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FAST FLUX-TEST FACILITY

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VOLUME 82

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Volume 82

FAST FLUX TEST FACILITY

CONCEPTUAL SYSTEM DESIGN DESCRIPTION
FOR THE
INERT GAS RECEIVING AND PROCESSING SYSTEM
No. 82

December 4, 1968

PACIFIC NORTHWEST LABORATORY
Richland, Washington 99352
Operated by
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INERT GAS RECEIVING AND PROCESSING SYSTEM

INTRODUCTION

Section 1.0, Functions and Design Requirements, of this CSDD is baseline data.

This document consists of the main body of the CSDD, and the appendices. The main body describes the various inert gas systems conceived to fulfill the requirements of the FFTF Overall Conceptual Systems Design Description.¹

Appendices B, C, and E directly support the main body in regard to Support Information Requirements, Interfaces, and Supporting Information. Appendix D contains the rationale leading to the choices of inert gases for the various applications. Appendix A contains the references used throughout this document.

This document summarizes and describes the inert gas systems' design concepts and the work which led to selection of the concepts.

1. Refer to References, Appendix A, Item 1.

SECTION 1.0 FUNCTIONS AND DESIGN REQUIREMENTS

1.1 FUNCTIONS

The following functions are provided by the Inert Gas Receiving and Process System:

- A. Receive, store, supply¹ and process gases for the FFTF applications listed in Section 1.2.2 Concept Related Design Requirements.
- B. Maintain a suitable environment including composition, temperature, purity, and pressure as appropriate in each space filled with inert gas.
- C. Provide controlled holdup for disposal of radioactive gases.
- D. Provide vacuum services for evacuation of sodium systems.
- E. Provide pressurized inert gas for pneumatic equipment, instrumentation, and miscellaneous services required in the inerted cells in the FFTF.
- F. Provide inert gas for flooding by the Plant Fire Protection System.
- G. Provide capability for filling, draining, and inert gas purging of the sodium systems.

1.2 DESIGN REQUIREMENTS

The following design requirements are imposed by the system functions listed in Section 1.1, by FFTF testing facility requirements, by interface relationships with other systems, and by considerations of plant operation, maintenance, availability and safety.

-
- 1. Refer to Inert Gas Selections for FFTF Applications, Appendix D.

1.2.1 Basic Design Requirements

The following basic design requirements pertain to system design regardless of system concept.

- A. Design, fabrication, and construction of the Inert Gas Receiving and Processing System shall conform to the most recent issue of codes and standards listed in Hanford Standard Design Criteria, HWS-10006, Chapter SDC-1.2 or FFTF standards which shall be prepared as necessary to meet special requirements. In addition, USAS B31.7 Code for Pressure Piping - Nuclear Power Piping shall apply to the piping systems containing radioactive gases. Pressure vessels for storing radioactive gases shall be designed as Class C vessels covered by Section III of the ASME Boiler and Pressure Vessel Code.
- B. Gas purity shall be maintained within prescribed limits.¹ Purity control for sodium cover gases shall be by means of feed and bleed.
- C. Gas pressures for all applications shall be maintained within prescribed limits.²
- D. Equipment shall be provided to prevent sodium vapors from entering inert gas system components which are sensitive to sodium vapor.³

-
- 1. Refer to Support Information Requirements, Appendix B, Item 1.
 - 2. Refer to References, Appendix A, Item 2 (page B-1) and Item 3 (page B-2).
 - 3. Refer to Support Information Requirements, Appendix B, Item 3.

- DDCN-2 E. Radiological Design Criteria, BNWL-MA-3 and Radiation Protection Procedures, BNWL-MA-6 shall be used as a guide in the design of the shielding and access barriers in order that shielding and/or access barriers will limit radiation exposures to within the requirements of AECM-0524.
- DDCN-1 F. (Paragraph Deleted)
- G. Gas sampling equipment shall monitor all inert gas atmospheres for radioactive and non-radioactive gaseous contaminants, as required.¹ Monitoring equipment for radioactive gas spaces shall not also be used for monitoring non-radioactive gas streams.
- DDCN-1 H. Gaseous service systems shall use gases consistent with the atmosphere in which they are operated. (Argon for pneumatic tools in argon cells, for examples.)
- I. Major piping and equipment items required for initial operation shall be designed to accommodate ultimate plant operating requirements.²
- DDCN-1 1. Refer to Support Information Requirements, Appendix B, Item 5.
2. Refer to References, Appendix A, Item 1.

- DDCN-1 J. (Paragraph Deleted)
- DDCN-1 K. (Paragraph Deleted)
- L. Inert gas systems shall be designed to prevent leakage and backflows of contaminants from low purity to high purity zones or from high radioactivity to low radioactivity zones.
- M. The Inert Gas Receiving and Processing System shall be designed consistent with achieving the FFTF overall plant availability goal of 75%.¹ Consideration shall be given to the effects of the system on the availability of interfacing systems, components, and facilities.
- DDCN-1 N. This system shall satisfy the criteria establishing quality which will be defined and documented during design. These criteria shall cover:
1. Design
 2. Fabrication and construction
 3. Operation
 4. Maintainability
- DDCN-1 O. An inert atmosphere shall be provided for equipment cells which normally contain primary sodium storage and processing systems, the reactor vessel, and primary sodium heat transport systems.

1. Refer to Support Information Requirements, Appendix B, Item 4.

- DDCN-1 P. Sufficient radioactive gas storage capacity shall be provided to permit control of activity levels in normally inert areas under FFTF design conditions¹ without exceeding the allowable radioactivity release criteria,² and without impairing FFTF operations. Allowance shall be made for vented fuel tests in the Closed Loops. Items or provisions required to permit future vented fuel operation in the open loops or in the driver core shall be determined by a study.³
- Q. Control of radioactive gases shall be exercised by sealing, and by feed-and-bleed purging. Sealing provisions for inert cells⁴ or inert gas filled systems⁵ shall be designed so that excessive feed-and-bleed is not required, and that allowable radionuclide concentrations⁶ in adjacent air-filled spaces are not exceeded due to gas leakage.
- R. The pressure reference used to provide pressure control for the various inert gas spaces shall be the same as that used by the Heating and Ventilation System.⁷
- S. Brush materials, voltage, and rating of electrical equipment shall be selected to be compatible with the atmosphere in which the equipment is to operate.⁸

-
- DDCN-1 1. Refer to Support Information Requirements, Appendix B, Item 6.
2. Refer to References, Appendix A, Item 7, and Interfaces, Appendix C, Item 8.
3. Refer to Support Information Requirements, Appendix B, Item 9.
4. Refer to Interfaces, Appendix C, Items 4 and 10.
5. Refer to Interfaces, Appendix C, Items 16, 17, and 21.
6. Refer to References, Appendix A, Item 7.
7. Refer to Interfaces, Appendix C, Item 8.
8. Refer to Inert Gas Selections for FFTF Applications, Appendix D, Section 4.2.1.4.

- T. Connectors other than standard fittings needed by interfacing systems to receive inert gas services shall be provided by the interfacing system.
- U. Inert gas system equipment and instrumentation requiring frequent maintenance shall be located in air filled areas insofar as is practical. Maintenance operations requiring life support suits for personnel shall be minimized.
- V. Instruments, controls, alarms, and protective devices shall be provided as required to meet operational and safety requirements.¹
- W. The FFTF shall be designed to permit continued reactor operation following driver or open test position fuel failures to limits to be determined.¹
- X. Sodium systems and loops shall be designed to facilitate sodium filling and draining and gas purging to avoid pressure buildup due to trapped gas pockets.

DDCN-1

1.2.2 Concept Related Design Requirements

- A. Provisions shall be included to permit replacing the atmosphere in normally inerted cells with air for personnel access.^{2,3} Provisions shall be included to minimize suffocation and fire hazards. Special consideration shall be given to the ventilation of air spaces immediately adjacent to inert gas cells to assure that suffocation hazards are minimized.

-
- 1. Refer to Support Information Requirements, Appendix B, Items 5 and 13.
 - 2. Refer to Interfaces, Appendix C, Item 8.
 - 3. Refer to References, Appendix A, Item 3 (pages 5-1 and B-3).

DDCN-1

- C. Gas cooling systems shall be provided for regulating temperature of the atmosphere in all inerted cells. Cooling shall also be provided for fuel and components in the fuel transfer and fuel examination cells.¹
- D. A vacuum system shall be provided for evacuating systems during outgassing and sodium filling and following maintenance operations.
- E. Filters shall be provided to remove particulate and volatile radioactive contaminants including plutonium from the recirculating gas in the fuel transfer and examination cells, and other spaces as required.²
- F. Fuel transfer and fuel examination cells shall have gas enter near ceilings and exhaust near floor (for control of aerosols and particulates).
- DDCN-1 G. (Paragraph Deleted)
- H. The design shall preclude oil from compressors and vacuum pumps entering systems which they service.
- I. Inert gas applications shall be according to Table I.
- J. Emergency electrical power shall be available to the components of the Radioactive Gas Decay and Disposal System, and the equipment used to cool fuel subassemblies.

1. Refer to References, Appendix A, Item 8 (page B-2).
2. Refer to Support Information Requirements, Appendix B, Item 12.

TABLE I. Inert Gas Applications¹

1.	Reactor Primary Heat Transport System	Argon
2.	Reactor Primary Sodium Processing System	Argon
3.	Closed Loop Primary Heat Transport System	Argon
4.	Closed Loop Primary Sodium Processing System	Argon
5.	Reactor Secondary Heat Transport System	Argon
6.	Reactor Secondary Sodium Processing System	Argon
7.	Closed Loop Secondary Heat Transport System	Argon
8.	Closed Loop Secondary Sodium Processing System	Argon
9.	Fresh Sodium Receiving and Processing System	Argon
10.	Contaminated Sodium Processing System	Argon
11.	Closed Loop Cell Atmosphere	Nitrogen
12.	Reactor Primary Sodium Processing Cell Atmosphere	Nitrogen
13.	Reactor Primary Heat Transport Equipment Cell Atmosphere	Nitrogen
14.	Contaminated Sodium Processing Cell Atmosphere	Nitrogen
15.	Radioactive Maintenance Cell Atmosphere	Nitrogen
16.	Fuel Transfer and Examination Cell Atmosphere	Argon

1. Refer to Inert Gas Selections for FFTF Applications, Appendix D.

- DDCN-1 in the Fuel Transfer and Examination Cells. Emergency power shall also be available to the gas system cooler units such that unacceptable damage is not incurred by equipment in each inert equipment cell as a result of loss of cooling following failure of normal power.
- K. The oxygen level in cells with a nitrogen atmosphere shall not exceed 5% by volume¹ except during periods when the cell atmosphere is air. The oxygen level shall normally be less than 2% and greater than 0.5% by volume to inhibit sodium fires and to prevent nitriding of stainless steels.²
- DDCN-1 L. Heaters shall be provided to permit heating of the gas³ in the reactor cavity so that reactor preheating may be accomplished by this method.
- DDCN-1 1.2.3 Design Safety Criteria Requirements
- A. Personnel radiation protection shall be provided such that personnel radiation exposures are within the limits of AECM-0524. (DSC 1.1)⁴
- B. Adequate holdup capacity will be provided for radioactive gases to allow sufficient decay in order to meet the requirements of AECM-0524 and RL Supplements when released via the filters and stack system. (DSC 1.2)⁴

-
- DDCN-1 1. Refer to References, Appendix A, Item 9.
2. Refer to References, Appendix A, Items 10 and 11.
3. Refer to Support Information Requirements, Appendix B, Item 2.
4. Refer to References, Appendix A, Item 5.

