FAST FLUX TEST FACILITY

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PACIFIC NORTHWEST LABORATORY
RICHLAND, WASHINGTON
operated by
BATTelle MEMORIAL INSTITUTE
for the
UNITED STATES ATOMIC ENERGY COMMISSION UNDER CONTRACT AT(45-1)-1830
FAST FLUX TEST FACILITY
OVERALL CONCEPTUAL SYSTEMS
DESIGN DESCRIPTION

JULY 7, 1967

PACIFIC NORTHWEST LABORATORY
Richland, Washington 99352
Operated by
Battelle Memorial Institute
for the
U. S. Atomic Energy Commission under Contract No. AT(45-1)-1830
Replace pages iii, iv, v, 1-1, 1-2, 1-3, 1-4, 1-5, 1-6, 1-7, 3-1, 3-3, 3-4, 3-13, 3-15, 3-17, 3-18, 3-19, 3-20, 3-21, 3-24, 3-28, 3-29, 3-30, 3-33, 3-37, 3-38, 3-39, 4-5, 4-6, A-2, and A-3 with the attached and place this sheet in the front of the subject document as a document change log.
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OVERALL CONCEPTUAL SYSTEMS DESIGN DESCRIPTION

PREFACE

The Overall Conceptual Systems Design Description (CSDD) for the Fast Flux Test Facility (FFTF) presented in this document is the first CSDD. Its purpose is to set forth the overall design philosophy for the reactor plant. As such, the Overall CSDD provides the starting point for conceptual design with the intent that all aspects of the design effort begin and proceed from a common base. The Overall CSDD describes the FFTF in terms of the systems that comprise it. Subsequent system design descriptions will furnish details of the individual systems.
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OVERALL CONCEPTUAL SYSTEMS DESIGN DESCRIPTION

SECTION 1.0 INTRODUCTION

1.1 FUNCTION

The Fast Flux Test Facility (FFTF) is a coordinated facility for investigation into the behavior of fuels and structural materials subjected to high, fast neutron flux prototypic of fast reactor environments. The primary function of the FFTF is to provide reliable closed-loop testing under closely controlled and instrumented environmental conditions. An important secondary function is to provide open test positions exposed to the primary coolant. The FFTF is to provide not only fuels and materials irradiation needs, but also experience in the design, fabrication, testing, and operation of sodium components and systems and fuel handling. In achieving these objectives, the FFTF is to be responsive to all U.S. requirements for fast flux testing, of which the LMFBR Program constitutes a major portion. Thus, functional requirements for the plant include provisions to meet programmatic needs for a wide spectrum of testing.

Additional functional objectives for the FFTF are:
- Capabilities to test fuel and structural materials up to and including failure in dynamic sodium
- Interim nondestructive fuel examination capability
- Means to test fuel for short time periods
- Reliable plant performance (high and predictable plant factors)
- Safe plant performance.

Consistent with a systems approach to the management and design of the FFTF, the facility is functionally subdivided into reactor and plant systems. Each system is identified with a single major function and the integrated systems then provide the broader functional capabilities given above.
1.2 SUMMARY DESCRIPTION

Comprising the FFTF are a number of basic, functional subdivisions housed in appropriate structures and consisting of the Fast Test Reactor (FTR), associated heat removal circuits, fuel handling equipment, and a variety of test and examination facilities.

The systems in this section are necessarily tentative at this time but they do represent a logical functional division of the overall facility. As the conceptual design proceeds and interfaces between systems are brought into sharper focus, the need for further subdivision, additions and modifications will become apparent. In general, the guiding philosophy will be to identify a system as an operating entity providing a single major function. The operation of each system will be described eventually in the "Plant Operating Manual."

1.2.1 Utility Systems

Systems under this grouping provide the essential services and functions necessary for the operating plant. Included are radioactive contamination control and pressure containment to retain released radioactive materials and gases in the event of an accidental release of fission products. Utility systems are categorized as follows:

- Primary Electrical Power
- Building Electrical Power
- Service Piping
- Heating and Ventilating
- Plant Fire Protection
- Reactor Containment
- Radioactive Waste
1.2.2 Reactor Systems

The principal component of the facility is the Fast Test Reactor that provides the fast neutron environment in which fuels and materials testing is accomplished. The fast neutrons are generated primarily by driver fuel which provides the critical mass and reactivity requirements for the reactor. Heat is removed from the reactor core by circulation of liquid sodium coolant through the reactor and associated heat exchangers. Since the primary mission of the reactor is reliable, fast flux testing, utilization of the heat energy is not an objective and the by-product heat may be rejected without power recovery. Coolant temperature conditions are of importance as they affect tests within the core. Systems that comprise the reactor proper are:

- Reactor Nuclear Control
- Reactor Safety
- Reactor Heat Transport
- Sodium Receiving and Processing
- Inert Gas Receiving and Processing.

1.2.3 Irradiation Test Systems and Facilities

Reliable closed-loop testing under closely controlled and instrumented environmental conditions is a primary objective. A closed loop is an isolated circuit which permits precise control over experimental parameters such as flow, temperature, purity, and pressure. Included in the closed loop circuit is an in-core test section exposed to a known, predictable neutron flux. A short-term irradiation system provides the means for short-term irradiation and retrieval of test specimens during operation. Irradiation testing functions are supplied by the following systems:
1.2.4 Component Handling Systems

Fuel handling constitutes one of the major plant features, since the method for inserting and removing fuel tests, driver fuel and core components strongly influence reactor design and other interfaced plant systems. Decay heat removal and preservation of test data are the overriding considerations in this operation. In addition, replacement of reactor core components and maintenance are essential. Component handling is provided by the following systems:

DDCN-1
- Reactor Refueling
- Radioactive Maintenance.

1.2.5 Examination Systems and Facilities

Maximum utility of the FFTF is achieved by closely coupled, irradiated fuels and materials examination facilities. Interim and postirradiation examination capabilities for a broad range of fast reactor fuels and materials are thus available with a minimum delay following discharge from the reactor. The system providing for the treatment of cooling and shielding liquid is called:

- Liquid Treatment System for Underliquid Examination.
Facilities within this grouping are the Inert Gas Cell Examination Facility, the Underliquid Cell Examination Facility, and a Radiometallurgy Facility.

1.2.6 Unified Instrument and Control Systems

Control and instrumentation are essential to operate the FFTF. In addition, these same functions are equally significant to assure and monitor the environmental
requirements for fuels and materials tests. The complex of instrument, control, and data logging devices necessary to perform these functions is unified to obtain maximum coordination between operating and experimental objectives. The following systems are included:

- Control and Data Handling
- Reactor Channel and Vessel Instrumentation
- Plant Instrumentation
- Fuel Failure Monitoring
- Flux Monitoring and Control
- Radiation Monitoring.

1.2.7 Facilities

In order to complete the summary description of the FFTF complex, some of the more important facilities that are not part of the above groupings are listed herein.

A. FFTF Structure - The FFTF structure is comprised of shelter space for offices, shops, and plant equipment. Work areas and convenient storage areas for fuel, materials, and maintenance items are also provided. Accessibility to various areas of the structure is controlled depending upon existent radiation levels.

B. Nuclear Proof Test Facility - This facility provides zero power critical measurements on nuclear simulations of the FFTF reactor and experimental assemblies. It consists of a nuclear simulation of the FFTF core, a mock-up cell, fuel storage vault, control room, an assembly work room, and necessary supporting equipment.

C. Reactor Core Mockup Facility - A core mockup facility provides closely coupled support of the FFTF reactor to assure high plant availability at startup and during subsequent operation. It will permit a broad scope of proof-of-principle testing related to core component
fitup, maintenance procedures, emergency procedures, and proof testing of experimental installations in nonradioactive environments.

1.3 DESIGN REQUIREMENTS

The broad objectives and requirements for the Fast Flux Test Facility included in this document reflect future program needs as nearly as they can be determined at this time. It should be pointed out that provision exists for changes in requirements if at any time these requirements prove to be impractical, undesirable, or too costly. Thus, studies to be completed during the conceptual design phase of the project may result in the modification or deletion of certain of these design requirements.*

To provide the functions listed in 1.1, the following design requirements are to be incorporated in the overall facility:

A. Instrumented, closed loops, up to 6 in. diam for a 3 to 4 ft core; and about four to eight in number.

B. Closed loops accessible and removable external to the reactor.

C. Adequate provision for closed-loop coolant control instrumentation and monitoring equipment, including all equipment for controlling and/or monitoring the test specimen, capsule, rod, or subassembly.

D. Instrumented in-core open test positions, about six in number.

E. Adequate provision for open test positions instrumentation and control equipment.

F. Accessibility from reactor exterior to disconnect and connect open test position instrumentation.

* Refer to Appendix A, Studies G-1 through G-7
G. A minimum of two reactor primary system loops, two secondary loops, and two heat sinks, designed to permit continued plant operation with one loop in a nonoperating status.

H. Short term irradiation facilities.

I. Provisions to meet programmatic needs for planned programs other than the LMFBR Program.

J. Facilities for interim fuel examination including disassembly, reinstrumentation, and reassembly of specimens, capsules, or rods.

K. Plant availability target of 75%.

Systems and components will utilize existing technology wherever possible. Development efforts aimed at providing small incremental improvements are to be avoided even if the development requirements appear minimal. The success of the FFTF should not be placed in jeopardy by being made dependent on the successful completion of development efforts when already proven systems and components are available and would suffice. However, development efforts considered necessary for the FFTF should take into consideration and contribute to the similar needs of the LMFBR Program.

Finally, the design requirements for the Fast Flux Test Facility should provide for the following operating capabilities:

1. An integrated peak flux of $10^{16}$ n/cm$^2$-sec, 75% above 0.1 MeV.

2. Specific power equivalent to 500 to 2000 or more W/gm plutonium.

3. Reactor core outlet sodium temperature capable of operating from 800 to 1200 °F.

4. Sodium impurity control capable of maintaining impurities to below the concentrations required to protect the
stainless steel, refractories, superalloys, or other cladding and structural materials. These impurities include oxygen, carbon, nitrogen, and hydrogen.

The overall FFTF design will incorporate features to provide for a broad surveillance program to assure continued high integrity of systems and components. Included are visual inspection, measurements such as corrosion and unit motion, and sampling techniques.

