RDT E6-5T

RDT STANDARD

COLLAPSIBLE-ROTOR ROLLER-NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

MARCH 1971

DIVISION OF REACTOR DEVELOPMENT AND TECHNOLOGY
UNITED STATES ATOMIC ENERGY COMMISSION

DISCLAIMER

Operated by
Westinghouse
Hanford Company
for the USAEC

A subsidiary of
Westinghouse Electric
Corporation

RDT Standards Transmittal

Hanford Engineering Development Laboratory

DISTRIBUTION	DATE December 11, 1972		NO. 83
Distribution List 1	RETURN COMMENTS TO	TYPE SUBMISSION	TYPE ACTION
	J. C. Noakes Westinghouse Hanford Company P. O. Box 1970 Richland, WA 99352	[ ] 1. PRELIMINARY [ ] 2. DRAFT [x] 3. TENTATIVE [ ] 4. FINAL [ ] 5.	[ ] A. APPROVAL [ ] B. INFORMATION [ ] C. COMMENTS [x] D. TRIAL USE [ ] E.
	NOT LATER THAN		

NUMBER	DESCRIPTION	ACTION
RDT E 6-5T	Collapsible-Rotor, Roller-Nut Control Rod Drive Mechanism for Sodium Service. Amendment 1 dated December 1972.	D

Enclosed Amendment is issued per TWX, RDT:RE:CM:220 dated November 17, 1972.

SIGNATURE [signature]

AEC-RL RICHLAND, WASH.

UNITED STATES ATOMIC ENERGY COMMISSION
DIVISION OF REACTOR DEVELOPMENT AND TECHNOLOGY
Date December 1972

COLLAPSIBLE-ROTOR, ROLLER-NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

AMENDMENT 1

This amendment forms a part of RDT E 6-5T
dated March 1971

1. Page 38, Paragraph 4.5.3 Requirements for Nondestructive Test Examination:
Delete the second sentence.

WESTINGHOUSE ELECTRIC CORPORATION
ADVANCED REACTORS DIVISION
BOX 158
MADISON, PENNSYLVANIA 15663

RDT STANDARDS TRANSMITTAL

DISTRIBUTION	DATE August 8, 1973	NO. DSC-317
Distribution List 1		

RETURN COMMENTS TO
C. Roderick
Westinghouse Electric
P. O. Box 158
Waltz Mill Site
Madison, Pa. 15663

NOT LATER THAN

TYPE SUBMISSION
- [ ] 1. PRELIMINARY
- [ ] 2. DRAFT
- [X] 3. TENTATIVE
- [ ] 4. FINAL
- [X] 5. Amendment

TYPE ACTION
- [ ] A. APPROVAL
- [ ] B. INFORMATION
- [ ] C. COMMENTS
- [X] D. TRIAL USE
- [ ] E.

NUMBER	DESCRIPTION	ACTION
RDT E 6-5T	Collapsible-Rotor, Roller-Nut Control Rod Drive Mechanism for Sodium Service, Amendment 2, dated August 1973	D

SIGNATURE

C. Roderick, Manager
Division Standards Coordination

COLLAPSIBLE-ROTOR, ROLLER-NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

AMENDMENT 2

This amendment forms a part of RDT E 6-5T
dated March 1971

1. Page 2, 2.2.1 RDT Process Standards: Add in sequence the following reference:

   RDT F 8-6T, Hoisting and Rigging of Critical Components and Related Equipment

2. Page 23, Add new paragraph 3.10.9 Handling as follows:

   3.10.9 Handling. The lifting and handling of parts or assemblies designated by the purchaser as critical shall be in accordance with the requirements of RDT F 8-6 as specified in the Ordering Data. These requirements shall be applied at all stages of fabrication after the parts or assemblies become critical items.

3. Page 49, 5.3.2 Shipping Instructions: Add a second sentence as follows:

   The instructions for handling and lifting of critical items shall be in accordance with the requirements of RDT F 8-6 as specified in the Ordering Data.

4. Page 49, 5.3.3 Loading: Revise second sentence to read as follows:

   All handling equipment and shipping containers shall be adequate to prevent any damage to components during handling and shipping operations in accordance with the requirements of Section 5.2 and the requirements of RDT F 8-6 as specified in the Ordering Data.

5. Page 49, 5.4 Handling: Revise to read:

   5.4 Handling. All handling, lifting, supporting, and shipping fixtures shall comply with requirements of RDT F 8-6 as specified in the Ordering Data.

6. Page 49, 5.4.2: Delete this paragraph.

RDT E 6-5T
March 1971

RDT STANDARD

COLLAPSIBLE-ROTOR, ROLLER NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

TABLE OF CONTENTS

Release for Announcement in
Nuclear Science Abstracts

RDT STANDARD

COLLAPSIBLE-ROTOR, ROLLER NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

TABLE OF CONTENTS

COLLAPSIBLE-ROTOR, ROLLER-NUT CONTROL ROD DRIVE MECHANISM FOR SODIUM SERVICE

1. SCOPE

1.1 Purpose. This Standard establishes the requirements for the design, fabrication, assembly, and quality assurance for the procurement of the electro-mechanical devices intended to move and position control elements within the core of a liquid sodium cooled nuclear reactor. Only those drive mechanisms based upon a collapsible-rotor, roller-nut mechanical motor, energized by a magnetic field generated by an electrical coil, are governed by this Standard. These control rod drive mechanisms (CRDMs) may be connected to control rods having specific functions such as power regulation, power shimming, or safety shutdown, or any sequence or combination of these functions. If these functions require variations in design parameters, this variation shall be specified in the Ordering Data document which accompanies this Standard.

1.2 Components and Services to be Provided. All components and services to be provided by the Supplier shall be as specified in the Ordering Data.

2. APPLICABLE DOCUMENTS

2.1 General. The documents listed below in this section are a part of this Standard to the extent that they are specified in the Ordering Data. The issue of each, including revisions, in effect on the date of procurement shall be applicable. Any conflicts between these documents and the specific requirements of this Standard shall be brought to the attention of the Purchaser for resolution. RDT Standards shall be used in place of other standards where an RDT Standard exists. If materials or standards not included in the following list are required in performance of the work, the Supplier shall submit for Purchaser approval, information concerning the proposed material or standard and the extent of applicability. Purchaser approval shall be obtained prior to the use of such material or standard. Later changes, revisions or additions to these documents may be implemented during the course of the contract by mutual agreement between the Purchaser and Supplier.

2.2 RDT Standards. The standards referenced below often contain sections titled "Additional Requirements" and "Optional Requirements." The applicability of these sections shall be specified in the Ordering Data.

2.2.1 RDT Process Standards*

RDT F 2-2T	Quality Assurance Program Requirements
RDT F 2-4T	Quality Verification Program Requirements
RDT F 3-3T	Ultrasonic Examination of Heavy Steel Forgings (Modified ASTM A388)
RDT F 3-4T	Ultrasonic Shear-Wave Examination of Plates (Modified ASTM A577)
RDT F 3-5T	Longitudinal-Wave Ultrasonic Examination of Plain and Clad Steel Plates (Modified ASTM A578)
RDT F 3-6T	Nondestructive Examination
RDT F 3-7T	Inspection Requirements for Materials in Wear Applications

*The letter "T" which appears at the end of RDT Standard numbers designates approval for use as "tentative" standard.

RDT F 3-8T	Ultrasonic Examination of Metal Pipe and Tubing for Longitudinal Discontinuities (Modified ASTM E213)
RDT F 5-1T	Cleaning and Cleanliness Requirements for Nuclear Reactor Components
RDT F 6-1T	Welding
RDT F 7-2T	Preparation for Sealing, Packaging, Packing, and Marking of Components for Shipment and Storage
RDT F 7-3T	Requirement for Identification Marking of Reactor Plant Components and Piping
RDT F 8-1T	Preloading Threaded Fasteners and Closures

2.2.2 RDT Material Standards*

RDT M 1-1T	Corrosion Resisting Chromium and Chromium-Nickel Steel Covered Welding Electrodes (Modified ASTM A298)
RDT M 1-2T	Corrosion Resisting Chromium and Chromium-Nickel Steel Welding Rods and Bare Electrodes (Modified ASTM A371)
RDT M 1-5T	Surfacing Welding Rods and Electrodes (Modified ASTM A399)
RDT M 1-9T	Brazing Filler Metal (Modified ASTM B260)
RDT M 2-2T	Stainless and Heat-Resisting Steel Forgings (Modified ASTM A182)
RDT M 2-6T	Low-Carbon Chromium Steel Forgings (Modified ASTM A473)
RDT M 3-2T	Seamless Ferritic and Austenitic Alloy Steel Tubes (Modified ASTM A213)
RDT M 3-3T	Seamless Austenitic Stainless Steel Pipe (Modified ASTM A376)
RDT M 4-3T	Cobalt-Chromium Alloy Castings, Wear and Corrosion Resistant
RDT M 5-1T	Chromium and Chromium-Nickel Stainless Steel Plate, Sheet and Strip (Modified ASTM A240)
RDT M 6-1T	Alloy Steel Bolting Materials for Low Temperature Service (Modified ASTM A320)
RDT M 6-2T	Mechanical Locking Devices
RDT M 6-3T	Alloy Steel Bolting Materials for High Temperature Service (Modified ASTM A193)

*The letter "T" which appears at the end of RDT Standard numbers designates approval for use as "tentative" standard.

