed is increased or the current decreased beyond the point of pole slippage, the roller nuts will roll out of the leadscrew and the mechanism will scram. The data from this test is shown in Table QCS760.176-1. At the design condition of 175 volts and 7.2 amps. rollout occurs at 43 ipm. The total force required is comprised of the net weight of translating assembly, friction and drag forces, and spring forces from the bellows and scram assist spring. The maximum force at the top of the stroke is 1135 lbs. and the minimum force at the bottom of the stroke is approximately 400 lbs. As the assembly is withdrawn the scram and bellows forces increase. Thus the force in Table QCS760.176-1 is dependent on the axial position of the translating assembly when rollout occurs.

To exceed the design voltage of 175 volts, a series of significant failures must occur in the controller and M-G sets. If all of these failures occurred at the same time, the maximum voltage which could be applied to the stator is 252 volts. As shown in the data in Table QCS760.176-1, at 258 volts, rollout will occur between 60 and 70 ipm if the translating assembly is withdrawn less than 10.5 inches where the spring forces are applied. If the translating assembly is in a normal operating range of 16 inches to 28 inches withdrawn rollout will occur between 50 and 60 ipm. Thus the PCRDM meets the design requirement that it shall never be withdrawn at a speed greater than 73 ipm.

II. All 18 mechanisms (9 plant units and 9 spares) were acceptance tested. The acceptance test data show that all 18 mechanisms met all test requirements.

III. To determine the response of the PCRDM to loss of stator coolant flow, a series of tests were run a W-ARD. In these tests the stator winding temperature and outlet coolant temperature were measured as a function of time for a variety of coolant flows including complete loss of flow. The results for a complete loss of coolant flow is shown in Figure QCS760.176-6. For this condition, the maximum stator temperature reached an asymtotic value of 660°F in 250 minutes. It should also be noted that the thermocouple measuring the outlet coolant temperature followed the maximum stator temperature heat up rate fairly closely. At 260 minutes, power to the stator was turned off and the stator temperature and outlet coolant temperature were monitored during the cooldown, without the benefit of coolant flow. As shown in Figure QCS760.176-6 the maximum stator temperature and outlet coolant temperature dropped rapidly.

During this test, the assembly was withdrawn to 36.0 inches and placed in 3-phase hold. In this condition the maximum spring force was applied to the driveline, and the maximum heat was generated in the windings. When the maximum stator temperature was obtained, the mechanism was drive down to 25 inches withdrawn and back up to 36 inches five times to demonstrate that the mechanism functioned properly and did not roll out or scram under these abnormal conditions. The mechanism was then scrammed and the unlatch time and scram time were measured. The results indicated that the unlatch time was faster than normal and the scram time was normal. When the test was completed and the stator had cooled to ambient temperature, the stator winding resistance and insulation resistance were measured and found to be unchanged. It was concluded that the mechanism and stator has functioned properly during these abnormal conditions and had suffered no degradation or loss of operating life.

In the plant unit mechanisms there is an operating thermocouple and a spare thermocouple which measures the temperature of the outlet cooling nitrogen. These thermocouples will alarm at 200°F to indicate a reduction in stator cooling and an increase in stator temperature. At this time some action may be taken to resolve the problem since the mechanism should not operate indefinitely without coolant flow. This condition is not a safety problem but one of degradation of the mechanism insulation.