Each of these requirements and capabilities are further expanded upon as they apply to specific systems design philosophy in subsequent sections of the Overall CSDD.
2.1 HAZARDS

Hazards that are normally associated with a large fast reactor facility can result from casualty conditions in one or more of the reactor systems or from operational errors. In the case of the FFTF, the probability of hazardous conditions arising may be considered somewhat greater because of its fuel testing mission. The principal hazards are loss of adequate cooling resulting in fuel melting, uncontrolled reactivity insertion, and breach of the containment. Of course, all three may be related to a degree, depending upon the details of a given accident. In addition to nuclear hazards, the possibility of violent sodium chemical reactions also exists.

Emergency conditions can occur which may result from one or more of the following:

A. Sudden accidental loss of normal electrical power to the plant or critical systems.
B. Radioactivity release forcing temporary abandonment of facilities or control stations.
C. A fire of such magnitude as to force temporary abandonment of facilities or control stations.
D. Earthquake of such magnitude as to disrupt plant processes.

2.2 PHILOSOPHY AND CRITERIA

The safety philosophy to be followed in the overall design of the FFTF includes general design safety criteria which apply to the entire FFTF, including experimental facilities, fuel handling, storage and examination facilities, and proof test facilities. Criteria applying to primary and secondary sodium systems apply to the respective portions of the closed loops as well as the main heat removal system.
2.2.1 Current Technology

The facility will be designed and constructed in accordance with demonstrated current technology to the maximum extent consistent with the testing objectives. Necessary extrapolations beyond current technology will be developed and demonstrated.

2.2.2 General Design Standards

The design, construction, and testing will conform to the following codes, as applicable:

- ASME Boiler and Pressure Vessel Code, Section III
- ASME Boiler and Pressure Vessel Code, Section VIII
- ASA Code for Pressure Piping, B-31.1
- Uniform Building Code.

Applicability of the above codes to specific plant components will be determined in studies to be carried out during the conceptual design. Applicability of and compliance with the Walsh-Healey Act as an extension of the Uniform Building Code will also be investigated.

The codes listed above represent the minimum requirements and may be supplemented as necessary for the unique FFTF application. In particular, additional requirements may be specified for the following:

A. Chemistry, heat treatment, and physical properties of alloys, including stainless steels, used in primary and secondary sodium service.

B. Welding procedures and qualifications for primary and secondary sodium systems and containment or confinement systems. Inspection and qualification may extend to sources of material for critical components and systems.

C. Vibration of all reactor heat removal systems, piping, and components.

D. Nil-ductility transition temperatures of ferritic steels used in containment or confinement systems.
E. Irradiation damage to reactor structural materials.
F. Resistance of the facility to damage from earthquakes and other natural phenomena.

2.2.3 Radioactivity Control and Containment

The facility will be housed in a building designed and equipped to meet the following requirements:

A. Limit the release of radionuclides to a level which will result in compliance with the AEC site criteria, 10 CFR 100 for:
   - The FFTF design basis accident
   - The most severe radioactive sodium fire
   - The most severe accident involving irradiated fuel
   - The Nuclear Proof Test Facility design basis accident.

Protection against damage, including that which could be caused by missiles generated in an accident, temperatures, and pressures which could prevent meeting this criterion, will be provided.

B. Control radioactivity release in accordance with AECM-0524 for normal plant operation and accidents or mishaps which can be reasonably anticipated or which can be caused by a single fault.

C. Provide shielding to reduce personnel radiation exposures to levels consistent with AECM-0524.

D. Provide containment or confinement isolation upon fission product release.

E. The reactor control room will be designed for occupancy and performance of necessary monitoring (including monitoring of the radioactivity release from the system) and control functions following a design basis accident. Instrumentation and alarms will be provided to indicate the reactivity and temperature status of the reactor and radioactivity, temperature, and pressure in the building. Instrumentation to determine radioisotope content within containment will also be provided.
The design basis accident will be determined for the FTR and the NPTF, and will correspond to the maximum energy release from the initial core or an anticipated future core in an excursion initiated by any potential reactivity insertion mechanism and terminated by an inherent shutdown mechanism.

2.2.4 Power Reactivity Coefficient

The reactor core will be designed to provide an overall negative power coefficient of reactivity.

2.2.5 Independence from Closed-Loop Operation

The facility will be designed to accommodate failure of any singled closed-loop fuel assembly without affecting adjacent tests and without material damage to the reactor. Meltdown within the loop is the worst consequence of failure and although loops will be designed for recovery from this eventuality, they are not intended to accommodate meltdown testing.

2.2.6 Simultaneous Occurrences

The facility will be designed so that:

A. No combination of two simultaneous, independent faults or abnormal conditions will result in uncontrolled or excessive release of radioactivity from the facility (i.e., any such accident is to be less severe than the design basis accident).

B. No single fault will result in rupture of sound fuel cladding, loss of cooling, or loss of protective systems.

2.2.7 Plant Protection

Plant Protection will be provided as follows:

A. At least two independent protective sensing systems, if possible, acting on different principles, will initiate immediate automatic protection upon existence of a
condition which would lead to fuel meltdown or uncontrolled reactivity insertion.

- Each such sensing system will have redundant, independent input channels.
- Each such sensing system will be fail-safe, or will incorporate appropriate self-checking features.

B. At least one protective sensing system will initiate automatic protection upon the occurrence of gross fuel failure, loss of cooling, loss of protective systems, or breach of containment; and upon existence of a condition which would lead to any of these.

- Redundancy of channels will be established by the designer to provide adequate reliability in consideration of potential damage and risk of unnecessary protection.
- Each such sensing system will be fail-safe, or will incorporate appropriate self-checking features.

C. Alarms and annunciators will be provided to indicate process conditions which potentially could lead to damage to the reactor, and to indicate important conditions associated with a reactor scram.

D. All protective systems (i.e., sensing, logic, trip, and scram shutdown) will be designed so as not to be disabled by the faults or conditions against which they are intended to protect.

E. Interlocks will be provided to prevent operation of the reactor, fuel handling systems and access control systems without required protective systems in service.

F. Status of key components and process variables, including reactivity control system, will be indicated in the control room.

2.2.8 Decay Heat Removal

Natural convection cooling, or at least two independent heat removal mechanisms, will be able to remove decay
heat without fuel clad failure. Draining, pumping, or siphoning of sodium from the reactor so as to prevent core heat removal will be prevented in case of any sodium pipe rupture. Provision will be made for fuel cooling in event of sticking in the reactor or in fuel handling or examination facilities.

2.2.9 Shutdown Safety

The safety system will provide adequate capability of reactor shutdown with the strongest safety element in its most reactive position under any projected operating condition and experimental loading. Safety element drive mechanisms will be driven in following the initial scram signal.

2.2.10 Maximum Controlled Reactivity Insertion

The maximum deliberate rate of reactivity insertion in the reactor will be limited by equipment capability such that the power excursion due to continued reactivity insertion at that rate would be terminated by protective action to prevent fuel clad failure.

2.2.11 Maximum Reactivity Insertion

The maximum amount and rate of reactivity insertion resulting from a single fault will be limited to values such that the resulting power excursion will be terminated:

A. By the first-line protective action without failure of sound fuel cladding and without local or bulk boiling of sodium.

B. By another protective action, assuming failure of the primary system, without fuel clad melting.

2.2.12 Single Element Worth

Single control and/or safety element reactivity worths will be designed to criteria 2.2.9-2.2.11.
2.2.13 **System Stability**

Stability and feedback mechanisms of the reactor, heat removal system, and control system will be analyzed to demonstrate the ability of the plant to operate without damaging transients or oscillations under normal conditions and upon occurrence of a single fault or malfunction.

2.2.14 **Chemical Reactions**

Provisions will be made to limit the possibilities and consequences of sodium fires and sodium-water reactions. Primary sodium systems will be enclosed in spaces capable of being inert-gas blanketed.

2.2.15 **Sodium Monitoring and Purity**

Provisions will be made to limit chemical contamination of sodium, and for monitoring and controlling impurities and contaminants. No hydrogenous or organic material will be used adjacent to the primary sodium system in such a way that a failure could contaminate the sodium.

2.2.16 **Fission Product Release Rate**

The plant will be designed to accommodate release of fission products from driver fuel and closed-loop test elements to the design limits of the system which will be established so as not to preclude the eventual use of vented fuel.

2.2.17 **Burnout Margin**

The maximum sodium temperature and maximum core heat flux during normal operation will be limited so as to provide a high degree of assurance that sodium boiling and boiling burnout cannot occur prior to activation of the protective system in operation of the reactor. (Exceptions may be made for special closed-loop tests.)
2.2.18 Criticality Safety
Fuel handling, examination, and storage facilities will be designed to be safe from criticality, with consideration for the possibility of fuel positioning errors and accidents, introduction of moderating materials, and loss of cooling leading to fuel melting.

2.2.19 Protective System Monitoring
Provisions will be incorporated for periodic testing of the protective systems and the containment system, and for surveillance of the primary and secondary sodium systems.

2.2.20 Instrumentation
Adequate instrumentation will be incorporated to provide:
A. Continual monitoring of the neutron flux and reactivity status of the reactor with fuel in the reactor vessel.
B. Continual monitoring of the test and reactor control variables such that adequate operating margins are maintained.
C. Continual monitoring of essential reactor and process variables during containment including overpressure.

2.2.21 Emergency Electrical Power
An independent source of electrical power will be available in case of loss of the normal electrical power sources to provide power for:
A. Critical instrumentation control and monitoring.
B. Containment or confinement operation.
C. Decay heat removal from the reactor.
D. Any other system or component essential to emergency operation.
2.2.22 Piping

Piping services critical to the safe operation and protection of the plant shall be designed for redundancy, incorporating such features as provision for feed from more than one circuit, bypass and isolation valves to permit continued supply in event of casualty in one part of the system and independent backup such as bottled gas for pneumatic functions and instruments.
SECTION 3.0 DETAILED DESCRIPTION OF FACILITY

The FFTF is comprised of six, broad functional subdivisions and these in turn are further subdivided into component systems. Each component system will be formally described in the Conceptual System Design Descriptions to be completed concurrently with the conceptual design.* The system objectives, requirements, and guiding design criteria and philosophy are presented in this section.