- C. The oxygen content of the cells serviced by the Inert Gas Receiving and Processing System will be measured and controlled at a safe level to minimize the potential for sodium fires. (DSC 1.3)¹
- D. The hydrogen content of the cells serviced by the Inert Gas Receiving and Processing System where sodium is normally reacted with homogeneous reagents will be measured and controlled at a safe level. (DSC 1.4)¹
- E. The release or venting of radionuclides from the Inert Gas Receiving and Processing System will be monitored and controlled within acceptable limits. (DSC 1.5)¹
- F. Provisions will be included in the design to facilitate maintenance repair or servicing of radioactive and/or contaminated components of the system. (DSC 1.6)¹
- G. Components and cells serviced by or part of the Inert Gas Receiving and Processing System that contain potentially radioactive pressurized gas will be protected by rupture discs and/or pressure relief valves which relieve to the radioactive gas decay and disposal system or areas serviced by that system. (DSC 1.7)¹
- H. The Inert Gas Receiving and Processing System will have sufficient isolation valving and instrumentation to facilitate leak checking and maintenance. (DSC 1.8)¹
- I. The design of the Inert Gas Receiving and Processing System will be consistent with the design of the reactor containment system to insure the containment functions of the latter system. (DSC 1.9)¹

1. Refer to References, Appendix A, Item 5.

SECTION 2.0 PHYSICAL DESCRIPTION OF THE SYSTEM

This section describes the systems which are provided to fulfill the functions and design requirements listed in Section 1.0. Design and development items required for completion of subsequent design efforts are identified in the text.

The Inert Gas System includes the systems listed below. The schematic drawings located in Appendix G indicate the components, piping, and valves symbolically in the enumerated systems.

<u>Schematic Number</u>	<u>System Title</u>
• SK-3-12783	Nitrogen Receiving and Distribution System
• SK-3-12784	Argon Receiving and Distribution System
• SK-3-12785	Argon Processing System Fuel Transfer and Fuel Examination Cells
• SK-3-12786	Radioactive Gas Decay and Disposal System
• SK-3-12787	Vacuum System.

Changes of these systems may be required as a result of further conceptual definition of interfacing systems; preliminary design work on these systems may also dictate changes. Preliminary estimates of sizes and capacities of the major components of these systems developed in Appendix E are given in Section 2.2 Detailed Description.

2.1 SUMMARY DESCRIPTION

A summary description of each of the subsystems of the Inert Gas System is given below.

2.1.1 Nitrogen Receiving and Distribution System

Nitrogen, received from vendor sources, is stored for distribution under controlled conditions. The distribution system supplies nitrogen gas at regulated pressure to provide an inert gas atmosphere in cells containing the primary sodium heat transport systems, the reactor, the contaminated sodium processing system, and the Radioactive Maintenance cell. Cooler units control the temperature in these cells. Atmospheric purity is maintained by feed and bleed. Nitrogen exhausted from these cells is vented to the heating and ventilating exhaust system, or to the Radioactive Gas Decay and Disposal System depending on the potential for contamination.

In the event that inert gas is chosen as a means of fighting fires¹ in certain plant areas, nitrogen from this system may be required for this purpose.

2.1.2 Argon Receiving and Distribution System

Argon, received from vendor sources, is stored for distribution under controlled conditions. The distribution system supplies argon gas at regulated pressure to provide an inert atmosphere in the Fuel Transfer and Examination Cells, and to provide cover gas for all sodium systems. Argon vented from the serviced systems passes directly to the heating and ventilating exhaust system, or to the Radioactive Gas Decay and Disposal System depending on potential for activity or contamination.

1. Refer to References, Appendix A, Item 12 (page B-1).

In the event that inert gas is chosen as a means of fighting fires¹ in certain plant areas, argon from this system may be required for this purpose.

2.1.3 Argon Processing System - Fuel Transfer and Fuel Examination Cells

Argon gas, received from the Argon Receiving and Distribution System, is used to provide a controlled inert environment within the Fuel Transfer and Examination Cells. Cooler units control the temperature in these cells. Cell pressure control is normally maintained by variation in cell temperature with pressure regulation devices providing control when pressure variations are beyond the capability of the normal method. Atmospheric purity is maintained by catalytic converters for oxygen and hydrogen, by molecular sieve beds for moisture, and by feed and bleed for other contaminants. Auxiliary pressure blowers provide argon for fuel subassembly cooling. Pneumatic tools in these cells are operated with argon supplied by a compressor-receiver unit. Argon exhausted from these cells is vented to the Radioactive Gas Decay and Disposal System for disposal.

2.1.4 Radioactive Gas Decay and Disposal System

Nitrogen and argon vented from potentially contaminated spaces is received by this system. The incoming gases are monitored and are released to the heating and ventilating exhaust system or are compressed into decay holdup tanks depending on the activity level. Gases stored in the decay holdup tanks are released under plant procedures to the

1. Refer to References, Appendix A, Item 12 (page B-1).

Heating and Ventilating exhaust stack after analysis determines that the activity of the gases in the tanks is acceptable for release. Inert gases received from fuel and component cleaning facilities are stored in separate tanks to preclude the formation of flammable hydrogen-oxygen mixtures in a storage tank.

2.1.5 Vacuum System

Vacuum systems are provided for evacuation of gas from sodium systems, and for evacuating other systems as required. One system is used for evacuation of radioactive systems; a portable vacuum pump discharges into the Radioactive Gas Decay and Disposal System. The other system is used for evacuation of non-radioactive systems; a portable vacuum pump discharges to the heating and ventilating exhaust system. Flexible hoses or removable conduits are used to connect the system being evacuated to the pumps, and to connect the pump to the collection manifolds.

2.2 DETAILED DESCRIPTION

This section describes the systems of the Inert Gas System in detail. Section 2.2.1 describes the major components of the systems, and Section 2.2.3 describes the instrumentation and controls associated with the various systems.

2.2.1 System Description

2.2.1.1 Nitrogen Receiving and Distribution System

The Nitrogen Receiving and Processing System¹ receives, stores, and distributes nitrogen to the following user systems:²

-
1. Refer to Drawings, Appendix G, SK-3-12783.
 2. Refer to Inert Gas Selections for FFTF Applications, Appendix D.

- Primary sodium storage and processing system cells
- Primary sodium heat transport equipment cells
- Reactor cavity
- Closed loop cells
- Maintenance and decontamination cell
- Contaminated sodium processing equipment cells
- Radioactive sodium piping galleries.

Liquid nitrogen is received from vendor sources and is stored in liquid storage units equipped with vaporizers, quantity instrumentation, and pressure controls which provide ambient temperature gas on demand at a regulated supply pressure.

Nitrogen gas flows through supply manifolds to pressure control valves which provide nitrogen to the cells at the desired pressure levels. The cell pressure regulators use the same pressure reference as does the Heating and Ventilation System¹ so that the desired pressure differentials² between air and nitrogen cells can be maintained.

Nitrogen purity³ within the inert cells is maintained by feed-and-bleed, as controlled by oxygen level sensing equipment.⁴ Normally, these cells are maintained between 0.5 and 2% by volume of oxygen,^{3,5} which is sufficiently low to minimize sodium oxidation which would follow the release of molten sodium into the cell through a sodium piping failure, and sufficiently high to inhibit nitriding of exposed stainless steels in the cell. Gas vented from these cells passes

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1. Refer to Interfaces, Appendix C, Item 8.
 2. Refer to References, Appendix A, Item 2 (page B-1).
 3. Refer to Support Information Requirements, Appendix B, Item 1.
 4. Refer to Interfaces, Appendix C, Item 21.
 5. Refer to References, Appendix A, Item 9.

through high efficiency filters to the Radioactive Gas Decay and Disposal System for disposition.

Heat exchanger-blower units^{1,2} are provided in these inert cells to circulate and cool the nitrogen atmosphere of the cells. Heating of the atmosphere in the reactor cavity will be necessary to assist in preheating the reactor vessel prior to the original sodium filling operation and to assist in maintaining the vessel temperature during reactor shut-down. The system requirements to achieve this will be determined during preliminary design.³

This system is similar in principle to systems used in other sodium reactors to maintain inert atmosphere in sodium equipment cells. Therefore, this system can be designed using state-of-the-art technology.

2.2.1.2 Argon Receiving and Distribution System

The Argon Receiving and Distribution System⁴ receives, stores, and distributes argon to the following user systems:⁵

- All sodium cover gases
- Reactor Refueling System
- Irradiated Fuel Handling Facility
- Fuel examination facility
- Sodium sampling and analysis facilities.

-
1. Refer to References, Appendix A, Item 13 (page B-2).
 2. Refer to Support Information Requirements, Appendix B, Item 4.
 3. Refer to Support Information Requirements, Appendix B, Item 2.
 4. Refer to Drawings, Appendix G, SK-3-12784.
 5. Refer to Inert Gas Selections for FFTF Applications, Appendix D.

Liquid argon is received from vendor sources and is stored in liquid storage units equipped with quantity instrumentation, vaporizers, and pressure controls which provide ambient temperature gas on demand at a regulated supply pressure. Argon gas flows through supply manifolds to pressure control valves which provide argon to the user systems at the desired pressure levels.

The cover gas for the reactor vessel, the reactor primary and closed loop primary heat transport systems, and for the primary sodium processing systems is provided by a recirculating gas system. This recirculating system receives argon from the main supply manifold, and stores it in a holdup tank. The gas is supplied as required by these radioactive systems at regulated pressures from an auxiliary supply manifold connected to this holdup tank. Argon vented from these systems flows to a collection manifold through a sodium vapor trap to a suction tank maintained at sub-atmospheric pressure by diaphragm type compressors¹ which compress the gas in the holdup tank. This recirculating system is used for following reasons. The first is that high demands for argon such as might occur following a reactor scram can be met by the gas in the holdup tank without requiring a sudden surge flow from the main supply manifold; this removes potentially stringent flow demands on the vaporizers on the liquid argon supply and on the piping and equipment between the argon supply and the reactor. The second reason is that the argon in the reactor vessel and the reactor and

1. Refer to Support Information Requirement, Appendix B, Items 4 and 11.

closed loop primary heat transport systems will be activated by neutron irradiation. Gas flows resulting from sodium volume changes would result in unnecessarily passing gas to the Radioactive Gas Decay and Disposal System unless this recirculating system were used. This would represent an unnecessary usage of the radioactive gas system since argon vented from radioactive sodium systems can normally be reused in the same user systems. The third reason is that the cover gas pressures are essentially atmospheric. A sub-atmospheric pressure tank is therefore desirable to provide good gas flow characteristics through the serviced systems. The compressor's suction can provide this subatmospheric pressure; a suction tank provides a reservoir which will allow the compressors to operate cyclically rather than continuously.

The argon gas for the other sodium cover gas application is supplied directly from the main supply manifold. The gas pressure in those systems will normally be somewhat higher than atmospheric, and the gas will not be activated. Therefore, the gas can be vented to the heating and ventilating exhaust system or directly to the uncontrolled atmosphere for sodium systems not located in a building.

DDCN-1 Normally, cover gas flows will occur only during barometric or temperature transients, or during purging, sampling, and fuel failure detection/location¹ operations. However, the cover gas of each sodium system may be purged as required by opening and closing the appropriate block valves.

The Contaminated Sodium Processing System, the Fuel Handling System, the Fuel Transfer and Examination Cells, and the Sodium Sampling and Analysis System are also supplied with

DDCN-1 1. Refer to Interfaces, Appendix C, Item 23.

argon from this system. These systems can be expected to cause radioactive contamination of the contained argon gas. Consequently, these systems discharge gases directly to the Radioactive Gas Decay and Disposal System for disposition since it would not be possible to vent the contaminated argon to the uncontrolled atmosphere, nor would it be desirable to contaminate the primary cover gases with the effluent products from these systems.