RDT M 7-1T	Low Carbon Chromium Steel Bars (Modified ASTM A276)
RDT M 7-2T	Nickel-Chromium-Iron Age-Hardenable Alloy Bars, Rods, and Forgings (Modified ASTM A461)
RDT M 7-3T	Stainless and Heat-Resisting Steel Bars and Shapes (Modified ASTM A479)
RDT M 7-4T	Nickel-Chromium-Iron Alloy Rod, Bar, and Forgings (Modified ASTM B166)
RDT M 7-6T	Chromium-Nickel Steel Bars and Forgings, Corrosion Resistant, Precipitation Hardening
RDT M 7-8T	Alloy Wire, Corrosion and Heat Resistant, Nickel Base Annealed
RDT M 8-1T	Helical Age-Hardenable Nickel-Chromium-Iron Alloy Springs
RDT M 9-1T	Materials and Fabrication Requirements for Nickel-Chromium-Iron Alloy Seal Applications
RDT M 9-2T	Examination Requirements and Acceptance Standards for Seal Membranes
RDT M 11-1T	Nonmetallic Seal Materials

2.3 Other Standards and Codes Applicable

ASTM Specifications

ASTM A 370	Methods and Definitions for Mechanical Testing of Steel Products
ASTM E 8	Methods of Tension Testing of Metallic Materials
ASTM E 23	Methods for Notched Bar Impact Testing of Metallic Materials
ASTM E 230	Temperature-Electromotive Force (EMP) Tables for Thermocouples

American National Standards Institute Standards (formerly the U.S.A. Standards Institute - USASI)

ANSI	B1.1	Unified Screw Threads
ANSI	B46.1	Surface Texture
ANSI	Y14	Standard Drafting Manual

ASME Boiler and Pressure Vessel Code

Section II	Materials Specifications
Section III and Applicable Code Cases and Addenda	Nuclear Vessels
Section XI	Code for In-Service Inspection of Nuclear Reactor Coolant Systems

NEMA MG 1 Motors and Generators

NBS H-28 Screwthreads for Federal Service

Military Specifications

MIL-W-583C Wire, Magnet, Electrical

2.4 Exceptions. No exceptions shall be made to the requirements of this Standard or referenced documents without written authorization from the Purchaser to do so. Should the Supplier desire to make an exception, he shall prepare and submit a written request, with sufficient justification for the request, to the Purchaser. Exceptions will only be permitted if the Supplier provides convincing evidence that:

a) Complete assurance that the exception will not prevent the mechanism from meeting the design objectives.
b) Cost will not be increased or the delivery schedule lengthened if the exception is permitted.

3. REQUIREMENTS

3.1 Definitions. The following definitions are applicable to this Standard.

Control Rod (or Control Element) - A mechanical component physically located in or about the nuclear core, and which by moving in and out of its respective region controls the nuclear reaction. This can be either a poison rod (absorbs the neutrons needed for fission) or a fuel-bearing rod (produces neutrons used in fission). The cross-sectional physical shape of the rod may be round, square, hexagonal, triangular, cruciform, etc.

Control Rod Drive Mechanism (CRDM) - An electro-mechanical component usually located outside of, but on, the reactor and which is used to move the control rods in or out of the core. For this Standard, this component includes rollers, roller-bearings, rotor-nut assembly, motor tube, torque restraint device, anti-ejection pawl, thrust bearings, radial bearings, guide bearings, stator assembly, stator cooling jacket, rod withdrawal housing, leadscrew, rotor arm release springs, gas connections, seals, position indication, and adaptors for mounting the CRDMs on the reactor head.

Motor Tube - A mechanical portion of the CRDM inside of which the rollers, rotor, etc. are located, and outside of which the stator is located. This item also forms part of the reactor primary system boundary when attached to a reactor head nozzle.

Rod Withdrawal Housing - A mechanical portion of the CRDM that is physically attached to the motor tube. This item provides a volume for movement of the leadscrew and generally forms a part of the reactor primary system boundary. The top of the rod withdrawal housing is sealed by a removable pressure cap.

Reactor Head Nozzle - This is the part of the reactor head to which an assembled CRDM will be attached. At this location, a static seal for the reactor to the CRDM internal environment is made.

Leadscrew - This is the item to which a control rod or extension shaft is attached, and which is physically contacted and translated by the roller-nuts.

Leadscrew Extension Shaft - If required, this shaft connects the CRDM leadscrew to the control rod.

Drive Line - A mechanical component which consists of the leadscrew, extention shaft, disconnects, and control rod, as applicable. The drive line provides direct motion for the control rod when the CRDM translates the leadscrew.

Scram-Assist Mechanism - If required this mechanism, upon the receipt of a scram signal from the plant control circuitry and release of the leadscrew by the CRDM, will move the drive line into the core at a rate greater than that caused by normal gravity.

Load - This is the force that the rollers are required to exert upon the leadscrew.

Stator Cooling System - A system provided to maintain the temperature of the CRDM stator below a specified temperature level as determined by the materials used in manufacturing the stator. This system shall not interact with, or be part of, the reactor primary cooling system if used for components outside the reactor primary coolant system boundary. However, it shall be compatible with the reactor coolant if the two inadverently come in contact.

Rod Position Indication System(s) - System(s) capable of determining the vertical position of the control rod in or about the reactor core.

Anti-Ejection Pawl - A mechanical device incorporated into the CRDM assembly to prevent accidental expulsion of the drive line from the reactor.

3.2 Component Identification. A control rod drive mechanism for reactor service consists of the following components:

a) the CRDM
b) drive line position sensors (a minimum of one acting independently of the CRDM to provide the position of the control rod in the core)
c) scram-assist mechanism, if required
d) an integral structural component for attachment to the reactor head nozzle
e) suitable cabling and connections for electrical power and cooling
f) special tools for installation, removal, and maintenance
g) seals and structural holddown devices
h) any additional equipment as specified in the Ordering Data

3.3 Plant Interfaces. The interfaces between the control rod drive mechanisms and the balance of the reactor plant are the following:

a) mechanical - attachment to control rods and extension shafts
b) structural - attachment to reactor vessel head
c) electrical - power requirements, instrumentation leads
d) thermal - radiation heating, coolant requirements
e) nuclear - irradiation effects on electrical and mechanical components

3.4 CRDM Operation. The following presents a general description of how a CRDM is expected to operate; see Figure 1.

A control rod drive mechanism moves the control rods in small step-like increments in response to electrical pulses sent to the stator. The control rod drive system controls reactivity by moving preselected individual control rods in or out of the active core of the nuclear reactor in response to commands of the reactor operator or in a programmed sequence controlled