3.1 UTILITY SYSTEMS

3.1.1 Electrical Systems

A. Objectives

The objectives of the Electrical Systems are:

1. To provide the total electrical energy requirements of the plant.
2. To provide adequate lighting levels to match each working area need.
3. To provide inter and intra-communications throughout the plant and site that will assure a high degree of coordination and communication between various locations, alert the personnel to any unusual conditions, and monitor operations and equipment.

B. Requirements

The Primary Electrical Power System will be sized to accommodate an increase in power needs of at least 30%, plus the addition of all closed loops that are not installed initially.

The availability goal of the normal power supply will be 99.9%. Two independent transmission lines will provide power to the FFTF complex and two independent sources of emergency power, each capable of supplying all emergency needs, will be available.

* Refer to Appendix A.
Communications shall function during normal power outage emergencies. Electrical equipment will be mounted outside of radiation or high temperature zones wherever possible. Where it is necessary to mount equipment within a radiation or high temperature zone, it will be designed for easy accessibility and rapid maintenance or replacement. All control equipment that is vital to reactor operation will be located in noncontaminated areas if possible.

Quick disconnect or plug-in connections will be used wherever maintenance may be frequent or difficult, especially in contamination zones.

Standardization and interchangeability of equipment will be the maximum that is practical and consistent with design and cost.

Spare penetrations in the containment vessel and elsewhere will be provided for future electrical service.

Emergency power supplies shall be sized to provide sufficient power to assure a safe reactor shutdown and maintained in this condition in the event of total loss of normal power. This will include provisions for sufficient lighting in the control room to conduct operation, sufficient lighting for personnel access, power to sensors, provisions for ensuring coolant flow to the primary loop and the secondary loop, emergency power provisions for the test loops, and similar provisions for all other equipment required to assure the safety of operating personnel and facilities.

Provisions will be made for supplying electrical heating to sodium piping.

* Refer to Appendix A, Study A-1
C. **Criteria**

Substation and outside line configurations will be arranged to establish high reliability in keeping with the high availability and safety requirements of the plant.

Electrical design of the inside electrical services for the FFTF will follow standard practice. The National Electric Code will be followed except that standard practice of 30% tray fill will be used for control wiring. Failures of equipment will be limited in their effects and will not spread to nor involve other systems nor parts of the same system. High reliability and ease of maintenance or replacement will be incorporated into the design.

Communications will be simple, easy to use, effective, and easy to maintain. There will be a few types of wide coverage systems rather than many specialist types.

Where costs are similar, eddy-current clutches will be used instead of wound-rotor motors for speed control of pump motors because of their better speed regulation performance.

Totally enclosed motors for pump drive units will be used where feasible to eliminate seal problems.

The Electrical System will be divided into two isolated sections.

**DDCN-1 3.1.2 Service Piping System**

**A. Objective**

The objective of the Service Piping System is to provide the utility services such as steam, water, compressed air, and vacuum as necessary to support the operations of the FFTF.

**B. Requirements**

The utility piping system requirements shall be determined...
from the building layout information and utility requirements of all systems. The piping system must provide for connection to mechanical equipment where required or connection to a central plant system.

A study task to evaluate the available building heat sources, including reactor heat, will be completed.*

Piping systems important to the operation of the facility shall be designed for maximum reliability.

C. Criteria

The piping services for the various group systems shall be designed in accordance with the applicable sections of National Codes and Hanford Standards.** Specifications will be developed for the Service Piping System which includes the following codes:

- Pressure Piping Codes (ASA-B31.1 Series)
- National Plumbing Code (ASA-A40.8)
- National Fire Protection Association Standards (NFPA Standards).

3.1.3 Heating and Ventilating System

A. Objectives

The objectives of the Heating and Ventilating System are to:

1. Control air conditions in the various spaces as required to meet the functions to be performed therein.
2. Provide contamination control in conjunction with building control features such as zoning, airlocks, etc.
3. Control release of contaminants to the atmosphere.

B. Requirements

The Heating and Ventilating System shall be of the central station type.

* Refer to Appendix A, Study A-2.
The supply and exhaust systems shall be matched insofar as practicable to permit balanced supply and exhaust conditions with reduced airflow during maintenance operations and high airflow for purge.

Provision will be made for air purging in spaces within the facility which arc normally maintained in an inert atmosphere.

Containment integrity will be maintained through the use of automatic closure valves in the ventilation system.

Ductwork shall be zoned to match the building contamination control zones to prevent cross-spread of contamination.

The control system shall provide for fail-safe operation in the event of failure of a component.

In order to meet the functional requirements above in the most economical manner, it is necessary to evaluate alternate methods of exhaust filtration, to determine ventilation filtration and cleanup requirements during containment and to study transient temperature conditions under conditions of normal power outage in order to determine emergency power requirements for ventilating equipment.*

C. Criteria

The Heating and Ventilating System shall be designed in accordance with Hanford Design Guide DG105-M, "Weather Data for Heating and Cooling Load Estimates," and Standard Design Criteria SDC 5.1, "Standard Design Criteria for Heating, Ventilating and Air Conditioning." (Additional recommended references such as the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) Guides are contained in SDC 5.1.)

* Refer to Appendix A, Studies A-3 through A-5.
Discharge of exhaust air to the atmosphere will be in accordance with AEC Criteria AECM-0524.


Methods will be provided for periodic filter replacement.

3.1.4 Plant Fire Protection System

A. Objective

The objective of the Plant Fire Protection System for the FFTF is to provide complete facilities for the control of fire within the FFTF reactor facility and plant site.

B. Requirements

In all zones where water will not jeopardize or be incompatible with materials or equipment of the facility, automatic sprinklers are a basic requirement. The piping system shall be designed for maximum reliability.

Where the possibility of sodium-water reactions or other considerations (including nuclear) precludes usage of automatic sprinklers, early warning of incipient fire by combustion detectors should be substituted.

Where costly electronic gear will be subject to water damage, detectors and inert gas and dry chemical systems actuated either by the detectors or by hand will be installed for positive fire protection. Critical equipment will be protected against wetting by sprinkler activation.

Customary backup of installed systems will be furnished by appropriately placed, hand-operated, first aid extinguishers such as carbon dioxide, dry chemical, and Met-L-X.
Where sodium fires are a high risk probability, special extinguishing materials will be provided for manual first aid or automatic fire protection.

Both the wet and dry fire protection systems will be completed by the conventional electrical circuitry with alarms, signals, and supervisory panels.

C. Criteria

Fire protection for FFTF will be provided on the basis of the dual criteria of compatibility with the facility processes and compliance with the AEC requirement of "improved risk" level of fire protection as defined in AECM-0552.

Sprinkler systems, where used, will be designed in accordance with applicable sections of the National Fire Protection Association Standards.

3.1.5 Reactor Containment System

A. Objective

The objective of the Reactor Containment System is to limit the release of radioactivity to the surrounding environs in the event of an accidental release from any of the reactor systems.

B. Requirements

The design pressure of the containment vessel shall be sufficient to withstand that arising from the design basis accident and/or the maximum sodium fire.

Blast shielding shall be provided in the reactor cell to withstand the design basis accident.

The containment shell shall be protected from penetration by reactor accident generated missiles.
All major gas and liquid lines including ventilation ducts penetrating the containment shell shall be equipped with independently actuated dual shutoff valves in series to prevent escape of vapor from the containment vessel following an accident. Provision for isolation of secondary sodium lines is to be determined on the basis of conceptual study.*

All penetrations in the containment vessel shall be designed to provide a positive seal and designed for periodic leak testing. Air locks used for access to the containment vessel shall be equipped with interlocks to permit opening an air lock door during operation only if the other door for that air lock is closed and sealed. Both doors shall be operable from either side of the door.

Containment will continue to be maintained during refueling of driver or test fuel, or during removal and replacement of other reactor internals while fuel is in the core.

Provision shall be made for the removal of heat from within the containment vessel as may be necessary to maintain the integrity of the vessel following an accident.

Provisions shall be made for initial pressure and leak rate testing of the entire containment system and for periodic leak rate testing thereafter of the entire system or individual penetrations and accessible welds.

C. Criteria

The containment system shall be designed to limit the release of radionuclides in any accident, including the design basis accident, to quantities that will be within the limits of the AEC Criteria AECM-0524 and 10 CFR 100. The containment structure shall be leak tested in accordance with the requirements of one of the following standards:

* Refer to Appendix A, Study A-7.
A study task is proposed to evaluate the feasibility of different containment structures such as a concrete design. Other studies such as the investigations of sodium fires are related to this effort to determine design pressure as well as blast shielding requirements to withstand the design basis accident.* Where applicable, codes such as ASME Boiler and Pressure Vessel Codes will be used in the design of the containment vessel.

3.1.6 Radioactive Waste System

A. Objective

The objective of the Radioactive Waste System is to insure that release of radionuclides to the environs will be controlled within the limits of AECM-0524.

B. Requirements

Provision will be made for safe handling and disposal of four general categories of potentially radioactive wastes: sodium waste, liquid wastes, solid wastes, and gaseous wastes.

All tanks in the system will be connected through a radioactive vent system to a condenser. Condenser off-gas will be discharged through the radioactive gas cleanup system for final disposal to atmosphere. Aqueous wastes will be released to adjacent river water for those wastes whose release is not prohibited. Other wastes will be held up and stored.

* Refer to Appendix A, Studies A-6 through A-8.
Each drain and holdup tank in the system will be provided with the following:
- Liquid Level Indication
- High Liquid Level Alarm
- Remote Sampling
- Steam Jet or Pump for Transfer of Waste.

In addition, each drain tank will be equipped with a chemical solution addition line for pH control. Drain tanks will be equipped with sparging nozzles.

Solid wastes will be stored in a shielding storage vault provided in the FFTF waste handling area for temporary storage to permit decay of short half-life radionuclides and/or to accumulate sufficient quantities for efficient disposal.

Solid, contaminated wastes will be disposed of in burial pits. Contamination control will be provided during transit to the burial ground to prevent the spread of loosely held contamination. Known plutonium-containing solid wastes will be segregated from other wastes and buried. At the FFTF, facilities will be provided to remove metallic sodium from waste before it is shipped to the burial ground.