This system is within the state-of-the-art. It is similar to the system used in the Enrico Fermi Atomic Power Plant where this type of system has proven to be satisfactory. The basic difference is that there is no gas purification system between the argon supply and the argon distribution system as there is in the Fermi system. A purification system is unnecessary due to the high purity of liquid argon. The maximum impurity specifications¹ in commercially available liquid argon are moisture 6 ppm, nitrogen 7 ppm, and oxygen 4 ppm. A typical analysis shows less than 1 ppm each of oxygen and moisture.¹ The oxygen and nitrogen impurity levels are lower than those measured² in the cover gas of operating sodium reactors; the moisture level is sufficiently low to pose no problem. A purification system is therefore unnecessary. In order to insure safety during operations, the argon in each freshly filled argon supply will be analyzed before any gas is admitted to the main supply manifolds. Once the quality of gas in the argon supplies is determined to be satisfactory, it will be opened to the main supply manifold for use.

1. Refer to References, Appendix A, Item 14 (page 21).

2. Refer to References, Appendix A, Item 10 (pages 6 and 8).

2.2.1.3 Argon Processing System - Fuel Transfer and Fuel Examination Cells

The Argon Processing System¹ circulates, filters, cools, and purifies the argon atmosphere in the Fuel Transfer and Fuel Examination Cells. Pressure controlled supply valves meter argon from a supply manifold to the cells for an atmosphere supply, and for auxiliary purposes such as seal buffering as appropriate. An oil seal for relieving gas over-pressures is provided in addition to pressure controlled exhaust valves. The cell exhaust is vented to the Radioactive Decay and Disposal System.

Compressors and pressure blowers drawing from the recirculating argon in the facility maintain a supply of compressed argon which is distributed to in-cell service outlets for operation of pneumatic equipment, and for cooling of fuel and material test specimens under examination or in temporary storage in the examination facilities.² A cooling system³ located outside of the transfer and examination cells controls the temperature of the argon circulating through the cells. The coolers are designed so that cell pressure may be controlled by cooling of the gas in the facility. The cell coolers provide the primary means of cell pressure control with pressure regulating valves acting as a secondary control.

Oxygen and water concentrations⁴ are controlled by a purification system which operates on a side stream of argon from

1. Refer to Drawings, Appendix G, SK-3-12785.

2. Refer to References, Appendix A, Item 8 (page B-2).

3. Refer to References, Appendix A, Item 13 (page B-2).

4. Refer to References, Appendix A, Item 15 (page 3).

the facility. A compressor passes this sidestream of argon through a catalytic converter which utilizes hydrogen gas as the reagent. Water vapor from inleakage and from operation of the catalytic converter is trapped in a molecular sieve bed. Nitrogen impurities in the cell atmosphere¹ are controlled by feed and bleed of argon as required.

This system is similar in principle to the argon system used in the Fuel Cycle Facility (FCF) of EBR-II which has operated quite satisfactorily for several years. However, the requirements and purposes of the FCF and the FFTF Fuel Transfer and Examination Cells are quite different. The main difference is that cooling of uncleaned fuel subassemblies with argon is necessary in the Fuel Transfer Examination and Cells of FFTF while only cleaned and unassembled fuel pins are cooled with argon at the FCF. This is the reason for the inclusion of the pressure blowers² which circulate argon through the fuel subassemblies within the facility and for the study to be performed to determine the means necessary to control sodium vapor and fission products in these cells.³

In other respects, the argon system for this facility is essentially the same as that of FCF, and should present no technical problems that have not been encountered and accommodated there.

2.2.1.4 Radioactive Gas Decay and Disposal System

The Radioactive Gas Decay and Disposal System⁴ receives, monitors, and disposes of gases vented from portions of the

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1. Refer to Support Information Requirements, Appendix B, Item 1.
 2. Refer to References, Appendix A, Item 8 (page B-2).
 3. Refer to References, Appendix A, Item 8 (page B-3).
 4. Refer to Drawings, Appendix G, SK-3-12786.

nitrogen and argon systems. The incoming gases are monitored for activity, and are released directly to the building ventilation exhaust system or are compressed into decay holdup tanks for controlled release.

The equipment in this system consists of activity monitors,¹ diversion valves, exhaust blowers, a suction tank, high efficiency filters, diaphragm type compressors,² and decay holdup tanks to contain active gases. The gases flowing into this system are segregated according to expected activity or chemical content: normally non-radioactive, normally radioactive, and hydrogen bearing. Normally all the gases entering the system pass directly to the ventilation exhaust stack of Heating and Ventilating System for release to the uncontrolled atmosphere. Should the activity of gases entering the system from a particular source be higher than a predetermined level,³ the applicable monitor¹ will operate a diversion valve to shunt the contaminated gas to the compressor circuit. The compressors, actuated also by the monitor, will then compress the gases into the decay holdup tanks. The gases will remain in the holdup tanks until released after analysis determines the activities and consequent allowable release rates under plant procedures. A final activity monitor at the exit to this system acts as a check on the total activity being released at any time. In event of out of excessive activity in the stack or in the discharge manifold the

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1. Refer to Interfaces, Appendix C, Item 22.
 2. Refer to Support Information Requirements, Appendix B, Item 11.
 3. Refer to Interfaces, Appendix C, Item 8.

holdup tanks are automatically shut off to assist in determining the source of the undesirable release.

Hydrogen bearing gases from the fuel and component sodium removal facilities in the Fuel Transfer and Examination cells, and from the Maintenance and Decontamination cell are treated separately although in the same general manner as above. This approach is taken to preclude the possibility of forming flammable gas mixtures in a holdup tank, such as might occur from adding hydrogen bearing inert gas to a tank containing some contaminated air from a sodium cell cleanup or maintenance operation.

This system is similar to the waste gas system used in other reactors, and is designed utilizing conventional technology.

2.2.1.5 Vacuum System

The vacuum system¹ is provided for evacuating sodium systems in preparation for filling with sodium and for evacuating other systems as required.

Two portable vacuum pumps are provided, one for radioactive systems and one for non-radioactive systems. Valved and capped connections which can be connected to the vacuum pump by flexible hoses or removable conduits are provided for piping systems requiring vacuum and sampling service. A vacuum exhaust header carries gas from radioactive systems to the Radioactive Gas Decay and Disposal System.

1. Refer to Drawings, Appendix G, SK-3-12787.

2.2.2 Components

This section describes the major components that make up the inert gas systems. Preliminary size estimates¹ of these components are given as part of the description.

2.2.2.1 Liquid Argon and Liquid Nitrogen Storage Units

Liquid storage tanks² with vaporizers, instrumentation, and pressure controls are sized for anticipated normal and emergency makeup requirements and to satisfy reliability considerations.³ These vacuum insulated units are designed for liquid nitrogen and liquid argon service. They are commercially available units that come in several standard sizes with standard auxiliary equipment. The units are self pressurizing with gas boil-off resulting from heat gains which will cause the units to lose approximately 0.5% per day of the contained liquid. Vaporizers attached to each unit will produce approximately 4000 cfh of ambient temperature nitrogen gas, utilizing the atmosphere to provide the necessary heat for this purpose. Further study⁴ is required to determine if auxiliary electrical vaporizers will be required to permit vaporization of nitrogen at rates substantially in excess of 4000 cfh per unit.

The required capacity and number of such units will be determined during preliminary design. Preliminary estimates⁵

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1. Refer to Supporting Information, Appendix E, Section 1.0.
 2. Refer to Supporting Information, Appendix E, Section 4.0.
 3. Refer to Support Information Requirements, Appendix B, Items 4 and 10.
 4. Refer to Support Information Requirements, Appendix B, Item 10.
 5. Refer to Supporting Information, Appendix E, Section 1.0.

based on estimated usage requirements indicate that four liquid storage units each containing approximately 3000 gallons of liquid nitrogen will be sufficient to fulfill the requirements for nitrogen for the FFTF. The liquid argon units are identical to the above although only one unit is required.

2.2.2.2 Vapor Traps

A sodium vapor trap is provided in the recirculating argon cover gas system to prevent sodium vapor from entering the suction tank and compressors. A study will be made¹ to determine which of several types² of vapor trap will be used in the recirculating gas system. This trap represents a contingency installation inasmuch as each sodium filled component will include a vapor trap to confine sodium vapor to the gas space within the component; the component vapor traps are the responsibility of the interfacing system. A preliminary estimate³ indicates that a vapor trap consisting of a NaK pool and a stainless steel wool column contained in an externally cooled tank will satisfy the need for the recirculating argon system. The vapor laden argon is bubbled through the NaK, and passes through the steel wool to remove the remaining sodium vapor. This vapor trap will handle 50 cfm of vapor laden argon. This type of unit has proven to be satisfactory in the Fermi reactor plant.

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1. Refer to Support Information Requirements, Appendix B, Item 3.
 2. Refer to References, Appendix A, Item 16.
 3. Refer to Supporting Information, Appendix E, Section 1.6.

The vapor trap described above represents a contingency installation inasmuch as each sodium filled component will include a vapor trap to confine sodium vapor to the gas space within the component. These component vapor traps are the responsibility of the interfacing system. It is unlikely that the component vapor traps will be as elaborate as the vapor trap for the recirculating argon system.

2.2.2.3 Filters

High efficiency particulate filters (99.97% efficient) are provided by the inert gas system in the inlet to the gas compressors for recirculating systems, on the reactor cavity outlet and other locations as required.¹ They are also provided on the fuel transfer and fuel examination cell outlets, and on the inlet to the argon blowers associated with those cells.² The pressure drop across these filters will be measured continuously to provide an indication as to when filter changes are required. Further study¹ is required to establish the need for roughing filters ahead of the high efficiency filters as well as the possible need for halogen filters in the fuel exam and fuel transfer cells.

2.2.2.4 Compressors

Gas compressors are required to circulate argon in the recirculating argon cover gas system, for providing compressed gas for service applications in the fuel exam and fuel transfer cells, for compressing radioactive gas into

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1. Refer to Support Information Requirements, Appendix B, Item 12.
 2. Refer to References, Appendix A, Item 17 (page 6).

the decay storage tanks, and for cooling fuel subassemblies in the Fuel Transfer and Examination Cells. Compressor types will be determined and the sizes will be verified during preliminary design.¹ Preliminary estimates² for compressors are given below:

<u>Application</u>	<u>Compressor Type</u>	<u>Delivery SCFM³</u>	<u>Discharge Pressure psig</u>
Cover Gas Recirculation	Diaphragm	28	40
Pneumatic Tools in Fuel Transfer and Exam Cells	Piston	220	100
Radioactive Gas Compressor (Large)	Piston	350	150
Radioactive Gas Compressor (Small)	Piston	45	150
Fuel Subassembly Cooling	Centrifugal ⁴	1000	5

2.2.2.5 Argon Purification Equipment

The equipment to control water and oxygen content in the Fuel Transfer and Examination Cells consists of a molecular sieve bed and catalytic reaction bed. A sidestream of argon from the cell atmosphere is mixed with an appropriate quantity of

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1. Refer to Support Information Requirements, Appendix B, Item 11.
 2. Refer to Supporting Information, Appendix E, Sections 1.5, 1.6, and 1.7.
 3. At 70 °F and 14.7 psia.
 4. Refer to References, Appendix A, Item 8 (page B-2).

hydrogen gas and is passed into the catalytic reactor. The hydrogen reacts with the oxygen impurity to form water vapor which is removed in the downstream molecular sieve bed. This equipment will also provide a measure of control of hydrogen in the cell atmosphere. This type of equipment is commercially available and is widely used in various industries to control oxygen levels in inert gases. A similar system is used in the Fuel Cycle Facility (FCF) of EBR-II and has operated very satisfactorily for several years. Based on preliminary estimates,¹ the purification equipment will have to handle approximately 83 cubic feet of argon per minute to maintain the oxygen content of the cell atmosphere at 25 ppm on a 50% duty cycle. The oxygen and water contamination level would be allowed to build up to a maximum level. The purification equipment would then be started to bring the levels down to a minimum. This method of operation has been adopted at the FCF and has proven to be satisfactory.