TABLE QCS760.176-1

MAXIMUM AXIAL FORCE FOR NO POLE SLIPPAGE IN POUNDS

Withdrawal Speed	6 amps/ 135 V	7 amps/ 170 V	8 amps/ 210 V	9 amps/ 258 V
1	2510	2890	3180	3270
5	2270	2700	2990	3180
10	1980	2420	2610	2890
15	1650	2030	2420	2840
20	1320	1700	2230	2610
30	Rolls out	900	1560	2030
40		Rolls out	980	1510
50			Rolls out	1080
60				600
70				Rolls out

Figure QCS760.176-1 Motor Tube, Hold-Down Ring, P. D. Housing, and Pressure Switch

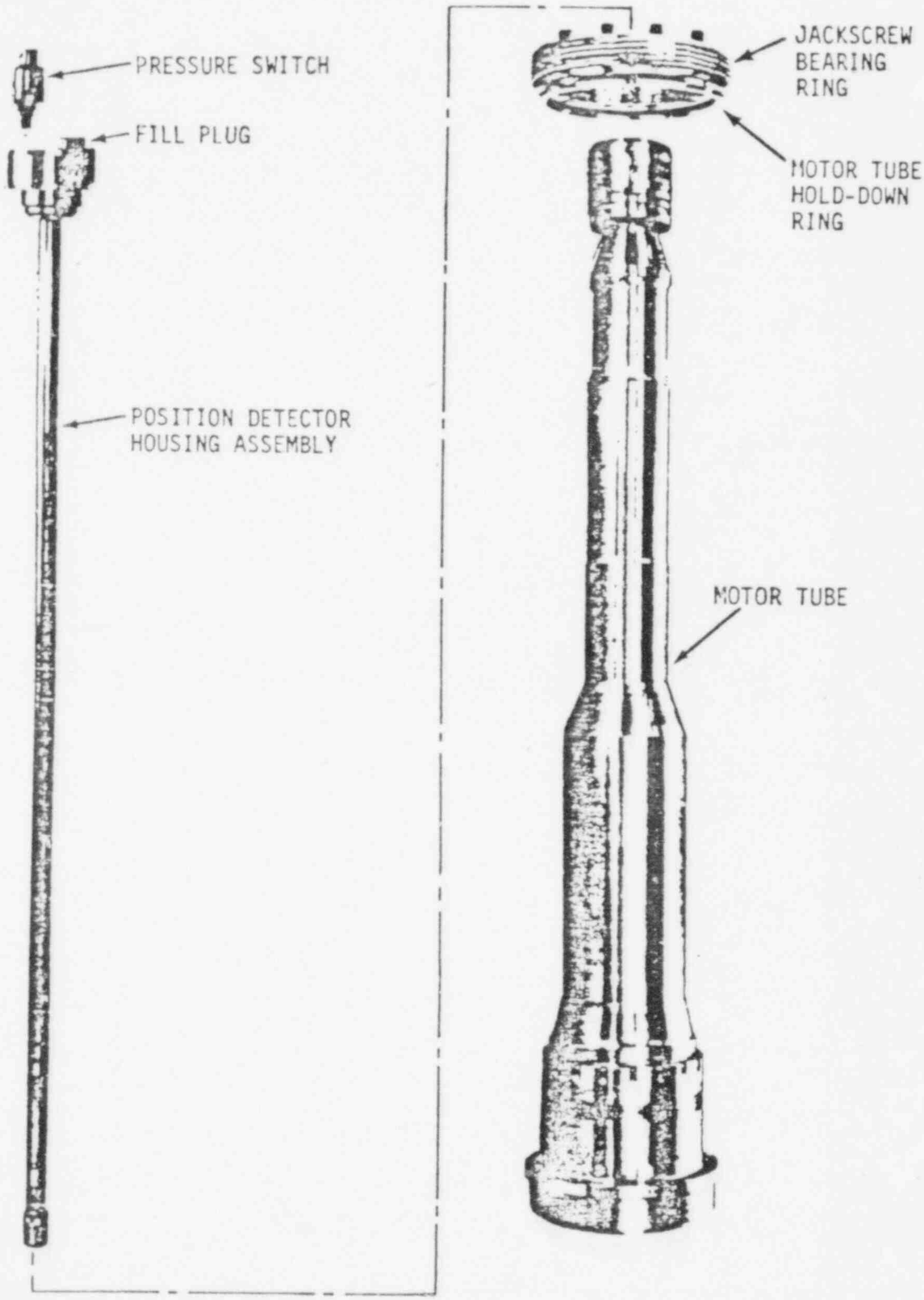

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Figure QCS760.176-2 Rotor Assembly