Provisions for waste sodium metal disposal should include offsite shipment. Provision should also be made for reacting sodium to the hydroxide or carbonate prior to shipment to a waste burial ground.

Gaseous wastes released to the atmosphere will be filtered through particulate and halogen filters before release through a stack. Activity monitors and integrating gas samplers will be provided downstream of the particulate and halogen filters.

C. Criteria

The Radioactive Waste System shall be designed to meet the standard for radiation protection in accordance with AECM-0524.
Radioactive waste disposal to river water shall conform to federal regulations. Continuous monitors for radioactivity and integrating samplers will be provided on aqueous waste discharge streams.

Piping systems will be designed in accordance with applicable sections of National Codes and Hanford Standard Specifications.* Typical of, but not necessarily all inclusive of the required codes are the National Plumbing Code and ASA Codes for Pressure Piping.

Tanks containing radioactive waste will be designed to meet applicable ASME Codes plus additional requirements of Hanford Standards.

3.2 REACTOR SYSTEMS

3.2.1 Reactor Nuclear Control System

A. Objective

The objective of the Reactor Nuclear Control System is to provide safe and reliable shutdown devices and means for controlling neutron multiplication in the reactor core with sufficient flexibility to achieve experimental goals.

B. Requirements

The combining of control and safety functions in the control devices shall not be precluded.

The nuclear control devices shall be capable of providing for startup, controlled and scram shutdowns and longer-term fuel burnup compensation or shim control.**

Control and safety devices shall be designed such that functional capability is unimpaired for the design earthquake or other abnormal conditions.

** Refer to Appendix A, Study B-1
Design methods shall include dynamic analysis of critical control components.

Control system design shall provide for normal shutdown automatically at a preprogrammed rate to prevent thermal shock damage to tests or reactor systems.

Control devices shall be designed to prevent their ejection from the core by the maximum expected pressure during any credible accident condition.

If movable poison or movable fuel control methods are used, consideration shall be given to making the control devices interchangeable with the subassembly envelope, permitting the location of these devices to be varied as needed to suit future core alterations.

Existing proven hardware or concepts shall be used where possible. Prototypes of final design shall be thoroughly tested under prototypic conditions.

The maximum reactivity worth of the control devices and the rate at which reactivity can be inserted must be held to values such that no single credible mechanical or electrical control system malfunction can cause a reactivity transient capable of damaging the primary system or causing significant fuel failure.* The maximum deliberate reactivity insertion rate will be limited such that the resulting power excursion will be limited by first line protective action without thermally induced plastic strain in fuel cladding.

It is considered undesirable to dismantle or remove the drive mechanisms of the control devices when refueling the reactor. The conditions under which such action may be acceptable will be investigated. Reactivity shutdown capability shall be provided to make and hold the reactor subcritical from any credible operation condition with any

* Refer to Appendix A, Studies B-3 and B-4.
one safety device at its position of highest reactivity. Means will be provided for verifying the adequacy of the shutdown margin during refueling operations.

The Reactor Nuclear Control System shall interface with the Reactor Safety System such that the safety control devices will initiate shutdown at the maximum rate upon receipt of trip signals from the latter, irrespective of other control modes.

C. Criteria

The basic control devices to be considered for nuclear control are movable poison, movable reflector and movable fuel.*

The basic control function is to provide adequate control margins to compensate for fuel burnup, temperature effects, shutdown, and to allow variation in power level when desired. Because of the experimental nature of the FTR, the reactor should be designed so that sufficient reactivity margin can be made available for experimental flexibility.

The safety devices must have reactivity shutdown capability to make and hold the reactor subcritical under any credible operating condition. Control and safety device insertion must be assured under abnormal conditions, including seismic disturbances. The control system should be fail-safe and designed to minimize disturbances to fuels and materials undergoing test.

3.2.2 Reactor Safety System

A. Objective

The objective of the Reactor Safety System is to provide the necessary electrical circuitry for rapid automatic shutdown of the reactor in the event of any condition that places the safety of the reactor plant in jeopardy.

* Refer to Appendix A, Study B-2
B. Requirements

It is a requirement that the safety circuit be of proven
design with demonstrated reliable service.

Safety circuit trips shall be limited to those items
that could be directly and immediately hazardous to the
reactor, building, occupants, or countryside. These
trips would normally include:

- Intermediate range neutron flux period, and flux
  level
- Power range flux level
- Power range power rate-of-change
- Sodium bulk over-temperature on primary loop
- Sodium over-temperature on each monitored reactor
  channel
- Loss of sodium flow in primary loop
- Loss of critical power supply
- Earthquake

All but the last item will be actuated by trip signals
from analog instruments feeding to the safety circuit.
There are also safety circuit trips on individual closed
loops. These trips would normally include for each closed
loop:

- Low Flow
- Coolant Over-Temperature.

In general, two out of three (or more) coincident trip
logic will be used. Only those trips requiring maximum
shutdown speed are included in the scram safety circuit;
all others are included in controlled shutdown circuits.

C. Criteria

The safety system shall provide reliable, redundant and
fail-safe circuity for the reactor. At least one of two
basic types of circuits will be utilized.
1. Fail-safe circuit, using contacts, operated on ungrounded, direct current with a battery backup supply.

2. Auctioneering, self-checking (highest voltage) circuit, using vacuum tubes or solid-state devices, operated on alternating current with two sources of ac power.

DDCN-1  3.2.3 Reactor Heat Transport System

A. Objective

The objective of the Reactor Heat Transport System is to move nuclear heat from the driver fuel, the open test positions, and the core components and dissipate the thermal energy to the surrounding natural environs.

B. Requirements

The power handling capability of the system will be defined on the basis of studies taking into consideration adequate design conservatism, ability to accommodate different types of driver fuel, power level needed to continue operating with a minimum of one loop out of service, and stretch capability to fulfill foreseeable future needs.*

The system is to be designed to operate from essentially zero power to full power as dictated by testing requirements. The design is to incorporate ability to follow power transients occurring during scram, startup, and normal shutdown. A reliable afterheat removal method is to be incorporated in the design such as natural convection cooling. The design must provide for adequate heat removal at all times, including the possibility of fracture of a major primary coolant carrying line. Undercovering the core under such conditions must be rendered incredible by the use of syphon brakes.

* Refer to Appendix A, Studies B-5 through B-7.
The system must contain radioactive materials resulting from activation and fission product release from vented or failed fuel. To avoid contamination of the secondary sodium, the primary and secondary sodium systems must be positively isolated throughout the plant. Provisions for limiting and extinguishing sodium fires are to be incorporated.

Personnel exposure to toxic materials is to be avoided. Ability to detect unsafe conditions such as sodium and gas leaks, plugging, radioactive release, and mechanical faults is to be incorporated in the design.

The reference coolant of the FTR is sodium. The heat removal system is to be constructed of materials compatible with this coolant such as austenitic stainless steels, nickel alloys, or high alloy steels.

Where feasible, the design is to employ products of existing technology.

Redundant features and multiple components or subsystems will be employed where applicable to permit continued operation when portions of the system become inoperative.

Component fabrication and inspection procedures will be specified for high confidence level.

A component proof-testing program is to be initiated to test design adequacy.

C. Criteria

The heat removal system shall have the capability to extract the heat from the reactor under all normal and emergency conditions.

The system is to be designed to provide safe operation from the standpoint of radiation, chemical, and fire hazards.
The system must have high reliability to allow high plant availability.

The system cost is to be minimized consistent with the objective of adequate capability and of safe and reliable operation.

The mechanical design is to be based on established design methods; this includes the conformance with applicable sections of the ASME Boiler and Pressure Vessel Code and the ASA Code for Pressure Piping.

**DDCN-1 3.2.4 Inert Gas Receiving and Processing System**

**A. Objective**

The objective of the Inert Gas Receiving and Processing System is to maintain an inert atmosphere in voids over molten sodium, areas which enclose equipment containing molten radioactive sodium, fuel and component processing cells containing sodium or sodium-bearing components, and areas in which oxygen or moisture reactive fuels are handled and inspected.

**B. Requirements**

Provisions shall be made for:

- Gas purity control.
- Heat removal and addition capacity, as required.
- Decay storage and disposal of radioactive gases in a safe, controlled manner.

The facility should be capable of reducing sodium impurities to the lowest level practicably attainable, and of controlling impurity levels at a constant level down to the minimum. Primary impurities to be controlled are oxygen, carbon, nitrogen, hydrogen, and fission products. Inert gas will be provided for each application which most nearly satisfies applicable system design requirements.
C. Criteria
Gas purity shall be maintained at required levels, including removal of fission gases from vented fuel in closed loops and reactor core.

The following codes and standards govern the design and construction of the Inert Gas Systems:
- ASA, B-31.1, Pressure Piping Code.
- ASME Boiler and Pressure Vessel Code
  Section III, Nuclear Pressure Vessels
  Section VIII, Unfired Pressure Vessels.

Additional criteria may be imposed on critical portions of the system. FFTF standards will be prepared as necessary for equipment which is not within the scope of the above codes.

DDCN-1 3.2.5 Sodium Receiving and Processing System

A. Objectives

The objectives of the Sodium Receiving and Processing System are:
1. To receive, store, purify and supply sodium as required for the reactor closed loops and fuel storage containers.
2. To receive, store and purify and/or dispose of highly contaminated sodium.

B. Requirements

The FFTF Sodium Receiving and Processing Systems are to receive, store, and process sodium coolant for the reactor heat removal systems and fuel storage facilities. The following are required:

1. Receive, analyze, purify and store fresh sodium for normal or emergency makeup to the reactor and closed-loop primary and secondary heat removal systems and fuel storage and equipment and facilities.
2. Provide storage capacity to permit draining of systems, portions of systems or components as necessary for servicing of equipment.
3. Analyze and purify sodium in the reactor and closed-loop primary and secondary heat removal systems, sodium storage tanks, fuel storage containers and in the contaminated sodium storage facility.

4. Provide for retention and subsequent purification or disposal of sodium which becomes excessively contaminated by chemical or radioactive materials.

5. Systems and equipment to be designed to avoid siphoning or self-draining in the event of leak or valving error.

6. Radioactive sodium processing equipment to be located in shielded rooms within the reactor containment boundary to maintain radiation levels outside the rooms at levels compatible with building occupancy requirements.