2.2.2.6 Cell Atmosphere Coolers

Cell atmosphere coolers are shown on the Nitrogen Receiving and Distribution System, and the Argon Processing System for the Fuel Transfer and Examination Cells. These coolers are conventional gas to liquid heat exchangers with temperature control exercised by variation in the flow of heat transport fluid. A ventilation fan provides the gas flow required for these coolers. The heat transport fluid used to carry the heat away from these cooler units will be supplied by another

1. Refer to Supporting Information, Appendix E, Section 1.8.

system.^{1,2} The required capacity of these coolers will be verified during preliminary design. Preliminary estimates³ are given below.

<u>Location</u>	<u>Heat Load, BtuH</u>	<u>Approximate Cell Outlet Temp., °F</u>	<u>Gas</u>	<u>Gas Flow cfm</u>	<u>Blower Motor HP</u>
Closed Loop Cells	100,000	100	N ₂	5,000	5
Reactor Cavity	3,500,000	200	N ₂	35,000	50
Maintenance & Decontami- nation Cell	210,000	100	N ₂	10,000	10
Primary Na Processing Cells	200,000	100	N ₂	10,000	10
Reactor Access Space	100,000	100	N ₂	5,000	5
Fuel Transfer & Exam Cells	1,430,000	110	Ar	70,000	60
Primary Na Heat Trans- port Cells	100,000	100	N ₂	5,000	5

2.2.2.7 Gas Receivers

A gas receiver and a suction tank are provided in the recirculating cover gas system. Receivers and suction tanks are also provided in the Radioactive Gas Decay and Disposal

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1. Refer to References, Appendix A, Item 13 (page B-2).
 2. Refer to Interfaces, Appendix C, Item 6.
 3. Refer to Supporting Information, Appendix E, Sections 1.2 and 1.4.

- J. The design of the Inert Gas Receiving and Processing System will be consistent with the design of the reactor heat transport system to insure reactor cooling and containment functions of the latter system. (DSC 1.10)¹
- K. The design of the Inert Gas Receiving and Processing System will be such that no single fault will result in loss of subassembly cooling. (DSC 1.11)¹

1. Refer to References, Appendix A, Item 5.

System to permit radioactive gases to be compressed and held until they may be released at a controlled rate so that radioisotopes normally released in the building stack effluent will not exceed the release limitations.¹ Study during preliminary design will verify the required capacity and number of the receivers² in the Radioactive Gas Decay and Vent System. Preliminary estimates³ of receivers are given below:

<u>Application</u>	<u>Pressure, psia</u>	<u>Total Tankage Volume, cubic feet</u>
Recirculating Cover Gas Holdup Tank	55	500
Recirculating Cover Gas Suction Tank	10-12	500
Radioactive Gas Holdup Tanks	165	10,000
Radioactive Gas Suction Tank	10-12	500

2.2.3 Instrumentation and Controls

Instrumentation for the monitoring and control of the inert gas system is indicated schematically in the schematic diagrams (Appendix F). In-line gas system components directly affecting parameters in the inert gas system will be provided by the inert gas system. Measurements and the controllers for gas system components will be provided by

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1. Refer to Interfaces, Appendix C, Item 8.
 2. Refer to Support Information Requirements, Appendix B, Item 6.
 3. Refer to Supporting Information, Appendix E, Section 1.0.

the Plant Instrumentation System. System control parameters will be established by the inert gas system requirements. Instrumentation pertinent to this system is listed in Tables F-1, F-2, and F-3 of Appendix F; this instrumentation is properly part of Systems 93 and 96.

2.2.3.1 Flow

Flow is a measured parameter. The Plant Instrumentation System is responsible for the design of flow measuring equipment using data provided by the inert gas system. Flow totalizers are provided primarily as an indication of gas usage which in turn is useful in determining system leakage. Flowmeters are provided on system supply mains. Flow is not normally controlled directly except in the fuel subassembly cooling circuits in the fuel transfer and examination cells. Flow control in those circuits will be exercised by varying¹ the speed of the blowers providing the cooling gas flow.²

2.2.3.2 Pressure

Total and differential pressures will be measured¹ in a variety of locations in the inert gas systems to provide data for control¹ purposes and for information as to system or component performance. Appropriate indicators and alarms are provided to indicate out of tolerance pressure levels. Vapor traps¹ will be used to prevent sodium vapor from degrading the performance of the instrumentation applying to the argon system.

1. Refer to Interfaces, Appendix C, Item 21.

2. Refer to References, Appendix A, Item 8 (page B-2).

The pressure in the inert gas spaces and cells will be controlled¹ according to the requirements of the application which will be established by the Inert Gas Receiving and Processing System requirements. Control of gas pressures will be provided by the Plant Instrumentation System using valves provided by the Inert Gas Receiving and Processing System.

Pressure is controlled in a vessel or facility by the operation of two regulating valves, one upstream to admit gas on low pressure or flow demand, and one downstream to maintain the selected system pressure by venting. The two valves which are elements of the inert gas system are governed by a split range (Duplex) controller as a direct function of the desired pressure. This controller is an element of the Plant Instrumentation System. Two gas admittance valves are provided for the cover gas pressure control system: one valve is for normal control and the other opens if the pressure in the vessel drops below the normal operating range. For inert cells the pressure reference for the control valves will be the same as that used by the Heating and Ventilation System² to assure that preset differential pressures can be maintained accurately.

The pressure control system for the Fuel Transfer and Examination cells is slightly different. Pressure control for those cells is exercised by the cell cooling system as well as the inlet and exhaust pressure regulators. Normally pressure control is maintained by the operation of the

1. Refer to Interfaces, Appendix C, Item 21.

2. Refer to Interfaces, Appendix C, Item 8.

cooling system which cools the cell atmosphere to reduce pressure, and allows the cell temperature to rise when an increase in pressure is needed. The controller which operates the coolant valve to the heat exchanger is an element in the Plant Instrumentation System. When the limits of control by this mode are reached, the inlet and outlet pressure regulators meter gas into or out of the cell as controlled by the Plant Instrumentation System. This approach to cell pressure control is taken to conserve argon as much as possible because of the cost factor. For example, if a barometer pressure drop of 0.5 inches of mercury occurred, it would be necessary to vent approximately 1600 cubic feet of argon to maintain the cell pressure differential. This assumes the total cell volume is approximately 100,000 cubic feet. However, no gas would need to be vented if the average cell temperature was reduced about 9 °F because this would automatically reduce the cell pressure. Venting and feeding will still be necessary but the use of cell temperature control as a pressure control will reduce the frequency of venting and feeding.

High efficiency particulate filters will be monitored by differential pressure measurement¹ across the filter. This measurement may be made directly by ΔP cells or inferentially by separate measurement of absolute pressures. In either case, a high-low alarm will be used to warn of out-of-limit operation. High ΔP alarm indicates filter plugging (or loading) beyond its design tolerance. Low ΔP alarm indicates failure because of unimpeded gas flow through or around the filter.

1. Refer to Interfaces, Appendix C, Item 21.

2.2.3.3 Temperature

Temperature will be measured¹ continuously in a variety of locations to provide data for control purposes,¹ and for information as to system or component performance as required by the inert gas system. Appropriate indicators and alarms¹ are provided to indicate normal and out of tolerance operation. Temperature of inerted cells is controlled automatically by operation of the cell coolers. The temperature control¹ system holds the circulating inert gas temperature within set limits by operating the coolant flow valve which varies the coolant flow through the heat exchangers in the cooler units. The coolant flow valve is an element of the inert gas system while the controller is an element of the Plant Instrumentation System.

2.2.3.4 Gas Quality

All gas systems will be monitored¹ for contaminants detrimental² to the equipment and materials in the inert atmospheres. These contaminants include hydrogen, oxygen, nitrogen, light hydrocarbons, water vapor, carbon monoxide and carbon dioxide. The instruments and controls¹ include appropriate sampling and analysis equipment,³ gas purification process variable controls,¹ and purging controls¹ for those spaces controlled by feed and bleed.

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1. Refer to Interfaces, Appendix C, Item 21.
 2. Refer to Support Information Requirements, Appendix B, Item 1.
 3. Refer to Support Information Requirements, Appendix B, Item 5.

SECTION 3.0 SAFETY CONSIDERATIONS

This section outlines the foreseeable hazards involved in the inert gas system, and describes the precautions necessary to allay the hazards.

3.1 HAZARDS

- A. Inadvertent or accidental admissions of air to an inert gas application. This could result in an immediate sodium-air reaction, as in the case of high temperature over-sodium applications or in a potential sodium-air reaction situation, as would exist in the case of substitution of air for nitrogen in a high temperature closed loop cell.
- B. Over-pressurization of systems, components or cells.
- C. Spread of radioactive contamination due to component failure.
- D. Personnel suffocation resulting from entry into an inert cell before air purging has been completed.
- E. Process failure from loss of inert gas pressure.
- F. Spread of radioactive contamination due to maintenance operations.
- G. "Burns" from personnel exposure to cryogenic gases.
- H. Uncontrolled release of radioactive gas to atmosphere or building spaces as might occur with failure of the radioactive gas decay-disposal system.
- I. Inadvertent injection of oil into sodium systems during evacuation.
- J. Hydrogen leakage into inerted cells from sodium cleaning equipment resulting in explosive mixtures while purging with air.

- K. Exposure of operating or maintenance personnel to unacceptable radiation dosage from gas systems or components containing radioactive gases.

3.2 PRECAUTIONS

These precautions describe the means to be taken to allay the hazards outlined in Section 3.1. The alphabetical listing in this section corresponds one-for-one with the listing in Section 3.1.

- A. Maintain sodium cover gas applications at positive pressure with adequate alarms to warn of loss of positive pressure. Positive sensing of oxygen levels is provided for inert cells atmospheres.
- B. Rupture discs are provided in critical installations as required by codes and good engineering practice. Normal controls will prevent overpressurization, with ultimate protection from rupture discs. Effluent gas from disc ruptures of normally radioactive systems will be vented to spaces which are serviced by the Radioactive Gas Decay and Disposal System.
- C. Radioactive contamination spread is minimized by thorough sealing of those systems containing radioactive gas under positive pressure. Zone control utilizing differential pressures among the various building spaces will confine any contamination to specific areas in event of an unplanned release of radioactive isotopes.
- D. In inert gas cells, instrumentation will continuously indicate oxygen levels so that personnel may be warned of anoxic conditions.

- E. Gas process equipment will be designed to reduce the probability of loss of pressure in case of failure of gas supplies. Check valves will be used to contain gas in systems in event of supply failure. Low pressure alarms are provided, and in event of accidental loss of gas pressure, suitable protection will be provided in the form of automatic process system shutdown.
- F. The system and components will be designed to prevent contamination spread from maintenance operation. For example, filter installation will permit bagging of contaminated filters. Mechanical equipment will be valved to permit isolation from the remainder of the system.
- G. Injury from contact with cryogenic gases will be prevented by proper procedures and by design utilizing adequate insulation of piping and components.
- H. Uncontrolled release of radioactive gas to the atmosphere must be precluded by sufficient redundancy¹ in activity sensors and shut-off valves to prevent such release from occurring. The radioactive gas tanks will be located in a confinement or containment area. The Heating and Ventilating stack monitor will have overriding control of all radioactive gas release systems.
- I. Design of vacuum systems will prevent oil or oil vapor from entering systems being evacuated.
- J. Normally inerted cells will be purged with inert gas prior to purging with air if gas sampling indicates the presence of potentially hazardous hydrogen levels.

