DOE-HTGR-86-097

Revision 1

HFD-43413

Revision 2

908500/2

CORE REFUELING SUBSYSTEM DESIGN DESCRIPTION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED HH

Issued By:
GA Technologies Inc.
P.O. Box 85608
San Diego, California 92138-5608

DOE Contract No. DE-AC03-84SF11963

GA Project 6300

JULY 1987

GA Technologies Inc.

GA 1485 (REV. 10/82)

ISSUE SUMMARY

TITLE CORE REFUELING SUBSYSTEM DESIGN
DESCRIPTION

☐ R & D
☐ DV & S
☒ DESIGN

APPROVAL LEVEL 5

DISCIPLINE
0

SYSTEM
3413

DOC. TYPE
SSDD

PROJECT
6300

DOCUMENT NO. 908500

ISSUE NO./LTR. 2

QUALITY ASSURANCE LEVEL
II

SAFETY CLASSIFICATION
NNS

SEISMIC CATEGORY
NON CAT I

ELECTRICAL CLASSIFICATION
Non 1E

ISSUE	DATE	PREPARED BY	APPROVAL				ISSUE DESCRIPTION/ CWBS NO.
			ENGINEERING	QA	FUNDING PROJECT	APPLICABLE PROJECT	
0	JUN 27 1986	J. K. Anderson 6/26/86	C. McDonald 6/26/86	G. P. Connors 6/26/86	G. Bramblett 6/26/86		Initial Issue (HFD-43413, Rev. 0) 6352-340-102
		R. Turner 6/26/86	Interface Assurance R. D. Dey				

CONTINUE ON GA FORM 1485-1

* See "List of Effective Pages"

NEXT INDENTURED DOCUMENTS

908445
(HFD-33400)

DISCLAIMER

**Portions of this document may be illegible
in electronic image products. Images are
produced from the best available original
document.**

ISSUE SUMMARY CONTINUATION SHEET

TITLE CORE REFUELING SUBSYSTEM DESIGN DESCRIPTION	DOCUMENT NO. 908500	ISSUE NO./LTR. 2
---	------------------------	---------------------

ISSUE	DATE	PREPARED BY	APPROVAL				ISSUE DESCRIPTION/ CWBS NO.
			ENGINEERING	QA	FUNDING PROJECT	APPLICABLE PROJECT	
1	SEP 09 1986	J.K. Anderson	C. McDonald R. Turner Interface Assurance	G.P. Connors	G. Bramblett		HTGR cover added HTGR-86-097/0 (HFD-43413, Rev. 1) Class II Change 6301998201
2	JUL 06 1987	E.C. Harvey J.K. Anderson	C. McDonald R. Turner Interface Assurance	G.P. Connors	G. Bramblett		(HTGR-86-097, Rev. 1) (HFD-43413, Rev. 2) Updated SSDD Class II Change 6352340204

LIST OF EFFECTIVE PAGES

<u>Page Number</u>	<u>Page Count</u>	<u>Revision</u>
i through xviii	18	2
1-1 through 1-21	21	2
2-1 through 2-40	40	2
3-1 through 3-28	28	2
4-1 through 4-17	17	2
5-1	1	2
6-1 through 6-12	12	2
7-1	1	2
8-1	1	2
9-1	1	2
A-1 through A-14	14	2
B-1	1	2
C-1	1	2
D-1	1	2
E-1	1	2
F-1	1	2
G-1	1	2
Total pages	<u>160</u>	

CONTENTS

	<u>PAGE</u>
LIST OF EFFECTIVE PAGES	iv
LIST OF APPENDICES	vii
LIST OF ILLUSTRATIONS	viii
LIST OF TABLES	viii
LIST OF ABBREVIATIONS AND ACRONYMS	x
DEFINITIONS	xi
PREFACE	xvi
SUMMARY	xviii
1 SYSTEM FUNCTIONS AND DESIGN REQUIREMENTS	1-1
1.1 SUBSYSTEM FUNCTIONS	1-1
1.2 SUBSYSTEM DESIGN REQUIREMENTS	1-2
1.2.1 Subsystem Configuration and Essential Features Requirements	1-2
1.2.2 Operational Requirements	1-5
1.2.3 Structural Requirements	1-8
1.2.4 Environmental Requirements	1-10
1.2.5 Instrumentation and Control Requirements	1-12
1.2.6 Surveillance and In-Service Inspection Requirements	1-14
1.2.7 Availability Assurance Requirements	1-14
1.2.8 Maintenance Requirements	1-15
1.2.9 Safety Requirements	1-17
1.2.10 Codes and Standards Requirements	1-19
1.2.11 Quality Assurance Requirements	1-19
1.2.12 Construction Requirements	1-21
1.2.13 Decommissioning Requirements	1-21
2 DESIGN DESCRIPTION	2-1
2.1 SUMMARY DESCRIPTION	2-1
2.2 SYSTEM CONFIGURATION	2-8
2.2.1 Fuel Handling Equipment Support Structure	2-9
2.2.2 Reactor Isolation Valve	2-9

2.2.3	Fuel Handling Machine	2-13
2.2.4	Fuel Transfer Cask Adapter	2-18
2.2.5	Fuel Transfer Cask	2-20
2.2.6	Fuel Handling Equipment Positioner	2-22
2.2.7	Plug Actuator and Turntable Assembly	2-24
2.2.8	Refueling Accessories	2-26
2.2.9	Fuel Handling Control Station	2-27
2.3	SYSTEM PERFORMANCE CHARACTERISTICS	2-29
2.3.1	Subsystem Operating Modes	2-29
2.3.2	Steady-State Performance	2-31
2.3.3	Plant Transients	2-32
2.3.4	Subsystem Failure Modes and Effects	2-32
2.4	SYSTEM ARRANGEMENT	2-35
2.5	INSTRUMENTATION AND CONTROL	2-35
3	SUBSYSTEM FUNCTIONS AND DESIGN REQUIREMENTS	3-1
3.1	COMPONENT FUNCTIONS	3-1
3.2	COMPONENT DESIGN REQUIREMENTS	3-3
3.2.1	Fuel Handling Machine	3-3
3.2.2	Fuel Transfer Cask	3-6
3.2.3	Fuel Handling Equipment Positioner	3-10
3.2.4	Reactor Isolation Valve	3-13
3.2.5	Fuel Handling Equipment Support Structure	3-16
3.2.6	Fuel Transfer Cask Adapter	3-18
3.2.7	Plug Actuator and Turntable Assembly	3-21
3.2.8	Refueling Accessories	3-23
3.2.9	Fuel Handling Control Station	3-26
4	SUBSYSTEM AND COMPONENT INTERFACES REQUIREMENTS	4-1
4.1	SUBSYSTEM INTERFACE REQUIREMENTS	4-1
4.2	COMPONENT BOUNDARY DEFINITION	4-1
5	SUBSYSTEM CONSTRUCTION	5-1
6	SUBSYSTEM OPERATION	6-1
6.1	SUBSYSTEM LIMITATIONS, SETPOINTS, AND PRECAUTIONS	6-1
6.2	PREOPERATIONAL CHECKOUT	6-6
6.3	INSTALLATION OF EQUIPMENT AND OTHER OPERATIONS	6-7

6.4	NORMAL OPERATION	6-7
6.5	REFUELING	6-8
6.6	SHUTDOWN	6-8
6.7	ABNORMAL OPERATION	6-9
6.8	CASUALTY EVENTS AND RECOVERY PROCEDURES	6-9
6.8.1	Casualty Events	6-9
6.8.2	Design Features to Mitigate Effects of Casualty Events	6-10
6.8.3	Recovery Procedures	6-12
7	SYSTEM MAINTENANCE	7-1
8	SYSTEM DECOMMISSIONING	8-1
9	REFERENCES	9-1

LIST OF APPENDICES

A	TRACEABILITY OF REQUIREMENTS	A-1
B	DRAWING LIST	B-1
C	TRANSIENTS	C-1
D	DESIGN BASIS SEISMIC INPUTS	D-1
E	EQUIPMENT LIST	E-1
F	PARAMETER LISTS	F-1
G	PROPRIETARY CLAIMS	G-1

LIST OF ILLUSTRATIONS

<u>FIGURE</u>	<u>TITLE</u>	<u>PAGE</u>
2-1	Location of Fuel Handling Equipment	2-2
2-2	In-Vessel Fuel Handling Operations	2-3
2-3	Spent Fuel Storage Facility	2-4
2-4	Fuel Element Construction for Handling	2-6
2-5	Arrangement of Refueling Penetrations and Equipment	2-7
2-6	Fuel Handling Equipment Support Structure	2-10
2-7	Fuel Handling Equipment	2-11
2-8	Reactor Isolation Valve	2-12
2-9	Neutron Control Assembly Handling Equipment	2-14
2-10	Fuel Handling Machine - Transport Configuration	2-15
2-11	Fuel Transfer Cask Adapter	2-19
2-12	Fuel Transfer Cask	2-21
2-13	Fuel Handling Equipment Positioner	2-23
2-14	Plug Actuator and Turntable Assembly	2-25
2-15	Fuel Handling Control Station	2-28
2-16	Refueling Control Scheme, Communications	2-38

LIST OF TABLES

<u>TABLE</u>	<u>TITLE</u>	<u>PAGE</u>
1-1	Expected and Design Primary Coolant Impurities	1-11
1-2	Federal Regulation Requirements	1-20
4-1	Core Refueling Interface Requirements Imposed on Other Systems	4-2
4-2	Core Refueling Interface Requirements Imposed on Other Subsystems Within the Fuel Handling and Storage System	4-10
4-3	Evacuation of Refueling and Reactor Service Equipment	4-11
4-4	Evacuation of Refueling and Reactor Service Equipment Interspaces	4-12
4-5	Purified Helium Requirements	4-13

LIST OF TABLES (Continued)

4-6	Location of Distribution Stations	4-15
4-7	Electrical Load List Interface Requirements	4-17

LIST OF ABBREVIATIONS AND ACRONYMS

AISC	American Institute for Steel Construction
ANS	American Nuclear Society
ANSI	American National Standards Institute
ASCT	Auxiliary Service Cask and Transporter
AOO	Anticipated Operational Occurrence
ASME	American Society of Mechanical Engineers
BSDD	Building and Structures Design Description
CDS	Component Design Specification
CFR	Code of Federal Regulations
CRS	Core Refueling Subsystem
CWT	Counterweight
DBE	Design Basis Event
DC	Direct Current
FHCS	Fuel Handling Control Station
FHEP	Fuel Handling Equipment Positioner
FHESS	Fuel Handling Equipment Support Structure
FHM	Fuel Handling Machine
FHSS	Fuel Handling and Storage System
FSIF	Fuel Sealing and Inspection Facility
FSV	Fort St. Vrain
FSW	Fuel Storage Well
FTC	Fuel Transfer Cask
HTGR	High Temperature Gas-Cooled Reactor
ICD	Interface Control Document
IEEE	Institute of Electrical and Electronics Engineers
ISI	In-Service Inspection
LEU	Low-Enriched Uranium
MHTGR	Modular HTGR
NA	Not Applicable
NQA	Nuclear Quality Assurance
NRC	Nuclear Regulatory Commission
OBE	Operating Basis Earthquake

LIST OF ABBREVIATIONS AND ACRONYMS (Continued)

OPDS	Overall Plant Design Specification
OSHA	Occupational Safety and Health Administration
PATA	Plug Actuator and Turntable Assembly
QA	Quality Assurance
RB	Reactor Building
RIV	Reactor Isolation Valve
RSB	Reactor Service Building
SDD	System Design Description
SFCS	Spent Fuel Cooling Subsystem
SFHS	Site Fuel Handling Subsystem
SFSF	Spent Fuel Storage Facility
SSDD	Subsystem Design Description
SSE	Safe Shutdown Earthquake
TBD	To Be Determined
USNRC	United States Nuclear Regulatory Commission

DEFINITIONS

Active Core: The assemblage of fueled graphite elements (containing the uranium and thorium fuel constituents).

Casualty Event: A casualty event is defined as an abnormal system or plant condition that affects the safety, integrity, or proper functional operation of the system or plant; could produce system or plant degradation or affect personnel safety; and requires action to restore the system or plant to a known, confirmed safe condition or to mitigate the consequences of the casualty event.

Core: See Reactor Core.

Core Sector: All the replaceable core elements handled from a single neutron control assembly housing.

Depressurized Condition: Primary coolant system pressure at a nominal subatmospheric condition of -0.5 psig.

Equivalent Core: The number of fuel elements in the reactor core for normal operation.

Full Size/Half Size Elements: A full size element in an HTGR core has the general appearance illustrated in Figure 2.3 and the maximum dimensions specified 1.2.3.1.2. Half size elements have the same hexagonal cross section as full size elements but are approximately one-half the height of a full size element. Half size elements are used only outside the fueled portion of the core.

Functional Analysis: A systems engineering technique or method used to develop (1) functions required to meet established goals, (2) the relationship between functions and related requirements, and (3) the basis and

DEFINITIONS (Continued)

justification for design selections through which the prescribed goals are met. (Functional analysis is one part of the Integrated Approach.)

Functional Requirement: A bounding quantification that is derived from a functional need versus being imposed by an institutional standard.

Institutional Requirement: A bounding quantification that is imposed by an institution as opposed to a quantification derived from a functional need.

Integrated Approach: A systems engineering technique for establishing and defending a well-developed nuclear plant design.

Irradiated Fuel or Reflector: Fuel or reflector elements which have become radioactive as a result of exposure to the environment within an operating reactor module.

LEU Fuel: Low-enriched uranium fuel in which the enrichment is less than 20%.

Neutron Control Assemblies: The equipment normally installed in the housings attached to the top head of the reactor vessel. These assemblies contain neutron control devices, including the control rods and their drive mechanisms, the reserve shutdown control equipment and instrumentation.

New Fuel or Reflector: Fresh fuel or reflector elements which have not been irradiated in the reactor core.

Nominal Refueling Outage: The estimated time to shutdown a single reactor module, achieve refueling conditions, exchange the average number of core elements and return to power.

DEFINITIONS (Continued)

The nominal refueling outage does not include any delays for other reactor maintenance or ISI and it assumes that sufficient trained operators are available to support a three shift operation for the duration of the outage. The net operating efficiency of the personnel and equipment is assumed to be [72]%.

Normal Refueling: The nominal condition when irradiated core elements are being replaced in a preprogrammed sequence and all handling and storage equipment is functioning properly.

Permanent Reflector Elements: Reflector elements which are not in direct contact with fuel elements. These elements have an estimated design life of at least 40 years. (Note: Some permanent reflector elements are handled by the CRS equipment).

Radionuclide: A synonym for radioactive nuclide. The term typically applies to the radioactive substances in and around irradiated fuel elements in the primary coolant.

Reactor Core: The active core plus the replaceable reflector elements.

Replaceable Reflector Elements: Hexagonal reflector elements in direct contact with or very close to fuel elements. These elements have an estimated life of 3.3 to 10 years based upon the neutron flux levels at their in-core location.

Special Refueling: All of the unusual or abnormal refueling operations which might occur as a result of malfunctions in fuel handling or storage equipment, special core maintenance, or inspections, etc.

DEFINITIONS (Continued)

Spent Fuel or Reflector: Irradiated fuel or reflector elements which have been exposed to the environment within an operating reactor module for their design life.

Whole Body Dose: A measure of the radiation delivered to the body of an individual located in a specified area during a standard time interval.

PREFACE

The objective of the HTGR plant project is to produce safe, economical power. Supporting this objective, four major goals and their associated plant states are identified as follows:

1. Maintain Safe Plant Operation
 - 1.1 Maintain Safe Energy Production
 - 1.2 Maintain Safe Plant Shutdown
 - 1.3 Maintain Safe Plant Refueling
 - 1.4 Maintain Safe Plant Startup/Shutdown
2. Maintain Plant Protection
 - 2.1 Protect the capability to maintain safe energy production
 - 2.2 Protect the capability to maintain safe plant shutdown
 - 2.3 Protect the capability to maintain safe plant refueling
 - 2.4 Protect the capability to maintain safe plant startup/shutdown
3. Maintain Control of Radionuclide Release
 - 3.1 Control radiation
 - 3.2 Control personnel access
4. Maintain Emergency Preparedness

The OPDS is the top-level technical document for the HTGR plant. The OPDS (based on owner requirements and regulatory requirements) establishes the overall performance, functional, institutional, operational, safety, maintenance, inspection and decommissioning requirements for design of the plant.

PREFACE (Continued)

In response to the OPDS, a series of lower tier documents, System Design Descriptions (SDDs), Subsystem Design Descriptions (SSDDs), Buildings and Structures Design Descriptions (BSDDs), Component Design Specifications (CDSs), and Interface Control Documents (ICDs), describe and control the individual designs. Traceability of requirement source from plant-level requirements to equipment-level requirements shall be maintained throughout this hierarchy of design documents.

SUMMARY

The Core Refueling Subsystem of the Fuel Handling and Storage System provides the mechanisms and tools necessary for the removal and replacement of the hexagonal elements which comprise the reactor core. The Core Refueling Subsystem is not "safety-related."

The Core Refueling Subsystem equipment is used to prepare the plant for element removal and replacement, install the machines which handle the elements, maintain control of air inleakage and radiation release, transport the elements between the core and storage, and control the automatic and manual operations of the machines. Much of the element handling is performed inside the vessel, and the entire exchange of elements between storage and core is performed with the elements in a helium atmosphere.

The core refueling operations are conducted with the reactor module shutdown and the primary coolant pressure slightly subatmospheric. The subsystem is capable of accomplishing the refueling in a reliable manner commensurate with the plant availability requirements.