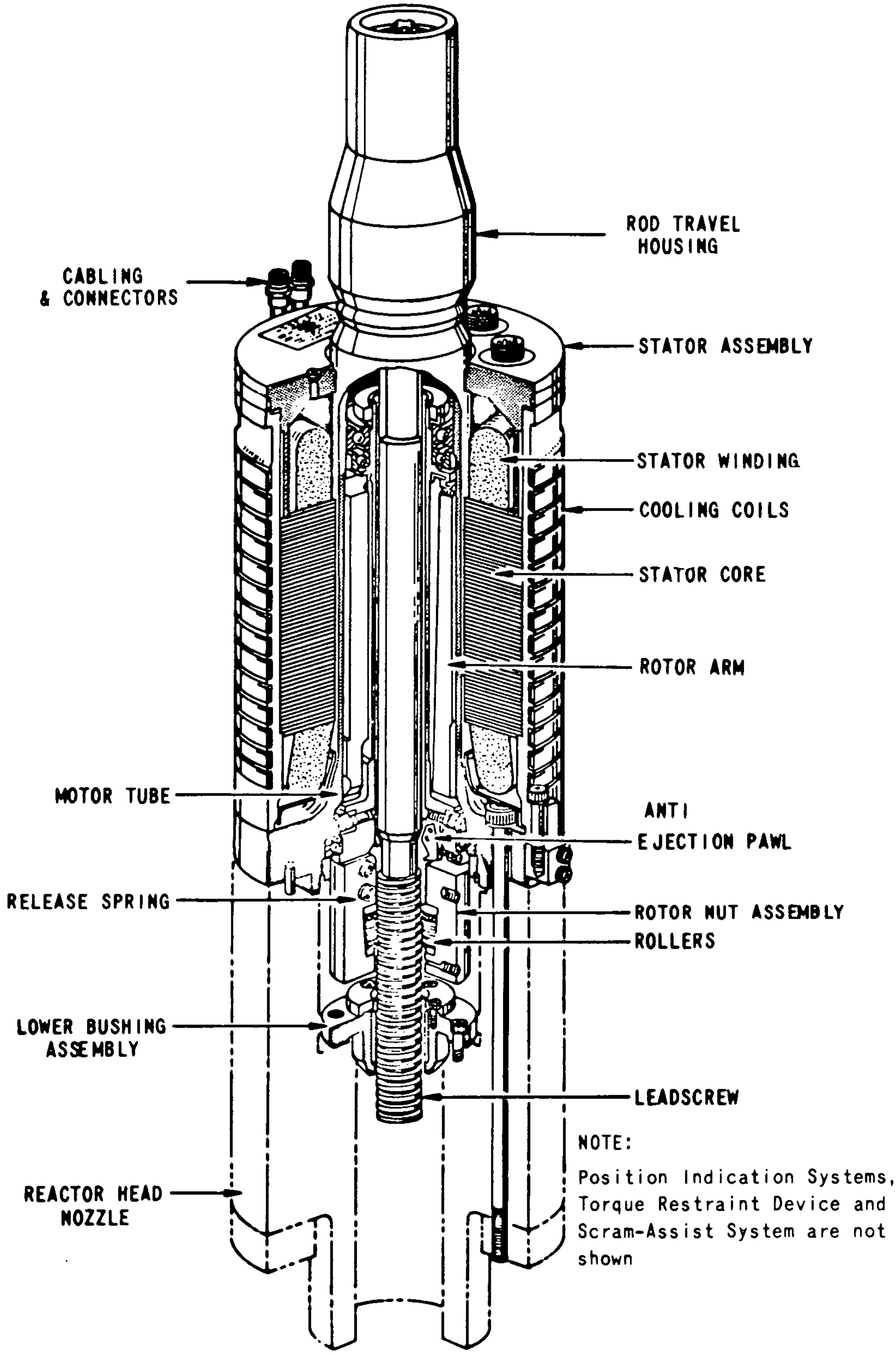

Figure 1. Typical Collapsible-Rotor, Roller-Nut Control Rod Drive Mechanism.

by the reactor control system. The rod drive system comprises CRDMs, power supplies and control circuitry. The leadscrew of each mechanism is mechanically coupled, or coupled through the use of an extension shaft, to a control rod with the parts moving in and out of the reactor core as an integral unit. Continuous direct current applied to the stator assembly, electro-magnetically causes the rotor nut assembly to engage the leadscrew and hold it in a fixed position. When the continuous direct current is changed to a low frequency pulse current, the rotor nut assembly is caused to rotate in a direction controlled by the pulse sequence, which, in turn, raises or lowers the lead-screw (control rod). When stator power is removed, the rollers disengage the leadscrew by action of the release springs and the rod scrams into the core by gravity or is driven into the core by an attached scram-assist mechanism located above or below the CRDM. The leadscrew and rotor nut assembly are contained by the motor tube which forms part of the reactor primary system boundary. The stator assembly imparts latching and rotary motion to the rotor nut assembly magnetically through the wall of the motor tube (environment boundary).

The locations where a) the CRDM motor tube and rod travel housing and b) the motor tube and the reactor head nozzle are joined together require that a static seal be made. It can be considered that these three parts form an extension of the reactor head and as such the inside surfaces of these parts are exposed to the reactor primary system environment. As all moving parts of the CRDM are contained inside these components, only static seals are required. If a dynamic seal is required it shall be specified by the Purchaser in the Ordering Data.

3.5 General Design Requirements. Because the control rod drive mechanisms also have the unique function of shutting down the reactor in an emergency situation, a primary consideration in their design must be their reliable and predictable operation, especially in their scram function. CRDM reliability in performing the normal function of positioning and holding the control rods is equally necessary because failure to perform this function properly may precipitate an emergency situation requiring the scram operation.

3.6 Detailed Design Requirements

3.6.1 Environment Boundary. Any parts, or assemblies, of the CRDM that are or may be considered to act as part of the reactor primary system boundary shall meet the requirements of the ASME Boiler and Pressure Vessel Code, Section III, for Class A vessels. These items shall be appropriately code-stamped.

3.6.2 Scram. Once the scram signal has been put into a control rod drive mechanism there shall be no way to over-ride or countermand it, or to delay completion of the scram cycle. Circuitry will be provided in the CRDM control system to assure this function. Scram action shall also occur if power to an individual CRDM is interrupted.

3.6.3 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 systemic, concurrent, undetected failures in the CRDMs resulting from commonality of components or susceptability to failure due to common environmental conditions, duty cycles, or loads. It shall be impossible for a failure in one CRDM or its associated control equipment to induce a failure in, or interfere with the operation of, any other CRDM or control equipment.

3.6.4 Drive Line Position Sensor(s). The drive line position sensor(s) shall sense the position of the leadscrew and shall produce an output signal indicating the relative position of the control rod in the core. Following loss of power for any reason, as soon as power is restored to the mechanism the position sensor shall indicate the rod position and shall resume producing the normal output signal.

3.6.5 Cooling. A stator cooling system shall be provided. This system shall not act as part of the reactor primary system boundary. Physically, this system shall consist of a stator cooling jacket and suitable lines and connectors to provide for a closed cooling system; both halves of the connectors shall be provided. This system shall be capable of maintaining the stator at a temperature level to provide a design life equal to that of the CRDM, and shall maintain the CRDM temperature levels as specified in the Ordering Data. The interface with the coolant supply will be specified in the Ordering Data.

3.6.6 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 periodic access to the top of the leadscrew so that disconnects contained in the drive line can be manually operated. The mechanism must be capable of holding the leadscrew, after disconnection of the control rod and extension shaft, in a withdrawn position for refueling operations and shall prevent any possibility of mechanical interference by the use of mechanical stops.

3.6.7 Corrosion. Materials shall be selected for resistance to attack by sodium vapor or liquid sodium or both.

3.6.8 Draining. The mechanism shall be designed and arranged so that any liquid sodium carried into or condensed in it shall drain back out of the rotor assembly of the CRDM.

3.6.9 Lubrication. Mechanism parts that are, or may be, exposed to the reactor primary coolant shall not have any lubricant which is not compatible with the reactor coolant.

3.6.10 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 all electrical components shall be possible without penetration of the primary coolant system boundary.

3.6.11 Threaded Components. All threaded components used in or on the CRDM shall be in accordance with ANSI B1.1, Unified Screw Threads, with RDT F 8-1, RDT M 6-2, and NBS H-28. The materials of manufacture shall conform to RDT M 6-1 or RDT M 6-3 or shall be specifically approved for their application.

Screw thread forms shall conform to the Unified Thread Form for sizes to which this form is applicable. Beyond the range covered by the Unified Thread Series, the National Thread Series, Class 2, may be used. For threads 1 in. diameter and larger, the 8-pitch thread series shall be used. Thread fit shall be Class 2A for external threads and 2B for internal threads unless otherwise specified and approved. Access shall be provided for cutting or otherwise destroying threaded fasteners in case of thread seizure. The length of thread engagement shall be sufficient such that the full load-carrying ability of the threaded fastener is developed. The Supplier shall specify quantitatively the method of preloading all fasteners and shall provide the necessary special equipment. Locking devices capable of retaining all components of a broken fastener shall be used on all threaded fasteners located inside the primary coolant system boundary.

An exception to this requirements is allowed for the CRDM leadscrew or rollers or both. These items may utilize a modified ACME type thread.

3.6.12 Mechanism Lifetime. The lifetime of the CRDM components inside the primary system boundary shall be no less than the reactor head lifetime. The mechanism shall function without extensive maintenance for its design life. This lifetime shall be specified in the Ordering Data.

3.6.13 Anti-Ejection Pawl. The anti-ejection pawl shall operate in the vertical position. The pawl shall not depend upon deviations from the vertical for engagement. The anti-ejection pawl shall prevent expulsion of the leadscrew (and connected components) at any time when the CRDM rollers are not engaged.

3.6.14 Effective Load. The effective load for the mechanism is the effective weight of the control rod and the leadscrew extension shaft accounting for appropriate immersion in the reactor coolant. This load will be specified in the Ordering Data.

The CRDM motor tube, rod withdrawal housing, seals, connections, etc. must all be capable of containing the normal pressure of the system as well as that occurring during any primary system pressure tests as often as they are run and, on the basis of a single occurrence, the pressure generated by the Hypothetical Core Disruptive Accident (HCDA).

3.6.15 Performance. The mechanism shall perform the following functions:

a. lift and lower the control rods (using the drive line) at rated speed or positioning rate (no drift shall occur during a holding cycle) throughout the entire stroke length as specified in the Ordering Data. A high degree of reliability shall be provided to not exceed the maximum withdrawal rate.

b. exert sufficient upward force to load an attached scram-assist mechanism, if required

c. hold control rod and drive line at any elevation against hydraulic forces, earthquake shocks, vibration, and other expulsion forces as specified in the Ordering Data

d. exert downward forces approximately equal to the upward forces developed, or as specified in the Ordering Data

e. release the control rod and drive line upon command or power loss

f. prevent upward motion of a scrammed control rod as a result of hydraulic forces, shock, etc.

g. provide unambiguous signals showing the position of the drive line, the control rod in or out of the fully inserted position, and the control rod in or out of the fully with-drawn position as indicated by the drive line

h. the CRDM does not have to function normally after the occurrence of an HDCA.