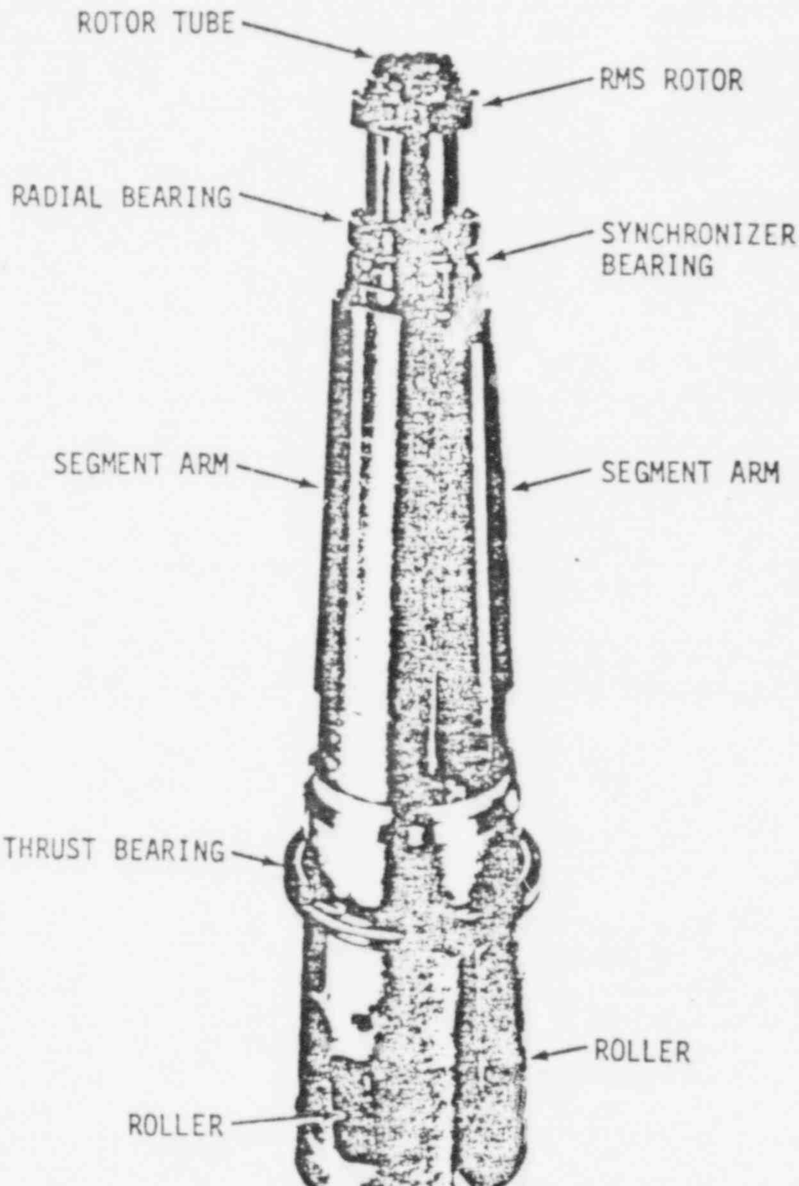

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Figure QCS760.176-3 Stator-Jacket Assembly