SECTION 1
SUBSYSTEM FUNCTIONS AND DESIGN REQUIREMENTS

1.1 SUBSYSTEM FUNCTIONS

The power generation functions of the Core Refueling Subsystem (CRS) are as follows:

1. Prepare the reactor for refueling operations.
2. Remove and replace the fuel, replaceable reflector, and plenum elements in the reactor core.
3. Transport the elements between the core and the spent fuel storage facility (SFSF).
4. Assist in maintaining accountability of the elements.
5. Perform in-vessel maintenance activities using special tools and attachments.

The radionuclide control functions of the CRS are as follows:

1. Limit release from the fuel handling and storage equipment.
2. Limit release from the reactor vessel during refueling.
3. Protect operating personnel from radiation during fuel handling operations.

1.2 SUBSYSTEM DESIGN REQUIREMENTS

1.2.1 System Configuration and Essential Features Requirements

The CRS design shall be based upon the use of a low enriched uranium fuel cycle with no reprocessing of spent fuel, but also with a capability for alternate fuel cycles (e.g., high enriched, recycle) which can be utilized without requiring any modifications to the basic core/fuel design, to the physical plant or to refueling components. (3413.0102.001)*

Provisions shall be made to perform refueling of a reactor module with the remaining reactor modules and the turbine plant(s) in operation. (3413.0102.002)

Core refueling shall be from the top of the core, through the cylindrical housings which normally contain inner neutron control assemblies. (3413.0102.003)

Six core sectors shall be refueled sequentially. Refueling a core sector shall require the temporary removal of two inner neutron control assemblies, i.e. one assembly located directly above the sector to be refueled and one located 180° from the first. (3413.0102.004)

The neutron control assemblies shall be removed, replaced and transported by the auxiliary service cask and transporter (ASCT) provided with the reactor service equipment subsystem. (3413.0102.005)

The CRS shall employ a removable fuel handling machine (FHM) similar to that at Fort St. Vrain (FSV) to handle elements within the reactor vessel. The FHM shall be temporarily installed in the empty neutron control assembly housing directly above the core sector to be refueled. (3413.0102.006)

*Requirement Traceability Number.

The CRS shall employ two portable fuel transfer casks (FTCs) to engage core elements at either the reactor vessel, the spent fuel storage facility (SFSF), or the fuel sealing and inspection facility (FSIF) and transport them to alternate locations. During refueling of a core sector, the FTCs shall remove or insert elements thru the empty neutron control assembly penetration located 180° from the sector being refueled. (3413.0102.007)

The CRS shall employ portable reactor isolation valves (RIVs) to limit air ingress into the primary system during refueling. (3413.0102.008)

The RIV shall provide a flexible seal capable of maintaining sealing contact with the top surface of the neutron control assembly housing during all expected relative movement of the penetration. (3413.0102.009)

The top surface of the RIV shall provide an acceptable interface with either the FHM or the ASC. (3413.0102.010)

An FTC adapter shall be used to provide an acceptable interface between the RIV and the FTCs. (3413.0102.011)

The CRS shall employ a portable fuel handling equipment support structure (FHES) to support the RIV, FHM, FTC. The FHES structure shall be supported by the refueling floor of the reactor building. (3413.0102.012)

The ASCT provided with the reactor service equipment subsystem shall be used to handle the FTC grapple guide sleeve. The sleeve shall be temporarily placed in the empty neutron control assembly penetration to align the FTC grapple as it moves elements in or out of the reactor vessel. (3413.0102.013)

The FTCs and FHM shall be moved by the fuel handling equipment positioner (FHEP). (3413.0102.014)

All portable CRS components except the FHM, the FTCs, and the FTC grapple guide sleeve shall be moved with the reactor building crane.

(3413.0102.015)

Movement of portable FHSS equipment shall be routed and controlled so as not to endanger the reactor modules.

(3413.0102.016)

The fuel storage facilities used during core refueling shall be arranged to provide two clusters of 36 storage wells in close proximity of any reactor module. The wells in each cluster shall be arranged in concentric circles and shall hold 10 elements/well in a vertical stack.

(3413.0102.017)

The fuel storage facilities used during core refueling shall be capable of maintaining a purified helium environment around the elements within the well and shall provide a shielded closure plug at the upper end of each well. The shielded closure plug shall be designed for remote removal and replacement with other FHSS equipment.

(3413.0102.018)

The CRS shall employ a plug actuator and turntable assembly (PATA) for efficient and rapid FTC access to the storage wells at the spent fuel storage facility (SFSF) and to form a seal against air ingress to the FTC and wells.

(3413.0102.019)

The PATA shall be supported by the storage pool structure and/or the refueling floor of the reactor building.

(3413.0102.020)

The FTC shall mount on and be supported by the PATA during element handling operations at the SFSF.

(3413.0102.021)

The CRS equipment shall provide biological shielding and design features to control gaseous releases as required to satisfy the radiation safety requirements of Section 1.2.9.2 during the core refueling operation.

(3413.0102.022)

The CRS shall include equipment used to position viewing devices and special tooling for in-core maintenance including removal of damaged elements from the core and in-service inspection. Specifically, the FHM shall be designed to accept the core service manipulator package in lieu of its normal grapple and the fuel handling control station (FHCS) shall incorporate the controls needed for operating the core service manipulator and its tools remotely. The core service manipulator provides the capability to remove damaged elements from the core. (3413.0102.023)

1.2.2 Operational Requirements

The CRS shall be designed to replace approximately one half of the fuel and one-third of the replaceable reflector elements in the core while satisfying the availability criteria of Section 1.2.7 during each refueling outage. The nominal interval between refueling outages for a given module shall be 20 months. (3413.0102.030)

The CRS design shall assume that:

- o The minimum design interval between the initiation of refueling outages of nonadjacent modules is [12] days.
- o The minimum interval between the initiation of refueling outages of adjacent modules is 10 months.
- o A maximum of two modules will be refueled in any 10 month interval. (3413.0102.031)

Core refueling shall be accomplished with the reactor in a shutdown condition and the primary system maintained in an inert atmosphere that is slightly subatmospheric and a core inlet temperature $\leq 250^{\circ}\text{F}$. (Refer to Section 1.2.4 for specific environmental conditions.) (3413.0102.032)

The CRS equipment shall be designed to handle hexagonal elements that are within the physical size and weight limits specified below:

	<u>kg</u>	<u>(lb)</u>
Minimum weight	63.5	(140)
Maximum weight	154.0	(340)
	<u>m</u>	<u>(in.)</u>
Maximum height	0.79	(31.22)
Minimum height	0.40	(15.61)
Maximum dimension over flats of hexagon	0.36	(14.2)
Maximum dimension over corners of hexagon	0.42	(16.4)

(3413.0102.033)

The FTCs, the FHM, and the FHCS shall have features for remote measurement of element characteristics and the comparison of the measured characteristics to the expected values to assist in the identification of damaged elements and/or possible errors in the refueling sequence.

(3413.0102.034)

The CRS equipment shall include equipment enabling an accounting including element location to be made for all fuel elements located at the plant site.

(3413.0102.035)

The CRS equipment shall be designed to ensure that critical arrays cannot occur. The k_{eff} of any array shall not exceed 0.95 during any applicable AOO or DBE.

(3413.0102.036)

Specific operating procedures in support of the preceding general criticality requirement include the following:

Refueling shall be completed in one sector prior to the start of refueling in another sector and no more than two outer and two inner control rods shall be removed from the core at one time during any normal refueling or core maintenance procedure. (3413.0102.037)

The outer replaceable side reflectors in a given core sector shall be separated into groups and the two groups shall be replaced at different refueling outages to ensure that at least one pair of outer control rods is inserted into the core sector at all times.

(3413.0102.038)

The removal and replacement sequence for core elements shall be planned and conducted in a manner which ensures that all of the elements in any given FTC load are the same type; i.e., either spent elements, reusable elements or new elements.

(3413.0102.039)

Elements to be reused shall be reinstalled at the same core location from which they were removed.

(3413.0102.040)

To the extent possible, reusable core elements shall remain in the reactor vessel during core refueling operations.

(3413.0102.041)

The CRS shall be capable of removing and replacing all hexagonal elements over the full height of the core columns, however, special equipment and/or procedures shall be used to assure core stability and shutdown margins if more than one sector is removed at one time.

(3413.0102.042)

The FHM shall be capable of partially withdrawing either but not both of the two outer neutron control assemblies in a refueling sector to gain access to the reflector elements at the outer perimeter.

(3413.0102.043)

The CRS equipment shall limit the oxidation rate of irradiated fuel elements having a maximum decay heat generation rate of [10,000] Btu/h to less than 0.01% of the element weight per hour for any applicable AOO or DBE during the interval that the element is being moved from the reactor core to the SFSF. (3413.0102.044)

The CRS equipment and operating procedures shall restrict the total air inleakage to the primary coolant during refueling to less than the following percentage of the allotted [860] cu ft. (3413.0102.045)

- a. While installing and removing RIVs - [15.0%].
- b. While providing access for FHM - [5%].
- c. While providing access for FTC - [5%].
- d. While exchanging elements with FTC - [35%] (includes leakage through structures and seals of FHM [3.0%] and FTC [2.0%].
- e. While installing and removing FTC - [30%].
- f. While installing and removing FHM - [2.0%].
- g. Other miscellaneous leak paths - [8%].

The RIV, PATA, FHM, and FTC designs shall utilize helium purge and supply systems to limit the release of radioactivity and the ingress of air. (3413.0102.046)

1.2.3 Structural Requirements

CRS components which experience pressure differentials while satisfying their operational requirements shall be designed to the applicable pressure vessel or piping codes. (3413.0102.051)

CRS components exposed to significant thermal gradients shall be designed to accommodate the resulting differential thermal expansion without creating internal stresses that exceed design limits for the materials selected when combined with other applicable stresses. (3413.0102.052)

Portable CRS components shall be capable of absorbing vertical impact loads of up to 3.0 g during handling, without damage. (3413.0102.053)

All CRS components shall be capable of withstanding the seismic excitation from the 0.15 g earthquake as defined in Section 1.2.4 of their respective design specifications so that following the earthquake the component shall be capable of continuing or resuming its operational functions without repair. (3413.0102.054)

CRS components shall be capable of withstanding the seismic excitation from 0.3 g earthquake as defined in Section 1.2.4 of their respective design specification without impairing their functional capability to:

1. Provide leaktight barriers to minimize the release of gaseous radionuclides from portable machines.
2. Provide radiation barriers to protect operating personnel from spent elements and/or other sources.
3. Provide leak-tight barriers to minimize the release of radionuclides from the reactor vessel and the spent fuel storage facility wells during refueling. (3413.0102.055)

The seismic response of each component of the CRS shall be determined from response spectra used as inputs to the boundaries of the CRS equipment. Because the CRS equipment is used in several of the buildings on the site, different response spectra at various elevations within the various buildings must be generated. (3413.0102.056)

Response spectra to be used for the analysis of CRS equipment will be provided in the design specifications for each item. Both horizontal and vertical accelerations must be considered in the analysis. Applicable requirements during and after the specified seismic events are identified above. (3413.0102.057)

1.2.4 Environmental Requirements

The specific environmental requirements for each of the extremely diverse components of the CRS will be identified in the design specifications for each component. The specific requirements for each component shall be selected from the following bounding requirements as appropriate for the operating requirements of the component.

The individual CRS components shall be able to satisfy their respective operating requirements at a plant site having the characteristics given in Appendix F1 as modified to reflect the location of the component within the reactor plant structures. (3413.0102.062)

The CRS shall be capable of refueling the reactor core under the plant performance characteristics and environmental parameters given in Table 1-1 and Appendix C. (3413.0102.065)

Many CRS components form part of the primary coolant boundary during core refueling and are subject to pressure transients that may occur in the primary coolant during the refueling plant state (see Appendix C). The environmental requirements for the affected components shall include these overpressure transients. (3413.0102.066)

Many CRS components must be evacuated during periodic changing from an internal atmosphere of air to helium and vice versa. The environmental requirements for these components shall include these pressure transients. (3413.0102.067)

Table 1-1 EXPECTED AND DESIGN PRIMARY COOLANT IMPURITIES^(a)

Chemical Impurities	Expected Impurity Level (μ atm)	Design Impurity Level (μ atm)
Water	31	125
Carbon dioxide	62.5	125
Carbon monoxide	125	310
Hydrogen	190	625
Methane	6.3	125
Nitrogen	125	625
Particulates	1 lb/yr	10 lb/yr

^(a)Impurity levels are at nominal reactor operating pressure of 918 psia and are reduced proportionately to determine the impurity levels at the start of refueling with the operating pressure at approximately 14.7 psia.

Many CRS components operate in close proximity to irradiated fuel elements which generate significant amounts of decay heat. The environmental requirements for these components shall include temperature transients generated by their anticipated exposure to irradiated fuel elements.

(3413.0102.068)

Many CRS components must periodically operate in the inert helium environment of the reactor primary coolant. The environmental requirements for these components shall include criteria defining the expected helium purity levels based upon Table 1-1 and the duration of the exposure to helium.

(3413.0102.069)

Many CRS components must periodically operate in radiation fields of varying composition and intensity. The environmental requirements for these components shall include criteria defining the expected radiation exposure in terms of composition, intensity and duration.

(3413.0102.070)

All CRS components shall be unaffected by extended storage in air in enclosed structures with a temperature range of 4.4°C to 48.9°C (40°F to 120°F) and a maximum relative humidity of 100%.

(3413.0102.071)

1.2.5 Instrumentation and Controls

A Fuel Handling Control Station (FHCS) shall be provided to serve as the control and coordination center for all fuel handling activities.

(3413.0102.080)

The CRS instrumentation and controls shall include features such as interlocks, internal diagnostic monitoring, redundant components, etc. for each individual FHSS equipment item which reflect the importance of that item to system availability and safety.

(3413.0102.081)

Human engineering techniques shall be employed in the design of the controls and instrumentation/operator interface to enhance operator response and reduce the probability of human error. (3413.0102.082)

Process control circuitry within the CRS shall be functionally independent from component monitoring and protective features. (3413.0102.083)

Instrumentation and controls shall provide for remote-manual operation of the refueling equipment. (3413.0102.084)

Refueling of the core shall be accomplished through an automated sequence of coordinated fuel handling operations. (3413.0102.085)

The refueling machines shall move at different speeds at different points in the operating cycle to protect the machines and to be consistent with the operating experience gained at FSV. (3413.0102.086)

Controls and instrumentation shall sense equipment loads and act to prevent equipment damage. (3413.0102.087)

Location and orientation of the fuel and reflector elements shall be monitored and recorded by the CRS using both element type numbers and unique serial numbers to ensure proper placement of all elements in the core and storage locations. (3413.0102.088)

The FHCS shall provide the capability to log and trend operational data with redundancy and backup functions to insure that fuel inventory and equipment status records are not lost due to failure of a single component. Probability of data loss shall be <[TBD]. (3413.0102.089)

The FHCS shall provide the capability to automatically detect and document the sequence of significant events (e.g., control inputs, changes in the operation of major components, protective trips, etc.) that occur during subsystem operation. (3413.0102.090)

Audio and video communications will be provided to link the FHCS to the various locations where fuel handling operations occur. (3413.0102.091)

1.2.6 Surveillance and In-Service Inspection

There are no surveillance and in-service inspection requirements for the CRS since the entire subsystem is classified as not "safety related" under the criteria provided in Section 1.2.9.1.

1.2.7 Availability Assurance

The CRS has no specific allocation for planned outage and overall reliability as typically specified for other MHTGR systems in Reference 5. Instead, the allocation is incorporated into the planned outage for refueling as defined below.

The CRS shall incorporate components and features to accomplish refueling of a single reactor module within 12 days or two modules in 21 days which is commensurate with the plant scheduled downtime requirement of 876 h/yr. (3413.0102.101)

The planned refueling outage shall:

- o Include an allocation of [100] h for module shutdown, depressurization, repressurization and startup.
- o Assume that qualified operators are available in sufficient numbers to support a continuous refueling operation (i.e., 3 shifts/day and 7 days/week).
- o Include an efficiency factor of [72]% to account for personnel problems and unscheduled malfunctions in the refueling equipment.

- o Exclude other plant ISI and/or maintenance activities which extend the planned refueling outage. (3413.0102.102)

Design modifications and improvements to achieve higher availability or to reduce unavailability shall be considered for incorporation in the design, if one percentage increase in the total capital investment produces, at a minimum, a seven tenths percentage improvement in the equivalent availability factor. (3413.0102.103)

1.2.8 Maintenance Requirements

The CRS arrangement and component design shall, to the extent allowed by operational design requirements facilitate the planned and unscheduled maintenance of the CRS components. (3413.0102.104)

The CRS equipment shall be designed to facilitate corrective maintenance or recovery from accidents during core refueling. Special features and/or tooling shall be provided as appropriate to place the equipment in a configuration compatible with the corrective maintenance task. (3413.0102.105)

The CRS equipment shall be designed to provide for all planned maintenance activities between refueling outages. The planned maintenance shall include the capability for periodic testing, and/or remote inspection and maintenance as appropriate. The planned maintenance of the CRS equipment shall not interfere with core refueling operations or have an adverse effect on the plant availability goal. (3413.0102.106)

A spare parts list listing and recommended spare parts inventory shall be developed consistent with the Preventive Maintenance Plan, anticipated unscheduled maintenance and plant availability requirements. (3413.0102.109)

Standard "off-the-shelf" components and materials shall be specified to the extent allowed by other design requirements in order to reduce costs associated with required spare parts and enhance the probability of an adequate source of supply over the life of the plant. Components performing comparable functions shall be classified to reduce the number of different types, sizes and temperature and pressure ratings. (3413.0102.110)

Design and fabrication of CRS components shall provide for reasonable and necessary interchangeability. This includes mechanical and electrical interchangeability of equipment where functional duplication is required. In addition, all spare parts shall be interchangeable with the original items. (3413.0102.111)

CRS equipment layout and design features shall facilitate installation, maintenance, testing, removal, and replacement of all major components. These components shall be accessible from normally provided floor and platforms to the greatest degree practicable. Where components are not accessible from floors or platforms, special access, such as permanently installed ladders and local platforms, shall be provided. (3413.0102.112)

Remote maintenance techniques shall be considered in the design where improved availability may result from time savings. (3413.0102.113)

The minimum design life for components in the CRS shall be:

1. Equipment structural components, 40 years plus development testing.
2. Elastomers, 5 years.
3. Lubricants, 10 years.

4. Drive components, 40-year goal with easy replacement for components with shorter predicted life.

5. Electrical and electronic components, [TBD]. (3413.0102.114)

1.2.9 Safety Requirements

1.2.9.1 Equipment Classification

The CRS is classified as not "safety-related".