1. Refer to Support Information Requirements, Appendix B, Item 4.

- K. All gas systems or components that will contain radioactive gases will be suitably shielded or will be located in shielded vaults to permit operating or maintenance personnel to perform their duties without incurring unacceptable radiation doses.

SECTION 4.0 PRINCIPLES OF OPERATION

This section will describe the usual operations performed with the Inert Gas Receiving and Processing Systems, illustrating how the systems will operationally fulfill the System Functions and Design Requirements, as well as pointing out a number of applications of items in Appendix B, Support Information Requirements.

4.1 STARTUP

Initial startup involves the performance of the necessary cleaning, testing, and purging operations; control settings are established to maintain proper temperatures, pressures, and atmospheric conditions within the inert gas systems. Sodium systems are preheated¹ and evacuated to an absolute pressure of one torr or less² by operation of the Vacuum System to reduce the oxygen and nitrogen concentrations in the system, and to outgas the sodium system. The evacuated system is then filled with pure argon prior to commencement of sodium filling operations. Sodium systems³ are designed with high-point vents so that gas displaced by sodium during a system or loop filling operation can be freely vented to avoid a buildup of gas pressure.

4.2 NORMAL OPERATION

4.2.1 Nitrogen Receiving and Distribution System⁴

A nitrogen atmosphere is normally maintained in the primary sodium storage tank cells, in the primary sodium purification

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1. Refer to Support Information Requirements, Appendix B, Item 2.
 2. Refer to Support Information, Appendix E, Section 2.0.
 3. Refer to Interfaces, Appendix C, Items 16, 17, and 20.
 4. Refer to Drawings, Appendix G, SK-3-12783.

cell, in the closed loop cells, in the machinery dome, in the reactor cavity, and in the main heat transport cells. Gas quality control instruments actuate nitrogen supply and exhaust valves to each of these spaces to maintain the required nitrogen purity by feed-and-bleed.

The gas pressure in each of these cells is controlled by a split range (or duplex) controller such that at pressures below a lower limit set point, gas is admitted to the cell and at pressures above an upper limit set point gas is vented from the cell. The set points are such that the vent valve is normally closed when the supply valve is open and vice versa. The cell pressures are set to maintain differentials between the cells and the surrounding air atmosphere areas; these differentials are balanced¹ so that radioactive contamination that may appear in the inert cells will be confined near the point of origin, and will not normally enter the air atmosphere areas. Should it be necessary to change the pressure in a nitrogen cell, this can be accomplished by adjusting the set points of the split range controller to the desired level.

The temperature in these cells is normally regulated between fixed limits by the cell cooler units. These units automatically vary the flow of coolant through the heat exchangers to hold the nitrogen temperature in the desired range, over a span of heat loads. No heaters are necessary in these spaces because the sodium systems and installed

1. Refer to References, Appendix A, Item 2 (page B-1).

mechanical/electrical equipment will normally liberate sufficient heat for temperature control even during times when the sodium systems are on standby.¹

Normally, flow into or out of the cell occurs only in response to a barometric or cell temperature change, or as required to maintain the oxygen content in the cells atmospheres between 0.5 and 2%. Exhaust gas from these spaces flows into the Radioactive Gas Decay and Disposal System or to the Heating and Ventilating System. Spaces containing equipment in which radioactive gases may normally be present are vented to the Radioactive Gas Decay and Disposal System. Purging of the individual cells with air for personnel access requires isolation of the nitrogen supply and admission of air from the building ventilation system. This can be accomplished for example, in Closed Loop Cell No. 6 by closing nitrogen supply valve V-4-43, and by opening air supply and exhaust valves V-4-76 and V-4-82. Each cell has a cooler unit for removing heat released from the cell equipment and for circulating the cell gas.

This system will have sufficient redundancy² to assure satisfactory operation both from operational availability and from a reliability standpoint.

4.2.2 Argon Receiving and Distribution System

The Argon Distribution System³ is divided into several branches to serve the following users:

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1. Refer to Supporting Information, Appendix E, Section 3.0.
 2. Refer to Support Information Requirements, Appendix B, Item 4.
 3. Refer to Drawings, Appendix G, SK-3-12784.

- The recirculating cover gas system.
- The contaminated sodium processing system.
- The Fuel Handling Machine.
- The fresh sodium storage and processing system.
- The reactor secondary heat transport system.
- The reactor secondary sodium processing system.
- The closed loop secondary heat transport system.
- The closed loop secondary sodium processing system.
- The Fuel Transfer and Examination cells.

The Argon system is made up of two sub-systems. One sub-system is a recirculating system utilizing compressors, suction and hold-up tanks, vapor traps and associated piping. The other sub-system is a nonrecirculating system (feed and bleed) with the discharge to the ventilation filtered exhaust system, or to the Radioactive Gas Decay and Disposal System.

The gas spaces served by the recirculating gas system are supplied with argon from the holdup tank TK-1-2 which receives argon from the main supply manifold as required. Pressure control instruments (typically PIC-1-1) actuate supply and exhaust valves to meter gas into or out of the circuit branch as required by the particular sodium system being serviced. Normally gas flow through these circuit branches occurs only as a result of barometric variation or sodium volume changes.

Gas vented from these circuit branches passes through vapor traps to the suction tank TK-1-3, which is maintained at subatmospheric pressure by compressors C-1-1 and C-1-2; these compressors also hold the pressure in holdup tank TK-1-2 at the desired level. Individual branches of this

recirculating system may be purged as desired by operating the appropriate valves to bypass pressure control valves which must be made inoperative during the purging sequence. Normally the purge flow remains in the recirculating system, flowing around the system because of the pressure differences induced by the compressors.

When it becomes necessary to purge the system to reduce the contained concentration of radioactive gas or the impurity concentration due to diffusional inleakage,¹ the appropriate valving can be operated to pass the purge gas to the Radioactive Gas Decay and Disposal System. During this time, fresh argon will automatically flow into the recirculating system from the main supply manifold.

The non-recirculating portions of the Argon Receiving and Distribution System operate similarly. The only difference is that gas vented from those circuit branches is vented directly to the Radioactive Gas Decay and Disposal System, or to the Heating and Ventilating exhaust system depending on the potential for radioactivity. It is not clear at this writing if the Fuel Handling Machine will be continuously connected to the argon system or will be intermittently supplied with argon at a service connection. The requirements for this interface will become known during preliminary design.

This system has sufficient redundancy to assure satisfactory operation both from an operational availability and a reliability viewpoint.²

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1. Refer to Support Information Requirements, Appendix B, Item 1.
 2. Refer to Support Information Requirements, Appendix B, Item 4.

4.2.3 Argon Processing System - Fuel Transfer and Fuel Examination Cells¹

Argon gas is supplied to the Fuel Transfer and the Fuel Examination cells from the argon distribution system described in the preceding section. The fuel transfer-fuel exam cell complex is serviced by manifold supply and exhaust ducts so that a single gas system serves all portions of the complex and maintains balanced pressure and temperature conditions. Argon from the distribution header is introduced into the cells through individual valves, for example, through supply valve V-1-227. This provides the basic cell atmosphere. A master controller MC-1-1, utilizing temperature and pressure input data from the cell complex, maintains the pressure and temperature in each cell according to a preselected value. Manual adjustment of this controller is provided. Particulate contamination is removed from the circulating argon by filters, for example, F-1-4 and F-3-1A. A portion of the gas, collected downstream from the coolers, is compressed by compressors C-1-4 or C-1-5 and is held in an accumulator TK-1-4 for distribution to service outlets within the cells for operation of pneumatic equipment. During examination of the fuel elements, cooling gas for the fuel assembly is supplied through auxiliary blower circuits² drawing argon from the cell through individual filters (e.g. F-1-5) and heat exchangers (e.g. HX-1-1). The argon is returned to the cell for sub-assembly cooling by the pressure blowers (e.g. B-1-1).

1. Refer to Drawings, Appendix G, SK-3-12785.

2. Refer to References, Appendix A, Item 8 (page B-1).

Another fraction of the cooled argon passes through an oxygen and moisture removal equipment to aid in controlling the atmospheric composition.¹ A gas analyzer is used to monitor the operation of this purifier.

Two pressure relief systems are provided to relieve possible over pressures during venting operation. The normal relief consists of a pressure regulator valve (PCV-1-38) which exhausts through an oil seal pit to the Radioactive Gas Decay and Disposal System; the oil seal acts as a check valve to prevent backflow of contaminants from the radioactive gas system. The backup pressure relief consists of an oil seal pit only. Gas can escape from the cell by bubbling through the oil. The backup relief system is used to guard against malfunction of the normal system and to provide a greater capacity relief system than the normal system affords. Air purging of the cells for personnel access is accomplished by isolating the argon gas supply and opening the air supply valve so that air may flow into the cell from the building ventilation system. For example, the fuel transfer cell may be air purged by opening air supply and exhaust valves V-1-176 and V-1-185 and closing argon supply and exhaust valves V-1-227 and V-1-184. If it were desired to purge the cells with argon it could be accomplished by opening valve V-1-226 to bypass the pressure control valves by closing the exhaust valve to the main coolers (e.g. V-1-184) and by opening the bypass valves to the Radioactive Gas Decay and Disposal System (e.g. V-1-185 and V-1-199). The exhausted gas from all purge or vent operations goes to the Radioactive Gas Decay and Disposal System.

1. Refer to References, Appendix A, Item 15.

This system has sufficient redundancy¹ to assure satisfactory operation both from an operational availability and from a reliability standpoint.

4.2.4 Radioactive Gas Decay and Disposal System

Potentially radioactive gases from the nitrogen, argon and vacuum systems are vented to the Radioactive Gas Decay and Disposal System.² Gas sample activity monitors¹ (S-3-1 through S-3-4) continuously check the gas streams entering this system for radioactivity. Normally these gas streams pass through diverting valves¹ DCV-3-1, DCV-3-3, DCV-3-5 and DCV-3-8 to the exhaust header from which the gases are directed to the Heating and Ventilation System vent stack after passing through a final activity monitor¹ S-3-5. High activity in any of the three gas streams cause the appropriate activity monitor to actuate the corresponding diverting valves (DCV-3-1 and DCV-3-2 for example) to pass the gas to compressors C-3-2 and C-3-3 which compress the gas into the decay storage tanks (e.g. TK-3-4).³

If the activity of the gases flowing through the exhaust header is less than the allowable limit as measured by monitor S-3-5, additional gases from the radioactive gas decay storage tanks may be released. The contents of a given tank (e.g. TK-3-4) are then analyzed to determine the activity. This activity level is determined by drawing off a specimen through the sampler connection (e.g. V-3-29) and

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1. Refer to Support Information Requirements, Appendix B, Item 4.
 2. Refer to Drawings, Appendix G, SK-3-12786.
 3. Refer to Support Information Requirements, Appendix B, Item 6.

performing the necessary analysis. The allowable rate of release is then calculated and the flow metering valve group (e.g. PCV-3-2 and FCV-3-2) is adjusted to release at the allowable rate. The gas shutoff valve (e.g. V-3-18) is then opened to permit the gas to be passed to the discharge system.¹ If excessive activity is released by error, monitor S-3-5 will automatically close valve DCV-3-9 preventing any release until the error has been corrected.

4.2.5 Vacuum System

This system functions during plant startup and maintenance operations. Paragraph 4.4.5 describes the normal operation of this system.

4.3 SHUTDOWN

The inert gas systems are necessary to assure the safety of many systems in the FFTF. This section of this document describes the procedure for complete shutdown of the various inert gas systems. Operationally, complete shutdown of a major inert gas system would occur under only the most exceptional circumstances and would necessitate shutting down portions of the reactor plant also. Routine maintenance may require partial shutdown or special operation of the inert gas systems; such operation is described in Section 4.4 of this document.