3.6.16 Seismic Shock. The mechanism shall be designed to withstand the Operating Basis Earthquake (OBE) without malfunction. The acceleration values to be used for this condition will be specified in the Ordering Data. The mechanism shall be designed such that assurance of control rod insertion under the Design Basis Earthquake (DBE) is provided. The acceleration values to be used for this condition will also be specified in the Ordering Data.

The seismic zone of interest will be provided by the Purchaser and included in the Ordering Data.

3.6.17 Vibration. The mechanism shall be designed so that the assembled mechanism, with and without associated equipment, will exhibit a natural frequency and multiples of this frequency differing from the forcing frequencies expected during normal plant operations. These frequencies will be specified in the Ordering Data. Vibrational testing will be performed by the Supplier to determine the actual natural frequency, and multiples, of the assembled CRDMs. The difference between these frequencies will be demonstrated by the Supplier to be adequate to avoid any resonant condition.

3.6.18 Inservice Inspection and Maintenance. The mechanism shall be designed to facilitate the recognition, location, replacement, and repair of failed parts and assemblies. The design shall provide for accessibility for inservice inspection of critical welds in accordance with Section XI of the ASME Boiler and Pressure Vessel Code.

3.7 Operating Conditions

3.7.1 External CRDM Environment. The control rod drive mechanism shall function surrounded by an atmosphere of normal air, air depleted of oxygen, or inert gas. The ambient temperature and pressure of this atmosphere will be defined in the Ordering Data.

3.7.2 Internal Environment. The control rod drive mechanism shall include a portion of the boundary membrane separating the external environment from the primary system of the reactor. Inside this boundary, mechanism components shall function in an atmosphere of inert gas alone, or inert gas and sodium vapor above a free surface of sodium with which a gas is in equilibrium. None of the equipment procured by this Standard shall normally be immersed in sodium.

The drive line of the mechanism projects downward into this pool of sodium. The mechanism will be cooled as necessary to maintain it within the normal operating temperature range selected by the Supplier despite heat deposition in the mechanism by thermal conduction through the drive line, radiation heating by the core and the radioactive sodium, convective heat transfer by the sodium vapor, and electrical heating from the operating circuits of the mechanism. The stator cooling jacket (system) shall be capable of removing this heat.

The data for the normally expected environment and the operating life for this environment will be specified by the Purchaser and included in the Ordering Data.

3.7.3 Mechanical and Thermal. The mechanism shall be designed such that it is capable of functioning with only minimal maintenance for the duty required by the expected reactor transients. These transients will result in a duty cycle for the mechanism. This cycle will be specified by the Purchaser in the Ordering Data. It will include, but not be limited to, startups, shutdowns, feet of travel, number of starts and stops, and scrams.

3.7.4 Electrical. The electrical equipment provided by the Supplier, and the interfaces with associated plant equipment, will be specified in the Ordering Data.

3.7.5 Power Fluctuations. The Supplier shall consider the effects of increases and decreases in the voltage and amperage supplied to the CRDM, and shall determine the maximum variation permissible prior to the termination of normal CRDM operation. If normal CRDM operation is terminated due to power fluctuations, scram action shall be initiated. This power fluctuation information shall be provided to the Purchaser.

3.8 Connections and Appurtenances

3.8.1 Auxiliary Systems. Purchaser approval shall be obtained for any auxiliary system requirements, such as cooling and/or purging, established by the Supplier for the successful operation of the mechanism. This approval shall be obtained prior to the initiation of manufacture. Any auxiliary systems required by the Purchaser to be attached to, or act in conjunction with, the mechanism will be specified in the Ordering Data.

3.8.2 Connectors. All electrical and mechanical connectors to the CRDM shall be designed such that incorrect connections cannot inadvertently be made during installation or maintenance operations. Both halves of all connectors shall be provided with the CRDM. All connectors shall be appropriately identified, and for electrical connectors, all lines running between connectors shall be color coded or carry appropriate identification at each end of the line.

3.8.3 Shielding. If shielding (nuclear or thermal) is required to enable the mechanism to meet the design objectives, it shall be recommended by the Supplier. Provisions for the incorporation of this shielding must be accounted for within the Purchaser specified maximum mechanism envelope. It is the responsibility of the Purchaser to specify the nuclear and thermal environment incident to the location of the CRDM, and to procure and install any required shielding.

3.9 Materials of Construction

3.9.1 Acceptable Materials. The RDT and ASTM Standards listed in Section 2.0 of this Standard provide a partial listing of acceptable materials. This list is not complete and should only be used by the Supplier as a guide in recommending material applications.

Welding electrodes and rods for each application shall be in accordance with RDT F 6-1, the applicable documents and material standards of Section 3.0 and the ASME Boiler and Pressure Vessel Code, Section III.

Materials used in fabrication of the CRDM electrical components shall be in accordance with MIL-W-583C, Class 180 or equivalent. At the option of the Supplier, materials may be used that are rated for operation at higher maximum temperatures.

3.9.2 Unacceptable Materials. Materials which do not meet the requirements of this Standard or of the referenced RDT Standards and Specifications are unacceptable, unless written authorization for their use is obtained from the Purchaser prior to any procurement.

Materials which are contaminated during production or fabrication to an extent which could adversely affect the mechanism or internal structures are unacceptable. Concentration of contaminants shall be maintained within the limits established by RDT F 5-1.

3.9.3 Material Identification. Identification of all materials, components, parts, assemblies and auxiliary equipment shall satisfy the following requirements:

3.9.3.1 All materials shall be identified in accordance with the requirements of the Material Standards. Each piece of material shall be identifiable until that piece is incorporated into an assembly. The identification shall be accurately transferred prior to fabrication to assure subsequent identification of each piece of material.

3.9.3.2 Components, parts, assemblies, and auxiliary equipment shall be identified in accordance with RDT F 7-3. Component parts, assemblies and equipment which are to be assembled or used on site shall be permanently marked with a part, serial, and appropriate assembly drawing number.

3.9.4 Material Examination and Tests

3.9.4.1 Qualification of Materials. All materials shall be ordered to conform to approved Material Standards. Some materials such as low alloy steel plates and bolting materials must be qualified by impact tests run on the material in the heat-treated condition. These tests shall be performed to qualify the material for use by the Supplier, or his designee, as specified in the ASME Boiler and Pressure Vessel Code, Section III.

3.9.4.2 Archive and Surveillance Samples. When requested by the Purchaser, the Supplier shall obtain samples of materials for radiation testing, long-term corrosion testing, and other purposes as specified in his proposal; this may be especially necessary for any ferritic materials which form a portion of the boundary of the primary coolant system. Samples shall be removed from the parent metal as late in the fabrication sequence as possible. In each case, the sample shall fully represent the finished component, including weld areas, insofar as possible. Each sample shall be marked according to the requirements of the Material Standard so that it may be identified with a specific Material Standard, heat (if heat treated) and lot number.

3.10 Fabrication

3.10.1 Equipment Cleanliness and Protection. During fabrication, handling, testing and storing operations, extreme care must be exercised to protect all surfaces from contamination. Surfaces shall be cleaned in accordance with RDT F 5-1 and shall be maintained in a clean condition up to and including final shipment.

A particular type of cleanliness, freedom from halide (especially chloride) ion contamination, is extremely important once fabrication operations begin. When stainless steel is stressed in contact with a chloride solution, a form of localized corrosion can occur which leads to embrittlement and ultimately to cracking ("stress-corrosion cracking"). Therefore, the pre-fabrication cleaning and all intermediate cleanings shall use no chlorinated solvents, no halogenated sprays (Freon), no detergents containing bleach, nor any other chlorine-bearing material. Furthermore, marking dyes, layout paints, and masking tapes shall be selected to avoid introduction of chlorine to the metal's environment. Carbon tetrachloride fire extinguishers, commonly used around electrical machines, shall not be used. Surface contamination by perspiration, food particles, etc., may be sufficient to initiate stress corrosion cracking, and such accidental contamination shall be promptly removed and recorded in the Quality Assurance Records.

Cleanliness of the CRDM stator throughout the fabrication process is of the utmost importance in the maintenance of the finished stator's reliability. Metallic slivers, chips, dust, etc., may produce insulation defects if allowed to contaminate the stator winding. All materials are to be protected, benches and machines shall be clean and work shall be done in an area separated from metal fabrication and processing areas. All tools that come in contact with windings during installation shall be made of fiber, plastic or polished metal and shall be completely free of any sharp corners or edges. The stator must not be set on the coil end turns at any time during fabrication.

To avoid embedment or adherence of foreign particles, all storage racks, handling devices, etc., shall be faced with stainless steel or other suitable materials. Only aluminum oxide abrasives shall be used for grinding or polishing stainless steels.

Procedures for preliminary and final cleaning processes that define the methods to be used and the acceptance criteria to be applied shall be furnished by the Supplier.

3.10.2 Surface Finish. The Supplier shall select fabrication processes to give the following surface finishes (AA values) unless otherwise specified:

a) All rolling or rubbing surfaces - as specified in Supplier's drawings
b) All locating surfaces - 63 microinch or better
c) All other machined surfaces - 125 microinch or better

d) Unmachined surfaces in contact with liquid sodium - 250 microinch or better

e) Unmachined surfaces not in contact with sodium coolant - adequate to eliminate foreign material, permit nondestructive examination, and to eliminate defects which could act as stress raisers; a finish of 250 microinch or better is adequate for such surfaces

f) Weld reinforcement - ground per RDT F 6-1

Surface finish shall be designated in accordance with ANSI B46.1, "Surface Texture."