1.2.9.2 Radiation Safety

The radioactivity associated with the CRS shall not lead to dose levels which exceed the top-level regulatory criteria applicable to Integrated Approach Goals 1, 2, 3 and 4. No credit shall be taken for sheltering or evacuating the public located beyond the exclusion area boundary.

(3413.0102.130)

The CRS design shall be compatible with the plant level requirement for individual personnel access to normally accessible areas of the facility for 40 hours per week in the performance of their operational, maintenance and testing duties while limiting the average, long-term whole body radiation exposure from all sources to no more than 100 man-rem/yr.

(3413.0102.131)

The CRS design shall be compatible with the plant level requirement to minimize the number of inaccessible areas due to high radiation levels during reactor operation and thereby facilitate routine operational and maintenance activities.

(3413.0102.132)

The CRS components shall provide biological shielding and operating procedures which protect the plant personnel from radiation from spent fuel, from surface contamination and from activated reactor components.

The CRS components shall also provide design features and operating procedures to restrict the release of gaseous radionuclides to ventilated areas. The expected strength and composition of the applicable radiation sources, the frequency and duration of the various exposures and the expected contribution to radiation levels in accessible areas shall all be defined in the applicable component design specifications.

(3413.0102.133)

1.2.9.3 Safety Analyses

Safety analyses of CRS components shall use element decay heat rates based upon normal operation at 102% of full power with appropriate adjustments for core peaking factors based upon initial loading, core location and burnup. Adjustments for elapsed time after shutdown shall also be applied.

(3413.0102.140)

There are no safety or investment risk requirements specified for the CRS in Reference 4.

1.2.9.4 Industrial Safety

Provisions for the safety of operating and maintenance personnel shall be incorporated into the CRS design to ensure that equipment installation, checkout, testing, and plant operation and maintenance can be accomplished with minimum hazard to personnel. Specifically, the design shall satisfy all applicable requirements of the U.S. Department of Labor "Occupational Safety and Health Standards" as set forth in 29 CFR 1910 and 29 CFR 1926.

(3413.0102.142)

An air atmosphere shall be provided wherever practical for personnel access to CRS components and consideration shall be given to explosion proofing, warning devices, protective clothing, escape devices, and emergency procedures.

(3413.0102.143)

1.2.10 Codes and Standards

Design, analysis, fabrication and construction of the CRS shall comply with applicable Codes of Federal Regulation and with Industry Codes and Standards that are needed to meet the Goals 1 and 2 of the Integrated Approach. All such applicable codes and standards shall be identified and documented in appropriate documentation during the design effort. Applicable state and local government regulations, codes and standards shall be identified and documented subsequent to the time a specific site is identified. (3413.0102.150)

The 10CFR requirements listed in Table 1-2 have been adopted as CRS design requirements. Several of the 10CFR regulations apply in intent, requiring that modifications and interpretations of wording to relate to unique features of the MHTGR may be made. Table 1-2 lists the 10CFR regulations that apply to the CRS design, including comments on required modifications. (3413.0102.151)

The following industry codes and standards have been adopted as CRS design requirements:

1. ASME Section VIII, Division 1.
2. ANS - [TBD].
3. IEEE - [TBD]
4. ANSI-NM16.1, "Nuclear Criticality Safety Standard for Operations with Fissionable Materials Outside Reactors."

(3413.0102.152)

1.2.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment

Table 1-2 FEDERAL REGULATION REQUIREMENTS

Part/Para.	Subject	Modifications
<u>10CFR</u>		
20/101	Radiation dose standard for individuals in restricted areas.	None.
20/103	Exposure of individuals to concentrations of radioactive materials in air in restricted areas.	None.
20/105	Permissible levels of radiation in unrestricted areas.	None.
20/106	Radioactivity in effluents to unrestricted areas.	None.
50	Domestic licensing of production and utilization facilities. 50.2(v), Definitions.	Change terminologies to HTGR specific.
	50.34a, Design Objectives for Equipment to Control Releases of Radioactive Material in Effluents - Nuclear Power Reactors.	
	50.36, Technical Specifications.	
	50.36a, Technical Specifications on Effluents from Nuclear Power Reactors.	--
	50.48, Fire Protection.	
	50.55a, Codes and Standards.	Change to be HTGR specific.

(NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0102.155)

1.2.12 Construction Requirements

The CRS arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0102.157)

1.2.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0102.160)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0102.161)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included. (3413.0102.162)

SECTION 2

DESIGN DESCRIPTION

2.1 SUMMARY DESCRIPTION

The Core Refueling Subsystem is comprised of the following major components:

1. Fuel handling equipment support structure.
2. Reactor isolation valves.
3. Fuel handling machine.
4. Fuel transfer cask adapter.
5. Fuel transfer casks.
6. Fuel handling equipment positioner.
7. Plug actuator and turntable assembly.
8. Refueling accessories.
9. Fuel handling control station.

The basic purpose of these components is to accomplish the periodic, remote replacement of core fuel and reflector elements in a safe and efficient manner.

Core refueling operations are predicated on 3.3 year fuel residence time whereby one-half of the fuel columns are replaced with new fuel every 20 months. Each fuel column consists of a vertical stack of 10 elements. Replaceable reflector elements adjacent to the active core have estimated lives of 3.3 to 10 years. Approximately one-third are replaced every 20 months.

The basic equipment for replacing fuel and replaceable reflector elements is illustrated in Figures 2-1 through 2-3. The refueling procedure involves the exchange of new core elements from the spent fuel storage

Figure 2-1 LOCATION OF FUEL HANDLING EQUIPMENT

Figure 2-2 IN-VESSEL FUEL HANDLING OPERATIONS

Figure 2-3 SPENT FUEL STORAGE FACILITY

facility for spent core elements. This exchange occurs after the reactor has been shut down and depressurized. Figure 2-4 illustrates the handling features of a core element. Figure 2-5 illustrates the general arrangement of the neutron control assembly housings and other components in the top head and upper plenum of the reactor vessel. The exchange of elements occurs in one-sixth of the core area (i.e., a core sector) at a time as shown in Figure 2-5.

To replace the outer side reflectors that contain the control rods of a refueling sector, two of the four rods in the sector are retracted during the refueling of the sector, and the corresponding reflectors are removed. The remaining two rods remain in the side reflector to assure adequate shutdown margin. Up to one-half of the side reflectors in each refueling sector are replaced with each refueling process, which provides for total side reflector replacement within the estimated life of the reflector elements.

Although only half of the fuel from each sector is replaced with each refueling process, nearly all of it is removed and transferred to the spent fuel storage facility to provide access for the fuel handling machine. When the partially used fuel is returned to the core sector, it is returned to its initial location. The balance of the fueled portion of the core sector is filled with new fuel. The replaceable reflector elements from the core sector are either replaced with new elements or returned to their original core location.

The CRS uses a digital computer to control all refueling operations and to monitor related refueling activities. Refueling of a sector is normally accomplished in an "automatic" mode with minimum operator involvement after initiation of the refueling cycle. The computer ensures the machines are operated within acceptable limits and in a predetermined sequence.

This process of removal and replacement of spent core elements, sector by sector, is repeated until the entire core has been refueled.

Figure 2-4 FUEL ELEMENT CONSTRUCTION FOR HANDLING

Figure 2-5 ARRANGEMENT OF REFUELING PENETRATIONS
AND EQUIPMENT

All refueling equipment is removed from the vessel upon completion of refueling.

2.2 SUBSYSTEM CONFIGURATION

The basic equipment for refueling the core is illustrated in Figures 2-1, 2-2, 2-3 and 2-4. Access to the various core sectors with the Fuel Handling Machine (FHM) is achieved through the sequential removal of the six inner neutron control assemblies (NCA) from their housings with the Auxiliary Service Cask (ASC) and transporter which is part of the Reactor Service Equipment Subsystem. The FHM is placed above the inner NCA housing corresponding to the sector to be removed, and one of the two Fuel Transfer Casks (FTCs) is placed above the inner NCA housing, 180 deg from the FHM location (see Figure 2-5). A Reactor Isolation Valve (RIV) is used to maintain the helium environment in the vessel during handling operations with the ASC or the FHM. The FHM moves each element, by means of vertical, radial, and azimuth movements, to a location over the core directly below the FTC. The FTC grapple raises the element into the FTC. After the FTC is loaded to its capacity of five elements, the FTC is taken to the spent fuel storage facility shown in Figure 2-3 with the Fuel Handling Equipment Positioner (FHEP). The FHEP then moves the second FTC to the reactor module for loading. The exchange of elements occurs in one-sixth of the core area (i.e., a core sector) at a time as shown in Figure 2-5.

During core refueling a Plug Actuator and Turntable Assembly (PATA) is installed over each of the two fuel storage pools immediately adjacent to the module being refueled as illustrated in Figure 2-3. The PATA supports the FTC over any designated storage well and provides efficient access into the well to minimize the time required to load or unload the fuel transfer cask.

All refueling equipment is removed from the vessel upon completion of refueling.

The preceding text describes the basic method of core refueling and shows where the refueling equipment is generally located within the reactor plant. The following subsections give brief descriptions of the equipment items in the subsystem.

2.2.1 Fuel Handling Equipment Support Structure

The top mounted neutron control assembly housings of the steel reactor vessel are not capable of resisting the potential loads from the refueling equipment during a seismic event. Therefore, an independent support structure is required to position the equipment at the desired location and to transmit the loads directly to the building structure. The fuel handling equipment support structure (FHESS) is designed to perform this function.

The FHESS is shown in Figure 2-6. The removal of the access plug and the installation of the FHESS with the building crane are the first major steps in refueling.

The FHESS is fastened to the refueling floor as shown in Figure 2-7. The structure is designed so that two 120 deg rotations will allow interfacing with all 18 top head penetrations.

2.2.2 Reactor Isolation Valve (RIV)

The RIV shown in Figures 2-7 and 2-8 serves as radiation and atmospheric barrier between the reactor and operating personnel on the refueling floor when none of the portable equipment is installed over an open NCA housing.

The valve mechanism consists of a shield gate supported on rollers and surrounded by steel shielding. Power is provided by an external actuator that mechanically locks the valve gate at the selected position. The valve gate may be operated manually in the event of a failure in the normal drive system. A flexible seal is provided between the NCA housing and the base

Figure 2-6 FUEL HANDLING EQUIPMENT SUPPORT STRUCTURE

Figure 2-7 FUEL HANDLING EQUIPMENT

Figure 2-8 REACTOR ISOLATION VALVE

of the RIV. The valve is secured to the FHESS and is designed to ensure that seismic loads do not affect the integrity of the closed system. The RIV is positioned over the NCA housing with either the building crane or with portable lifting equipment. Once the RIV is placed in position over the NCA housing, either the FHM or the ASC can fit over it and seal to the RIV with inflatable seals. The top of the RIV and the base of the ASC and FHM are stepped to minimize radiation streaming. Figure 2-9 shows the ASC in its transporter in preparation for removal of a neutron control assembly.

The RIVs are controlled from local control stations on either the ASC or the FHM. Interlocks assure that the RIVs cannot be operated inadvertently. Limit switches are provided to indicate the gate positions.

2.2.3 Fuel Handling Machine (FHM)

The Fuel Handling Machine (FHM) (see Figures 2-7 and 2-10) is a shielded, gastight structure containing all the necessary mechanisms required to transfer fuel and reflector elements between the reactor core and the upper plenum where they are picked up by the FTC grapple. The FHM is the most complex machine in the core refueling subsystem and its motions are a significant factor in the length of the scheduled refueling outage. The FHM is similar to other prismatic fuel handling machines developed for earlier HTGR plants; however, it does have increased radial and vertical strokes to accommodate the specific requirements of the 350 MW(t) HTGR. The weight of the FHM is approximately 40 tons and is moved with the FHEP. During refueling of a core sector, the FHM is secured to the FHESS.

Together with the RIV, the FHM housing provides atmospheric and radiation barriers for protection of personnel on the refueling floor.

Vertical motion of the element handling mechanism is achieved with four telescoping tubular members, of which the guide tube is the outer, all guided and oriented one within the other. Initially, all four tubes are

Figure 2-9 NEUTRON CONTROL ASSEMBLY HANDLING EQUIPMENT

Figure 2-10 FUEL HANDLING MACHINE
(Shown in transport configuration)

supported by a multistrand chain passing over a system of hydraulically driven sprockets located in the base of the FHM housing. The chain is attached to the inner tube with the remaining tubes being supported at their upper ends with internal shoulders that rest on the next smaller tube. The element handling mechanism is mounted inside the smallest tube.

The installation of the guide tube is accomplished with a special drive that lowers all four tubes simultaneously by changing the elevation of the first set of chain sprockets. When the guide tube is deposited on the support surface in the neutron control assembly penetration, vertical motion of the first set of chain sprockets is terminated. The sprockets will remain at this elevation for all subsequent tube movements within the refueling sector.

The main vertical hydraulic drive system which is used for tube movements during core refueling operations is hydraulically powered to obtain a wide range of operating speeds. Tube separation for maximum extension is accomplished by progressively stopping the concentric tubes on internal shoulders built into the tube just outside the tube which is to cease its motion. The maximum tube separation occurs at the lowest operating point. All service lines to the handling mechanism in the inner tube are routed to the inner tube over sprockets and counterweights.

The vertical drive system has as its prime mover, a variable flow hydraulic pump/hydraulic motor arrangement continuously driven by an ac motor. The hydraulic motor and a large "fail safe" brake are mounted at opposite ends of the common driveshaft. Rate and direction of fluid flow to the hydraulic motor are controlled by electro-hydraulic servo valves. The servo valves control a cylinder which, in turn, controls the wobble plate (and the flow rate) of the hydraulic pump. Vertical position of the inner tube is sensed by redundant position indicators coupled to the common drive shaft. Chain tension is monitored directly with a torque arm/load cell arrangement and indirectly by the pressure drop across the hydraulic motor.

A grapple head at the lower end of the element handling mechanism performs the actual coupling of the machine to the core elements, as it is designed to engage the central handling hole of the elements with a tapered probe and latch arrangement (see Figure 2-4). The probe enters the hole with the latch pawls retracted until a spring-mounted floating plate contacts the top of the element and limit switches signal that the latch can be engaged. The pawls, which are spring-loaded to the engaged position, and retracted with an electrically driven ball screw, are then extended into engagement with a shoulder in the handling hole. Other limit switches verify that engagement (or retraction) has occurred.

Spring-loaded, self-centering alignment mechanisms incorporated into the grapple head are used to adjust the radial and azimuthal position of the grapple head. These mechanisms signal if misalignment side contact occurs between the probe and the side of the handling hole. This causes downward motion to cease and corrective horizontal movements to be automatically initiated. This procedure continues until the probe can enter without being deflected sideways (i.e., until true axial alignment is achieved). A similar centering mechanism is used to adjust the rotation of the grapple head to assure true rotational alignment. The final coordinates of the grapple are automatically recorded and used to predict the position of the next element to be handled.

A force sensing system in the grapple head is used to determine the weight of components suspended from the grapple. This system stops vertical movement if abnormal forces are encountered and also prevents operation of the grapple release mechanism if there is an element on the grapple. Provision is made for rotating the grapple and floating plate about the probe axis through a range of 1.75 rad (100 deg) on either side of zero orientation. The prime mover is a dc torque motor with a resolver transmitter coupled to its output shaft giving position feedback to the computer and also to a digital display.

The grapple head is suspended from the inner tube by a linkage system, shown in Figure 2-2, which produces a horizontal displacement of the head as it moves outward away from the center of the FHM operating one. The linkage is actuated by a dc torque motor-driven ball screw, referred to as the arm extension drive system. A multispeed resolver transmitter, a precision potentiometer and a spring-set electromagnetic brake all connected to the output shaft of the torque motor complete the arm extension drive system.

Azimuth rotation of the linkage and grapple assemblies about the center of the inner tube is also accomplished by a dc torque motor and multispeed resolver transmitter, precision potentiometer, gear reducer and electromagnetic brake arrangement. This is referred to as the theta drive system and is also computer controlled.

A closed circuit television camera and lights are mounted on the linkage structure for use in monitoring FHM operations and other in-vessel activities.

2.2.4 Fuel Transfer Cask Adapter

A FTC adapter shown in Figures 2-7 and 2-11 supports the FTC when it is loading or unloading elements at the reactor vessel. The adapter mates with the top of the RIV and the base of FTC to provide a sealed system during element transfers. The thick walls of the adapter provide the necessary shielding to protect operating personnel during the movement of spent fuel.