7. Inert cover gas to be provided in all sodium containing equipment.

C. Criteria

1. Reduce and maintain sodium impurities to less than the level required for preserving reactor equipment for the planned reactor lifetime and for meeting closed loop and open test position testing requirements.

2. The following codes and standards will govern the design and construction of the sodium receiving and processing systems:
   - ASME Boiler and Pressure Vessel Code
     Section III, Nuclear Pressure Vessels
     Section VIII, Unfired Pressure Vessels.
   - FFTF standards will be prepared as necessary for equipment which is not within the scope of the above codes.

3. Design shall preclude cross-contamination from radioactive to nonradioactive systems.

3.2.6 Reactor Components

The reactor vessel, shielding and driver fuel are components of the reactor systems. Each is common to several reactor
systems. Because they are the interfaces of many systems and are important items of the FFTF complex they are described separately in this section.

- **Reactor Vessel**

  **A. Objective**

  DDCN-1  

  A high integrity, twenty-year minimum life, enclosure for the fuel, reflector, coolant, open test positions and closed loops, core support and other hardware comprising the nuclear assembly.

  **B. Requirements**

  The reactor vessel shall be designed to withstand the maximum predicted fluid pressures. Design pressure selections shall include comprehensive consideration of hydrodynamic shock and excess pressure potential from the external sources (by failure of pressure regulating and relieving devices and by remote chemical reactions such as sodium-air or sodium-water). Pressure barriers within chambered vessels with different chamber-design pressures shall be designed to withstand the maximum possible pressure differential across the barriers. Coolant bypass may be permitted to reduce the core outlet temperature to acceptable design temperature levels for austenitic stainless-steel structural materials and the selected design temperature for each structural part shall result from thermal or mechanical loads, thermal shock, coolant mixing effectiveness, and irradiation damage. Particular care shall be applied to limit the thermal shock damage to structural parts of the reactor vessel during scram transients.

  **C. Criteria**

  The Reactor Vessel is expected to be a principal feature of any reactor concept. In this context, the reactor
vessel consists of the sodium filled reactor core container and essential internal parts. Certain more or less fixed core components such as the coolant plenums, core support, thermal barriers, neutron reflectors, and neutron shields may be considered as essential reactor internals. While core elements such as fuel, control and safety devices, instrument sensors, closed loops and open test position test assemblies, might be treated and described separately, the strong interactions of core components in a fast reactor require the complete unit to be designed as an integrated assembly.

The reactor vessel shall be designed and fabricated in accordance with the requirements of Section III, Nuclear Vessels, ASME Boiler code, and supplemented by the special requirements of creep range design, liquid metal thermal shock, and sodium corrosion and mass transport. Considerations of structural material property degradation due to irradiation shall be as complete as the prevailing state-of-art permits. Irradiation damage considerations shall be based upon the specific neutronic (including energy spectra), temperature, and stress environment for each structural element.

In addition to the structural problems of core support and coolant distribution, significant structural problems arise in the general support structure of the reactor vessel and the requirements for containment of the energy of the design basis accident. These structural problems must be solved for both steady-state and transient conditions. Particular attention is required to eliminate or restrain potential primary and secondary missiles during the DBA.
• Reactor Shielding

A. Objective

To degrade and absorb the intense nuclear radiation emanating from the reactor core and to serve as a kinetic energy absorbing device, protecting the containment facilities, in the event of violent accidental disruption of the reactor vessel.

B. Requirements

Definition of plant areas and specified radiation levels shall be as follows:

- Unrestricted access for full-time occupancy, such as offices. (<0.2 mrem/hr)
- Limited access, not routinely occupied. (<2 mrem/hr)
- Areas to which access is rigidly controlled by Radiation Work Procedures. (>2 mrem/hr)
- Entrance to areas where the dose rate can exceed 10 rem/hr shall be controlled by a physical barrier.

The reactor shielding shall be capable of reducing neutron and gamma dosages to a level below that which would cause significant degradation of the surrounding containment structure.

Shielding cooling circuits that utilize a coolant compatible with both the nuclear and chemical safety of the other reactor systems shall be provided. In particular, hydrogenous materials that could conceivably enter the reactor core must be avoided.

Developed shielding designs shall include allowances for radiation source self-absorption, localized radiation peaking due to shield penetrations and fits at shield joints.
C. Criteria

The reactor neutron and biological shields must reduce radiation levels to values consistent with controlled personnel exposure limits.

Since the reactor shield will also serve as a blast shield, it should be capable of absorbing the kinetic energy generated in the design basis accident without breaching the reactor containment. Shield materials should be employed that do not deteriorate appreciably throughout the design plant life.

Shield operating temperatures shall not exceed values which would shorten the shield life.

- **Driver Fuel**

A. Objective

To provide the fast neutron flux test environment consistent with core safety requirements and reactor goals of testing flexibility and economy.

B. Requirements

Consistent with the safety requirements of the core, the driver fuel shall provide a reliable inherent negative reactivity temperature coefficient throughout its lifetime.

Fuel pin centerline temperatures shall be limited below fuel melting temperatures by a margin of safety to be determined, and fuel subassembly design will minimize hot-channel factors to the lowest practical values.

Selection of materials and processes shall be fully investigated insofar as existing data and technology permit.

Fuel element hold-down shall be provided.

Subassembly design will permit instrumentation of driver fuel and driver coolant for control and monitoring.
Provisions should be made for fuel-pin failure monitoring and for incipient sodium boiling monitoring devices to be incorporated when available. Vented fuel pins will not be considered for initial core driver fuel application because of undesirable effects on open test position tests. Vented fuel pins are not, however, ruled out as driver fuel in later cores nor will they be excluded by design from consideration for future open test position testing.

C. Criteria

Because the core performance is highly dependent upon driver fuel characteristics, the fuel element design is a major consideration. The reference fuel is a mixed oxide. In general, the design of the FTR driver fuel pins and subassemblies will be addressed to the principal criteria of nuclear safety, endurance and economy.

Anticipated test failures require a large, prompt negative power coefficient from the driver core. Likewise net negative reactivity temperature coefficients for all off-normal, as well as normal, operating conditions are required for driver fuel and coolant.

A low, overall fuel cycle cost, although considered an important criterion, will be subordinate to nuclear safety and functional adequacy. Direct applicability of driver fuel to the LMFBR Program goals is a desirable criterion, but secondary to nuclear safety, endurance, and economy.

Materials, processes, components and prototypes must be fully tested under prototypic and abnormal operation conditions insofar as existing facilities, and those to be available will permit.
3.3 IRRADIATION TEST SYSTEMS AND FACILITIES

3.3.1 Closed Loop System

A. Objective

The objective of the Closed Loop System is to provide isolated cooling circuits in the FFTF for testing fast reactor fuels, materials, coolants, and technology with main emphasis on liquid metal cooling.

B. Requirements

Testing is to permit determination of effects and limits of operating and fabrication variables with the ultimate goal of developing reliable and economic FBR fuel.

Studies of FFTF functional testing requirements will be completed to aid in determining the specific number, sizes, and operating characteristics of closed loops and specific tests.* Closed loops will be required to:

1. Test at anticipated LMFBR conditions to determine combined flux, exposure, temperature, power, and coolant quality effects in the following ranges:
   a. Neutron flux levels from $10^{15}$ to $>10^{16}$ n/cm$^2$-sec.
   b. Neutron flux spectrum $\sim 75\% >0.1$ MeV. Spectrum "softening" may be desired.
   c. Material exposures to total integrated doses from $10^{20}$ to $10^{24}$ nvt.
   d. Fuel exposures from 20,000 to 200,000 MWD/ton.
   e. Temperatures from 1000 to $>1400$ °F (initial temperatures expected to be $\sim 1200$ °F).
   f. Fuel powers from 5 to 45 kW/ft, depending on fuel type.
   g. Coolant qualities to permit testing of stainless steel and/or refractory metal structural materials and/or fuel cladding; expected ranges of $O_2$ from $\sim 2$ to $\sim 40$ ppm; C from $\sim 4$ to 25 ppm.

* Refer to Appendix A, Study C-1.
h. Plumb vertical orientation and upward coolant flow.

i. Test varied sizes and numbers of structural and/or fuel specimens in an assembly; expected individual specimen diameter range is 0.2 to 0.6 in.

j. Test various sizes and lengths of fuel subassemblies and assemblies ranging from 1 1/2 to ~6 in. diam and fueled zone lengths from ~2 to 4 ft with overall fuel assemblies incorporating reflectors and fission gas plena ranging to ~11 ft.

2. Provide knowledge and control of test conditions and specimen operation independent from the reactor conditions, except for flux. Provision for ex-reactor control specimen tests will also be included.

3. Provide ability to instrument test specimens and to lead out and disconnect instrumentation leads. During reactor operation anticipated measurements for specimens are: surface and internal temperatures and fission gas pressure. Anticipated measurements in the loop proper are: test section coolant inlet and outlet temperatures and pressures (or specimen ΔP), coolant flow, specimen power generation, fuel failure, and neutron flux.

4. Contribute in the development of technology for operating materials and fuels with sodium coolant in the 1100 to 1400 °F range.

5. Test fuels to maximum limits, including tests up to failure. Although meltdown testing is precluded from closed-loop requirements, recovery from accidental meltdown is to be included in the design.

6. Operate with fission products in coolant to allow testing of vented fuel types or to determine effects of operation after fuel failure.

7. Test individual fuel pins, fuel pin subassemblies, and full-fuel assemblies. Full assembly testing may be required if desired test conditions are not attainable in open-loop test facilities.
8. Assure a fuel handling method compatible with preserving test data including the capability for removing stuck fuel from the reactor (probably by leaving in the tube) with minimum effect on test results.

9. Allow loop and reactor operation with as few cross-effects as practical.

10. Permit maximum reactor operating and testing effectiveness by considering component reliability, tests run, and loop and reactor cross-effects.

11. Provide adequate nuclear safety with respect to containment, criticality, driver fuel damage, fuel meltdown and high risk testing, reactivity excursions, and personnel shielding.

12. Provide adequate industrial safety with respect to handling clean and radioactive sodium, inert atmospheres, and high temperatures and pressures.

13. Allow future capability for testing with alternate liquid metal or gas coolant.

14. Use standard, interchangeable components and loop designs wherever practical to provide the most economical initial and testing costs.