3.10.3 Plating and Surface Treatment. All stainless steel threaded fasteners shall be suitably treated for their particular application. Plating shall not be used for any surfaces that may come in contact with sodium or sodium vapors unless specifically approved by the Purchaser.

3.10.4 Welding and Thermal Cutting. All welding, brazing, hard-facing, and thermal cutting operations for the CRDM and associated equipment shall comply and be in accordance with RDT F 6-1. The written detailed procedures for these operations, as well as for operator qualification and repair welding, shall be furnished by the Supplier for Purchaser approval. All welds shall have a final surface of 250 micro-inches or better.

All weld repairs must be performed in accordance with the following requirements:

a) One weld repair cycle is permitted at the fusion zone or the adjacent base metal or both.

b) Two weld repairs cycles are permitted in welds that are heat treated after each repair cycle.

c) Not more than three weld repairs cycles are permitted for welds not covered above.

d) The surface finish of a repair shall equal that of the original weld.

Specific approval is required to make weld repairs in excess of those permitted above.

3.10.5 Heat Treatment. All heat treatments performed after receipt of the material by the Supplier, i.e., all heat treatments not specified by the individual Material Standards, shall be performed according to detailed written procedures furnished by the Supplier.

3.10.6 Assembly. Assembly of component parts and all subassemblies shall be in accordance with detailed written assembly procedures prepared by the Supplier.

Each procedure shall contain as a minimum:

a) Assembly sequence
b) Cleaning procedure for each component and special precautions
c) Special fitting or machining required as assembly progresses
d) Intermediate and final examination acceptance criteria
e) Tightening limits for threaded components
f) Locking device installation procedures
g) Drawings or photographs if required
h) Special data, measurements, or observations to be recorded in quality control records.
i) Handling methods and precautions

   NOTE: copper or aluminum blocks shall not be used to protect components during lifting or handling operations

3.10.7 Field Modifications of Components. The Supplier shall provide engineering services and technical direction for any field modifications to components delivered by him through the period of operational testing. Should field modifications become necessary, the Supplier shall furnish a written procedure for these modifications. These procedures shall contain, as a minimum, the following information:

a) Nature of the modification

b) An addendum to the Design Report demonstrating that the proposed modification will not impair the integrity of the item or invalidate the Code Stamp. This addendum must be approved and certified by a Registered Professional Engineer.

c) Detailed drawings and procedures explaining how the modifications will be accomplished.

d) Procedures for testing and inspection including criteria for acceptance

e) Cost and schedule estimates

The Supplier shall direct all field modifications. Upon completion of the modification, the Supplier shall verify that the modification has been made satisfactorily in accordance with the approved procedures and requirements. All as-built drawings, quality control records, manuals, etc., shall be modified to incorporate the field modifications in accordance with the requirements of this Standard and referenced documents.

3.10.8 Site Spare Parts. As part of the Fabrication Plan, the Supplier shall recommend a list of spare parts to be maintained with the CRDM. This list is to contain those parts and tools likely to be damaged or expended during delivery or operation or both. If required, the Supplier shall process these spares or selected spares, in accordance with the requirements for deliverable items.

3.11 Drawings. The Supplier shall prepare engineering drawings and associated drawing lists for all items included under this Standard. Drawings shall be prepared in accordance with ANSI Y14. As a minimum, one top assembly drawing and one drawing list, referencing all drawings associated with this procurement shall be provided and shall be designated with a drawing number provided by the Purchaser. Following are listed requirements for the drawings associated with the design and fabrication of the equipment covered by the Standard.

3.11.1 Preliminary Drawings. The Supplier shall furnish preliminary drawings, sketches or data necessary to amplify and clarify major design features. These drawings will form the technical basis for the initial formal design reviews and shall include, but not be limited to:

a) Design and salient features including principal and critical dimensions
b) Dimensional detail sufficient to establish limits of space in all directions plus clearance required for service or replacement of parts
c) Size and location of all connections and fittings
d) Estimated weight and center of gravity

3.11.2 Detail Drawings. These drawings shall include, but not be limited to, the following:

a) Tolerance block including general geometric tolerances
b) Detailed dimensions, specific tolerances, and maximum roughness of each surface
c) Material specification and any special requirements including nondestructive examination, heat treatment, and hardness
d) Fabrication instructions including welding, plating, hard-surfacing, cleaning, examination symbols, and assembly procedure requirements
e) Applied finishes
f) Include on each drawing such additional information necessary to describe the equipment, including special features or characteristics

3.11.3 Assembly Drawings. These drawings shall include, but not be limited to, the following:

a) Location, identity (drawing number), and material type of each part
b) Location of final closure welds and seal welds with the appropriate procedures referenced
c) Reference dimensions establishing general size of each major part
d) Design and test pressure and temperature data
e) Definition of Assembly operations and procedures
f) Pertinent references to cleaning, marking, loadings, lockings, handling, and packaging instructions
g) Identification of any special tools required for assembly

3.11.4 Shop Drawings. All details from shop drawings shall be incorporated directly into assembly or composite drawings by the Supplier.

3.11.5 As-Built Drawings. At the completion of fabrication, the Supplier shall certify that each component was fabricated in accordance with approved drawings, specifications and approved engineering design changes. All approved engineering design changes shall be noted on applicable drawings. In addition, should field modifications become necessary the Supplier shall incorporate all approved changes into the appropriate drawings.

3.11.6 As-Built Dimensions. The Purchaser will require the Supplier to record actual final measurements for certain critical dimensions. Where required, these measured dimensions shall be recorded on appropriate drawings or listings or both. Critical dimensions to be recorded shall be recommended by the Supplier for Purchaser approval.

3.11.7 Drawing and Parts Lists. The Supplier shall furnish an initial Drawing List as part of the Design Plan. This list shall be periodically updated by the Supplier. The list shall include all assembly and detail drawings necessary to define the components covered by this Standard and shall be divided into two sections for cross referencing. The first section shall contain a listing of all drawings in numerical order and shall show the latest revision number of the drawing, title of the drawing and the drawing number of the next higher assembly. The second section shall contain a listing by assembly in a tier arrangement beginning with the highest order assembly down through details.

A parts list shall be provided to the Purchaser. This list shall identify all distinguishable parts of the CRDM, the material to be used for a particular part, and the standard or specification for procurement of the material for the part. If a component is purchased for inclusion in the CRDM, the standard by which it is fabricated shall also be identified.

3.12 Reports and Documentation. The Supplier shall prepare and submit certain documentation during the course of the Contract. This documentation shall be prepared according to the requirements of this Standard and referenced documents. The requirements of the Purchaser approval or information shall be provided in the Ordering Data. Following is a description of the minimum technical documentation requirements with which the Supplier shall comply. Where possible the Supplier is encouraged to consolidate several of the following into a single document with the objective of minimizing the number, volume, and redundancy of required submittals.

3.12.1 Work Plans. The Supplier shall prepare a Design Plan, a Fabrication Plan, a Delivery Plan, and a Field Services Plan. These plans shall contain a detailed description of the manner in which the Supplier plans to perform his work during specified phases. Technical requirements for these plans are described in the following sections. Additional requirements (administrative, format, etc.) may be specified in the Ordering Data.

3.12.1.1 Design Plan. The Supplier shall furnish a detailed Design Plan. This plan shall describe all engineering design services to be provided by the Supplier for each item covered by this Standard. These services shall include, but not be limited to providing the following:

a) Detailed equipment drawings
b) Engineering drawings
c) Equipment specifications
d) Material specifications
e) Process requirements
f) Inspection and testing requirements
g) Listing required "as-built" dimensions for each CRDM
h) Handling requirements
i) Packaging, shipping, storing, installation, etc., requirements

Descriptions of design activities shall include as a minimum, scope of work, technical approach, methods to be used, expected end-products, and schedule for performance. As part of the Design Plan, the Supplier shall recommend a list of all technical documentation to be prepared by him, such as drawings, bills of material, reports, manuals, etc., including a proposed schedule for submittal.