The height of the adapter is selected to place the FTC at a common elevation at both working positions (i.e., over the reactor vessel or at the spent fuel storage facility) to minimize the operating cycle for the FHEP.

Before the FTC adapter is installed, several setup operations must be completed. First, the second RIV is mounted over the inner neutron control

Figure 2-11 FUEL TRANSFER CASK ADAPTER

assembly which is located 180 deg opposite the sector to be refueled and the neutron control assembly is removed and transported to temporary storage with the ASC and transporter. After the neutron control assembly is deposited in storage, the ASC then picks up a FTC grapple guide sleeve (shown in Figure 2-2 and part of the refueling accessories described below in Section 2.2.8) and deposits the guide sleeve within the penetration.

The FTC adapter is now moved into position with the reactor building crane and secured to the FHES.

2.2.5 Fuel Transfer Cask

The FTC shown in Figures 2-3, 2-7, and 2-12 is similar to the cask developed for earlier HTGRs. Each of the two casks provided has a capacity of five full-sized elements and weighs approximately 70 tons. The FTCs are moved from place to place with the FHEP. An automated anchoring system is provided to clamp the FTC to the mating support structure before its closure valve is opened.

The element grapple within the FTC is suspended from redundant cables and moves vertically as the cable storage drum is rotated. Electrical cables routed over fixed pulleys and counterweights transmit power and instrument data between the moving grapple and the fixed cask structure. The grappling portion of the FTC grapple assembly is similar to the FHM grapple described earlier but has no built-in system to move the grapple horizontally to correct positioning errors. The task of aligning suspended blocks so that they may be properly stacked is accomplished with a set of three vertical members containing centering mechanisms. These vertical members establish contact with the block below the suspended element and force the two mating surfaces into proper alignment.

Vertical motion of the FTC grapple is accomplished by rotation of the cable storage drum. Both ends of the support shaft for the cable drum extend through the pressure boundary of the FTC and this drive system is

Figure 2-12 FUEL TRANSFER CASK

functionally similar to the FHM vertical drive system described earlier. A hydraulically powered motor is mounted on one end of the support shaft and a large "fail safe" brake is mounted on the opposite end.

Individual elements are grappled and lifted into the FTC where they are deposited on one of two translating tables built into the base of the FTC housing. When the grapple is released and retracted, the translating table is moved aside and the grapple is lowered out through the bottom of the cask to pick up the next element. Each translating table has space for two full-size elements and one more element can be transported while suspended from the grapple to provide the stated capacity of five elements.

All operations of the fuel transfer cask are controlled automatically from the fuel handling control station and are interlocked to prevent improper sequencing of the various mechanisms.

2.2.6 Fuel Handling Equipment Positioner

The Fuel Handling Equipment Positioner (FHEP) illustrated in Figures 2-7 and 2-13 is essentially a special purpose gantry crane used primarily to move the FTCs between their various operating points in a safe but highly efficient manner since this motion is on the critical path for the refueling outage. The FHEP is also used to move the FHM at various times in the refueling sequence but the frequency of this movement is much lower than the FTC movements.

Unlike most cranes, the FHEP has a very short vertical stroke. Therefore this motion is achieved with Acme screws rather than the more conventional cable configuration used in most cranes. The FHEP also provides for a powered rotation of the suspended load. This feature permits an automatic coupling of the FHEP to its load through a breech-lock type attachment built into the top of both the FTCs and the FHM.

Figure 2-13 FUEL HANDLING EQUIPMENT POSITIONER

Horizontal translation of the load in two coordinates with the FHEP is similar to that of a typical traveling bridge and trolley with several major differences. First, chain drives are used to assure predictable movement of the load for a given angular movement of the drive motors. Second, position readout devices are provided to permit controlled repetitive movements to specified spatial coordinates without visual adjustments at each cycle. Third, all of the FHEP movements are hydraulically powered to permit variable speed operations. Finally most of the FHEP movements will be controlled automatically by the fuel handling control station computers rather than manually.

The bridge structure of the FHEP is designed to clear the installed FHM or FTCs, the ASC in its transporter, and the building crane to permit the maximum flexibility in planning the many equipment movements needed to complete the refueling sequence.

2.2.7 Plug Actuator and Turntable Assembly

During core refueling, a Plug Actuator and Turntable Assembly (PATA) is installed over each of the two fuel storage pools immediately adjacent to the module being refueled. As illustrated in Figure 2-3, each storage well in a pool has a shielded closure plug at its upper end to provide biological shielding for personnel on the refueling floor. Elastomer seals on the bottom surface of the plug prevent mixing of the ambient air with the helium environment inside the well.

The PATA which is shown in Figure 2-14 performs several functions as listed below. First, the plug actuator provides a structural support for the FTC over any of the 36 wells within the pool. Second, expandable seals on the top and bottom of the plug actuator form a gastight boundary during element loading or unloading operations. Third, the actuator utilizes a remotely operated grapple and hoist mechanism to engage the closure plug and lift it up into the rotating gate of the plug actuator. Finally when the translating gate is repositioned and the FTC closure valve is opened, there is

Figure 2-14 PLUG ACTUATOR AND TURNTABLE ASSEMBLY

direct access into the well for the FTC grapple. At this point, insertion or withdrawal of elements may be initiated. Each well has a capacity of ten elements (i.e., two FTC loads).

The turntable has two drive mechanisms which are used to position the plug actuator over any selected storage well. One drive rotates the entire turntable while the second drive changes the radial position of the plug actuator within the turntable.

2.2.8 Refueling Accessories

The refueling accessories are a family of small special purpose tools, fixtures, etc. which may be required at some point in the core refueling operation. These include the special attachments, fasteners, and torque wrenches required to secure the portable core refueling equipment at the various operating positions. Other accessories help to align these attachments so that they interface properly with the portable equipment. A grapple guide sleeve is used to guide the FTC grapple within the vessel refueling penetration and upper plenum.

Another group of equipment is used to remove neutron control assemblies safely and with a minimum amount of air ingress to the primary coolant. The flexible hoses and cables used to provide services to the portable core refueling equipment are also part of the refueling accessories.

The final group of tools in the refueling accessories category are the manual tools provided to manipulate various internal mechanisms to an acceptable configuration for removal and remote servicing following postulated malfunctions of the normal drive system for these internal mechanisms.

2.2.9 Fuel Handling Control Station

The Fuel Handling Control Station (FHCS) (see Figure 2-15) is located above the personnel service building and is oriented to permit visual observation of operations on the refueling floor. The FHCS provides control and monitoring for the FHM and all other equipment required for core refueling operations. The FHCS also functions as a centralized control center providing supervision of site refueling operations, spent fuel cooling, and any core service operations.

The FHCS provides the primary control system for all fuel handling and core service activities. The system is controlled by either of two redundant on-line supervisory computers. In addition, each major component in the CRS has its own local programmable controller which is directed and monitored by the central supervisory computer. A redundant central computer and uninterruptible power supply are provided to assure that critical data on equipment status or element accountability is not lost in the event of a computer failure or loss of primary electrical power.

The FHCS also has a manual operation capability in which the command for a particular function is operator-initiated but the function itself is computer controlled. The FHCS design also provides independent protection logic which assures that faulty commands from the operator, the computer, or from computer failure, will not allow maloperation of the CRS equipment.

The FHCS also provides for the identification and location of all fuel and reflector elements at all times, including data recovery and preservation capability. All communications between the operator and the system that modify accountability or operating parameters are permanently recorded.

The FHCS has audio and video communications with all of the plant locations where fuel handling operations may occur and is physically situated to permit direct observation of all activities on the refueling floor.

Figure 2-15 FUEL HANDLING CONTROL STATION

Additional information regarding the fuel handling control station is provided in Section 2.5.

2.3 SUBSYSTEM PERFORMANCE CHARACTERISTICS

2.3.1 Subsystem Operating Modes

2.3.1.1 Startup/Shutdown

The core refueling subsystem only operates when a reactor module is shut down, and has no function during startup or shutdown.

2.3.1.2 Normal Operation

The core refueling subsystem only operates when a reactor module is shut down, and has no function during normal operation.

2.3.1.3 Refueling

Normal Operation Mode

The CRS is designed to remove and replace core elements automatically while reactor is shut down and depressurized. The reactor is prepared for automatic operation by the manual placement of the portable refueling equipment on top of the vessel and on top of the Spent Fuel Storage Facility (SFSF) wells.

The automatic operations include all element handling between the core and the SFSF wells. The automatic operations are monitored from the FHCS to ensure that all manipulations are proceeding as planned.

The control programs for automatic operation of the refueling equipment can be altered to make adjustments for changes in equipment configuration or

alignment. After the program changes are made, refueling can continue in the automatic mode.

Manual Operation Mode

In the event that the program for automatic refueling cannot be used, the refueling equipment can be controlled manually. A circumstance in which this might be required is when a penetration is misaligned with its refueling sector due to construction errors or creep as the plant ages. Also, broken elements must be handled manually, and if elements are found to be out of order, the reshuffling operation is manually controlled.

In such cases, the necessary tasks can be performed under operator control from the FHCS.

Because manual operation is slower than automatic, every effort is made to minimize its use.

Use of Special Tools

There is a set of special tools provided with the reactor service equipment subsystem which are used by the FHM to perform unscheduled in-vessel maintenance such as removing dropped elements, removing broken pieces of elements, removing broken control rods and other similar tasks. These are manual actions under the control of the FHCS operators. These special tools are installed in place of the FHM grapple at the lower end of the FHM handling mechanism.

Preparation for ISI of the Graphite Core Support Structure

The construction of the graphite core support structure includes provisions for periodic removal of the portions of the structure with the fuel handling machine. The removable components include individual core support

posts to permit the insertion of ISI equipment used for visual inspection of the surrounding posts and structures.

The geometry and physical size of the graphite core support components prevent their removal from the reactor vessel in the normal fashion with the fuel transfer cask and special temporary in-vessel fixtures are required for storage of the core support post and other components in the upper plenum during the ISI operation.

After the fuel handling machine has provided access for ISI and stored the post and other components in the upper plenum, the FHM is removed from the inner neutron control assembly penetration and replaced by the ISI equipment which inspects the surrounding support posts. After inspection is complete, the FHM is returned to the penetration, the support post and other components are reinserted, and the core is rebuilt to a functional configuration.

2.3.1.4 Shutdown

Core refueling and other operations such as ISI are performed only when the plant is shut down to the refueling mode as described above. The core refueling subsystem has no function during other shutdown modes.

2.3.2 Steady-State Performance

The steady-state performance of the CRS is set to meet the requirement of completing refueling in the specified period of time. Each piece of equipment moves at speeds which are determined so that they allow the coordinated completion of all necessary tasks as efficiently as possible and still stay within the allotted time. The time and motion studies are complicated by the fact that the equipment moves at different speeds at different parts of travel. The speed constraints are necessary to prevent equipment damage and assure smooth, reliable operation.

alignment. After the program changes are made, refueling can continue in the automatic mode.

Manual Operation Mode

In the event that the program for automatic refueling cannot be used, the refueling equipment can be controlled manually. A circumstance in which this might be required is when a penetration is misaligned with its refueling sector due to construction errors or creep as the plant ages. Also, broken elements must be handled manually, and if elements are found to be out of order, the reshuffling operation is manually controlled.

In such cases, the necessary tasks can be performed under operator control from the FHCS.

Because manual operation is slower than automatic, every effort is made to minimize its use.

Use of Special Tools

There is a set of special tools provided with the reactor service equipment subsystem which are used by the FHM to perform unscheduled in-vessel maintenance such as removing dropped elements, removing broken pieces of elements, removing broken control rods and other similar tasks. These are manual actions under the control of the FHCS operators. These special tools are installed in place of the FHM grapple at the lower end of the FHM handling mechanism.

Preparation for ISI of the Graphite Core Support Structure

The construction of the graphite core support structure includes provisions for periodic removal of the portions of the structure with the fuel handling machine. The removable components include individual core support

posts to permit the insertion of ISI equipment used for visual inspection of the surrounding posts and structures.

The geometry and physical size of the graphite core support components prevent their removal from the reactor vessel in the normal fashion with the fuel transfer cask and special temporary in-vessel fixtures are required for storage of the core support post and other components in the upper plenum during the ISI operation.

After the fuel handling machine has provided access for ISI and stored the post and other components in the upper plenum, the FHM is removed from the inner neutron control assembly penetration and replaced by the ISI equipment which inspects the surrounding support posts. After inspection is complete, the FHM is returned to the penetration, the support post and other components are reinserted, and the core is rebuilt to a functional configuration.

2.3.1.4 Shutdown

Core refueling and other operations such as ISI are performed only when the plant is shut down to the refueling mode as described above. The core refueling subsystem has no function during other shutdown modes.

2.3.2 Steady-State Performance

The steady-state performance of the CRS is set to meet the requirement of completing refueling in the specified period of time. Each piece of equipment moves at speeds which are determined so that they allow the coordinated completion of all necessary tasks as efficiently as possible and still stay within the allotted time. The time and motion studies are complicated by the fact that the equipment moves at different speeds at different parts of travel. The speed constraints are necessary to prevent equipment damage and assure smooth, reliable operation.

2.3.3 Plant Transients

The two types of transients which might have an impact on the CRS equipment are reductions in core cooling and moisture ingress.

Reductions in core cooling cause increased temperatures for all core refueling equipment in the reactor vessel. However, most of the portable equipment such as the FHM handling mechanism and the FTC grapple can be withdrawn from the main coolant stream until acceptable temperatures are reestablished. The only equipment which cannot easily be protected is the FTC grapple guide sleeve which is therefore designed to withstand all anticipated thermal transients. In very prolonged loss-of-cooling situations, the portable equipment can be removed from the reactor vessel.

Moisture ingress events cause problems of increased pressure and increased potential for oxidation (corrosion). The corrosion problem for portable equipment is not significant because they can be serviced outside the vessel.

The increase in pressure due to moisture ingress does cause unusually high loads on the pressure boundary of components attached to the reactor vessel. However, they are designed to withstand the highest credible loads from this event. The design of the operating equipment is such that it is unaffected by increased pressure.

2.3.4 Subsystem Failure Modes and Effects

Because the plant is in a shutdown and depressurized condition during refueling, credible CRS failures do not have a significant impact on other equipment.

Should one piece of the core refueling equipment fail, core refueling is normally interrupted while the defective component is replaced or repaired. Manual tooling and other design features are provided to assure that the

equipment can be removed from the reactor and the faulty component replaced or repaired without excessive delay.

The ability to recover quickly from postulated equipment failures or casualty events is an important feature of the core refueling equipment because the plant cannot be returned to an energy production state until core refueling has been completed.

The remote nature of most fuel handling operations creates additional motivation for design features that mitigate the effects of casualty events and well developed recovery procedures for these postulated events.

The following subsections identify some of the equipment failures or casualty events which may affect core refueling equipment and give general information on applicable mitigating features or recovery procedures which are provided.

Loss of Electrical Power

In general, the core refueling equipment is designed to fail "in place" upon a loss of electrical power.

Control System Malfunctions

The primary protection from control system malfunctions is provided through the use of independent protection sensors and logic which monitors the primary control sensors and logic and interrupts erroneous actions or commands. Diagnostic information regarding the cause of the interruption is provided to accelerate the recovery procedure.

Mechanism Malfunctions

Redundant features are provided to mitigate the effects of many mechanism malfunctions. The redundant features within an assembly are provided to

prevent damage to surrounding components and structures or are used to place the assembly in a configuration where removal for maintenance is possible. For example, most remotely operated drives have redundant position and/or load sensors such that a failure of one sensor will not permit unsafe operation of the equipment.

Most of the CRS components are not redundant even though they contain redundant features. Malfunctions in CRS components such as the FHM, FHEP, FHESS, PATA, and FTC adapter must be repaired before refueling can proceed. It is possible to continue refueling with a single fuel transfer cask in the event of a serious malfunction in the other FTC.

Stuck or Broken Elements

Stuck elements may occur as a result of excessive side loads from surrounding elements or from postulated coupling to the element below it in the core. Several mitigating features are provided to permit recovery from this event without causing a more serious casualty.

The first feature provided is a sensing system that monitors the actual force required to lift an element versus the expected weight of the element. Excessive force terminates the automatic handling sequence before the core array is disrupted or the element is damaged. At this point, the operator has several options:

1. The operator may override the interlock and use additional force to move the element.
2. The operator may remove adjacent elements to minimize the side loads and/or create clearance around the element.
3. With clearance around the element, the operator can apply limited side loads with the FHM grapple in an attempt to "rock" the element and dislodge it from the element below.

4. A final option is to exchange the FHM grapple with the core service manipulator, and any one of several tools which provide additional capability for either vertical or horizontal movements of the stuck element.

Damaged or misaligned elements are retrieved by the core service manipulator using various tools designed to upright tipped elements, to engage elements with damaged handling holes, or to retrieve fragments of broken elements.

2.4 SUBSYSTEM ARRANGEMENT

The equipment for refueling is located in the reactor core cavity and upper plenum, over the reactor vessel, over the SFSF, and on the refueling floor. The portable equipment which is placed in position for refueling is stored in the RSB where it is available for maintenance and checkout when not in use.

The arrangement of the core refueling equipment during refueling is shown in Figures 2-1, 2-2, 2-3, 2-7, and 2-9.

2.5 INSTRUMENTATION AND CONTROL

The CRS uses a distributed computer control system to control all refueling operations and to monitor related refueling activities. Refueling of a sector is normally accomplished in an "automatic" mode with minimum operator involvement after initiation of the cycle. The computer ensures that the machines are operated within acceptable limits and in a predetermined sequence.