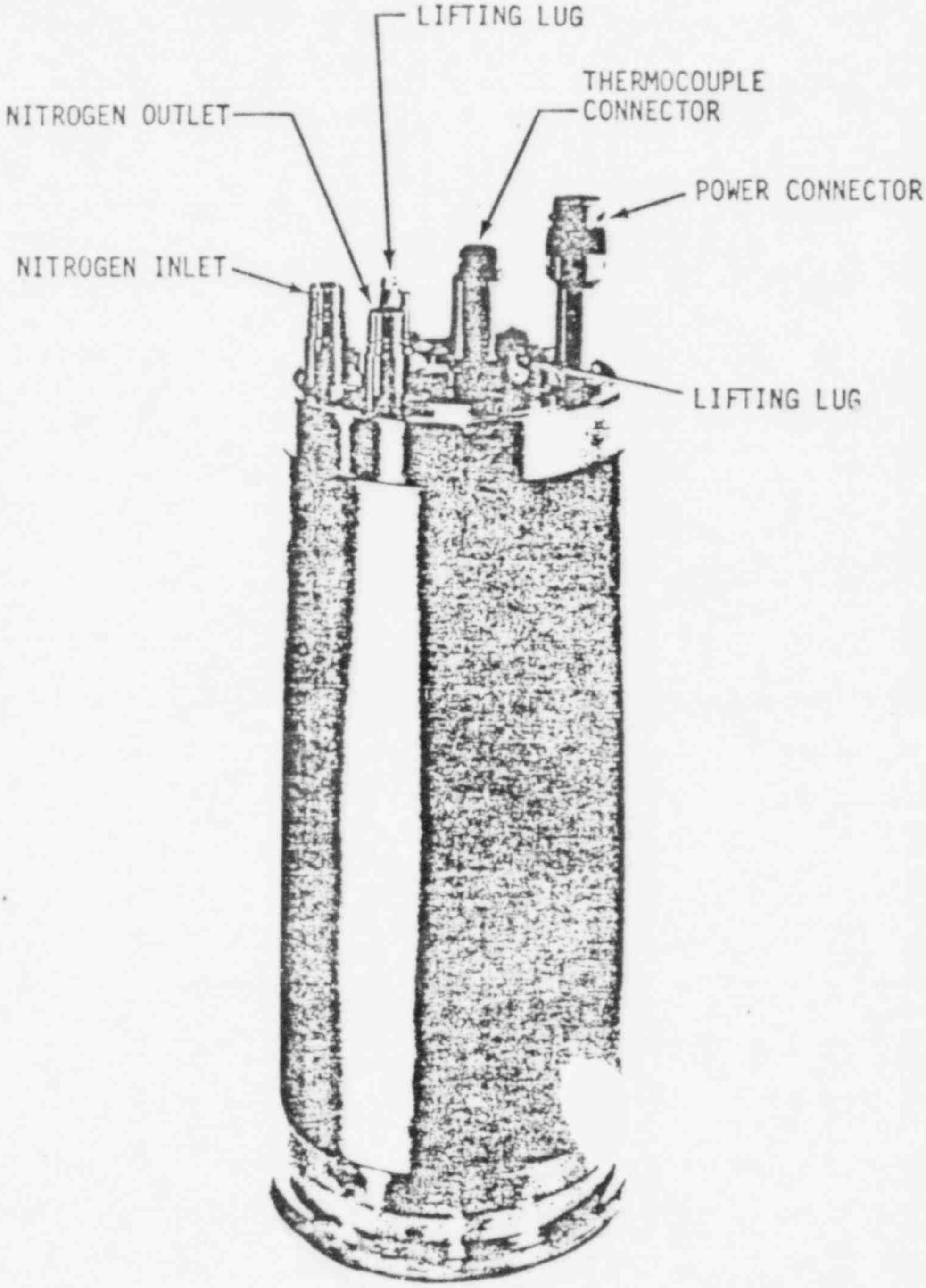


Figure QCS760.176-4 PCRDM and Controller System Schematic