3.12.1.2 Fabrication Plan. The Supplier shall furnish a Detailed Fabrication Plan. This plan shall cover the Supplier's fabrication and testing efforts beginning with materials procurement through final acceptance tests. The Detailed Fabrication Plan shall include, as a minimum, a detailed description of each operation on the fabrication schedule. This description will typically consist of, but is not limited to, the following:

a) Identification of the operation on the network chart
b) A statement of the objective of the operation
c) Identification of the piece being worked upon, or pieces being joined in an assembly operation
d) Reference to the drawing which describes the piece or shows the assembly

e) A list of special tools, jigs, or fixtures used in the operation, with identification of same
f) Shop equipment and special facilities to be used
g) Qualification level of operator
h) Sequence or procedure to be followed (this may be a reference to a standard procedure)
i) Tests, demonstrations, etc., required
j) Fabrication and quality assurance hold control points
k) Criteria for satisfactory completion of operation
l) Recommended spare parts
m) Documentation and fabrication schedules

3.12.1.3 Delivery Plan. The Supplier shall prepare a detailed Delivery Plan for all items for which he has delivery responsibility; paragraphs 5.3, 5.4, and 5.5 of this Standard are pertinent to this plan. This plan shall cover all Supplier operations from the final shop acceptance test for each deliverable item through delivery to the unloading facilities near the designated site including a schedule for performance. This plan shall include, but is not limited to, a description of the following operations (where applicable):

a) Preparation for delivery
b) Packing, packaging and marking
c) Handling and storing
d) Shipping
e) Unloading
f) Inspection and release
g) Protection and service required while in storage
h) Documentation

3.12.1.4 Field Services Plan. The Supplier shall furnish a detailed Field Services Plan describing services to be provided by him at the delivery site; paragraph 5.5 of this Standard is pertinent to this plan. This plan shall cover field operations beginning with the arrival on site of items for which the Supplier has delivery responsibility through installation and operational testing operations relating to these items. These operations shall include, but are not limited to, the following:

a) Requirements and instructions for component cleaning and assembly
b) Reviewing procedures established by others for the above operations for concurrance
c) Providing on-site inspections and examinations of equipment he has furnished
d) Providing pre-installation checks or pre-operational tests
e) Providing engineering services and technical direction for field modifications to items furnished by him
f) Documentation of all service performed

Many of the requirements and instructions for field operations are to be prepared by the Supplier as part of the Design Plan (Section 3.12.1.1). The purpose of the Field Services Plan is to describe the technical services to be provided by the Supplier in implementing these instructions and in verifying that items delivered by him function properly.

The Field Services Plan shall be prepared with the Delivery Plan. A detailed schedule for site operations will be furnished to the Supplier for planning purposes prior to the date the Field Services Plan is to be submitted.

3.12.2 Technical Reports. To the extent possible, the Supplier shall identify the need for specific technical reports, including the schedule for submittal, as part of the Design Plan. Should the need for additional reports arise during design, the Supplier will identify the need and shall submit a schedule for submission of such a report on an ad hoc basis.

As a minimum, a technical report shall contain the following information:

a) The purpose of the report
b) A detailed description of the component
c) A description of all loading conditions
d) All assumptions and approximations used or to be used
e) A description of the analytical model
f) A description of analytical methods
g) Supporting sketches, calculations and data

3.12.2.1 Stress Report. The Supplier shall prepare a certified Stress Report. This report shall include all appropriate calculations required by Section III of the ASME Boiler and Pressure Vessel Code for the CRDM components making up part of the primary system environmental boundary (treat as Class A vessels) and by applicable Code Cases as described in Appendix X to Section III. This report shall also include, but is not limited to, the following:

a) Summary of applicable performance capabilities and limitations
b) Calculated deflections and stresses in key functional and interface areas during normal, transient and off-normal operations
c) The calculated behavior of the mechanism housings and supports under the influence of the HCDA.

The applicability of analytical techniques shall be appropriately established in the Stress Report. The results shall be validated where possible by comparison with proven analytical methods of stress analysis, other verified computer programs, or experimental results. The information presented in the Stress Report with respect to computer programs employed in the stress analyses shall be in sufficient detail to enable independent verification of the input data, the analytical model adopted, the assumptions, and boundary conditions as they relate to the conditions for design.

The Supplier shall be responsible for having the Stress Report reviewed and certified by a Registered Professional Engineer per the requirements of Section III of the ASME Boiler and Pressure Vessel Code, paragraph N-142 - "Stress Report." This review will consider the report with respect to:

a) The applicability of the analytical methods employed as related to the conditions of design and design configurations

b) The acceptability of the assumptions, loading combinations, boundary conditions, and mechanical properties of materials as applied in the analyses for the service conditions specified in the Design Specification

c) The extent of design agreement with similar analyses for components of comparable design with similar service conditions, if available

The report of this review shall be appended to the Stress Report along with the Code-required certification at the time of submission of the design report for approval. The schedule for submittal of the Stress Report shall be established by the Supplier as part of the Design Plan.

3.12.2.2 Design Report. The Supplier shall prepare and furnish a Design Report covering all components defined by this Standard. The schedule for submittal of the Design Report (and any interim portions) shall be established by the Supplier as part of the Design Plan. Specific portions of the Design Report (as technical reports) shall be furnished by the Supplier prior to material procurement and fabrication. The Final Design Report shall include, but not be limited to, the following information:

a) A listing and description of the baseline requirements for all components covered by this Standard
b) A thorough description of the functions, materials, and configuration of these components
c) All known parameters, assumptions, approximations, and calculations in sufficient detail to permit independent checking
d) A discussion of the validity of the data employed and conclusions which support the recommended designs
e) Completely identified references from which data and formulae are taken
f) Bearing life calculations demonstrating load carrying capability and design life of the mechanism
g) A clearance and alignment study which confirms that the accumulated tolerances and thermal expansions, and thermally and pressure-induced operating motions, will not result in interferences or excessive mis-alignment between the Supplier's components
h) A failure mode and effects analysis (FMEA) shall be performed on the CRDM final design. In addition, a comprehensive reliability analysis shall be provided for all components that exhibit a failure mode that could possibly invalidate the scram function.

3.12.2.3 Modifications to the Design Report. The Supplier shall make such additions or corrections to the report as are required to maintain the information current. When corrections are made, they shall be certified by the person or organization responsible for the stress analysis calculations to have been satisfactorily reconciled with the stress analysis calculations and the Design Specifications. The revisions are to be numbered and dated and prepared in a format similar to the original report. The limit of Supplier responsibility for making additions or corrections to the design report is limited to the end date of the contract.

3.12.3 Quality Assurance Documents. The Supplier shall prepare the following documents based on the requirements of RDT F 2-2.

3.12.3.1 Quality Assurance Program Plan. The Supplier shall prepare a Quality Assurance Program Plan in accordance with RDT F 2-2 paragraphs 2.2.2, 3.2, and 4.2.

3.12.3.2 Inspection and Test Plan. The Supplier shall prepare an inspection and Test Plan in accordance with RDT F 2-2 paragraph 5.3.

3.12.3.3 Special Process Control and Nondestructive Test Procedures. The Supplier shall prepare and qualify procedures and equipment for special processes and nondestructive tests in accordance with RDT F 2-2 paragraph 5.5.

3.12.3.4 Inspection and Test Procedures. The Supplier shall prepare inspection and test procedures in accordance with RDT F 2-2 paragraph 5.6.2. These procedures shall include the details of all sampling plans proposed by the Supplier and the basis for selection of the proposed sampling plan in accordance with RDT F 2-2 paragraph 5.9.

3.12.3.5 Non-Conforming Item Documentation. The Supplier shall establish, implement, and maintain procedures for control of parts, materials, components, systems, and processes that do not conform with requirements in accordance with RDT F 2-2, paragraph 5.10.

3.12.3.6 Proposed New Design Standards, Codes, Practices, and Criteria. The Supplier shall propose new design standards, codes, practices, and criteria in accordance with RDT F 2-2, paragraph 3.3.2.

3.12.3.7 Quality Records. As a minimum the Supplier shall submit the following documents to the Purchaser pertinent to each CRDM and associated equipment:

a) Parts List - List of items by part number, drawing number and revision, part name, serial number and/or lot or heat number.
b) Drawings - A reproducible set of assembly drawings and final outline drawings identified as "as built."
c) Special Processes and Nondestructive Test Qualifications - Certifications of special processes and nondestructive testing procedures and equipment qualifications as specified in RDT F 2-2 paragraph 5.5.
d) Nonconformance Records - A copy of each nonconformance and corrective action record including rework and repair and retest procedures.
e) Certification - Certification of conformance as specified in RDT F 2-2 paragraph 5.6.5 including:

- Material certifications - chemical and physical test results, nondestructive test results, heat treatment data and test results, heat treatment data and test results of material test coupons. This data shall be traceable to their related finished components

- Nondestructive examination - results of final nondestructive examinations including radiographic films, recorder charts and pictures.

- Test reports - certified copy of test results, analysis of test results, final performance curves, test fluid temperature and metal temperatures including temperature corrections made to test pressure.

- Final inspection - a copy of final inspection data and results.

3.12.4 Other Documents The Supplier shall prepare the following additional documents.

3.12.4.1 Periodic and Progress Reports. Reports of progress in design, fabrication, inspection, testing, Quality Assurance and shipping shall be made at specified intervals. These reports shall relate the progress made since the last report with only enough repetition of previously reported events to frame the contents of the present report. These periodic reports should also include difficulties encountered (such as failures and malfunctions) and the efforts made or planned for overcoming them. Problems foreseen as possible disruptions of the schedule shall be brought to the attention of the Purchaser as early as possible. Breakthroughs of significance should be discussed.