The CRS controls consist of the following equipment:

1. One main fuel handling console.
2. Six local control panels.

3. Supervisory controllers.
4. Equipment controllers.
5. Protection logic.
6. Electrical components, process I/O devices, and surveillance equipment.

2.5.1 Control Stations

The main fuel handling console functions as a centralized control center which provides for the supervision of the core refueling process and most site fuel handling tasks. Both automatic and remote-manual functions are initiated and controlled from this console.

The automatic functions control the operation of the equipment needed to remove spent fuel from the reactor, move it to the fuel storage wells, move new fuel from the fuel storage wells to the reactor plenum, and to place the new fuel into its designated position within the reactor.

The main fuel handling console is equipped with the following features and capabilities:

1. Alarm annunciation for equipment malfunctions.
2. Video monitoring and optional video recording of core refueling operations.
3. Audio communication between the fuel handling console and the various operator work stations.
4. Hard copy for alarm messages, audit trail of all operator commands, control actions and data entries, etc.
5. Video displays for fuel and equipment status and alarms.

6. Controls for automatic refueling operations, remote manual refueling operation, video viewing and recording, alarm annunciation, data display, and data entry.

2.5.2 Distributed Control

Three types of distributed intelligence are used for the fuel handling controls:

1. Supervisory controllers.
2. Equipment controllers.
3. Protection logic.

One supervisory controller coordinates the main refueling console functions. It communicates with the equipment controllers, provides operator demand displays, alarm annunciation, and maintains fuel inventory accounting. A second supervisory controller provides redundant backup for the first supervisory controller. Both supervisory controllers communicate with each other.

Single loop programmable controllers operate each of the refueling mechanisms. For the automatic refueling functions, the equipment controllers communicate with each other as well as the supervisory controllers.

Figure 2-16 shows schematically how the operator communicates with each controller and the communication links between controllers.

Another set of programmable controllers provides the independent protection logic. These controllers monitor a set of signals from detectors which are independent of process control and cause operation of a mechanism to cease when malfunction conditions are detected. Information on each trip is communicated to the supervisory controller for alarm annunciation and display. Trips are reset by operator action after resolution of the cause of the problem.

Figure 2-16 REFUELING CONTROL SCHEME, COMMUNICATIONS

2.5.3 Specific Features of Instrumentation and Control

2.5.3.1 Reactor Isolation Valve

The RIV is controlled from local control stations on either the ASC or the FHM. Interlocks assure that the valve cannot be operated inadvertently. Limit switches are provided to indicate the valve gate position.

2.5.3.2 Fuel Handling Machine

Limit switches are used to determine when the fuel element latch attached to the end of the FHM grapple head can be engaged and when engagement or disengagement has been accomplished.

A spring-loaded, self-centering alignment mechanism is incorporated into the grapple head. This mechanism signals if misalignment side contact occurs between the probe and the side of the handling hole. This causes downward motion to cease and corrective horizontal movements to be automatically initiated. This procedure continues until the probe can enter without being deflected sideways (i.e., until true axial alignment is achieved). A similar centering mechanism is used to adjust the rotation of the grapple head to assure true rotational alignment. The final coordinates of the grapple are automatically recorded and used to predict the position of the next element to be handled.

A force sensing system in the grapple head is used to determine the weight of components suspended from the grapple. This system stops vertical movement if abnormal forces are encountered and also prevents operation of the grapple release mechanism if there is an element on the grapple.

Signals from the resolver transmitters on the linkage extension and linkage rotation drives are relayed to both FHM programmable controllers as primary position feedback. A potentiometer on each drive supplies a back-up

position feedback signal which is monitored by the programmable controller providing safety control.

A closed circuit television camera and lights are mounted on the linkage structure for use in monitoring FHM operations and other in-vessel activities.

2.5.3.3 Fuel Transfer Cask

Grapple elevation is determined from redundant instruments measuring shaft rotation. The weight supported by the grapple is measured by a load cell and torque arm arrangement plus pressure drop measurements across the hydraulic motor.

All operations are controlled automatically from the fuel handling control station and are interlocked to prevent improper sequencing of the various mechanisms.

2.5.3.4 Fuel Handling Equipment Positioner

Position readout devices are provided to permit repetitive movements of the positioner to specific spatial coordinates, automatically, and without manual adjustments at each cycle.

2.5.4 Electrical Components, Process I/O Devices, and Surveillance Equipment

Process I/O requirements are directly related to the specific sensors and electrical components involved in the operation of the equipment.

SECTION 3

COMPONENT FUNCTIONS AND DESIGN REQUIREMENTS

3.1 COMPONENT FUNCTIONS

3.1.1 Fuel Handling Machine (FHM)

The FHM transfers elements between the core and the upper plenum where the elements are picked up by the Fuel Transfer Cask. It also provides a leak-tight barrier and a radiation shield for personnel.

3.1.2 Fuel Transfer Cask (FTC)

The FTC takes elements from the upper plenum, transfers them to the storage wells, and places them onto the wells. It can also be used to move elements between the wells and the Fuel Service and Inspection Facility. Like the FHM, it provides a leak-tight barrier and a radiation shield for personnel.

3.1.3 Fuel Handling Equipment Positioner (FHEP)

The FHEP is used to move the FHM and FTC between storage and positions above the vessel and on the fuel storage wells and FSIF.

3.1.4 Reactor Isolation Valve (RIV)

The RIV seals the open neutron control assembly housing when there is not another piece of equipment mounted on the housing. The RIV prevents leakage of air or helium and provides radiation shielding for personnel.

3.1.5 Fuel Handling Equipment Support Structure (FHESS)

The FHESS supports the portable machines used in the refueling operations. It permits the loads to be carried by the building structure rather than the neutron control assembly housings.

3.1.6 Fuel Transfer Cask Adapter

The FTC adapter supports the FTC when the FTC is loading or unloading elements at the reactor. The FTC adapter thickness is chosen to minimize the time required to move the FTC by placing the top surface of the FTC anchor points at the same height as the refueling floor. This minimizes the vertical movements of the FTC.

3.1.7 Plug Actuator and Turntable Assembly (PATA)

The PATA mounts on the fuel storage wells and is used to remove and replace the storage well plugs. The PATA stores the plugs in the PATA body. The PATA supports the FTC when it is working at the storage wells and forms a leak-resistant boundary with the FTC and storage well.

3.1.8 Refueling Accessories

These small equipment items serve a number of positioning, alignment, and service functions for the portable refueling equipment.

3.1.9 Fuel Handling Control Station

All refueling activities, both automatic and manual, are directed, monitored and appropriate data recorded at the control station.

3.2 COMPONENT DESIGN REQUIREMENTS

3.2.1 Fuel Handling Machine

3.2.1.1 Component Configuration and Essential Features Requirements

The FHM shall have a maximum weight of [40] tons. (3413.0302.001)

3.2.1.2 Operational Requirements

The FHM shall be capable of handling a total of 2352 elements while replacing 560 in a single refueling. (3413.0302.002)

The FHM shall be capable of being moved from its storage position to any of its operating positions in less than [30] minutes, including anchoring operations. (3413.0302.003)

The FHM shall be capable of handling full and half-height hexagonal elements. Full height elements have these characteristics:

Weight: 154 kg (340 lb) maximum

Height: 0.75 m (3.2 in.) maximum

Maximum dimension over corners of hexagon:

0.42 m (16.4 in.) maximum (3413.0302.004)

The FHM shall be capable of extending its handling mechanism into the reactor vessel through the RIV and NCA housing in less than [5] min after the RIV is open. (3413.0302.005)

The FHM shall be designed to provide a lifting force of up to 2215 N (500 lb) at the discretion of the equipment operator for removal of "stuck" elements. (3413.0302.006)

3.2.1.3 Structural Requirements

The FHM shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.007)

3.2.1.4 Environmental Requirements

[Later]

3.2.1.5 Instrumentation and Control Requirements

The FHM shall have video equipment capable of reading the serial numbers on the elements remotely. (3413.0302.010)

The FHM shall have a local control panel mounted on it. (3413.0302.011)

3.2.1.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel handling machine since it is classified as not "safety-related." Refer to Section 3.2.1.8 for maintenance requirements.

3.2.1.7 Availability Assurance Requirements

[Later]

3.2.1.8 Maintenance Requirements

[Later]

3.2.1.9 Safety Requirements

[Later]

3.2.1.10 Codes and Standards Requirements

[Later]

3.2.1.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 02-1.3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.020)

3.2.1.12 Construction Requirements

The FHM arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.030)

3.2.1.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement or Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.040)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safe storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.041)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included. (3413.0302.042)

3.2.2 Fuel Transfer Cask

3.2.2.1 Component Configuration and Essential Features Requirements

The maximum weight of the FTC shall be [70] tons. (3413.0302.050)

The FTC shall have a remotely operated hoist and cable supported grapple for handling elements. (3413.0302.051)

An isolation valve shall be built into the FTC to help limit air ingress to the FTC or storage well when the FTC is mounted on a PATA. (3413.0302.052)

The FTC shall be capable of mounting on the access port of the FSIF. (3413.0302.053)

3.2.2.2 Operational Requirements

The FTC shall be capable of handling both full and half-height hexagonal elements. Full height elements have the following characteristics:

Weight: 154 kg (340 lb) maximum

Length: 0.79 m (31.2 in.) maximum

Maximum dimension over corners of hexagon:

0.42 m (16.4 in.) maximum (3413.0302.060)

The FTC shall have the capacity for five full height or nine half-height elements. (3413.0302.061)

The FTC shall be capable of being moved between any of its operating positions (including its storage position) within [10] minutes, including mounting and unmounting operations. (3413.0302.062)

The FTC hoist shall have sufficient vertical stroke to place an element at the lowest position in a fuel storage well; i.e., $\geq$ [38.6] ft. (3413.0302.063)

The FTC shall be capable of grappling and moving a single element between cask interior and bottom of storage well in less than [2.0] min, round trip. (3413.0302.064)

The FTC shall be capable of being moved from the FSIF to any storage well in less than [5.0] min, including mounting and unmounting. (3413.0302.065)

The FTC unload sequence at the storage well shall take $<$ [8.3] min. (3413.0302.066)

The FTC load sequence at the storage well shall take $<$ [8.0] min. (3413.0302.067)

3.2.2.3 Structural Requirements

The FTC shall be capable of absorbing vertical impact loads of up to 3.0 g during handling without suffering damage. (3413.0302.068)

3.2.2.4 Environmental Requirements

[Later]

3.2.2.5 Instrumentation and Control Requirements

The FTC shall have instrumentation capable of measuring the height and weight of elements being handled. (3413.0302.075)

The FTC shall have a local control panel mounted on it. (3413.0302.076)

3.2.2.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel transfer cask since it is classified as not "safety-related." Refer to Section 3.2.2.8 for maintenance requirements.

3.2.2.7 Availability Assurance Requirements

[Later]

3.2.2.8 Maintenance Requirements

[Later]

3.2.2.9 Safety Requirements

[Later]

3.2.2.10 Codes and Standards Requirements

Design, analysis, fabrication and construction of the FTC shall comply with applicable Codes of Federal Regulation and with Industry Codes and Standards that are needed to meet the Goals 1 and 2 of the Integrated Approach. All such applicable codes and standards shall be identified and documented in appropriate documentation during the design effort. Applicable state and local government regulations, codes and standards

shall be identified and documented subsequent to the time a specific site is identified. (3413.0302.085))

The 10CFR requirements listed in Table 1-2 have been adopted as CRS design requirements. Several of the 10CFR regulations apply in intent, requiring that modifications and interpretations of wording to relate to unique features of the HTGR may be made. Table 1-2 lists the 10CFR regulations that apply to the FHSS design, including comments on required modifications. (3413.0302.086)

The following industry codes and standards have been adopted as FTC design requirements:

1. ASME Section VIII, Division 1.
2. ANS - [TBD].
3. IEEE - [TBD]
4. ANSI-NM16.1, "Nuclear Criticality Safety Standard for Operations with Fissionable Materials Outside Reactors."
5. [TBD]. (3413.0302.087)

3.2.2.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.090)

3.2.2.12 Construction Requirements

The FTC arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.095)

3.2.2.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.100)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.101)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included.

(3413.0302.102)

3.2.3 Fuel Handling Equipment Positioner

3.2.3.1 Component Configuration and Essential Features Requirements

[Later]

3.2.3.2 Operational Requirements

The positioner shall be capable of moving the FHM between its storage position and any operating position within [30 min] including anchoring operations.

(3413.0302.110)

The positioner shall be capable:

1. Remotely engaging the top of the FHM in its storage or operating positions.
2. Lifting the FHM [1.0] ft and lowering it [4.0] ft below the refueling floor. (3413.0302.111)

The positioner shall be capable of moving the FTC from the FSIF to any storage well in less than [5.0] min, including mounting and unmounting. (3413.0302.112)

3.2.3.3 Structural Requirements

The FHEP shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.113)

3.2.3.4 Environmental Requirements

[Later]

3.2.3.5 Instrumentation and Control Requirements

[Later]

3.2.3.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel handling equipment positioner since it is classified as not "safety-related." Refer to Section 3.2.3.8 for maintenance requirements.

3.2.3.7 Availability Assurance Requirements

[Later]

3.2.3.8 Maintenance Requirements

[Later]

3.2.3.9 Safety Requirements

[Later]

3.2.3.10 Codes and Standards Requirements

[Later]

3.2.3.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.120)

3.2.3.12 Construction Requirements

The FHEP arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.125)

3.2.3.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.130)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.131)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included.

(3413.0302.132)

3.2.4 Reactor Isolation Valve

3.2.4.1 Component Configuration and Essential Features Requirements

Maximum weight of RIV is [10] tons.

(3413.0302.140)

The RIVs shall provide biological shielding to reduce the dose to plant operators from the reactor cavity to ≤ 100 man-rem/yr when no other equipment is mounted over or inside the neutron control assembly penetrations.

(3413.0302.141)

3.2.4.2 Operational Requirements

Maximum allowable leak rate into primary system when valve is open and FTC or ASC or FHM is in place is [0.2] ft³/h of air. The same allowable leak rate shall apply when valve is closed and no equipment is mounted on it.

(3413.0302.143)

RIV shall be capable of being moved from storage and placed into operation within [20 min]. (3413.0302.144)

Maximum valve closing or opening time shall be [2.0] min. (3413.0302.145)

The fraction of total allowable air ingress while removing and installing the RIVs shall be 15% of 860 standard ft³. (3413.0302.146)

3.2.4.3 Structural Requirements

The RIV shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.147)

3.2.4.4 Environmental Requirements

[Later]

3.2.4.5 Instrumentation and Control Requirements

[Later]

3.2.4.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the reactor isolation valve since it is classified as not "safety-related." Refer to Section 3.2.4.8 for maintenance requirements.

3.2.4.7 Availability Assurance Requirements

[Later]

3.2.4.8 Maintenance Requirements

[Later]

3.2.4.9 Safety Requirements

[Later]

3.2.4.10 Codes and Standards Requirements

[Later]

3.2.4.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.165)

3.2.4.12 Construction Requirements

The RIV arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.166)

3.2.4.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.167)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.168)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included.

(3413.0302.169)

3.2.5 Fuel Handling Equipment Support Structure

3.2.5.1 Component Configuration and Essential Features Requirements

The FHES shall be capable of being moved between its storage position and any of its operating positions in less than [20] min including mounting operations.

(3413.0302.180)

3.2.5.2 Operational Requirements

The FHES shall be capable of supporting [150] tons.

(3413.0302.181)

3.2.5.3 Structural Requirements

The FHES shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage.

(3413.0302.182)

The FHES shall provide support for the RIV, FHM, FTC adapter and the FTC.

(3413.0302.183)

3.2.5.4 Environmental Requirements

[Later]

3.2.5.5 Instrumentation and Control Requirements

[Later]

3.2.5.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel handling equipment support structure since it is classified as not "safety-related." Refer to Section 3.2.5.8 for maintenance requirements.

3.2.5.7 Availability Assurance Requirements

[Later]

3.2.5.8 Maintenance Requirements

[Later]

3.2.5.9 Safety Requirements

[Later]

3.2.5.10 Codes and Standards Requirements

[Later]

3.2.5.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic

requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.185)

3.2.5.12 Construction Requirements

The FHESS arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.186)

3.2.5.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.187)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.188)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included.

(3413.0302.189)

3.2.6 Fuel Transfer Cask Adapter

3.2.6.1 Component Configuration and Essential Features Requirements

The FTC adapter shall have a maximum weight of [17] tons.

(3413.0302.200)

3.2.6.2 Operational Requirements

The FTC adapter shall be capable of being moved between any of its operating positions (including storage) within [20] min, including mounting operations. (3413.0302.201)

3.2.6.3 Structural Requirements

The FTC adapter shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.202)

3.2.6.4 Environmental Requirements

[Later]

3.2.6.5 Instrumentation and Control Requirements

[Later]

3.2.6.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel transfer cask adapter since it is classified as not "safety-related." Refer to Section 3.2.6.8 for maintenance requirements.