1. Refer to Interfaces, Appendix C, Item 8.

4.3.1 Nitrogen Receiving and Distribution System

This system is shut down in the following sequence.

- A. The nitrogen filled spaces are air purged by
 - 1. First purging each space with nitrogen to sweep out accumulated hydrogen if the sampling instrumentation indicates that such is necessary.
 - 2. Purging with air to provide a breatheable atmosphere in each space normally filled with nitrogen.
- B. The nitrogen supply tanks are then shut off.
- C. The cooler units are then shut down.
- D. Electrical power is then turned off.
- E. The nitrogen storage tanks are then emptied.

4.3.2 Argon Receiving and Distribution System

The following steps are necessary to shut down this system should it become necessary:

- A. The argon storage tanks are isolated by operating the appropriate valves.
- B. The electrical power to the system component and instrumentation is turned off.
- C. The storage tanks are then emptied.

4.3.3 Argon Processing System - Fuel Transfer and Fuel Examination Cells

This system is shut down in the same general manner as described for the Nitrogen Receiving and Processing System, Paragraph 4.3.1.

4.3.4 Radioactive Gas Decay and Disposal System

It is unlikely that this system would be completely shut down after the FFTF becomes operational. The following procedure describes the steps necessary to accomplish the shutdown should it become necessary.

- A. The areas serviced by the inert gases are purged as necessary to reduce gas activity levels, and operations curtailed sufficiently to remove major radioactive gas sources. The gas sampling instrumentation is used extensively to reach assurance that radioactive gas evolution is at a low enough level that the gases may be vented to the stacks.
- B. Referring to SK-3-12786, Appendix G, valves V-3-9, V-3-11, and V-3-13 are closed to isolate the main compressors from the tanks.
- C. Compressors C-3-1, C-3-2 and C-3-3 are turned off.
- D. Sufficient time is allowed for the system to dispose of the radioactive gas in the Decay Storage Tanks. The gases contained in the tanks are continuously checked to provide current data on activity of gas being discharged.
- E. Valves V-3-9, V-3-11 and V-3-13 are then opened.
- F. Compressors C-3-1, C-3-2 and C-3-3 are started and the tank pressure is built up to a selected level.
- G. This shutdown sequence is re-entered at B above. This allows purging of the Decay Storage Tank.
- H. After several such purges, the tanks have been purged of radioactive gases. The shutdown sequence is then ended at D above and the electrical power is shut off.

4.3.5 Vacuum System

Operational and shutdown procedures will be described in Paragraph 4.4.5.

4.4 SPECIAL OPERATION

This section describes special operations of a non-emergency nature that may be expected for these systems.

4.4.1 Nitrogen Receiving and Distribution System

This system can be operated with one or more cells isolated from the system as explained in Section 4.2.1.

Another special operation that will be performed is periodic testing to verify the adequacy of the cell sealing provisions by measuring the cell leakage. Testing of individual cells can be performed by raising the cell pressure to a specified value and measuring the volume makeup rate necessary to hold the cell pressure at the selected value. The cell test pressure would be chosen as appropriate to the type of test being performed. The exact testing methods and criteria have not been resolved at this writing, but guidance is available.¹

4.4.2 Argon Receiving and Distribution System

This system can be operated with one sodium system isolated from the system. For example, if maintenance is required on one of the closed loop primary pumps, it can be isolated by closing supply and exhaust valves V-1-58 and V-1-161.² The remainder of the gas system can still be operated during this process.

1. Refer to References, Appendix A, Item 77.

2. Refer to Drawings, Appendix G, SK-3-12784.

When it is desired to operate the Fuel Handling Machine, the supply valves to those systems must be opened. For example, to operate the Fuel Handling Machine, valves supply and exhaust valves¹ V-1-103 and V-1-104 are opened to provide a source of argon and an exhaust connection.

4.4.3 Argon Processing System - Fuel Transfer and Fuel Examination Cells

During standby storage or examination of fuel assemblies, cooling of the fuel assemblies are required. For example, assume a fuel assembly in the Fuel Transfer Cell that requires axial cooling. A hose is remotely connected to the fuel assembly and the other end is connected to the line controlled by supply valve V-1-200.² The blower B-1-1 is then started but is run below maximum speed because relatively high pressure argon at reduced flow is necessary to provide axial cooling.³

Lower pressure and greater volume flow is required when the flow is transverse to the fuel bundle center line: this is the normal cooling mode when fuel assemblies are under pin examination. To provide this cooling, a hose is connected between the transverse cooling shroud and the argon line on the blower suction. The cooling is provided by drawing argon from the cell atmosphere through the fuel subassembly to the blower suction; the circulating argon is discharged into the cell on return. Using the Fuel Transfer Cell again as an example, the hose connects to the line filtered by filter F-1-5.

1. Refer to Drawings, Appendix G, SK-3-12784.

2. Refer to Drawings, Appendix G, SK-3-12785.

3. Refer to References, Appendix A, Item 8 (page B-2).

The blower is then started and is run at full speed, drawing cooling argon through the fuel subassembly. The proper flows are obtained by adjusting the system pressure drop with valve V-1-201. The heat exchanger HX-1-1 cools the argon to a level tolerable to the blower.

4.4.4 Radioactive Gas Decay and Disposal System

No special or infrequent operation of this system is planned other than partial shutdown for routine maintenance.

4.4.5 Vacuum System

The vacuum system is used for evacuating sodium systems or segments thereof prior to filling of sodium systems and following maintenance operations. Evacuation is necessary to remove air and to outgas the sodium system, thus assuring an initially clean system.

Two portable vacuum pumps are provided. The first pump¹ (VP-2-1) services the radioactive systems, which include the reactor vessel and the primary heat transport system, the reactor primary sodium storage tanks, the contaminated sodium dump tank, the irradiated driver-fuel decay storage vessels, the closed loop primary systems and the Short Term Irradiation Facility. The second pump (VP-2-2) is for non-radioactive service including the fresh sodium storage tank, the reactor secondary heat transport systems, the closed loop secondary tanks, and the closed loop secondary transport systems. Vapor traps installed on the suction side of the pumps are necessary to reduce the risk of damaging the

1. Refer to Drawings, Appendix G, SK-3-12787.

pumps by the sodium vapor. These traps are also portable. The trap for pump VP-2-2 may be simply installed on the pump stand, but the trap for pump VP-2-2 must be adequately shielded inasmuch as it may trap radioactive sodium.

To establish vacuum in the above systems, the vacuum pump is transported to the point at which it will be used, and is connected to the component or system to be evacuated by a flexible hose or a removable conduit. The vacuum pump is then started. The appropriate valves are then activated. For example, evacuation of the Fresh Sodium Storage Tank will be accomplished by following the above procedure. Sodium valves V-1-4, V-1-5, V-1-9 and V-1-18 are closed to isolate the tank from the sodium systems.¹ Gas supply and exhaust valves V-107 and V-110 are closed.² Vacuum valves V-2-16, V-2-18, and V-2-17 are then opened.³ The required vacuum is then obtained by the pump. This system cannot be operated for radioactive systems unless the Radioactive Gas Decay and Disposal System is operating also. To shut down this system, the above procedure is followed in reverse especially in regard to closing the vacuum system valves before turning off the vacuum pump.

4.5 EMERGENCY OPERATION

The inert gas system interfaces with almost every system in the FFTF. As a result it is not practical to consider in detail in this document every possible emergency situation that

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1. Refer to References, Appendix A, Item 13 (Appendix G, SK-3-12715).
 2. Refer to Drawings, Appendix G, SK-3-12784.
 3. Refer to Drawings, Appendix G, SK-3-12787.

could arise during operation of the FFTF. Consideration of certain emergencies is given below. All credible emergencies will be considered in preliminary and final design to assure that the reliability and safety of the facility will not be jeopardized by design deficiencies in the inert gas system.

4.5.1 Depletion of Inert Gas Supplies

Normal operations will call for frequent checking of the inventory of inert gas for the various systems and refilling the storage vessels as required. In event of incipient depletion of one of the inert gas supplies in spite of these precautions, each gas supply can be replenished during operation.

Schematics SK-3-12783 and SK-3-12784 of Appendix G show single supplies for cryogenic nitrogen and argon. This feature should not be construed to mean that one single vessel is proposed. It is estimated that six 3000 gallon dewars will be necessary to store the required quantity of nitrogen.¹ Design and reliability studies² will determine the number and arrangement of cryogenic dewars and associated equipment necessary to satisfy both safety and operational availability criteria for the inert gas systems. The design will allow in service replenishment of the inert gas supplies.

4.5.2 Sodium Spills in Inert Gas Cells

Sodium spills in inert gas cells are the result of failure of some portion of the sodium containing equipment. Two

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1. Refer to Supporting Information, Appendix E, Section 1.1.
 2. Refer to Support Information Requirements, Appendix B, Item 4.

related problems result from such a failure: a chemical problem and a radioactivity problem. Standard methods of dealing with these problems exist but are not a part of the inert gas system. The inert gas system will maintain an atmosphere in the various radioactive sodium areas that will prevent any serious sodium-air reactions. Radioactivity monitors¹ and/or leak detectors will provide intelligence of spillage of radioactive sodium. The cooler units and pressure controls in these areas will continue operation to control temperatures and pressure in the affected cell. The affected sodium system will be shut down as quickly as possible, commensurate with other safety aspects. The spilled sodium will then freeze. Special recovery techniques will be employed to clean up the spill and repair the sodium system.

4.5.3 Inert Gas Purity Level Problems

All inert gas systems spaces are monitored by gas sampling equipment designed to provide quantitative data on gas purity. If the instrumentation indicates that purity tolerances have been exceeded in a certain area, steps are taken to re-establish the required purity level. For example, if the instrumentation indicated an out of tolerance purity in the Fuel Examination Cell, appropriate action would be taken. If the oxygen or moisture content was too high or too low, flow through the purification equipment would be increased or decreased as necessary to get back in limits. If the instrumentation indicated an excessive level of other contaminants such as nitrogen, purging would be required to return to standard conditions. This latter course would also be applied to the nitrogen filled spaces.

1. Refer to Interfaces, Appendix C, Item 22.

SECTION 5.0 MAINTENANCE PRINCIPLES

5.1 PREVENTIVE MAINTENANCE

- A. Gas system components requiring periodic maintenance (preventive or repair) will be located insofar as is practical in a manner that permits air access to the maintenance features of the component, whether it is to be maintained during reactor operation or shutdown. The principal items requiring ready access for maintenance are valves, compressors, purification system components, and instrumentation.
- B. Remote maintenance methods will be employed for equipment which is too radioactive or contaminated for contact maintenance.^{1,2} For example, contaminated vapor traps and filters may require such treatment.
- C. Suitable detection techniques for argon and nitrogen will be used to detect leaks occurring in those systems.
- D. A maintenance program defining maintenance schedules and procedures for servicing equipment is required.
- E. Periodic routine checks are required to verify proper operation of equipment and controls and to perform such services as are necessary to assure continued reliable operation. Special emphasis will be placed on maintaining filtration and purification equipment in the necessary condition for effective operation.

5.2 TROUBLE SHOOTING

Specific trouble shooting provisions will be initiated in Preliminary System Design Descriptions for the gas systems. General types of malfunctions, cause, and correction are presented in Table II.

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- 1. Refer to Support Information Requirements, Appendix B, Item 7.
 - 2. Refer to Interfaces, Appendix C, Item 15.