15. Equipment cells should be arranged for maintenance considering alpha and gamma radiations.

16. Provisions are required for cleaning up both cover gas and sodium including fission product removal, in-line instrumentation, and sampling for determining purity.

It is not expected that all closed loops will incorporate all the above requirements; economic and design tradeoff studies based on the results of the continuing FFTF functional testing requirements studies will be necessary to determine the testing parameter combinations and number of closed loops needed.* As each loop becomes identified

* Refer to Appendix A, Studies C-1 through C-5.
with specific testing objectives, it will be treated as one or more separate systems.

C. Criteria

Closed loop piping and components will be designed in accordance with the following applicable codes:

- ASME Boiler and Pressure Vessel Code, Sections III, VIII, and IX
- ASA Code for Pressuring Piping, B31.1
- National Electrical Code
- Uniform Building Code.

The design will also conform to the applicable sections of Section 2.0, Safety Philosophy, of this Overall CSDD.

DDCN-1 3.3.2 Short Term Irradiation Facility

A. Objective

The objective of the Short Term Irradiation Facility is to provide test irradiations less than one reactor operating cycle in duration, utilizing automatic insertion, timing of irradiation period, and removal of fuel and material samples from the reactor.

B. Requirements

A testing requirements study will permit determination of sample carrier size and velocity, irradiation temperature, heat removal capacity, and whether the system should use rapid insertion and removal methods, such as a pneumatic or hydraulic rabbit, or slower methods such as a trail cable.

The requirements of the system will probably include:

- Average test flux 0.5 to 5 x 10^{15} \text{n/cm}^2/\text{sec}
- Irradiation times \text{\leq} 1 \text{ min to } <1 \text{ reactor operating cycle}

* Refer to Appendix A, Study C-1.
** Refer to Appendix A, Study C-6.
Accessibility to counters or examination from out-of-core station
Optional automatic operation
Accessibility of out-of-core lines for maintenance or replacement
The test specimen content must be limited to prevent an excessive reactivity insertion rate.

C. Criteria

DDCN-1 Short Term Irradiation Facility piping and components will be designed in accordance with the following applicable codes:
  - ASME Boiler and Pressure Vessel Code, Sections III, VIII, IX
  - ASA Code for Pressure Piping, B31.1
  - National Electrical Code
  - Uniform Building Code.
The design will also conform to the applicable sections of Section 2.0, Safety Philosophy, of this Overall CSDD.

3.3.3 Irradiation Facilities

The other testing facilities not constituting systems per se, but required to meet testing needs are:

DDCN-1
  - Open test positions for testing at reactor coolant conditions. Since open test positions can potentially occupy any reactor position not occupied by closed loops or control rods, wide testing capability is provided, including the ability to test statistically significant quantities of fuel pins.
  - Capsule testing in either driver fuel or reflector positions, depending on experimental aims.

DDCN-2

Maximum use of test space will be provided by consideration of areas such as the following for test locations (mainly materials tests):
  - Nosepieces on control rods
• Accessibility to counters or examination from out-of-core station
• Optional automatic operation
• Accessibility of out-of-core lines for maintenance or replacement
• The test specimen content must be limited to prevent an excessive reactivity insertion rate.

C. Criteria

DDCN-1

Short Term Irradiation Facility piping and components will be designed in accordance with the following applicable codes:

• ASME Boiler and Pressure Vessel Code, Sections III, VIII, IX
• ASA Code for Pressure Piping, B31.1
• National Electrical Code
• Uniform Building Code.

The design will also conform to the applicable sections of Section 2.0, Safety Philosophy, of this Overall CSDD.

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• Capsule testing in either driver fuel or reflector positions, depending on experimental aims.

Maximum use of test space will be provided by consideration of areas such as the following for test locations (mainly materials tests):

• Nosepieces on control rods
3.4 COMPONENT HANDLING SYSTEMS

DDCN-1 3.4.1 Reactor Refueling

A. Objective

The primary objective of the FFTF Reactor Refueling System is to remove and replace fuel assemblies from the reactor core under a controlled environment to permit maximum acquisition and preservation of experimental data.

B. Requirements

1. The fuel handling machine requirements may be distributed among more than one machine and are as follows:* 
   - Replace irradiated driver fuel in the core.
   - Replace irradiated test fuel in open test positions.
   - Replace irradiated test fuel in closed loops.
   - Replace packaged loops in the core.
   - Move fuel to and from decay storage or transfer cells.
   - Refueling rate to be adequate for high plant availability.
   - Critical equipment to be designed so that failure will terminate in a fundamentally safe state.
   - Interlocks are required to assure that no function can be initiated until conditions exist for safe and complete execution of the function.
   - Adequate instrumentation and read-out shall be provided to monitor critical functions and parts of the machine.
   - Equipment shall be designed for abnormal conditions such as the DBA, fuel meltdown during handling operation or stuck fuel within the core.

* Refer to Appendix A, Studies D-1 through D-6.
Requirements on operator's skill shall be minimized to avoid the need for specialists to operate the machine. Equipment shall be remotely operable, remotely maintainable and capable of being remotely decontaminated.

2. Nonirradiated fuel handling has the following requirements:
   - Receive and store nonirradiated driver fuel.
   - Receive and store nonirradiated test fuel pins, sub-assemblies or capsules.
   - Assemble nonirradiated test fuel and specimens.
   - Provide transport to and from flow and pressure-drop test facility.
   - Provide means to connect, calibrate and check instrumentation to a fuel assembly.
   - Provide preheat capability for fuel assemblies.
   - Provide shipping pallet for nonirradiated fuel.
   - Provide cell service and monorails.
   - Provide ventilation control of airborne particulate such as plutonium that might be released from damaged fuel assemblies.
   - Provide positive protection against criticality during fuel transfer or storage.
   - Preserve experimental data of fuel to be examined.

3. Irradiated fuel handling has the following requirements:
   - Receive and transfer fuel from the fuel handling machine.
   - Provide means for disconnecting instrumentation from irradiated fuel.
   - Provide a storage basin for long term decay of fuel.
   - Clean irradiated fuel in preparation for transfer to examination facility or basin storage.
   - Leakage and spills shall be controlled and provision made for cleanup.
   - The cleaning provisions shall preclude mixing of non-compatible gases and liquids and shall be compatible with the radioactive waste disposal system.
• Maintain fuel temperatures within an acceptable range during handling, storage or examination. A redundant cooling system shall be provided for back-up cooling.
• Provide positive protection against criticality.
• Preserve experimental data of fuel to be examined.
• Provide loadout basin for offsite shipping cask.
• Provide offsite shipping cask.
• Provide means to return irradiated fuel to the fuel handling machine.
• Provide decay storage for irradiated fuel within the containment structure.
• Provide decay storage for irradiated fuel inside the examination cell.
• Provide for personnel and nuclear safety.
• Provide an easy-to-maintain system.

C. Criteria

Reliability will be achieved by emphasis on installed spares, modular design with quick replacement techniques of subassemblies, and primary emphasis placed on replacement of failed components rather than repair in place. The equipment for critical operations will be designed wherever possible so that the simultaneous failure of any two components will not result in a condition which could jeopardize personnel, the reactor, or plant availability.

Additional storage capacity will be provided in the examination cells so that dependency on the fuel handling system is minimized because scheduling of the handling equipment is no longer critical.

In the design of remote mechanisms, each motion will be positive and simple. Minimum reliance will be placed on gravity and friction.
Appropriate engineering design and construction codes and federal regulation codes will be considered minimum to achieve safety and reliability.

DDCN-1 3.4.2 Radioactive Maintenance System

A. Objective

The objective of the Radioactive Maintenance System is to service and maintain irradiated components, both within and outside the reactor core.

B. Requirements

The Radioactive Maintenance System will include the following requirements:

- Provide highly efficient maintenance capability for the closed-loop cells.
- Provide for replacement of core components including closed loops and open test positions with or without a stuck subassembly.
- Provide devices which preclude the possibility of foreign matter being introduced into the core.
- Provide capability for replacing large reactor components such as primary pumps, heat exchangers, etc.
- Provide for remote repair of control rods.
- Provide for remote repair of heat exchangers, pumps, and other large, primary loop components.
- Provide for solid waste disposal.
- Provide portable maintenance tools for contaminated maintenance.
- Provide for decontamination and rebuild of in-cell equipment such as manipulators, jigs, and fixtures.*
- Provide for replacement of process instrumentation and electrical connections and lines.
- Provide adequate storage for handling equipment and removed components.

* Refer to Appendix A, Study D-8.
C. Criteria

The FFTF will have major emphasis placed on the area of radioactive maintenance as a means of obtaining high plant factor. The system includes all equipment, cells, and techniques to perform maintenance on components which have become contaminated or radioactive.

A multipurpose maintenance cell will be provided for remote repair and preventative maintenance; however, contact maintenance after decontamination will be used whenever possible.

The equipment for critical operations will be designed wherever possible so that the simultaneous failure of any two components will not result in a condition which could jeopardize personnel, the reactor, or the plant availability.

Maintenance versatility is a necessity in order for the FFTF to handle a wide variety of experiments.

Appropriate engineering design and construction codes and federal regulations codes will be applied where applicable.

3.5 Examination Systems and Facilities

3.5.1 Liquid Treatment System for Underliquid Examination

A. Objective

The objective of the liquid treatment system is to provide control of temperature, optical clarity, decontamination, and flow of the liquid inspection medium.

B. Requirements

The following key requirements must be fulfilled to meet the system's objective:

- Bulk temperature of the liquid must be controlled to limit humidity within the examination cell.
- Fuel surface temperatures must not exceed in-reactor temperatures.
Turbidity must be controlled and particulate matter removed for good visual observation.

Contamination must be controlled by removal of soluble and non-soluble fission products.

Criticality control shall be accomplished by a soluble neutron poison additive or a nonhydrous liquid.* If a neutron poison is used, there shall be frequent monitoring of poison concentration.

Basin overflow discharge rate (gravity flow) equivalent to the maximum liquid supply rate.

Contaminated overflow and drain liquids must be discharged into radioactive waste lines.

Equipment above liquid level must be shielded and accessible for maintenance.

Submerged equipment must be remotely removable for decontamination and maintenance.