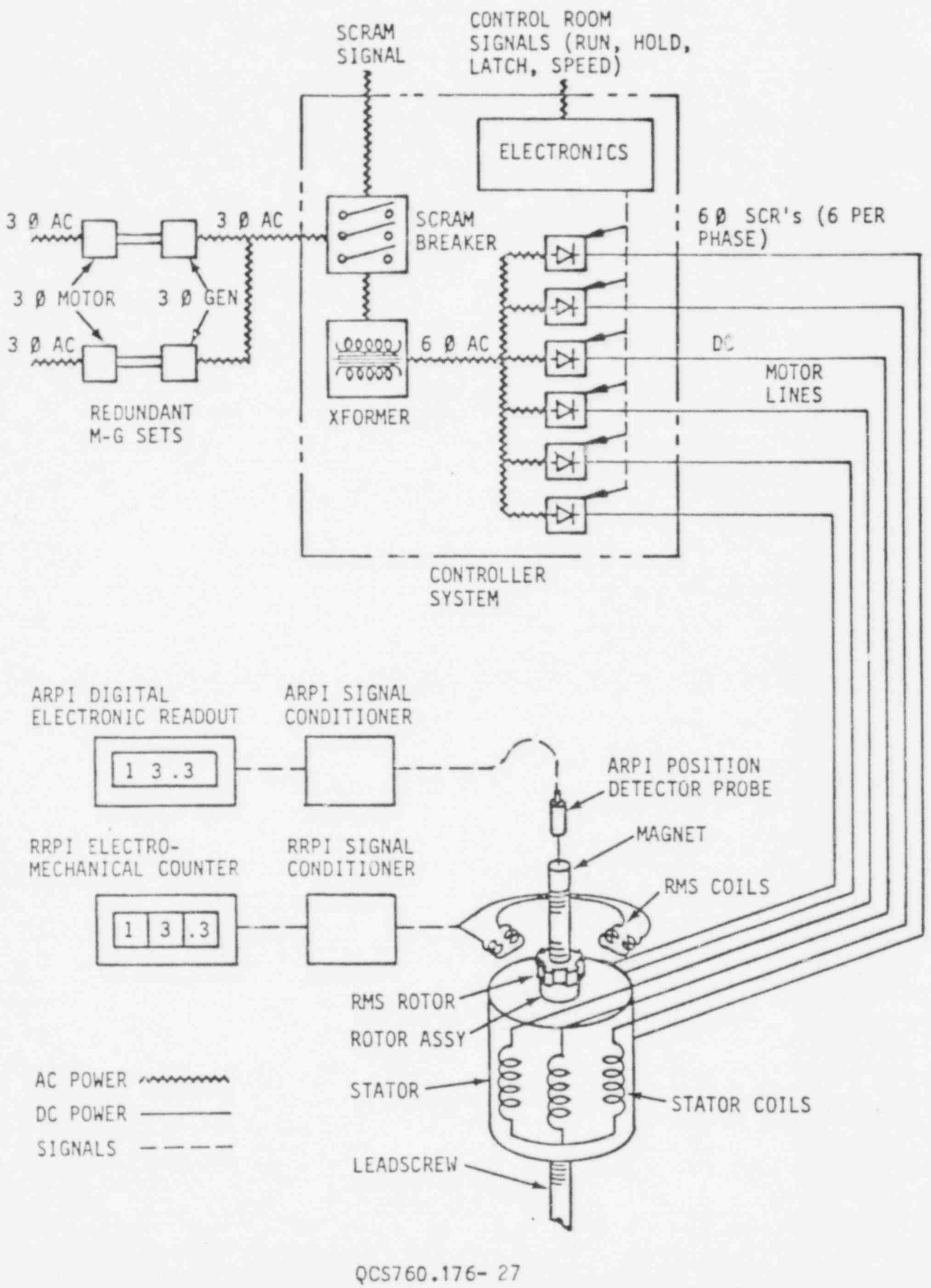


Figure QCS760.176-5