TABLE II. Troubleshooting

<u>Component</u>	<u>Symptom</u>	<u>Possible Cause</u>	<u>Correction</u>
Compressors	Loss of receiver pressure	Mechanical failure Controller failure Loss of supply Power supply failure	Switch to standby and repair
Filters and Vapor Traps	Loss of flow	Plugged filter	Replace filter
	Increase in P	Plugged filter	Replace filter
	Filter activity increase	Plugged filter	Replace filter
	Increase in down-stream impurity level	Ruptured filter	Replace filter
Valves	Loss of pressure on flow control	Valve seat leakage	Isolate and repair valve
		Steam sticking on remote operated valves	Isolate and repair valve
	Excessive gas losses	Controller failure	Repair controller
Argon Purification System	Buildup of impurities	Valve seat leakage	Isolate and repair valve
		Bonnet leakage	Repack stem or replace bellows, as applicable
		Depletion of molecular sieve beds	Isolate and regenerate beds
		Loss of H ₂ supply	Restore hydrogen supply
		Failure of circuit compressor	Repair compressor

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APPENDIX A

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REFERENCES

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APPENDIX B

SUPPORT INFORMATION REQUIREMENTS

APPENDIX B
SUPPORT INFORMATION REQUIREMENTS

<u>Item</u>	<u>Information Required</u>	<u>Type of Effort</u>	<u>Source</u>	<u>When Required</u>
1	Determination of Required Inert Gas Purity Levels	Development Study	PNL(189 Tasks SG-6 and FE-1B)	Mid-preliminary Design
2	Determination of Gas System Requirements for Reactor Preheating	Conceptual Design	Architect-Engineer (189 Task RD-3)	Late Conceptual Design
3	Selection of Sodium Vapor Trap Design	Design Study	Architect-Engineer (189 Task RD-3)	Late Conceptual Design
4	Determination of Equipment Redundancy Necessary to Satisfy Operating and Safety Requirements	Reliability and Design Study	Architect-Engineer and PNL	Late Preliminary Design
5	Selection and Development of Inert Sampling and Analysis Instrumentation	Design and Development	PNL(189 Task SG-6)	Mid-final Design
6	Establishment of Required Number and Capacity of Radioactive Gas Storage Tanks, and of Activity Monitors	Design Study	Architect-Engineer	Mid-preliminary Design
7	Establishment of Required Shielding and Special Features to Facilitate Gas System Equipment Maintenance	Design Study	Architect-Engineer	Mid-preliminary Design

<u>Item</u>	<u>Information Required</u>	<u>Type of Effort</u>	<u>Source</u>	<u>When Required</u>
8	Determination of Inert Gas Requirements for Sodium Sampling Facility	Design and Development	PNL(189 Task SG-4)	Early Preliminary Design
9	Determination of FFTF Requirements to Accommodate Vented Fuels in Open Loop Test Positions and in the Driver Positions	Design Study	Planning to be performed by PNL(189 Task SG-2)	Early Preliminary Design
10	Determination of Maximum Inert Gas Makeup Flow Requirements	Design Study	Architect-Engineer	Mid-preliminary Design
11	Selection and Sizing of Gas Compressors	Design Study	Architect-Engineer	Mid-preliminary Design
12	Determination of Filter Requirements for Inert Cells	Design Study	Architect-Engineer	Mid-preliminary Design
13	Determination of Operational and Safety Factors that Limit Reactor Operation After Failure of Fuels in Driver or Open Test Positions	Design Study	Architect-Engineer	Mid-preliminary Design
14	Determination of Required Features to Prevent Occurrence of Undesirable Gas Pockets in Inert Atmosphere Cells	Design Study	Architect-Engineer	Mid-preliminary Design

Item 1 - DETERMINATION OF REQUIRED INERT GAS PURITY LEVELSObjectives

Determine the limits of impurities that may be allowed or required in the inert gas spaces of the FFTF.

Description of Work

- A. Determine impurity levels allowable in sodium cover gas. Impurities to be considered are nitrogen, oxygen, hydrogen, methane, carbon dioxide and carbon monoxide. Reaction rates of impurities with sodium or stainless steels will be used as the major criterion for determining the acceptable levels.
- B. Determine minimum oxygen level in nitrogen cells required to limit nitriding of hot stainless steel surfaces to acceptable levels.
- C. Determine allowable impurity levels in argon atmospheres of the Fuel Transfer and Examination Cells. Impurities to be considered are oxygen, nitrogen, water vapor, and hydrogen. Reaction of these impurities with fuel cladding materials as the major criterion for determining the allowable rates.

Item 2 - DETERMINATION OF GAS SYSTEM REQUIREMENTS FOR REACTOR PREHEATINGObjective

To identify specific requirements for the inert gas system imposed by the requirement that the reactor vessel be preheated prior to sodium filling, and be maintained at temperature during times when the reactor is not critical after sodium filling.

Description of Work

- A. Determine temperature and heating rate requirements associated with reactor preheating and temperature maintenance during non-critical times after sodium filling.
- B. Identify direct and indirect means of satisfying requirements.
- C. Determine best method of satisfying requirements. Identify and incorporate changes to inert gas system that are necessary to implement preheating and temperature maintenance system.

Item 3 - SELECTION OF SODIUM VAPOR TRAP DESIGN

Objective

To determine which type of vapor trap would best be suited for use in the recirculating loop of the Argon Receiving and Distribution System and at interfaces of gas and sodium systems.

Description of Work

- A. Survey available information on condensing and refluxing sodium vapor traps used in nuclear and chemical plants. Summarize performance and design information in a report which recommends the type of vapor trap to be used in the recirculating argon loops, and other applications.

Item 4 - DETERMINATION OF EQUIPMENT REDUNDANCY NECESSARY TO SATISFY OPERATING AND SAFETY GOALS

Objective

To determine system reliability and availability goals for the inert gas system, and to specify equipment redundancy to satisfy those goals.

Description of Work

- A. Perform an analysis to predict reliability and availability goal associated with the Inert Gas System.
- B. Specify equipment redundancy and other features necessary to assure that the Inert Gas System will meet the allocations from the overall reliability/availability goals of the FFTF.

Item 5 - SELECTION AND DEVELOPMENT OF INERT COVER GAS
SAMPLING AND ANALYSIS INSTRUMENTATION

Objective

To develop cover gas sampling system design parameters, and to select instrumentation to fulfill the analysis needs as determined in Item 1 above.

Description of Work

- A. Select and test cover gas sampling system.
- B. Define design criteria for trace heating, valve leakage and sodium vapor removal.
- C. Select and proof test gas analysis equipment to complete design criteria for cover gas sampling system.

Item 6 - ESTABLISHMENT OF REQUIRED CAPACITY OF RADIOACTIVE
GAS STORAGE SYSTEM AND NUMBER OF TANKS

Objective

To determine the required radioactive gas decay system capacity, and to determine the required number of tanks based on radioactive gas release rates and safety considerations.

Description of Work

- A. Determine design requirements for radioactive gas handling based on vented and failed fuel testing in the closed loops, vented fuels and fuel failures in driver and open test positions, and accident and normal conditions in nitrogen and argon cells.
- B. Define radioactive gas release criteria.
- C. Establish radioactive gas decay and vent system gas handling requirements and specify number and size of gas storage tanks.
- D. Determine radiation levels adjacent to radioactive gas tanks for design of shielding and location of tanks.

Item 7 - ESTABLISHMENT OF REQUIRED SHIELDING AND SPECIAL
FEATURES TO FACILITATE MAINTENANCE OF GAS SYSTEM
EQUIPMENT

Objective

To assure that equipment maintenance is considered as a factor in gas system equipment installation and shielding design.

Description of Work

- A. Determine radiation levels of inert gas system components resulting from expected FFTF operating conditions. Consider radiation levels resulting from normal operation and from contamination.
- B. Determine shielding and maintenance provisions for radioactive and nonradioactive gas system equipment.

Item 8 - DETERMINATION OF INERT GAS REQUIREMENTS FOR SODIUM
SAMPLING FACILITY

Objective

To define inert gas requirements for sodium sampling and analysis facility.

Description of Work

- A. Define inert gas requirements for sodium sampling and analysis facility by reviewing AE Conceptual Designs of this facility and abstracting that information pertaining to inert gas applications.

Item 9 - DETERMINATION OF FFTF REQUIREMENTS TO ACCOMMODATE
FUTURE VENTED FUELS IN REACTOR OPEN LOOP TEST AND
DRIVER POSITIONS

Objective

To identify FFTF design features that are necessary to permit operation of vented fuels in the open loop test positions and in the driver core.

Description of Work

- A. Determine probable release rates of radioactive gases from vented fuels.
- B. Determine probable cover gas leakage rates.
- C. Define and size equipment necessary to permit vented fuel tests in open test positions and in the driver core.
- D. Identify and outline any development items that would be necessary to permit vented fuel operation.
- E. Identify salient features of initial FFTF design that are affected by vented fuel testing requirements.

- F. Recommend FFTF design changes as appropriate to provide initial design that can be modified in the future at minimum overall cost to permit open loop testing of vented fuels and operation of vented driver fuels.

Item 10 - DETERMINATION OF INERT GAS MAKEUP FLOW REQUIREMENTS

Objective

To determine design flow conditions for the inert gas systems.

Description of Work

- A. Determine makeup flow requirements for nitrogen system based on purge and/or fire fighting requirements.
- B. Determine makeup flow requirements for argon system based on purge requirements, reactor scrams, and accident requirements.

Item 11 - SELECTION AND SIZING OF GAS COMPRESSORS

Objective

To select and size gas compressors for the inert gas system applications.

Description of Work

- A. Select type, size and number of compressor for recirculating argon loop of Argon Receiving and Processing System.
- B. Select type, size and number of compressors for Radioactive Gas Decay and Disposal System.
- C. Select type, size and number of vacuum pumps.
- D. Select type of compressor for fuel subassembly cooling in Fuel Transfer and Examination Cells.
- E. Select type and size of compressor for argon purification loop for Fuel Transfer and Examination Cells.

Item 12 - DETERMINATION OF FILTER REQUIREMENTS FOR INERT CELLS

Objective

To identify filter requirements for circulating inert atmospheres, and to recommend filter installations.

Description of Work

- A. Identify the nature and form of radioactive volatile and particulate matter expected in the argon atmosphere in the Fuel Transfer and Examination Cells, for normal and abnormal conditions. Include the findings of Design Study 4 of the Conceptual System Design Description for the Inert Gas Cell Examination Facility No. 71.
- B. Determine the filter needs for the recirculating argon system, considering equipment to be maintained, and possible release of contaminants during maintenance or in event of malfunction of cell pressurization equipment.
- C. Identify the nature and form of radioactive volatile and particulate matter expected in the nitrogen atmospheres in the inert cells in the containment for normal and abnormal conditions.
- D. Determine the filter needs for the recirculating nitrogen systems, considering equipment to be maintained, and possible release of contaminants during maintenance or in event of malfunction of cell pressurization equipment.

Item 13 - DETERMINATION OF OPERATIONAL AND SAFETY FACTORS
THAT LIMIT REACTOR OPERATION AFTER FAILURE OF
FUELS IN DRIVER OR OPEN TEST POSITIONS

Objective

To identify FFTF operational and safety factors that limit reactor operation after reactor fuel failure, and to

recommend design features that will permit reactor operation with limited numbers of failed fuels.

Description of Work

- A. Identify plant safety factors that are affected by fuel failures in the open test or driver positions.
- B. Identify operational factors that are affected by fuel failures in the open test or driver positions.
- C. Identify FFTF system components and systems that will be strongly affected by such fuel failures.
- D. Recommend design features that will permit reactor operation with limited numbers of failed fuels. State the basis for this recommendation.
- E. Specify limits to operation with failed fuels in driver and/or open test positions. State the basis for this specification.

Item 14 - DETERMINATION OF REQUIRED FEATURES TO PREVENT
OCCURRENCE OF UNDESIRABLE GAS POCKETS IN INERT
ATMOSPHERE CELLS

Objective

To provide design of inert cells with features that will prevent formation of undesirable gas pockets.