3.12.4.2 Operations and Maintenance Manuals. The Supplier shall provide CRDM operation and maintenance information to form part of the plant operations manual. Information shall include, but not be limited to, the following:

a) A detailed description of the CRDM and associated equipment and instructions for installation, operation, preventive maintenance, and repair of equipment
b) Procedures for maintenance, removal, and replacement of electrical components
c) Instructions for use of lifting and handling fixtures, and special tools and equipment
d) Reduced size drawings for operation, maintenance, and instructional purposes, including drawings of special tools and equipment
e) Instructions for disassembly, cleaning, preparing for shipment, and crating constituent parts
f) A list of recommended spare parts

3.12.4.3 Special Tool List. The Supplier shall prepare and keep current a list of all special tools, including gages, required for this contract. The list will identify each tool by name, drawing number, function, operation(s) for which it is required, and whether it is an in-process tool or a deliverable item.

4. QUALITY ASSURANCE PROVISIONS

4.1 Qualitv Assurance Requirements. The Supplier shall plan, establish, implement, and maintain a quality assurance program. This program shall be based on the requirements of Sections 1 through 5 and Section 8 of RDT F 2-2. The requirements of this Standard are not to be interpreted by the Supplier in a manner that would result in a duplication or derogation of work effort in light of the requirements of the other applicable standards.

4.2 Quality Assurance Documents. Quality assurance documentation required to be prepared by the Supplier and submitted to the Purchaser are listed in paragraph 3.12.3 of this Standard.

4.3 Marking and Identification

4.3.1 Materials. All materials used in the manufacture of items shall be examined to ensure compliance with requirements of paragraph 3.9.3.

4.3.2 Permanent Marking. All finished components, spare parts and special handling fixtures to be delivered as part of the contractual requirements shall be examined to ensure that they are permanently marked for purposes of identification in accordance with paragraph 3.9.3. Marking of any required sample material shall be examined for identification, location and orientation.

4.4 Nondestructive Examination Requirements

4.4.1 Calibration. All instrumentation associated with nondestructive examination shall be calibrated and controlled in accordance with RDT F 2-2, paragraph 5.8.

4.4.2 Personnel Qualification. Personnel performing nondestructive examination shall be qualified in accordance with RDT F 3-6.

4.5 Examination of Materials

4.5.1 General. In the following section, acceptance standards and calibration levels shall be as specified in the applicable RDT material standard. Detailed nondestructive examination procedures to be used shall be prepared by the Supplier.

4.5.2 Visual Examination of Materials. All raw materials shall be examined visually to detect obvious defects and state of cleanliness.

4.5.3 Requirements for Nondestructive Text Examination. The requirements for examination of materials by nondestructive testing shall be in accordance with the applicable RDT Standard, RDT F 3-4, RDT F 3-5, RDT 3-6, RDT F 3-3, RDT F 3-8 and the ASME Boiler and Pressure Vessel Code, Section III, and addenda. At all times, the use of liquid penetrant materials from pressurized spray cans, using freon as the propellant, on austenitic stainless steel is prohibited.

4.5.3.1 Bolting Material. Bolting material (bolts, studs, stud bolts or nuts) shall be ultrasonically tested prior to threading in accordance with the requirements of RDT M 6-1 or RDT M 6-3. This requirement only applies to bolting material used to secure a seal between components forming part of the reactor primary system boundary and any similar items used inside the primary boundary.

4.5.3.2 Seal Membranes. Seal membranes, both integral and non-integral types as defined in RDT M 9-2, shall be examined by liquid penetrant examination in accordance with RDT F 3-6 using a solvent removable penetrant.

4.5.3.3 Alternate Inspection Methods. Questionable indications located by one type of nondestructive test shall be investigated with a different nondestructive test method where possible and as determined on a case basis by the Supplier and Purchaser.

4.5.4 Material Repairs

4.5.4.1 Repair Welding. Where the applicable material standard and procurement specification allows the use of welding processes for repair of major defects in the material, the quality assurance provisions of the repair weld shall be accomplished in accordance with the requirements of RDT F 6-1. No repair welds are permitted on material defects in bolting material for either high temperature or low temperature service.

4.5.4.2 Examination of Material Repairs. The examination of the weld repair shall be in accordance with the requirements of RDT F 3-6. The weld repaired area shall be re-examined by the inspection method(s) which revealed the original defect.

4.6 Examination of Fabricated Components

4.6.1 Visual and Dimensional Examination

4.6.1.1 General. All items shall be subjected to visual and dimensional examination to verify conformance with the drawings submitted to the Purchaser and all of the requirements of this Standard which do not involve tests.

4.6.1.2 Bolting. Bolting shall be visually examined in accordance with the requirements of RDT M 6-1 and RDT M 6-3 as applicable.

4.6.1.3 Welds. All welds shall be visually examined for the following characteristics (in addition to those required in RDT F 6-1):

a) weld identification

b) weld thickness shall be equal to or greater than the parent (base) metal thickness at its thinnest section (no concave welds), unless specifically allowed by RDT F 6-1

c) weld surface and adjacent base metal shall blend smoothly without reduction of the metal thickness in excess of 10 percent of the base metal thickness or 1/64 inch, whichever is less. The remaining thickness shall not be reduced below the minimum allowable thickness

d) weld width shall be uniform and when manual welds are performed, string beading is preferred

4.6.1.4 Brazes. Brazes shall be examined prior to and after brazing in accordance with the requirements of RDT F 6-1.

4.6.2 Nondestructive Examination. Following fabrication, all components shall be nondestructively tested to verify the quality of the finished product. The Supplier shall recommend for Purchaser approval, as part of the Inspection and Test Plan (3.12.3.2), the method and acceptance criteria to be used for examination of the finished product.

Materials subjected to wear applications shall be examined in accordance with RDT F 3-7.

4.7 Testing. The Supplier shall furnish a test plan for all tests required by this Standard. This plan shall follow the test program requirements contained in RDT F 2-2.

4.7.1 Stator Testing. 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 than ± 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 D. C. Insulation Test and an A. C. Dielectric Strength Test as described below; see paragraph 4.7.1.2 and 4.7.1.3.

The leads shall be permanently connected to the stator by brazing. The brazing material shall conform to RDT M 1-9. The brazing shall be performed using a neutral to slightly oxidizing flame. After brazing, all sharp edges shall be smoothed off and the bond shall be examined at 10X magnification. The completed joint shall show no evidence of lack of bond or base metal erosion and shall be free of cracks in both the base metal and the brazed joint. The braze and adjacent base metal shall also be free of globules of filler metal.

Upon completion of the lead connections and before varnish impregnation, the stator shall be subjected to the following tests:

4.7.1.1 D. C. 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.

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

4.7.1.3 A. C. Dielectric Strength Test. Apply 1200 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 1200 volts for 60 seconds, then reduced to zero at approximately 100 volts per second. All of the phases of the stator shall be checked. The maximum compensated current leakage allowed is 4.0 milliamps between coils and 1.25 milliamps between the windings and the core stack.

4.7.1.4 Surge Comparison Test. Surge testing shall be conducted using 1200 volts D. C. and shall check the waveform of power thru the stator phases. Any sharp or jagged indication of a trace, regardless of proximity or comparison between traces, shall be cause for rejection of the stator.

After successful completion of these tests, the stator shall be varnish vacuum impregnated and baked. During this processing, the stator lead-wires must be protected to prevent the varnish from making them inflexible. Upon completion of this processing, the tests described in paragraphs 4.7.1.1 thru 4.7.1.4 shall be reperformed and the results recorded.

4.7.2 Helium Leak Test. A helium leak test shall be performed, in accordance with RDT F 3-6, 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 as specified in the Ordering Data. The helium used for this testing shall be of a quality specified in RDT F 3-6.

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

4.7.2.1 Cooling Jacket Leak and Strength Test. The cooling jacket supplied with the CRDM shall be tested for leakage and strength in accordance with procedures and acceptance criteria (3.12.3.4) provided by the Supplier.

4.7.3 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. As part of the Fabrication Plan, the Supplier shall recommend a strength test with detailed procedures and sufficient justification for the recommended method. This test shall be in accordance with Article 7 of Section III of the ASME Boiler and Pressure Vessel Code.

4.7.3.1 General Requirements for Strength Tests.

a) Prior to testing, all interior surfaces shall be cleaned to meet the cleanliness requirements of RDT F 5-1. The Supplier shall prepare and submit a detailed cleaning procedure as part of the Fabrication Plan.

b) Prior to and during the performance of the strength test, the material temperature shall be maintained at least 60°F above the highest of the impact test temperatures required to meet the impact values of the ASME Code, Table N-421, taking into account materials and welds contained in the fluid and gas boundary, and the materials of the parts welded directly to either the inside or the outside surfaces. The test temperature and metal temperatures shall be reported in the Fabrication Report.

c) The number of tests above design pressure shall be minimized.

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

e) The studs, bolts, nuts, washers and other closure members furnished with the mechanism shall be replaced with new components after completion of the strength tests.

f) If a hydrostatic strength test is performed, the water shall be equal to RDT F 5-1, Grade A.

g) 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. The mechanism shall be protected from contamination by maintaining the sealed condition and internal environment of dry nitrogen until the helium leak test required by Section 4.7.1 is performed.