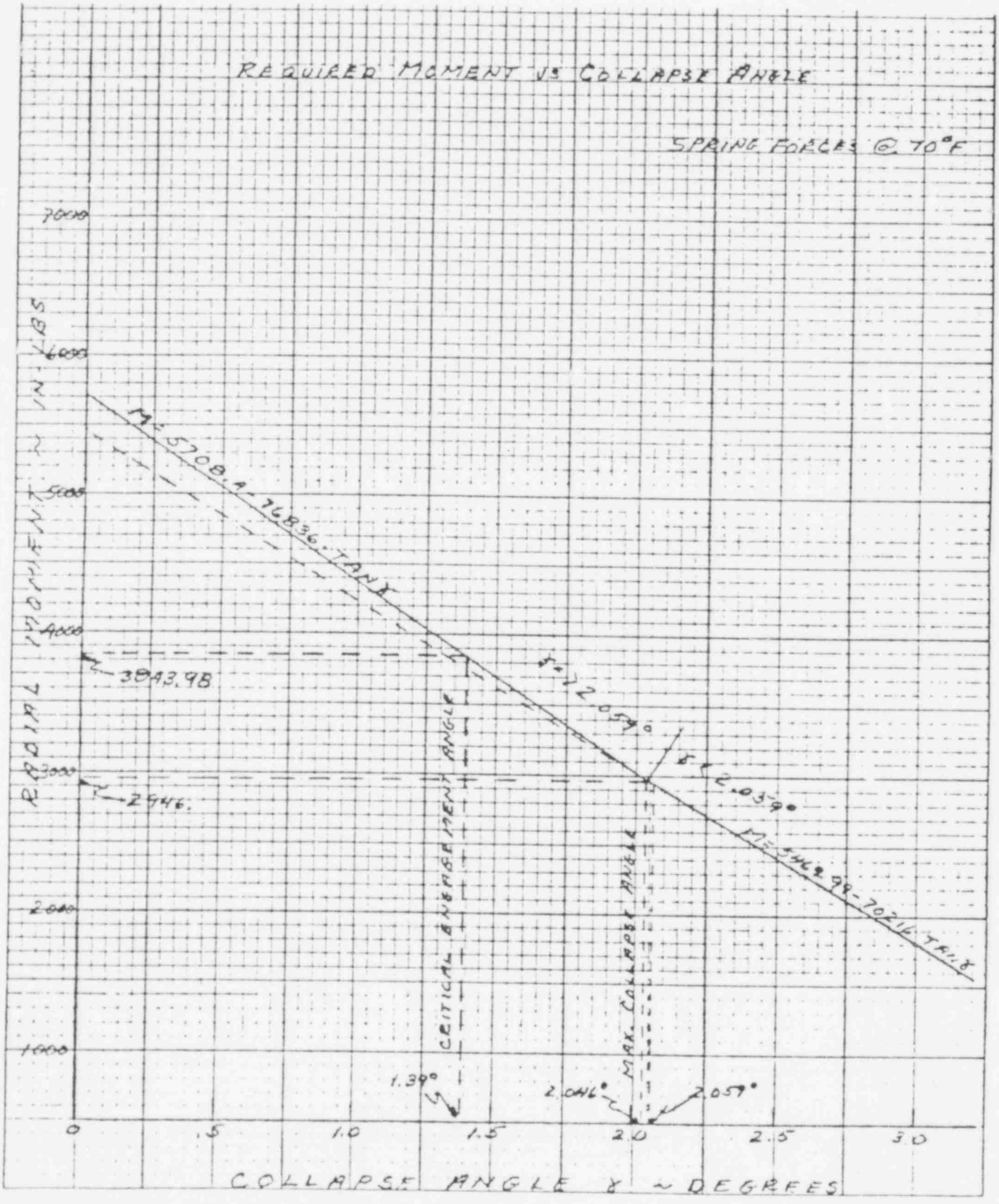
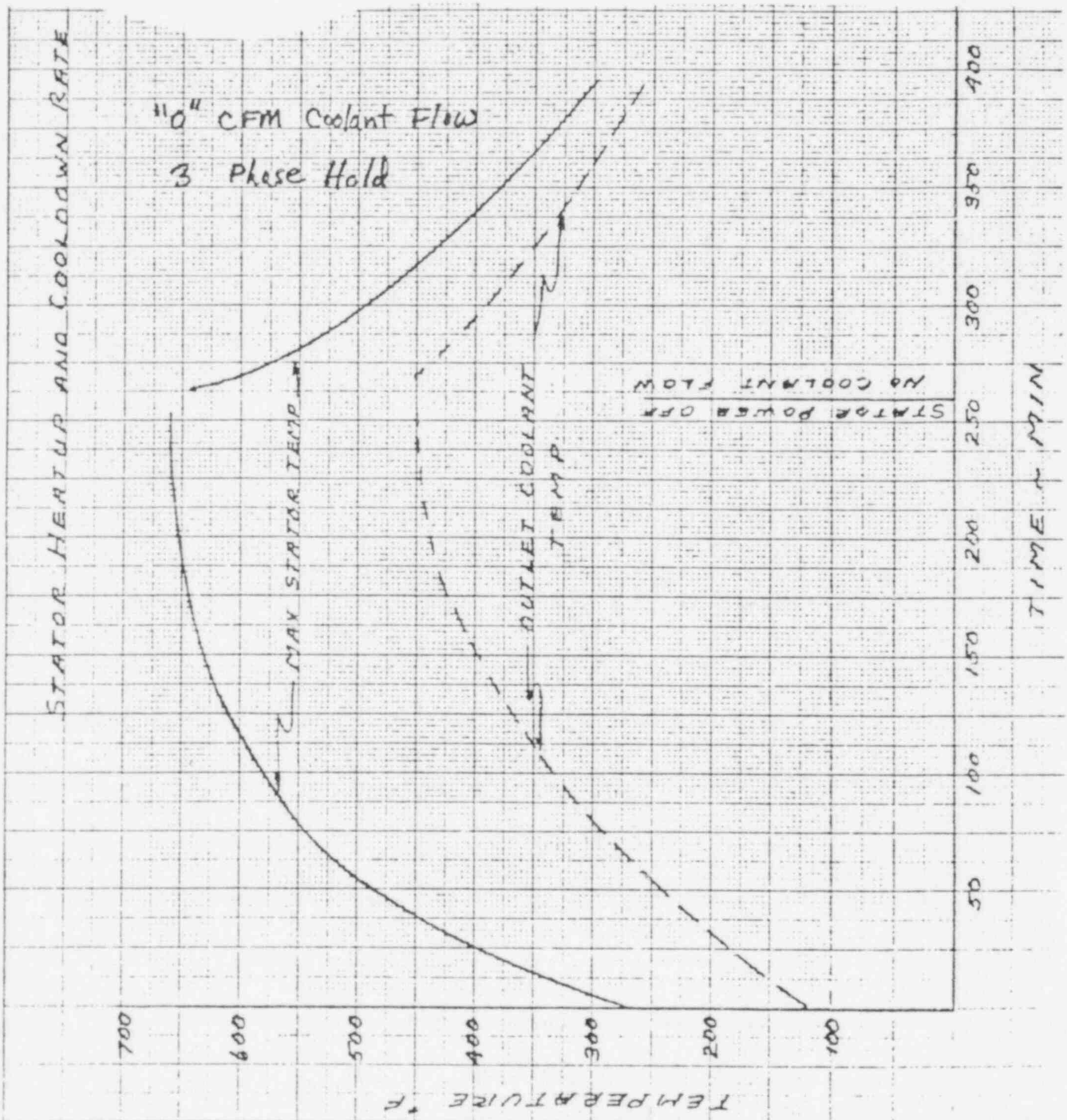


Figure QCS760.176-6 Stator Heatup and Cooldown Rate



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