3.2.6.7 Availability Assurance Requirements

[Later]

3.2.6.8 Maintenance Requirements

[Later]

3.2.6.9 Safety Requirements

[Later]

3.2.6.10 Codes and Standards Requirements

[Later]

3.2.6.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.210)

3.2.6.12 Construction Requirements

The FTC adapter arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.211)

3.2.6.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.212)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years

and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site. (3413.0302.213)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included. (3413.0302.214)

3.2.7 Plug Actuator and Turntable Assembly (PATA)

3.2.7.1 Component Configuration and Essential Features Requirements

The PATA shall be designed to be moved by the maintenance bay building crane. (3413.0302.220)

The PATA shall have a built-in isolation valve and seals to limit air ingress into the FTC or the storage well when the FTC is mounted on the PATA. (3413.0302.221)

The PATA shall be capable of removing/installing seal plugs in the storage wells automatically and remotely. (3413.0302.222)

3.2.7.2 Operational Requirements

The PATA shall remove the storage well plug and store it in the body of the PATA until it is reinserted into well. (3413.0302.223)

3.2.7.3 Structural Requirements

The PATA shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.224)

3.2.7.4 Environmental Requirements

[Later]

3.2.7.5 Instrumentation and Control Requirements

[Later]

3.2.7.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the plug actuator and turntable assembly since it is classified as not "safety-related." Refer to Section 3.2.7.8 for maintenance requirements.

3.2.7.7 Availability Assurance Requirements

[Later]

3.2.7.8 Maintenance Requirements

[Later]

3.2.7.9 Safety Requirements

[Later]

3.2.7.10 Codes and Standards Requirements

[Later]

3.2.7.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic

requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.230)

3.2.7.12 Construction Requirements

The PATA arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.231)

3.2.7.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.232)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.233)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included.

(3413.0302.234)

3.2.8 Refueling Accessories

3.2.8.1 Component Configuration and Essential Features Requirements

A grapple guide sleeve shall be used to guide the FTC grapple within the vessel refueling penetration and upper plenum.

(3413.0302.240)

3.2.8.2 Operational Requirements

The grapple guide sleeve to be capable of being installed into or removed from the vessel penetration in less than [20] min. (3413.0302.241)

3.2.8.3 Structural Requirements

The refueling accessories shall be capable of absorbing vertical impact loads during handling of up to 3.0 g without suffering damage. (3413.0302.242)

3.2.8.4 Environmental Requirements

[Later]

3.2.8.5 Instrumentation and Control Requirements

[Later]

3.2.8.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the refueling accessories since they are classified as not "safety-related." Refer to Section 3.2.8.8 for maintenance requirements.

3.2.8.7 Availability Assurance Requirements

[Later]

3.2.8.8 Maintenance Requirements

[Later]

3.2.8.9 Safety Requirements

[Later]

3.2.8.10 Codes and Standards Requirements

[Later]

3.2.8.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.250)

3.2.8.12 Construction Requirements

The refueling accessories arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.251)

3.2.8.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.252)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years

and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site. (3413.0302.253)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included. (3413.0302.254)

3.2.9 Fuel Handling Control Station

3.2.9.1 Component Configuration and Essential Features Requirements

The fuel handling control station shall be based on the use of microprocessor controllers. (3413.0302.260)

The FHCS shall have a "refueling control console." (3413.0302.261)

3.2.9.2 Operational Requirements

[Later]

3.2.9.3 Structural Requirements

[Later]

3.2.9.4 Environmental Requirements

[Later]

3.2.9.5 Instrumentation and Control Requirements

[Later]

3.2.9.6 Surveillance and In-Service Inspection Requirements

There are no surveillance and in-service inspection requirements for the fuel handling control station since it is classified as not "safety-related." Refer to Section 3.2.9.8 for maintenance requirements.

3.2.9.7 Availability Assurance Requirements

[Later]

3.2.9.8 Maintenance Requirements

[Later]

3.2.9.9 Safety Requirements

[Later]

3.2.9.10 Codes and Standards Requirements

[Later]

3.2.9.11 Quality Assurance Requirements

Structures, systems, and components that are not "safety-related" shall come under a Quality Assurance Program which complies with selected basic requirements and appropriate supplements of ANSI/ASME NQA-1 and the four additional supplements from DOE NE F2-10 regarding Management Assessment (NE 02-4.3.0), Engineering Holds (NE 03-1.3.2), Design Reviews (NE 03-1-3.4), and Engineering Drawing Lists (NE 03-1.3.5).

(3413.0302.265)

3.2.9.12 Construction Requirements

The FHCS arrangement and components design shall, to the extent allowed by the operational design requirements, facilitate the manufacture, installation, and required removals and replacements of the components.

(3413.0302.266)

3.2.9.13 Decommissioning Requirements

Until more specific criteria and/or rules are developed, NUREG-0586, "Draft Generic Environmental Statement on Decommissioning of Nuclear Facilities," January 1981, shall be used as guidance for the CRS design.

(3413.0302.267)

It shall be assumed that upon completion of its useful life, the facility shall be put into a condition of safety storage for a period of 10 years and then decontaminated and dismantled as required to allow unrestricted use or continued use as a power plant site.

(3413.0302.268)

Features that facilitate decommissioning or refurbishment of one reactor while maintaining others in operation shall be included. (3413.0302.269)

SECTION 4

SUBSYSTEM AND COMPONENT INTERFACE REQUIREMENTS

4.1 SUBSYSTEM INTERFACE REQUIREMENTS

4.1.1 Interface Design Requirements Imposed on Other Systems

Interface requirements, at the system level, are presented in tabular form in Table 4-1 for each system (subsystems are also identified for information) on which requirements are imposed. The tabulation includes a brief descriptive statement of the nature of the interface, interfacing component, and interface requirement. The interfacing systems are arranged in numerical order.

4.1.2 Interface Requirements Imposed on Subsystems Within the Fuel Handling Storage and Shipping System

Interface requirements, at the subsystem level, are presented in tabular form in Table 4-2 for the component within the Core Refueling Subsystem on which requirements are imposed.

4.2 COMPONENT BOUNDARY DEFINITION

[Later]

Table 4-1
CORE REFUELING INTERFACE REQUIREMENTS IMPOSED ON OTHER SYSTEMS

4.1.1 Identification of Interfaces Between Systems

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
4.1.1.1 Reactor System (1000)			
Neutron Control (1012)	Biological shielding	On refueling floor, etc. where refueling personnel work	The neutron control assemblies (and other equipment and structures) shall limit dose rates during refueling operations [TBD]. (3413.0401.001)
Reactor Internals (1017)	A refueling plenum for handling of elements above the core.	In-vessel refueling equipment operates in the plenum	The dimensions of the refueling plenum shall be: [TBD]. (3413.0401.001)
	Alignment and horizontal support for FHM outer telescoping tube	Upper plenum shroud	The upper plenum shroud shall provide six horizontal supports for FHM tube. Supports to have a diameter of [TBD • TBD]; maintain a true position within [TBD] and support a load of [TBD] in any horizontal direction. (3413.0401.003)
Reactor Core (1018)	Standard alignment and handling features of elements.	At point of contact between grapples and elements and elements and transporting equipment.	The handling holes will have dimensions of [TBD]. Alignment features will be [TBD]. (3413.0401.002)
	Standard weights and dimensions of elements.	At point of contact between grapples and elements and elements and transporting equipment.	Weights and dimensions of elements shall be as given in 1.2.2. (3413.0401.003)
	The element identification features for remote viewing.	At FHM viewing equipment in reactor upper plenum and at viewing/inspection equipment in FSIF.	The identification must be unique and have readability characteristics of [TBD]. (3413.0401.004)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
	Gap between elements.	FHM and elements.	The elements shall have a nominal 1.102 mm (0.040 in.) gap between them. (3413.0401.005)
4.1.1.2 Heat Transport System (2100)			
Main Circulator (2101) Steam Generator (2102)	Core gas temperatures during refueling.	Upper core plenum where gas impinges on refueling equip- ment.	The helium flow to and through core shall maintain the inlet temperature below 115.6°C (240°F). (3413.0401.040)
4.1.1.3 Shutdown Cooling System (5700)			
All four subsystems	Core gas temperatures during refueling.	Upper core plenum where gas impinges on refueling equipment.	The helium flow to and through core shall maintain the inlet temperatures below 115.6°C (240°F). (3413.0401.050)
4.1.1.4 Reactor Cavity Cooling System (5600)			
No interfaces identified at this time.			
4.1.1.5 Vessel System (1100)			
Vessel & Ducts (1106)	Structural support and alignment features.	Penetrations and refueling plenum where in-vessel refueling equipment is mounted and operated.	The neutron control assembly penetrations shall support [TBD] loads and shall assure alignment of equipment within tolerances of [TBD]. (3413.0401.010)
	Biological shielding	On refueling floor where refueling personnel work.	The vessel (and other equipment and structures) shall limit dose rates during refueling operations [TBD]. (3413.0401.011)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
4.1.1.6 <u>Plant Protection and Instrumentation System</u> (3200)			
Special Nuclear Instru- mentation (3203)	Electrical signals	Control cabinet	Neutron flux levels in the reactor core and undesirable trends shall be monitored, evaluated, and reported to the fuel handling control station. (3413.0401.047)
	Electrical signals	Control cabinet	The number and location of neutron control assemblies out of service during refueling shall be monitored and reported to the fuel handling control station. If more than four control rod drives or four reserve shutdown release mechanisms are out of service, this condition shall be alarmed at the fuel handling control station. (3413.0401.048)
4.1.1.7 <u>Fuel Handling and Storage System</u> (3400)			
See Section 4.1.2 for interface within this system.			
4.1.1.8 <u>Reactor Services Group</u> (2000)			
Reactor Service Equipment (2016)	Storage, service, and maintenance of equipment.	In reactor service building adjacent to reactor modules.	Storage space with dimensions of [TBD] shall be provided for storage, service, and maintenance of portable fuel handling equipment. (3413.0401.020)
	Remote handling of neutron control assemblies and FTC grapple guide sleeve.	At top head of reactor module.	The ASC and transporter assembly shall remove/install a guide sleeve or neutron control assembly in less than [TBD] minutes to facilitate refueling operations. (3413.0401.021)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
Helium Purification (2023)	Decontamination equipment, tools, and storage space.	In the reactor service building adjacent to the reactor building.	Storage space and service equipment [TBD] shall be provided for decontamination of portable fuel handling equipment mechanisms. (3413.0401.022)
	Removal of in-vessel neutron detector assembly prior to start of refueling operations.	In-vessel neutron detectors located in reflector elements. Access penetration in bottom head of reactor.	Service equipment [TBD] required for removal of detectors. (3413.0401.023)
	Atmosphere during refueling.	Connection of services system to the primary coolant system.	Subsystem shall be capable of maintaining the primary coolant slightly subatmospheric (pressure range - later) during refueling. The subsystem shall remove the helium released into the primary coolant system for cooling of television cameras, etc., during the refueling interval and compensate for changes in average temperatures of the primary coolant inventory. This requirement shall be satisfied during any of the transient evacuations listed in requirement numbers 3413.0401.032 and .033. (3413.0401.025)
Helium Storage and Transport (2024)	Distribution stations/connections.	See Table 4-6 for the location of the distribution stations/connections.	The subsystem shall provide evacuation services and purified helium service to distribution stations adjacent to each plant location where fuel handling or reactor service operations are anticipated. The final connections from the distribution station to the portable component will be accomplished with flexible metal hoses to be provided with the NSSS equipment. (3413.0401.029)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
		See Table 4-6 for the location of the distribution stations/connections.	Each service outlet at each distribution station shall be equipped with a manometer attachment for maintenance of vessel sub-atmospheric pressure, check valve to prevent reverse flow, a manually operated isolation valve, and a quick disconnect fitting compatible with the mating fitting on the flexible metal hose. (Note: hose sizes and fittings [TBD]). (3413.0401.030)
		See Table 4-6 for the location of the distribution stations/connections.	Each station shall be located within [30] ft of the specified location to permit operations with flexible hoses having a maximum length of [50] ft. (3413.0401.031)
		See Table 4-6 for the location of the distribution stations/connections.	The subsystem shall be capable of evacuating gaseous mixtures from the internal cavities of various fuel handling and reactor service equipment components within the time limits specified in Table 4-3. The initial pressure is assumed to be atmospheric and the final pressure shall be less than [TBD] mm Hg absolute. (3413.0401.032)
		See Table 4-6 for the location of the distribution stations/connections.	The subsystem shall be capable of evacuating gaseous mixtures from the interspaces between portable fuel handling and reactor service components within the time limits specified in Table 4-4. The initial pressure is assumed to be atmospheric and the final pressure shall be less than [TBD] mm Hg absolute. (3413.0401.033)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
	Purified helium service	See Table 4-6 for the location of the distribution stations/connections.	The subsystem shall provide purified helium at a pressure of [100] psig and a maximum temperature of 120°F for the application tabulated in Table 4-5. (3413.0401.034)
	Other services at the distribution stations.	See Table 4-6.	Subsystem shall provide electrical power and in some cases, control connections and/or audio communication with the fuel handling control station. Additional outlets for power, control, and communication cables shall be considered. (3413.0401.035)
4.1.1.9 <u>Power Conversion Group</u> (5000)			
No interfaces identified at this time.			
4.1.1.10 <u>Heat Rejection Group</u> (5200)			
No interfaces identified at this time.			
4.1.1.11 <u>Plant Control Data and Instrumentation System</u> (3700)			
No interfaces identified at this time.			
4.1.1.12 <u>Electrical Group</u> (9200)			
AC Distribution (9202)	Power to equipment.	Electrical connections to components.	The electrical system shall satisfy the following power requirements: (See Table 4-7). (3413.0401.071)
4.1.1.13 <u>Miscellaneous Control and Instrumentation Group</u> (3000)			
Radiation Monitoring (3003)	Radiation monitoring in work areas.	Refueling floor, FSIF, and fuel handling control station, fuel shipping and receiving areas.	Radiation monitoring of inhabited areas shall be provided during all fuel handling and storage operations. (3413.0401.045)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
4.1.1.14 <u>Mechanical Services Group</u> (9000)			
No interfaces identified at this time.			
4.1.1.15 <u>Buildings, Structures and Building Service Group</u> (7000)			
Reactor Building (7001)	Equipment support from refueling floor.	FHESS mounts.	Refueling floor must have capacity to support support FHESS and equipment to be mounted on it, [TBD] kg (TBD lb). (3413.0401.060)
	Removal/installation of floor hatches before/after refueling	Access to refueling penetrations for portable equipment.	Floor hatches to be removed/installed in less than [60] min using the reactor building crane. (3413.0401.061)
	Movement of FHESS.	Lifting features of FHESS and building crane hook.	Reactor building crane shall be capable of moving FHESS between its storage position and any operating position in $\leq$ [20] min. (3413.0401.062)
	Movement of RIV.	Lifting feature of RIV and building crane hook.	Reactor building crane shall be capable of moving the RIV between its storage position and any operating position in less than [20] min. (3413.0401.063)
	Support rails for fuel handling equipment positioner.	Refueling floor and building walls.	Rails to extend over all operating points for fuel handling equipment positioner. Reactor building to support refueling equipment weight of [TBD] plus the dynamic forces from a 0.3 g earthquake. (3413.0401.064)
	Movement of plug acuator and turntable assembly (PATA).	Lifting features of PATA and building crane hook.	Reactor building crane shall be capable of moving the PATA between its storage position and any operating position in less than [20] min. (3413.0401.065)

Table 4-1 (Continued)

Interfacing System (With Subsystem/ Identification)	Nature of Interface	Interfacing Component	Interface Requirements
Personnel Service Building (7009)	House fuel handling control station.	Physical support for con- trol equipment and routing for connecting cables.	Personnel service building shall house the FHCS and provide required ambient conditions and viewing of refueling floor. (3413.0401.070)

Table 4-2
CORE REFUELING INTERFACE REQUIREMENTS IMPOSED ON OTHER SUBSYSTEMS IN THE SYSTEM

4.1.2 Interface Requirements Imposed on Subsystems Within the Fuel Handling and Storage System

Interfacing Subsystems	Nature of Interface	Interfacing Component	Interface Requirement
4.1.2.1 <u>Core Refueling (3413)</u>			
	Not Applicable		
4.1.2.2 <u>Site Fuel Handling (3414)</u>			
	Administrative	None.	The SFHS shall assure that new fuel and reflector elements are physically intact and properly positioned in the fuel storage wells prior to refueling. (3413.0401.080)
4.1.2.3 <u>Spent Fuel Cooling (3487)</u>			
	Alignment & support	PATA assembly support points at perimeter of fuel storage well shield structure.	The SFCS shall align the PATA with any of the four groups of storage wells and support the combined weight of the PATA and the FTC during all transient conditions including seismic events. The design loads are [TBD]. (3413.0401.085)
	Removable access plugs to storage wells.	Lifting point on plug/plug grapple on PATA.	Each individual fuel storage well shall provide a removable access plug with the following features: [TBD] (3413.0401.086)
	Controlled atmosphere in storage wells.	Inflatable seal on PATA assembly/seal face around each storage well plug.	The SFCS shall provide seal faces, seals, leak-tight construction, etc., to maintain a helium environment within each storage well and permit the exchange of elements between the well and the FTC in a helium environment. (3413.0401.087)
	Guidance for FTC grapple.	FTC grapple/storage well inside diameter and vertical alignment key.	Movement of the FTC grapple within the storage well shall be controlled within [TBD] by the be controlled within [TBD] by the following features: [TBD]. (3413.0401.088)

Table 4-3 EVACUATION OF REFUELING AND REACTOR SERVICE EQUIPMENT

Equipment to be Evacuated	Internal Volume	Frequency of Evacuation
1. Fuel handling machine (FHM)	TBD	TBD
2. Fuel transfer cask (FTC)	TBD	TBD
3. Auxiliary service cask (ASC)	TBD	TBD
4. Main circulator cask	TBD	TBD
5. Shutdown circulator cask	TBD	TBD
6. Truck shipping cask	TBD	TBD
7. Rail shipping cask	TBD	TBD