4.7.4 CRDM Performance Tests. The CRDM shall be tested to show conformance with the design objectives. This testing will be performed in accordance with detailed requirements designated in the Ordering Data. 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:

a) Maximum possible lifting force exerted

b) Normal lifting force exerted

c) Maximum possible driving-down force exerted

d) Normal driving-down force exerted

e) Maximum torque exerted on the leadscrew

f) Normal torque exerted on the leadscrew

g) Minimum single increment of motion for the leadscrew

h) Maximum single increment of motion for the leadscrew

i) Total travel during the test for maximum, and normally exerted forces

j) Stator coil amperage and voltage for maximum, and normally exerted, forces and drive line speeds

k) Stator coil amperage, voltage, and resistance as functions of temperature

l) Stator coil steady-state temperature variation during operation and holding periods

m) Magnetic field decay time and total release time as a function of temperature, load, and stator power

n) The CRDM scram characteristics as functions of the stator power, rod speed, and load

o) Mechanism internal environment parameters including, but not limited to,

- temperature
- pressure
- contained atmosphere
- lubrication

p) Mechanism cooling system parameters, as applicable

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

4.7.4.1 The Supplier shall notify the Purchaser at least five (5) days prior to the start of this testing. The Supplier shall also provide access to his facilities and any test data available, at the time, for inspection by the Purchaser or his designee.

4.7.5 Test Reports. Within one month of the completion of any tests, the Supplier shall submit to the Purchaser a preliminary test report. This report shall highlight the results of the test and specifically delineate the impact of the results upon the CRDM design. Within three months of the completion of any tests, the Supplier shall provide to the Purchaser a detailed test report. This test report shall include the results of the test, and analysis of the test results, final performance curves, the impact of the test results on the CRDM design (if applicable), and other data and discussion as pertinent.

4.7.6 Other Tests

4.7.6.1 Vibration and Shock Tests. The Supplier shall propose, at that time when the design is sufficiently advanced that a test recommendation can be justified, a program to perform vibration and shock tests on any item included in this Standard. For each test proposed, the Supplier shall recommend test conditions such as environment, loading, etc. and shall prepare and submit for Purchaser approval a detailed test procedure. The results of testing shall be recorded in a Test Report.

5. DELIVERY REQUIREMENTS

5.1 General Requirements. The Supplier shall deliver all items to the site designated in the Ordering Data in accordance with a Delivery Plan which shall be in accordance with the requirements of this section and RDT F 7-2.

5.1.1 Preparation for Delivery. Upon completion of all shop testing and inspection, the Supplier shall prepare all materials and components for delivery to the designated site. This shall include, but is not limited to, all disassembly (as required), recleaning (if necessary), surface preparation, examination, etc. Following preparation, all deliverable components as defined in the Ordering Data shall be packaged in accordance with the requirements of Section 5.2.

5.2 Packaging

5.2.1 General Requirements. Items subject to deterioration, corrosion or damage shall be packaged in a manner to preserve them. All sealing, packaging, packing and identification marking shall be in accordance with RDT F 7-2. Packaging shall be adequate to protect the item while at the Supplier's facilities, during transportation to the site and at the site. The Supplier shall recommend the specific method of packaging individual components to be shipped. If field fabrication, or field assembly, of any component(s) is required, recommendations shall apply to the conponents being shipped to the field as well as to the final movement of the component to its in-place position.

5.2.2 Specific Requirements. As a minimum, the Supplier shall satisfy the following requirements for all components or materials or both for which he has delivery responsibility. Specific requirements and procedures for each application shall be prepared by the Supplier as part of the Design, Fabrication, and Delivery Plans.

a) If cleaning, in accordance with RDT F 5-1, of the component after delivery to the site is not possible or practicable, the component shall be cleaned, sealed, and filled with inert gas before shipment. If final cleaning of the component after delivery is possible, sealing for shipment need only meet the minimum requirements of RDT F 7-2. This provision does not release the Supplier from the responsibility of meeting the cleanliness or other requirements of this Standard.

b) Suitable shipping containers for all components delivered under this Standard shall be provided. The shipping container design shall provide adequate protection to critical areas, such as closure sealing surfaces, seal membranes, and sealing surfaces, to prevent damage caused by dropping of tools and similar conditions during component shipment and installation.

c) Moisture control provisions during shipping and storing. Descriptions and locations of all dessicants shall be provided with the documents accompanying the shipment.

5.3 Shipping. The Supplier shall be responsible for the delivery of all items covered by this Standard to the delivery site. These responsibilities include, but are not limited to the following items.

5.3.1 Routing. As part of the Delivery Plan, the Supplier shall specify routing for all materials or components or both for which he is responsible. When approved by the Purchaser, the Supplier shall make all arrangements necessary to ship these items in accordance with the terms of the contract and the requirements of this Standard.

5.3.2 Shipping Instructions. The Supplier shall prepare suitable instructions to the shipper for handling, shipping, in-transit storage, and storing of all major items for which the Supplier has delivery responsibility.

5.3.3 Loading. Required shipping position, supports and shipping container design shall be specified by the Supplier. All handling equipment and shipping containers shall be adequate to prevent any damage to components during handling and shipping operations in accordance with the requirements of Section 5.2 of this Standard.

5.3.4 Documentation. As part of the Delivery Plan, the Supplier shall identify all technical documentation, e.g., instructions, drawings, reports, manuals, etc., which are to accompany deliverable items during shipment.

5.4 Handling. All handling, lifting, supporting and shipping fixtures shall comply with the following requirements, as a minimum:

5.4.1 Each separate component weighing more than 50 pounds that must be handled shall be designated or provided with a means of lifting and handling using standard crane equipment. Each component shall be capable of being handled in its normal operating position so that it can be readily assembled into, or disassembled from, the normal assembled position.

5.4.2 All special lifting or handling fixtures shall be designed for a static load of five times normal anticipated static loads, based upon ultimate material strength, or will be demonstrated to be capable of meeting this requirement.

5.4.3 Shipping containers shall be provided with lifting points which permit both the lifting of the empty container and the lifting of the container and the components as a single unit.

5.4.4 If the component to be handled requires upending, points of attachments for chain falls, trunnions, or other features shall be provided so that upending can be done in a safe, controlled manner.

5.4.5 Use of cast iron, cast steel, and bronze in any lifting or handling fixture on the mechanism components is prohibited.

5.5 Field Service Requirements. The Supplier shall provide certain technical services for field operations involving equipment he has furnished. These services shall include, but are not limited to the requirements as given in paragraphs 3.12.1.3 and 3.12.1.4 of this Standard.

6. NOTES

6.1 Ordering Data. The Procurement Documents shall specify the following as a minimum. The numbers in parentheses after the listing refer to particular paragraphs in this standard.

6.1.1 Project Identification

a) Title, number, and date of the specification

6.1.2 Mechanism Identification

6.1.3 Allowable Envelope (drawing)

6.1.4 Equipment to be Purchased with the CRDM (3.2, 3.8.1)

6.1.5 General Requirements (3.5)

6.1.6 CRDM Specific Functional Requirements

a) Maximum load (3.6.14)

b) Maximum stuck rod load (3.6.15)

c) Maximum permissible withdrawal step (3.6.15)

d) Maximum and minimum positioning rate (3.6.15)

e) Maximum and minimum drive line travel (3.6.15)

f) Fast rundown requirement (3.6.15)

g) Emergency insertion (scram) requirements (3.6.2)

1) Stroke - driven

2) Rate of Insertion

3) Release Time

h) Design Life (3.6.12)

i) Duty Cycle (3.7.3)

6.1.7 Attachment and Disconnect Requirements, with sketch or Drawing (3.3)

6.1.8 Structural Interface Requirements (3.3)

6.1.9 Environmental Requirements

a) Atmosphere in mechanism (3.7.2)
b) Temperature (3.7.2, 3.6.5)
c) Pressure (3.7.2)
d) Atmosphere outside mechanism (3.7.1)
e) Temperature (3.7.1)
f) Pressure (3.7.1)
g) Radiation Dosage (3.8.3)

6.1.10 Vibration (3.6.17)

6.1.11 Shock Loading (3.6.16)

1) Without scramming
2) Maximum

6.1.12 Supporting Services

a) Electrical Power (3.7.4)
   1) Voltage and frequency
   2) Current
b) Cooling (3.6.5)
   1) Coolant
   2) Flow Rate
   3) Temperature
   4) Pressure

6.1.13 Testing Requirements (4.7)

6.1.14 Delivery Requirements (5.)

a) Components to be delivered

b) Delivery schedule

c) Purchaser

d) Delivery site

6.1.15 Documentation (3.12)

6.2 Proposal Information Required. The CRDM Proposer's response shall include, but is not limited to, the following items.

6.2.1 Conceptual Layout Drawing

6.2.2 Parts List and Bill of Materials

6.2.3 Design Description

6.2.4 Statement of Exception (including justification) to Any Item of Ordering Data

a) Alternate offered

b) Statement of development problems. Each notification shall include, as a minimum, the following information:

1) What new development is required
2) Why the development is required
3) When the development must be completed
4) Recommended steps to achieve the development objective

6.2.5 Engineering Plans

6.2.6 Schedule for Completion of Work

6.2.7 Cost Proposal