C. Criteria

The design of system components will conform to applicable ASME codes. Radiological design criteria will be in accordance with AECM-0524. A criticality safety margin to be determined will be applied.*

3.5.2 Fuel Examination Facilities

The following fuel examination facilities are included in the FFTF Project but not categorized as systems.

A. Inert Gas Cell Examination Facility

This facility provides shielded cells and equipment for nondestructive inspection, packaging, and shipment of FFTF driver and test pins and specimens. The facility will provide:

1. Interim inspection without disassembly of subassemblies and return to the reactor;

* Refer to Appendix A, Study E-1.
2. Inspection, disassembly, reassembly and reinsertion of test subassemblies into the reactor; or
3. More complete inspection, disassembly, and nondestructive testing of subassemblies whose irradiation is complete.*

B. Underliquid Cell Examination Facility

The FFTF Underliquid Cell Examination Facility is planned to take advantage of underliquid inspection and disassembly technology because certain fuel and test subassemblies can be handled more easily under a clear liquid. The facility will provide disassembly, limited inspection, and packaging of selected fuel subassemblies, reactor components, and material test subassemblies.

C. Radiometallurgy Facility

The method for providing onsite-radiometallurgy facilities has not been fully established.** The three methods under consideration are:
- Use of an existing facility
- Modification to the existing facility
- Providing a completely new facility.

This facility would provide shielded cells and equipment for complete destructive examination of FFTF fuel pins and material samples after disassembly and nondestructive examination in the Inert Gas and Underliquid Cell Facilities. The laboratory would consist of a bank of research hot cells and supporting laboratories attached to the reactor building so that complete metallurgical, chemical, and physical testing programs could be conducted on fuel pins and material samples.

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* Refer to Appendix A, Studies E-2 and E-3.
** Refer to Appendix A, Study E-4
3.6 UNIFIED INSTRUMENTATION AND CONTROL SYSTEMS

DDCN-1 3.6.1 Control and Data Handling System

A. Objective

The objective of the Control and Data Handling System is to provide all plant and process information which is necessary to assure safe and continuous plant operation, or is useful to an experimenter.

B. Requirements

Requirements are that all systems information must be present in the control room. These data and trends must be handled, displayed, recorded, and routed to the point that requires this knowledge. Redundancy, cross checks, and malfunction detection is required to assure that the quality, or value, of data is not changed while being processed or routed.

In addition, all plant and process data shall be available to customers to supplement the test data acquired independently by the test customer.

Control and data handling methods will be evaluated and the one that best meets the objective of this system will be recommended.*

C. Criteria

The criteria applied to the design of this system include considerations of equipment and personnel safety, operating continuity, adequacy, and protection of test data, test flexibility, maintenance factors and cost. More specifically, the following criteria will be applied:

1. Reactor safety functions shall be independent of automatic control system functions.
2. Redundant equipment will be made available for processing critical test data.

* Refer to Appendix A, Study F-1.
3. If a computer system is utilized for central control, the facility will be operable in a limited mode even though the computer malfunctions.

4. Equipment shall be designed to facilitate rapid correction of equipment malfunctions, consistent with appropriate cost and plant availability tradeoff factors.

5. The ability to provide and display a large amount of information without cluttering the control room is a desirable goal in the design of this system.

DDCN-1 3.6.2 Reactor Channel and Vessel Instrumentation System

A. Objective

The objective of the Reactor Channel and Vessel Instrumentation System is to sense and provide knowledge of the reactor and in-core conditions for operating, safety and data logging purposes.

B. Requirements

A basic requirement is that reliable measurements of important reactor variables be available. Included are nuclear flux level under all operating modes, temperatures of reactor coolant, release of fission products, and position of control elements or rods. These in-core measurements are of prime importance to the FFTF and yet are difficult to obtain. Therefore, definition of in-core measurement needs and availability of adequate sensors is to be determined.*

Other in-core conditions of interest include, but are not necessarily limited to, the following:

- Coolant Boiling
- Structural Strain
- Vibration
- Coolant Flow
- Coolant Differential Pressure.

* Refer to Appendix A, Study F-2.
Display of key process variables affecting the reactivity status of the reactor will be convenient to the operator station in the control room.

All significant process variables will be available for display in the control room with provision for duplicate readout at local stations if necessary.

Studies to precisely define needs and practical methods of satisfying these needs will continue. Where the need is sufficiently urgent, R&D projects shall be initiated to provide the required technology.

C. Criteria

Data must be of such quality and timeliness that proper decisions concerning plant startup, operation, reactor scram or controlled shutdown can be made. These decisions may be equipment-performed (automatic) or based upon operator knowledge.

Reactor instrumentation shall be selected to meet or exceed the performance specified by reactor safety, control and experimental test requirements and philosophy, within the limits of available technology.

Redundant sensors shall be provided for where test or operational data are sufficiently critical to justify them.

3.6.3 Plant Instrumentation System

A. Objective

The objective of the Plant Instrumentation System is to provide means for obtaining plant and process measurement and control information and for transmitting this to and from the Control and Data Handling System.
B. **Requirements**

The requirements include coordination of all instrumentation needs of the individual FFTF process systems, development of uniform instrument application guides and provision for all peripheral services and environments needed by sensor, actuator and signal conditioning equipment to insure proper functioning of the associated data and control systems. The required process measurements include heat removal system coolant and piping temperatures, flow rates and pressures; fuel handling and examination facilities instrumentation, cover gas pressures, sodium liquid levels, pump speeds, coolant purity, smoke detection and radiation monitoring. Control signal converters and actuators for valves, pumps and other final control elements shall be provided.

Purity instrumentation requirements include gas system moisture analyzers, oxygen analyzers for all gas and sodium systems, plugging meters and other special instruments to be developed or purchased as the process system requirements become more clearly defined.

Strain and vibration measurements on piping and critical components are also of interest and will be provided where needed to monitor equipment conditions or provide useful data.

**Criteria**

Plant instrumentation shall be selected to meet or exceed the minimum performance required to satisfy process objectives.

Data must be of such quality and timeliness that proper decisions concerning plant startup, power operations, emergency and controlled shutdown procedures, and fuel
handling and other reactor shutdown operations can be made. These decisions may be equipment-performed (automatic) or based upon operator knowledge.

Redundant sensors and actuators shall be used where loss of a sensor or actuator would cause significant loss of test data or reduction of plant availability.
SECTION 4.0 PRINCIPLES OF OPERATION

4.1 STARTUP CONTROL

Prior to nuclear startup, with all control mechanisms positioned for maximum worth, the primary coolant and core will be preheated (500 to 600 °F) to permit the major portion of the core expansion to occur before any control mechanisms are withdrawn. Also, this preheating will reduce thermal stresses on fuel elements and components during startup. As nuclear startup begins, and heat is being generated in the core, the coolant flows in the heat dissipation systems will be adjusted to maintain temperature control stability.

Neutron flux will be monitored by the subcritical instrumentation as the reactivity is adjusted during startup. As subcritical multiplication is increased, inverse multiplication plots will be calculated and displayed to the operator for use in determining the proper approach to criticality. When criticality has been achieved, the reactivity will be adjusted to maintain a prescribed reactor period. The intermediate range instrumentation will be used to monitor reactor period and power level as soon as sufficient flux is available at the flux sensors to provide a reliable indication.

When the power range is reached (above 1% of design power), linear power level and rate-of-rise instrumentation take precedence over other nuclear channels. Also, significant changes in reactor coolant outlet temperatures will begin to appear. Depending on the particular tests involved, it may be advisable simultaneously to raise power level and inlet temperatures. Provision will be made for automatic control of these functions as well as manual control of various control devices.
\section*{4.2 NORMAL REACTOR OPERATION}

Compared to other fast reactors, the distinguishing features of FFTF operating cycles will be the high burnup rate and operation of multiple closed loops. An on-line efficiency goal of 75\% may be achieved by alternate 6 week operating, 2 week shutdown periods, for example. The startup swing will be of the order of 1.0\% \(\Delta\text{k}\) depending upon operating sodium and fuel temperatures.

Indicators, dials, video monitors, and strip chart recorders will be arranged near the console for convenience and ease of observation by the reactor operator. The operator, observing the indicating and recording instruments, can control the power level of the reactor by operating control mechanisms on the console. Parameters affecting reactivity will be on display continuously or intermittently available to the console operator. Other controls in the control room can be used to regulate sodium temperature, flow, pressure, level, and other pertinent reactor and test loop parameters.

Instrumentation and control devices will be used to permit either manual or automatic control. It is anticipated that the reactor will be started up initially by manual methods. Prior to its use, any automatic control system will receive comprehensive acceptance testing by means of a reactor simulator. During future operations, as detailed knowledge of the plant characteristics is accumulated, and as certain portions of the reactor control system demonstrate clearly that they can be controlled by automatic means without compromising reactor safety, these portions will be switched to automatic control.

Three methods of power level detection are used for control purposes:

- Neutron Flux (Neutron Chambers, Etc.)
- Reactor Outlet Temperature
- Thermal Power Calculation from Reactor Differential Temperature and Flow Rate.

Although it is expected that constant long-term power level operation will be a prime objective for a majority of the in-reactor tests, the nature of the test assemblies is such that relatively rapid changes in reactivity may occur during testing. Plant safety and continuity of operation will be improved by detecting power level changes as soon as possible. A combination of the first and third methods above best achieves this objective.

Neutron flux measurements in the power range are rapid, making it possible to achieve relatively tight control of power level. Good reliability can be achieved by use of multiple chambers and averaging-rationality check logic circuitry. Therefore, neutron flux measurements are used for direct control of power level through the medium of control mechanism actuation. The reference setpoint for this controller is calculated from a master power level controller. The master controller determines the actual thermal power level, compares it to the desired power level and generates the required setpoint signal for reactivity adjustments. In this way, flux chamber calibration drifts are compensated and the fast response of the flux chambers is fully utilized to enhance reactor stability and safety. The relatively slow, but more accurate, thermal measurements also are used effectively to maintain an accurate power level condition. This philosophy is similar to the EFFBR power level design. Optimum power level control modes will be determined by more detailed analysis and simulation as the control mechanism and process design progresses.
4.3 SHUTDOWN

Two types of reactor shutdown modes will be used; one is the fast scram mode described in 4.5, where the reactor will be shut down as fast as possible. The other is a "controlled shutdown" mode in which control mechanisms are inserted into the reactor core automatically at a rate which causes least disturbance to the fuel test specimens or the least damage to the reactor structure.