Table 4-4 EVACUATION OF REFUELING AND REACTOR SERVICE EQUIPMENT INTERSPACES

Description of of Interspace	Volume of Interspace	Frequency of Evacuation
1. FHM to RIV	TBD	TBD
2. ASC to RIV	TBD	TBD
3. FTC to RIV	TBD	TBD
4. FTC to PATA	TBD	TBD
5. PATA to FSW	TBD	TBD
6. PATA and FSW*	TBD	TBD
7. Main circulator cask to isolation valve	TBD	TBD
8. Shutdown circulator cask to isolation valve	TBD	TBD
9. (Later)	TBD	TBD

Acronyms not specified earlier

*FSW - fuel storage well

Table 4-5 PURIFIED HELIUM REQUIREMENTS

Component Requiring Helium	Frequency of the Requirement	Volume Req'd Per Event, ft ³	Nominal Flow Rate lb/h	Comments on Application
1. <u>FHM</u>				
a. Viewing system cooling	TBD	TBD	TBD	TBD
b. Seals & interspaces	TBD	TBD	TBD	TBD
c. Backfill interior cavity	TBD	TBD	TBD	TBD
2. <u>FTC</u>				
a. Seals & interspaces	TBD	TBD	TBD	TBD
b. Backfill interior cavity	TBD	TBD	TBD	TBD
3. <u>ASC</u>				
a. Seals & interspaces	TBD	TBD	TBD	TBD
b. Backfill interior cavity	TBD	TBD	TBD	TBD
4. <u>PATA to FSW</u>				
a. Seals & interspaces	TBD	TBD	TBD	TBD
b. Backfill PATA & FSW	TBD	TBD	TBD	TBD
5. <u>Main Circulator Cask</u>				
a. Seals & Interspaces	TBD	TBD	TBD	TBD
b. Backfill interior cavity	TBD	TBD	TBD	TBD

Table 4-5 (Continued)

Comments	Component	Frequency of the Requirement	Nominal		
	Requiring Helium Application		Volume Req'd Per Event, ft ³	Flow Rate	on lb/h
6.	<u>Shutdown Circulator Cask</u>				
	a. Seals & interspaces	TBD	TBD	TBD	TBD
	b. Backfill interior cavity	TBD	TBD	TBD	TBD
7.	<u>Penetration Purge Before Opening</u>				
	a. Neutron control assembly penetrations	TBD	TBD	TBD	TBD
	b. Main circulator penetration	TBD	TBD	TBD	TBD
	c. Shutdown circulator penetration	TBD	TBD	TBD	TBD
8.	(Later)	TBD	TBD	TBD	TBD

Table 4-6
LOCATION OF DISTRIBUTION STATIONS

Number and Location	Purpose	Outlets Per Location by Type				
		Evacuation	Helium	Power	Control	Communication
4 max, on refueling floor near module access hatches	Provide services during refueling and neutron control assembly replace.	2	2	2	FHM and FTC	1
6 max, on refueling floor near fuel storage pools	Provide services to PATA and FTC during FSW loading and unloading	2	2	2	1 for FTC and PATA	1
3 max, on refueling floor near equip. storage wells, RESF and FSIF	Provide services to equip. at wells, RESF and FSIF	1	1	1	FHM and FTC	1
1, on operating level for RESF manipulators	Provide services to equip. in RESF when needed	1	1	1	--	2
1, on operating level for FSIF equip.	Provide services to equip. in FSIF when needed	1	1	1	--	2
1, below FSIF, RESF for shipping cask equip.	Provide services to fuel shipping equip.	1	1	1	--	1

Table 4-6 (Continued)

Number and Location	Purpose	Outlets Per Location by Type				
		Evacuation	Helium	Power	Control	Communication
1, in reactor service bldg. basement near shutdown circulator storage wells	Provide services to shutdown circulator service equip.	1	1	1	--	1
4, 1 per silo near main circulator	Provide services to main circulator service equip.	1	1	1	--	1
4, 1 per silo below reactor vessel	Provide services to shutdown circulator service equip., etc.	1	1	1	--	1

Table 4-7
ELECTRICAL LOAD LIST INTERFACE REQUIREMENTS

Interfacing System (with Subsystem Identification)	Nature of Interface	Electrical Load List Interface Requirement											
Electrical Group (9200)													
AC Distribution (9202)	Power to Equipment	<u>Core Refueling Subsystem</u>				Required							
		Comp.	No. Per 4 x 350 MW(t) Plant	Equip. Elect. Load	Volt. Req.	Operation(a)							
						C	I	S	N	Sh	R		
		FHM	1	70 HP	480 Vac	X						X	
		FHEP	1	80 HP	480 Vac	X	X	X	X	X	X	X	
		PATA	2	15 HP	480 Vac	X	X	X	X	X	X	X	
		RIV	2	1 kW	480 Vac	X						X	
		FTC	2	40 HP	480 Vac	X	X	X	X	X	X	X	
		Refuel. Access.	1 lot	1 kW	480 Vac	X						X	
		Cont. & Inst.	1 lot	10 kW	120 Vac	X	X	X	X	X	X	X	
		Not "Safety-Related"											

(a) "Required Operation" abbreviations:

C = continuous	N = normal
I = intermittent	Sh = shutdown
S = startup	R = refueling

SECTION 5
SUBSYSTEM CONSTRUCTION

[Later]

SECTION 6

SUBSYSTEM OPERATION

6.1 SUBSYSTEM LIMITATIONS, SET POINTS AND PRECAUTIONS

6.1.1 System Limitations and Set Points

6.1.1.1 Temperature Control

6.1.1.1.1 Spent Fuel

The temperature of spent fuel elements in transit from the reactor core to the spent fuel storage facility must be maintained at less than [TBD] to assure compliance with the maximum oxidation requirement of Section 1.2 in requirement 3413.0102.044.

6.1.1.1.2 Mechanisms

Temperature limits for the mechanisms in the core refueling equipment are difficult to establish. Past experience has shown that the television cameras used for remote viewing are the most sensitive components, followed by electromechanical components (i.e., motors, potentiometers, etc.) which generate heat internally as they are operated. Conventional lubricants are also thermally sensitive.

6.1.1.2 Operating Speeds

The operating speeds for the core refueling equipment affect plant availability and require detailed studies to optimize the operating times for each component. These studies of the core refueling operations have

shown that the estimated time to refuel a reactor module is controlled primarily by the following three factors:

- a. The operating speed for the fuel handling machine.
- b. The time to load or unload the fuel transfer casks.
- c. The time to move the FTCs between the reactor and the storage wells.

The selection of operating speeds for the core refueling equipment is, therefore, based on the following general criteria. First, the FHM and FTCs will be designed to operate as rapidly as possible within limits established by analysis and past operating experience. Improving the operating speed of the FHM and FTC results in the use of variable speed drive motors and "permissible speed profiles" in the control system. A "permissible speed profile" establishes maximum speed limits as a function of position and direction of movement. In effect, each drive is forced to move at a slow velocity in critical areas of its stroke while being permitted to move significantly faster in noncritical areas.

Secondly, the fuel handling equipment positioner was developed to provide an automated handling device for the FTCs. The positioner also uses variable speed drives and "permissible speed profiles" to provide the optimum combination of operating speed and conservative performance in critical areas.

Finally, the entire sequence for refueling a sector of the reactor is controlled and monitored by the computerized control system to minimize delays caused by operator indecision or error.

The "permissible speed profiles" for each variable speed drive in the CRS will be provided later when additional analysis and design definition is available.

6.1.1.3 Protective Interlocks

Protective interlocks are used extensively in the CRS to ensure that the equipment is being operated within specified limits and in the proper sequence. Some of the interlocks used are:

1. All hoist mechanisms and most counterweight systems incorporate load cells, with high and low limits designed to interrupt drive motion if abnormalities occur. When abnormalities occur, the operator must then determine its cause and take corrective action before continuing the initial motion.
2. Mechanisms which must interact with each other to ensure proper transfer of fuel between the core and the fuel storage wells are interlocked with limit switches and other position readout devices to ensure that motions occur in the proper sequence, or are prohibited under specific conditions.
3. All grapple mechanisms are interlocked to prevent release of the grapple mechanism if the grapple is supporting any weight from the component to which it is engaged.

6.1.1.4 Setpoints

[Later]

6.1.2 Precautions

6.1.2.1 Radiation Exposure Control

6.1.2.1.1 Shielding

The CRS and the interfacing structures are designed to permit all required fuel movements within heavily shielded equipment. In addition, heavily

shielded casks and isolation valves are provided for the removal of potentially contaminated and/or activated components from penetrations in the top head of the reactor vessel.

As a result, plant operators and maintenance personnel should receive minimal dose rates from most refueling activities. The exceptions which may require special precautions are as follows:

1. During removal and replacement of neutron control assemblies, a limited amount of direct contact is required to disconnect service lines, retract control rods, etc. before the item is drawn into its handling cask. This activity must be carefully monitored to assure that unanticipated contamination has not occurred and that no operator receives excessive exposure while performing this task.
2. The maintenance and checkout of fuel handling equipment which has been in direct contact with core components must be carefully monitored to ensure that excessive contamination has not occurred, thereby precluding direct maintenance.
3. Certain types of equipment malfunctions may require unusual operator activity to overcome the malfunction and complete the designated handling procedure. These unusual activities must be carefully planned and monitored to ensure that no operator receives excessive exposure while performing a special repair procedure.

6.1.2.1.2 Control of Contaminants

6.1.2.1.2.1 Contamination Sources

A small fraction of the fuel particle coatings are expected to fail during their lifetime, thereby releasing fission products into the primary coolant

or the surrounding atmosphere of the storage facility. The fission products may either remain in the atmosphere or be dispersed as plateout on the graphite structures of the core elements or other surfaces within the primary coolant circuit.

Impurities within the circulating helium coolant may become activated while passing through the reactor core to form another source of circulating contamination.

Finally, impurities within the graphite structures and the metallic components that are inserted into the reactor (i.e., control rods, in-reactor flux monitors, etc.) will all become activated to varying degrees, and corrosion or erosion of these structures can spread contaminated dust throughout the primary coolant loop.

The helium purification system functions to reduce the level of circulating contamination but is not able to eliminate all of the potential sources. To minimize the release of radioactivity during refueling, potentially contaminated helium is evacuated from portable casks and the interspaces between the casks. This ensures that the potential contamination is not released to the atmosphere as the casks are used to transfer components from the reactor vessel to storage, or vice versa.

6.1.2.2 Reactivity Control Within the Core

Core refueling requires the removal of some of the neutron control assemblies with their control rods, to provide access for the FHM and FTC. The refueling sequence must be carefully planned and monitored to assure that too many control rods are not removed at the same time. In addition, the sequence must ensure that no more than two outer and two inner rods are out of the core at any one time.

6.2 PREOPERATIONAL CHECKOUT AND PLANNING

6.2.1 Planning the Refueling Sequence

Detailed planning for the refueling sequence is a significant operating procedure which has a major impact on the efficiency of core refueling. The refueling sequence is selected based on the following considerations:

[Later]

The detailed planning provides a step-by-step sequence of major machine movements for the entire sequence, including the storage locations for components to be installed in or removed from the reactor.

When the sequence for visiting sectors has been completed, the detailed sequence for removing and storing each element within each sector is developed. Similar sequences deal with the movements of new elements from the storage wells to the core. The latter sequence provides the basis for loading new elements at specific locations in the storage wells.

6.2.2 Preparation of Operating Instructions

Automatic control of the core refueling sequence within a refueling sector requires the preparation of operating instructions data for each sector. The instructions are similar for similar types of sectors, but must be updated to reflect the serial number and storage coordinates of each element involved and vary if reflectors are being replaced, etc.

The actual loading of new fuel and reflector elements into fuel storage wells is a site fuel handling operation.

6.2.3 Equipment Maintenance and Checkout

All core refueling equipment receives preventive maintenance and an operational checkout prior to refueling. Equipment normally installed in the reactor vessel for refueling is checked out at the reactor equipment service facility. Detailed operating procedures are provided for the operational checkouts to ensure that all significant machine functions are demonstrated in a safe and efficient manner.

6.3 INSTALLATION OF EQUIPMENT, AND OTHER OPERATIONS

[Later]

6.4 NORMAL CORE REFUELING OPERATIONS

After the preparatory operations, the operations and procedures for actually moving spent elements from the core sectors to the fuel storage wells and moving fresh elements from the storage wells into the reactor and placing them in position are carried out as described in this subsection.

The CRS utilizes a FHCS incorporating a computer to control all critical fuel handling operations and monitor related refueling activities. The refueling of a sector is normally accomplished in an "automatic" mode with minimum operator involvement after initiation of the refueling cycle. The control station ensures that the machines are operated within acceptable limits and in a predetermined sequence.

The handling mechanism and grapple assembly of the FHM operating under the control of the FHCS is lowered into the reactor vessel and set to the predetermined position of the element to be removed. The mechanism is slowly lowered until the tip of the probe on the grapple enters the handling hole in the selected element. As the probe enters the hole, it may be laterally deflected as the result of some initial misalignment, in which case an error signal is generated and used to automatically correct

the head position. Downward travel of the mechanism is arrested above the top of the fuel element until correct alignment is achieved. The head then proceeds downward until stopped by the "grapple inserted" limit switch. A second switch system with substantial overtravel, independent of the primary switch system, provides a redundant indication of grapple position. When signals from limit switches indicate the grapple to be engaged, the element is lifted into the upper plenum and deposited in the FTC grapple guide sleeve. The FTC grapple raises the element into the FTC. After the FTC is loaded to capacity, it is taken to the fuel storage wells by the fuel handling equipment positioner. The FTC is mounted on the plug actuator and turntable assembly (PATA) which opens the well and permits the FTC contents to be placed in the well.

Each refueling region is entirely emptied of spent element before the replacement is initiated. The loading of element into the core region is accomplished by the reverse process, with new elements being picked up by the FTC at the fuel storage well where they are stored.

When the region has been refueled, the handling mechanism of the FHM, the FTC grapple, and its guide tube are retracted, the RIVs closed, the inter-spaces evacuated and backfilled with air, and the service lines disconnected. The positioner is used to remove the FHM and FTC to a storage location while the next sector is prepared for refueling.

6.5 REFUELING

Operation of the CRS during refueling is described in Subsection 6.4.

6.6 SHUTDOWN

The operation of the CRS during shutdown is described in Subsection 6.4.

6.7 ABNORMAL OPERATION

No abnormal operations other than those described under Subsection 6.8 have been identified.

6.8 CASUALTY EVENTS AND RECOVERY PROCEDURES

The ability to recover quickly from postulated casualty events is an important feature of the core refueling equipment because the plant cannot be returned to an energy production state until core refueling has been completed.

The remote nature of most fuel handling operations creates additional motivation for design features that mitigate the effects of casualty events and well developed recovery procedures for these postulated events.

The following subsections identify some of the casualty events which may affect equipment in the CRS and give general information on applicable mitigating features or recovery procedures which are provided.

6.8.1 Casualty Events

The following types of casualty events are postulated for the design of the CRS:

1. Loss of electrical power.
2. Loss of cooling.
3. Control system malfunctions.
4. Mechanism malfunctions.
5. Stuck or broken elements.

6.8.2 Design Features to Mitigate the Effects of Casualty Events

6.8.2.1 Loss of Electrical Power

In general, the fuel handling equipment is designed to fail "in place" upon a loss of electrical power.

6.8.2.2 Loss of Cooling

Mitigating design features for loss of cooling casualty events include provisions for redundant cooling system components and/or alternate storage locations with adequate cooling capability.

The combination of low heat generation rates, high specific heat capacity in the element and its surroundings, and the ability of the element to survive at high temperatures provides ample time to take corrective action (i.e., activate a redundant cooling system or move elements to an alternate location).

Also, the CRS equipment can be protected from loss of cooling by moving it to cooler positions in the vessel or removing it from the vessel entirely.

6.8.2.3 Control System Malfunctions

The primary protection from control system malfunctions is provided through the use of independent protection sensors and control logic which monitors the primary control sensors and logic and interrupts erroneous actions or commands. Diagnostic information regarding the cause of the interruption is provided to accelerate the recovery procedure.

6.8.2.4 Mechanism Malfunctions

Redundant components are provided to mitigate the effects of most mechanism malfunctions. The redundant components within an assembly are provided to

prevent damage to surrounding components and structures or are used to place the assembly in a configuration where removal for maintenance is possible.

Not all mechanisms are redundant. Malfunctions in the single items such as the FHM, FTC, positioner, FHESS, PATA, ASC and transporter, and FTC adapter must be repaired before refueling can proceed.

6.8.2.5 Stuck or Broken Elements

Stuck elements may occur as a result of excessive side loads from surrounding elements or from postulated coupling to the element below it in the core. Several mitigating features are provided to permit recovery from this event without causing a more serious casualty.

The first feature provided is a weight-sensing system that monitors the actual force required to lift an element versus the expected weight of the element. Excessive force terminates the automatic handling sequence before the core array is disrupted or the element is damaged. At this point, the operator has several options:

1. The operator may override the interlock and use additional force to move the element.
2. The operator may remove adjacent elements to minimize the side loads and/or create clearance around the element.
3. With clearance around the element, the operator can apply limited side loads with the FHM grapple in an attempt to "rock" the element and dislodge it from the element below.
4. A final option is to exchange the FHM grapple with the core service manipulator, and any one of several tools which provide

additional capability for either vertical or horizontal movements of the stuck element.

The core service manipulator is also used to retrieve damaged or misaligned elements through various tools designed to upright tipped elements, to engage elements with damaged handling holes, or to retrieve fragments of broken elements.

6.8.3 Recovery Procedures

[Later]

SECTION 7
SUBSYSTEM MAINTENANCE

[Later]

SECTION 8
SUBSYSTEM COMMISSIONING

[Later]

SECTION 9
REFERENCES

1. "Overall Plant Design Specification Modular High-Temperature Gas-Cooled Reactor," HFS-20100, Rev. 4; HTGR-86-004, Rev. 4, (GA Document 908397/4), May 1987.
2. "MHTGR Plant Design Basis Transient Analysis," HTGR-86-121, Rev. 1, (GA Document 908754, Rev. 1), April 1987.
3. "FY 86 Seismic Assessment (Bechtel National Inc.)," HTGR-86-119, Rev. 0, September 1986.
4. "Reliability Allocations for the Standard MHTGR," HTGR-87-008, Rev. 0, (GA Document 909279/0) February 1987.

APPENDIX A
TRACEABILITY OF REQUIREMENTS

Table A-1 TECHNICAL REQUIREMENTS TRACEABILITY SUMMARY

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
1. CONFIGURATION AND ESSENTIAL FEATURES			
3413.0102.001	Low enriched fuel	1	3.2.1.1
3413.0102.002	Remove and return to service one reactor	1	3.2.1.1
3413.0102.003	Refuel through top head	1	3.2.1.1
3413.0102.004	Refuel six core sectors sequentially	1	3.2.1.1
3413.0102.005	Handle Neutron Control Assemblies	1	3.2.1.1
3413.0102.006	Handling with portable machines	1	3.2.1.1
3413.0102.007	Use two fuel transfer casks	1	3.2.1.1
3413.0102.008	Use reactor isolation valves	1	3.2.1.1
3413.0102.009	Use flexible seal on isolation valve	1	3.2.1.1
3413.0102.010	Reactor isolation valves interface with either FHM or auxiliary service cask	1	3.2.1.1
3413.0102.011	Use FTC adapter to interface RIV and FTC	1	3.2.1.1
3413.0102.012	FHESS shall support the RIV, FHM, FTC adapter and FTC	1	3.2.1.1
3413.0102.013	The ASCT shall be used to handle the FTC grapple guide sleeve	1	3.2.1.1
3413.0102.014	The FTC and FHM shall be moved by the FHEP	1	3.2.1.1
3413.0102.015	Move everything with the reactor building crane except the FHM, FTC and FTC grapple	1	3.2.1.1
3413.0102.016	Move machines without endangering reactor modules	1	3.2.1.1
3413.0102.017	Two clusters of 36 storage wells	1	3.2.1.1

A-2

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0102.018	Provide shielded closure plug and helium environment	1	3.2.1.1
3413.0102.019	The CRS shall use two plug actuator and turntable assemblies for access to wells	1	3.2.1.1
3413.0102.020	PATA shall be supported by storage structure or refueling floor	1	3.2.1.1
3413.0102.021	FTC shall mount on the PATA	1	3.2.1.1
3413.0102.022	CRS shall provide biological shielding	1	3.2.1.1
3413.0102.023	CRS shall be used to position in-core devices	1	3.2.1.1
	2. OPERATIONAL REQUIREMENTS		
3413.0102.030	Replace one-half of fuel and one-third reflectors each refueling	1	3.2.1.2
3413.0102.031	Minimum intervals between refueling	1	3.2.1.2
3413.0102.032	Refueling with reactor shutdown maintain inert atmosphere	1	3.2.1.2
3413.0102.033	Weight and size limits	1	3.2.1.2
3413.0102.034	Remote measurement to determine abnormalities	1	3.2.1.2
3413.0102.035	Element accountability	1	3.2.1.2
3413.0102.036	Ensure no critical arrays	1	3.2.1.2
3413.0102.037	Refuel one sector at a time	1	3.2.1.2
3413.0102.038	One pair of outer control rods is inserted at all times	1	3.2.1.2
3413.0102.039	FTC load to be all one type	1	3.2.1.2
3413.0102.040	Reused elements returned to same location	1	3.2.1.2

A-3

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0102.041	Reusable elements left in core	1	3.2.1.2
3413.0102.042	CRS capable of handling all core elements	1	3.2.1.2
3413.0102.043	FHM capable of moving either of two outer neutron control assemblies	1	3.2.1.2
3413.0102.044	Graphite oxidation rate limit	1	3.2.1.2
3413.0102.045	Restriction on oxidation rate of spent fuel	1	3.2.1.2
3413.0102.046	Restriction on air inleakage to primary coolant	1	3.2.1.2
3. STRUCTURAL REQUIREMENTS			
3413.0102.051	Design to applicable PV or piping code	1	3.2.1.3
3413.0102.052	Account for thermal stress	1	3.2.1.3
3413.0102.053	Vertical impact load	1	3.2.1.3
3413.0102.054	0.1 g seismic loads	1	3.2.1.3
3413.0102.055	0.3 g seismic loads	1	3.2.1.3
3413.0102.056	Effect of elevation on seismic response	1	3.2.1.3
3413.0102.057	Effect of horizontal and vertical seismic loads	1	3.2.1.3
4. ENVIRONMENTAL REQUIREMENTS			
3413.0102.062	Satisfy operating requirements at specified plant site	1	3.2.1.4
3413.0102.065	Capable of refueling under plant characteristics and parameters	1	3.2.1.4
3413.0102.066	Include overpressure transients	1	3.2.1.4

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0102.067	Include vacuum in pressure transients	1	3.2.1.4
3413.0102.068	Include thermal transients	1	3.2.1.4
3413.0102.069	Helium purity and its effects	1	3.2.1.4
3413.0102.070	Radiation exposure	1	3.2.1.4
3413.0102.070	Effects of storage in air with high humidity	1	3.2.1.4
5. INSTRUMENTATION			
3413.0102.080	Provide Fuel Handling Control Station	1	3.2.1.5
3413.0102.081	Include interlocks, diagnostics, redundancy	1	3.2.1.5
3413.0102.082	Include human engineering techniques	1	3.2.1.5
3413.0102.083	Include process control circuitry	1	3.2.1.5
3413.0102.084	Remote or manual operation	1	3.2.1.5
3413.0102.085	Automatic sequence of operations	1	3.2.1.5
3413.0102.086	Variable speed capability	1	3.2.1.5
3413.0102.087	Sense equipment loads	1	3.2.1.5
3413.0102.088	Element accountability with redundancy	1	3.2.1.5
3413.0102.089	FHCS shall log operation data	1	3.2.1.5
3413.0102.090	FHCS shall automatically detect and record sequence of events	1	3.2.1.5
3413.0102.091	Provide audio and video communications	1	3.2.1.5

A-5

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
6. AVAILABILITY REQUIREMENTS			
3413.0102.101	Time to perform refueling	1	3.2.1.7
3413.0102.102	Planned refueling outage conditions	1	3.2.1.7
3413.0102.103	Consider design modifications and improvements	1	3.2.1.7
7. MAINTENANCE REQUIREMENTS			
3413.0102.104	Provide for planned and unscheduled maintenance	1	3.2.1.8
3413.0102.105	Design for ease of maintenance	1	3.2.1.8
3413.0102.106	Design for planned maintenance	1	3.2.1.8
3413.0102.109	Document spare parts	1	3.2.1.8
3413.0102.110	Specify off-the-shelf components and materials	1	3.2.1.8
3413.0102.111	Provide reasonable interchangeability	1	3.2.1.8
3413.0102.112	Design for installation, maintenance, test, removal and replacement	1	3.2.1.8
3413.0102.113	Remote maintenance	1	3.2.1.8
3413.0102.114	Design life	1	3.2.1.8
8. SAFETY REQUIREMENTS			
3413.0102.130	Radioactivity associated with CRS	1	3.2.1.9
3413.0102.131	Personnel access	1	3.2.1.9
3413.0102.132	Radiation induced inaccessible areas	1	3.2.1.9

A-6

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0102.133	Biological shielding	1	3.2.1.9
3413.0102.140	Decay heat rate basis	1	3.2.1.9
3413.0102.142	Personnel hazard	1	3.2.1.9
3413.0102.143	Personnel access consideration	1	3.2.1.9
9. CODES AND STANDARDS REQUIREMENTS			
3413.0102.150	Codes to design and build	1	3.2.1.10
3413.0102.151	10CFR requirements	1	3.2.1.10
3413.0102.152	Adopted codes and standards	1	3.2.1.10
10. QUALITY ASSURANCE REQUIREMENTS			
3413.0102.155	Requirements for non "safety-related" items	1	3.2.1.11
11. CONSTRUCTION REQUIREMENTS			
3413.0102.157	Design for ease of building	1	3.2.1.12
12. DECOMMISSIONING REQUIREMENTS			
3413.0102.160	Use NUREG-0586	1	3.2.1.13
3413.0102.161	Disposal after end of useful life	1	3.2.1.13
3413.0102.162	Decommission/refurbish of one reactor at a time	1	3.2.1.13

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
1. FUEL HANDLING MACHINE			
3413.0302.001	FHM weight	[TBD]	
3413.0302.002	Number of elements handled during refueling	2	1.2.2
3413.0302.003	Movement of FHM time allocation	2	2.2
3413.0302.004	Element weight	2	1.2.2
3413.0302.005	Time to extend handling mechanism	[TBD]	
3413.0302.006	Lifting force capability of mechanism	[TBD]	
3413.0302.007	Absorb vertical impact loads	2	1.2.3
3413.0302.010	Provide video capability	2	1.2.5
3413.0302.011	Provide local control panel	2	1.2.5
3413.0302.020	Quality assurance requirement	2	1.2.11
3413.0302.030	Construction requirements	2	1.2.12
3413.0302.040	Decommissioning per NUREG-0586	2	1.2.13
3413.0302.041	Storage after useful life	2	1.2.13
3413.0302.042	Decommission one module at a time	2	1.2.13
2. FUEL TRANSFER CASK			
3413.0302.050	FTC weight	[TBD]	
3413.0302.051	Remove operation	2	1.2.1
3413.0302.052	Limit air ingress	2	1.2.2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0302.053	Mount on FSIF port	2	2.2
3413.0302.060	Element characteristics	2	1.2.2
3413.0302.061	Five element capacity	2	1.2.1
3413.0302.062	Movement time	[TBD]	
3413.0302.063	Stroke required	2	1.2.1
3413.0302.064	Time to remove an element from a well	[TBD]	
3413.0302.065	Time to move FTC	[TBD]	
3413.0302.066	Unloading time	[TBD]	
3413.0302.067	Loading time	[TBD]	
3413.0302.068	Absorb vertical impact loads	2	1.2.3
3413.0302.075	Instrumentation	2	1.2.1
3413.0302.076	Provide local control panel	2	1.2.5
3413.0302.085	Codes and standards	2	1.2.10
3413.0302.086	Design per 10CFR regulations	2	1.2.10
3413.0302.087	Industrial codes	2	1.2.10
3413.0302.090	Quality assurance	2	1.2.11
3413.0302.095	Construction requirements	2	1.2.12
3413.0302.100	Decommission per NUREG-0586	2	1.2.13
3413.0302.101	Storage after useful life	2	1.2.13
3413.0302.102	Decommission one module at a time	2	1.2.13

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3. FUEL HANDLING EQUIPMENT POSITIONER			
3413.0302.110	Movement time transporting FHM	[TBD]	
3413.0302.111	Capability	2	2.2
3413.0302.112	Movement time transporting FTC	[TBD]	
3413.0302.113	Absorb vertical impact loads	2	1.2.3
3413.0302.120	Quality assurance	2	1.2.11
3413.0302.125	Construction requirements	2	1.2.12
3413.0302.130	Decommission per NUREG-0586	2	1.2.13
3413.0302.131	Storage after useful life	2	1.2.13
3413.0302.132	Decommission one module at a time	2	1.2.13
4. REACTOR ISOLATION VALVE			
3413.0302.140	Weight	[TBD]	
3413.0302.141	Provide biological shielding	2	1.2.1
3413.0302.143	Maximum air ingress	2	1.2.2
3413.0302.144	Movement time	[TBD]	
3413.0302.145	Valve open/close time	[TBD]	
3413.0302.146	Air ingress allocation	2	1.2.2
3413.0302.147	Absorb vertical impact loads	2	1.2.3
3413.0302.165	Quality assurance	2	1.2.11

A-10

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0302.166	Construction requirements	2	1.2.12
3413.0302.167	Decommission per NUREG-0586	2	1.2.13
3413.0302.168	Storage after useful life	2	1.2.13
3413.0302.169	Decommission one module at a time	2	1.2.13
5. FUEL HANDLING EQUIPMENT SUPPORT STRUCTURE			
3413.0302.180	Time to move FHESS	[TBD]	
3413.0302.181	Support load	[TBD]	
3413.0302.182	Absorb vertical impact loads	2	1.2.3
3413.0302.183	Support RIV, FHM, FTC and FTC adapter	2	1.2.1
3413.0302.185	Quality assurance	2	1.2.11
3413.0302.186	Construction requirements	2	1.2.12
3413.0302.187	Decommission per NUREG-0586	2	1.2.13
3413.0302.188	Storage after useful life	2	1.2.13
3413.0302.189	Decommission one module at a time	2	1.2.13
6. FUEL TRANSFER CASK ADAPTER			
3413.0302.200	Weight	[TBD]	
3413.0302.201	Time to move FTC adapter	[TBD]	
3413.0302.202	Absorb vertical impact loads	2	1.2.3

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
3413.0302.210	Quality assurance	2	1.2.11
3413.0302.211	Construction requirements	2	1.2.12
3413.0302.212	Decommission per NUREG-0586	2	1.2.13
3413.0302.213	Storage after useful life	2	1.2.13
3413.0302.214	Decommission one module at a time	2	1.2.13
7. PLUG ACTUATOR AND TURNTABLE ASSEMBLY			
3413.0302.220	Move with maintenance bay crane	2	1.2.1
3413.0302.221	Provide built-in isolation valve	2	1.2.1
3413.0302.222	Remove and replace storage well plug	2	1.2.1
3413.0302.223	Store storage well plug	2	1.2.1
3413.0302.224	Absorb vertical impact loads	2	1.2.3
3413.0302.230	Quality assurance	2	1.2.11
3413.0302.231	Construction requirements	2	1.2.12
3413.0302.232	Decommission per NUREG-0586	2	1.2.13
3413.0302.233	Storage after useful life	2	1.2.13
3413.0302.234	Decommission one module at a time	2	1.2.13

A-12

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-1 (Continued)

Traceability Number	Summary Requirement Description	Source Description/Reference	
		Reference	Section
8. REFUELING ACCESSORIES			
3413.0302.240	Provide grapple guide sleeve for FTC	2	2.2.8
3413.0302.241	Grapple guide sleeve installation time	[TBD]	
3413.0302.242	Absorb vertical impact loads	2	1.2.3
3413.0302.250	Quality assurance	2	1.2.11
3413.0302.251	Construction requirements	2	1.2.12
3413.0302.252	Decommission per NUREG-0586	2	1.2.13
3413.0302.253	Storage after useful life	2	1.2.13
3413.0302.254	Decommission one module at a time	2	1.2.13
9. FUEL HANDLING CONTROL STATION			
3413.0302.260	Provide microprocessor controllers	2	2.2.9
3413.0302.261	Provide a refueling control console	2	2.2.9
3413.0302.265	Quality assurance	2	1.2.11
3413.0302.266	Construction requirements	2	1.2.12
3413.0302.267	Decommission per NUREG-0586	2	1.2.13
3413.0302.268	Storage after use life	2	1.2.13
3413.0302.269	Decommission one module at a time	2	1.2.13

A-13

DOE-HTGR-86-097/Rev. 1

908500/2

Table A-2
TRACEABILITY SUMMARY REFERENCE LIST

1. "Fuel Handling and Storage System Design Description," HFD-33400, Rev. 2; HTGR-86-098, Rev. 1; GA Document 908445, Rev. 2; July 1987.
2. "Core Refueling Subsystem Design Description," HFD-43413, Rev. 2; HTGR-86-097, Rev. 1; GA Document 908500, Rev. 2; July 1987.

APPENDIX B
DRAWING LIST

<u>Drawing Number</u>	<u>Title</u>
GA 030047	Fuel Handling Machine Layout
GA 028875	Fuel Handling Equipment Positioner
GA 028980	Core Refueling Equipment Interface
GA 028981	Fuel Handling Plenum Clearance
GA 028988	Plug Actuator and Turntable Assy.
GA 029056	Plug Actuator Layout
GA 030039	Fuel Transfer Cask Layout

APPENDIX C
TRANSIENTS

Transient results for each MHTGR event are presented in a standard set of figures in Ref. 2, "MHTGR Plant Design Transient Analysis." The transient curves applicable to the core refueling subsystem have not been developed and will be provided later.

APPENDIX D
DESIGN BASIS SEISMIC INPUTS

Design basis seismic inputs are obtained from a standard set of figures in Ref. 3, "FY86 Seismic Assessment (Bechtel National Inc.)." The curves applicable to the Core Refueling Subsystem have not been developed and will be provided later.

APPENDIX E
EQUIPMENT LIST

Equipment Number(a)	Core Refueling	
H 1301	Fuel handling machine	1
H 1302 A/B	Reactor isolation valve	2
H 1303 A/B	Fuel transfer cask	2
H 1304	Fuel transfer cask adapter	1
H 1305	Fuel handling support structure	1
H 1306 A/B	Plug actuator turntable assy.	2
H 1307	Fuel handling equip. positioner	1
H 1308	Refueling accessories	1 lot
H 1309	Fuel handling control station	1
Z 1300	Instr/hardware/software	1 lot

(a) Equipment number designation is temporary until a numbering format is established for the MHTGR program.

APPENDIX F
PARAMETER LISTS

F1 Site Parameters (later)

APPENDIX G
PROPRIETARY CLAIMS

There is no proprietary information in this document.