Trips which do not require maximum reactor shutdown rates will be included in the controlled shutdown program. These trips monitor such incidents as loss of a secondary pump, single power line failure, secondary loop over-temperature, and fire. In each case, the hazard to the reactor does not require a two-second shutdown (scram) of the reactor with its attendant thermal shock problems. A 4, 6, 8, or perhaps a 30 sec shutdown time greatly reduces the thermal shock problem, which in turn is less likely to destroy test results on elements being tested and invariably results in less damage and reduced maintenance on the overall system.

Slower shutdown rates for noncritical reactor problems in no way compromises the safety of the reactor because the fast scram safety circuit will always detect when any parameter approaches unsafe operating limits and shut the reactor down as fast as possible.

A third shutdown method which will probably be the one used whenever possible, at least at first, will be the manual controlled shutdown handled by the operator, thereby inducing the least possible thermal stresses to the systems and damage to the test specimens.

Once the reactor is shut down, a normal outage period might typically be two weeks. A normal two-week outage would be
used with five days for refueling 8 to 10 driver elements, two open test positions, one closed loop, startup preparations and interim examination. Nine days would be allowed for maintenance, loop adjustments, delays, scrams, etc.

4.4 SPECIAL OR INFREQUENT OPERATION

The FFTF will provide a large and varied capability for fuel and material testing in open test positions. Thus, instrumented open test position or closed-loop testing in any core lattice position not otherwise occupied may require special treatment. Indeed, driver fuel positions may be considered to be open test positions since they may be instrumented to record operating performance data. In addition, the following experimental facilities will necessitate special operation.

DDCN-2 Reflector open test positions are all located in reflector stations adjacent to the outer row of core fuel positions. While these reflector positions may be charged with fuel specimens at the reactor operator's option, it is assumed that all reflector positions normally will be used for material (nonfuel) tests only.

DDCN-1 A reflector open test position hole may be assigned to the Short Term Irradiation System wherein short-term tests may be performed. The irradiation test positions in the FTR are not limited to closed loops, and open test positions. Other locations may be considered near the core which are accessible from the top of the reactor. These spaces can be utilized as additional test holes without enlarging the reactor or without jeopardizing proposed loop tests.

DDCN-1 Generally, the reflector open test positions will be charged and discharged by the fuel handling machine with the same techniques used for driver fuel positions. The
FFTF provisions for post-irradiation examination of fuel are equally suitable for materials examination; hence, the facilities will exist within the FFTF complex to permit comprehensive examination of all types of test specimens, including test hole material specimens.

Another special or infrequent operation may be a traveling wire flux monitor. This records the flux profile at several points inside and outside the reactor core. A single traveling wire flux monitor involves the operation of a switch block to direct it to any of several desired channels.

Finally, it is likely that brief periods of reactor operation will be required at specialized conditions of neutron flux, temperature or other environmental factors. Failed fuel testing may require operating periods of briefer duration than the normal cycle in many instances.

4.5 EMERGENCY OPERATION

4.5.1 Scram and Transient Behavior

The relatively large differential temperatures existing across reactor core, combined with a relatively low heat storage capacity in the core, cause rapid changes in reactor outlet temperatures during scrams. Because of the thermal strains caused by these temperature changes, fast scrams will be avoided whenever possible. Analog simulation studies indicate that fuel temperature changes approaching $300^\circ F/sec$ may be expected from scram reactivity rates of $5\$/sec. Therefore, the number of events which can cause a fast scram will be minimized consistent with adequate safety considerations. Typical safety circuit trips are listed in 3.2.2, Reactor Safety System.

No outside occurrence can find its way into the reactor to cause damage without being detected by one of these
safety circuit trips. In any case, the scram safety circuit will override the controlled shutdown circuit and would shut the reactor down rapidly if some parameter exceeded safe conditions during a controlled shutdown. The reactor and its components will last longer, be stressed less, and be inherently safer to operate if controlled shutdowns are applied to noncritical conditions requiring shutdown.

Emergency procedures will be formulated for all reactor and plant systems where action is necessary to maintain safety and high plant availability in the event of casualty conditions. The plant design will incorporate features to minimize the complexity of emergency actions.
SECTION 5.0 MAINTENANCE PHILOSOPHY

The order of preference of performing maintenance work at FFTF is as follows:

A. Contact maintenance - repair of components in place to the extent permissible, consistent with radiation exposure and other personnel safety considerations.

B. Removal of components for decontamination and repair by contact maintenance.

C. Decontamination, either internal, external or both, of components and cells to permit either A or B above, or for remote repair in maintenance cell.

D. Remote maintenance - in those areas in which irradiation or excessive contamination would prohibit contact maintenance, facilities will be provided to either perform remote maintenance in place, or to remotely remove and replace components.

The process portion of the ventilation system is to be designed for maintenance on fans, equipment and filter replacement only under reduced air flow conditions. Matching supply and exhaust are provided for this purpose and maintenance work will require scheduling with reactor operation to permit the reduced airflow conditions. This method of maintenance is proposed in lieu of standby ventilation equipment, except for hot cells which have standby exhaust equipment.

Maintainability is to be designed into the reactor heat dissipation system. In most instances maintenance operations will be of the replacement type in contrast to in-situ repair work. Maintenance of the primary loop components will largely depend on remote operations, the secondary system may be maintained by direct contact. Essential maintenance tooling is to be designed and built to be available for prooftesting prior to reactor operation.
Provision shall be made for maintaining and removing either complete loops or loop components considering problems inherent in alpha and gamma radiation, radioactive contamination and sodium environment.

In summary, the FFTF maintenance philosophy will be to emphasize contact maintenance and direct operation to the extent possible. Replacement of failed components rather than repair in place will be stressed; however, where required, facilities will be provided for remote repair.
APPENDIX A

LIST OF CONCEPTUAL DESIGN DESCRIPTIONS
AND SUPPORTING MAJOR STUDIES

A. UTILITY SYSTEMS

Structure*

Site*

Primary Electrical Power System

Building Electrical Power System
  1. Study of Alternate Heating Methods for Sodium Piping

Electrical Control System

Communications System

Lighting System

Service Piping System
  2. Building Heat Source Study

Heating and Ventilation System
  3. Study of Ventilation, Filtration and Cleanup During Containment
  4. Ventilation, Exhaust Filter Requirements Study
  5. Ventilation, Transient Temperature Study & Emergency Power Requirements

Plant Fire Protection System

Reactor Containment System
  6. Concrete Cooling Methods Study
  7. Containment Criteria Study
  8. Sodium Fire Study

Radioactive Waste System

B. REACTOR SYSTEMS

Reactor Nuclear Control System
  1. FTR Control Method Evaluation Study
  2. Study of Mechanisms for Reactor Control
  3. Criteria for Reactivity Worth of Control Safety Rods

* Conceptual Facility Design Description
4. Nuclear Design Criteria - Split Core FTR Reactor Safety System

DDCN-1

Reactor Heat Transport System

5. Factors in Heat Removal System Evaluation
6. Technical Basis for FFTF Main Heat Removal System Concept and Concept Configuration Selections
7. Control Concepts Study

DDCN-1

Inert Gas Receiving and Processing System
Sodium Receiving and Processing System

REACTOR COMPONENTS

Reactor Core*
Reactor Vessel and Shielding*

8. Comparative Evaluation of FTR Concepts
9. Blast Containment Study
11. Thermal and Hydraulics Design Criteria - Split Core FTR
12. FFTF Mixed Oxide and Full Performance Fuel Core Design Analysis
13. Effect of Test Elements and Test Loops on FTR Neutronics
14. Material Design Curves - Type 304 Stainless Steel
15. Shielding Calculations for Manipulating Irradiated FTR Fuel
16. Shielding Calculations for FFTF Sodium Systems
17. Preliminary FTR Shielding Calculations

C. IRRADIATION TEST SYSTEMS AND FACILITIES

Closed Loop System
1. Functional Testing Requirements
2. Gas Cooled Loop Feasibility Study
3. Evaluation of Primary Piping Methods
4. Value Analysis - Closed Loop Concepts
5. Physics Evaluation of Closed Loop Effects

DDCN-1

Short Term Irradiation Facility
6. Evaluation of Specimen Insertion methods

DDCN-1

Open Test Position Facility**

* Conceptual Component Design Description
** Conceptual Facility Design Description
D. COMPONENT HANDLING SYSTEMS

Reactor Refueling System
1. Preliminary Study - Decay Heat Removal
2. System Effectiveness Study
3. Auxiliary Tool Cask Study
4. Wet Fuel Handling Machine Study
5. Gas Fuel Handling Machine Study
6. Secondary Gamma Shield Study

Nonirradiated Fuel Handling System

Irradiated Fuel Handling System
7. Fuel Transfer Cell Study

Radioactive Maintenance System
8. M&D Cell Size and Capability Study

E. EXAMINATION SYSTEM AND FACILITIES

Water Treatment System for Underwater Examination
1. Criticality Safety Study

Inert Gas Examination Facility*
2. Fuel Subassembly Gas Cooling Study
3. Contamination Control Study

Underwater Cell Examination Facility*
Radiometallurgy Facility*
4. Justification Study

F. UNIFIED INSTRUMENTATION AND CONTROL SYSTEM

DDCN-1 Control and Data Handling System
1. Conceptual Evaluation Study

DDCN-1 Reactor Channel and Vessel Instrumentation System
2. Technical Basis - Core Instrumentation

DDCN-1 Plant Instrumentation System
Fuel Failure and Control System
Flux Monitoring and Control System
Radiation Monitoring System

* Conceptual Facility Design Description
G. MAJOR FFTF CONCEPTUAL DESIGN STUDIES

1. BNWL-470 Progress Report Fast Flux Test Facility Reference Concept
2. APDA Alternate Skewed Core Reactor Concept
3. APDA Fixed Shield Plug Vertical Core Concept
4. INC Alternate Reactor Arrangement
5. PNL II Alternate Concept
6. GE Alternate Concept
7. W Alternate Concept
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