Description of Work

- A. Determine potential of forming hydrogen pockets in high points of inert cells through inadequate purging or flows of inert gases.
- B. Determine potential of forming oxygen pockets in inert cells either through inleakage of air or through inadequate purging or flows of inert gases.

- C. Determine potential of forming argon pockets in nitrogen atmosphere cells through leakage of argon gas systems.
- D. Recommend design features to prevent occurrence of hydrogen, oxygen, or argon pockets in inert cells.

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APPENDIX C

INTERFACES

<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
1	All inert gas systems	12	Building Electrical Power System	System 12 provides normal and emergency power to System 82. System 82 provides power requirements and locations. The physical interface between Systems 12 and 82 is the electrical terminals on the mechanical equipment belonging to System 82.
2	All inert gas systems	15	Communications System	System 15 provides service communication for gas system equipment locations. System 82 provides equipment location information.
3	All inert gas systems	16	Lighting System	System 16 provides lighting for gas system equipment locations. System 82 provides equipment location information. System 82 removes heat generated by lighting system within inert gas cells.
4	All inert gas systems	21	Structures	Structures, which are the physical facilities of the plant not covered by Systems 22 and 27, provide space and enclosures for gas system equipment, structures for equipment support, overhead crane for maintenance, access to gas system equipment, sealing provisions for inerted cells, building penetrations for inert gas piping and area shielding for radioactive gas equipment items. System 82 provides information on locations and size of penetrations, preferred arrangement of equipment, controlling dimensions of gas system equipment, equipment weight and special installation requirements.

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<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
5	All inert gas systems	22	Site Facilities	System 22, which covers the physical facilities outside of the containment and the other major buildings, provides space and enclosures for gas system equipment, structures for equipment support, access to gas system equipment, and access road to gas storage area. System 82 provides information as to preferred equipment arrangement, controlling dimensions of gas system equipment, equipment weight and special installation requirements.
6	Nitrogen Receiving and Distribution System/ Argon Processing System-Fuel Transfer and Exam Cells/ Radioactive Gas Decay and Disposal System	23	Service Piping System	System 23 provides coolant for heat exchangers (subject to results of a study in Appendix A, Item 27, page B-1), System 82 provides heat loads and coolant temperature requirements. The physical interface between Systems 23 and 82 is the coolant connections on the heat exchangers.
7	Nitrogen Receiving and Distribution System/ Argon Processing System-Fuel Transfer and Exam Cells/ Radioactive Gas Decay and Disposal System	24	Radioactive Waste System	System 24 disposes of contaminated filter units. System 82 provides information as to the number of such units to be handled.

<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
8	Nitrogen Receiving and Distribution System/ Argon Processing System-Fuel Transfer and Exam Cells/ Radioactive Gas Decay and Disposal System	25	Heating and Ventilation System	System 25 provides air alternate for normally inerted cells, disposal of radioactive gases, and pressure reference for inert cell pressure controllers. System 82 provides information as to radioactive gas disposal requirements.
9	Nitrogen Receiving and Distribution System/ Argon Receiving and Distribution System	26	Plant Fire Protection System	System 82 provides inert gas to System 26 (subject to a study by System 26 to determine needs). System 26 provides requirements to System 82.
10	All inert gas systems	27	Reactor Containment System	System 27, which covers the physical facilities within the containment building, provides space and enclosures for gas system equipment structures for equipment support, overhead crane for maintenance access to gas system equipment, sealing provisions for inerted cells building penetrations for inert gas piping, area shielding for radioactive gas equipment items. System 82 provides information on locations and size of penetrations, preferred equipment arrangements, controlling dimensions of gas system equipment, equipment weight and special installation requirements.

<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
11	Argon Receiving and Distribution System/Nitrogen Receiving and Distribution System/Vacuum System	32	Reactor Vessel and Shield Component	System 82 provides argon for the reactor cover gas, and provides nitrogen at controlled pressure temperature and flow for cooling of the neutron shield and reactor cavity. System 32 sets requirements for these services. System 93 controls cover gas pressure. The physical interface between Systems 32 and 82 is the argon connections on the reactor cover, and the ducting connections on the neutron shield.
12	Argon Receiving and Distribution System	33	Reactor Nuclear Control Components	System 82 provides cover gas for control rod drives. System 33 sets requirements for this service. The physical interface is the gas connections on the control rod drive assemblies.
13	Argon Receiving and Distribution System	41	Reactor Refueling System	System 82 provides argon for the Fuel Handling Machine and the Interim Fuel Decay Storage cover gas. System 41 sets requirements for these services. The physical interface is the gas connections on the FHM and the supply connection to the interim fuel decay storage vessels.

<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
14	Argon Receiving and Distribution System/Argon Processing System Fuel Transfer and Exam Cells	43	Irradiated Fuel Handling System	System 82 provides atmosphere at controlled pressure, purity, and temperature for fuel transfer cell. System 43 sets requirements such as heat loads, temperature requirements and pressures. The physical interface is the supply connections from the in-cell filters.
15	All inert gas systems	44	Radioactive Maintenance System	System 44 provides maintenance for gas system equipment that is radioactive. System 82 provides requirements as to weight, size, and maintenance features of such equipment. System 82 provides nitrogen at controlled temperature and pressure for Maintenance and Decontamination cell atmosphere and miscellaneous services. System 44 sets requirements for M & D cell atmosphere.
16	Argon Receiving and Distribution System/Vacuum System/Radioactive Gas Decay and Disposal System	51	Reactor Heat Transport System	System 82 provides argon for sodium cover gas use, and disposes of argon vented from cover gas spaces. System 82 provides vacuum as required. System 51 is designed to facilitate evacuation down to 1 torr. System 51 sets requirements such as pressures and flows. System 51 provides means to vent surplus gas during sodium filling operations; System 82 accepts the vented gas. The physical interface is the gas supply and exhaust connections to the sodium vapor traps of the heat transport system components.

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<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
17	Argon Receiving and Distribution System/Radio- active Gas Decay and Disposal System/Vacuum System	61	Closed Loop System	System 82 provides argon for sodium cover gas use, and disposes of argon vented from cover gas spaces. System 82 provides vacuum as required. System 61 is designed to facilitate evacuation down to 1 torr. System 61 sets requirements and provides information as to quantities and activities of radioactive gases to be vented. System 61 provides means to vent surplus gas during sodium filling operations; System 82 accepts the vented gas. The physical interface is the gas connections to the sodium vapor traps of the closed loop systems components.

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<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
19	Argon Processing System-Fuel Transfer and Exam Cells	71	Inert Gas Cell Examina- tion Facility	System 82 provides argon at controlled purity, pressure, and temperature for atmosphere and miscellaneous services in this facility. System 82 provides equipment to cool fuel subassemblies in this facility, and provides high pressure argon for pneumatic tools. System 82 purifies and filters the argon to maintain purity. System 71 sets requirements and provides information such as cell pressures, heat loads, temperatures, purities, etc. The physical interface is the supply connections entering the cell and the exhaust connections to the in-cell filter banks.
20	Argon Receiving and Distribution System/Vacuum System/Radio- active Gas Decay and Disposal System/Nitrogen Receiving and Distribution System	81	Sodium Receiving and Pro- cessing System	System 82 provides argon at controlled pressure for cover gas use, and provides vacuum as required. System 82 provides nitrogen for atmosphere in cells containing System 81 equipment. System 82 disposes of gases vented from System 81. System 81 sets requirements as to pressures and flows. The physical interface is the gas connections to the sodium vapor traps. System 81 provides means to vent surplus gas during sodium filling or transfer operations; System 82 accepts the vented gas.

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<u>Item</u>	<u>Inert Gas System</u>	<u>Inter- facing Number</u>	<u>System Title</u>	<u>Interfacing Areas</u>
21	All inert gas systems	93	Plant Instrumentation System	System 82 sets requirements for instrumentation and control. System 93 designs instrumentation and controls to fulfill the requirements. System 82 designs gas system components to be controlled by System 93. The physical interface is the place where the control impulse enters a gas system component to be controlled.
22	All inert gas systems	96	Radiation Monitoring System	System 96 supplies gas activity monitors to provide gas diversion signals to System 93 to operate valves in Radioactive Gas Decay and Disposal System. System 96 provides activity monitors for all inert gas areas. System 82 sets requirements.
DDCN-1 23	Argon Receiving and Distribution System/Radioactive Gas Decay and Disposal System	94	Fuel Failure Monitoring System	System 82 provides vapor free cover gas samples for detection system. System 82 disposes of radioactive gases collected by system 94. System 94 sets requirements for 82 to satisfy fuel failure gas detection and location subsystem requirements.

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APPENDIX D

INERT GAS SELECTIONS FOR FFTF APPLICATIONS

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INERT GAS SELECTIONS FOR FFTF APPLICATIONS

SECTION 1.0 INTRODUCTION

Inert gases will be used in FFTF applications to provide atmospheres that will prevent undesirable chemical changes of sodium, fuels or test materials. Such gases can also be used as required to cool equipment. Inert atmospheres must be amenable to purity control and other technical requirements. Nitrogen, argon, and helium are being considered as the candidates for selection. Other inert gases such as krypton, neon, xenon, and carbon dioxide are not considered because they are expensive and relatively unavailable, or because they will react with molten sodium or structural materials under expected FFTF conditions.

The various criteria and applications are considered in this appendix in order to select the gases from the candidates that best fulfill the application requirements, considered singly and as an integrated whole.

SECTION 2.0 SUMMARY

There are two main categories for which inert gas selections were made. The first category is cover gas for molten sodium systems. The second category is atmosphere for inert cells. Inert gas selections were not made for a third category which encompasses the short-term irradiation test facility. The gas or gases for that application will be made in the governing conceptual design description.

Candidate gases were evaluated and selected for the various applications in Section 4.0 of this Appendix. The selections are summarized in Table D-1. The selections assume a piped heat removal system, and external fueling of the reactor. The impact of "single gas" concepts is discussed in Section 5.0 of this appendix.

SECTION 3.0 DISCUSSION

A wide range of applications and criteria must be considered in selecting inert gases for FFTF uses. The criteria upon which the final selection is based are first developed, and the gas evaluations and selections are then shown.

3.1 SELECTION CRITERIA

3.1.1 Criterion A

The inert gas must prevent serious chemical reactions which could occur if air came into contact with molten sodium.

Justification: This is the fundamental requirement that established a need for inert gas systems. Inert cover gas is needed in sodium systems to prevent fires or unacceptable chemical reactions with sodium. Inert atmospheres are required for cells containing radioactive sodium systems to prevent radioactive sodium fires in event of sodium leaks or system ruptures.

3.1.2 Criterion B

The inert gas must facilitate control of fission product gases which may be present from reactor fuels.

Justification: This is a fundamental requirement for the inert cover gas system.¹ Initially it is expected that any fission gases present in the reactor cover gas will be the result of fuel failures. Eventually vented fuels may be used in the driver positions. However, the cover gas choice made in this appendix will be made with respect to initial

1. Refer to References, Appendix A, Item 1, page 2-7, and page 3-18.

conditions which are: (a) failed fuels in the reactor, and (b) vented or failed fuels in the closed loops.

3.1.3 Criterion C

The inert gas chosen must facilitate control of material damaging impurities and must not itself damage materials or equipment.

Justification: This is a fundamental requirement for the inert gas system.¹ Some of the FFTF systems will be operating at conditions requiring close control of impurity levels to prevent damage to piping and components by those impurities. The inert gas system is required to provide this control.

3.1.4 Criterion D

The inert gas choice must not cause unnecessary effects in the design and operation of other systems.

Justification: This criterion is imposed by good engineering practice. Other things being equal if a design choice is offered, the choice involving the least complication should be made.

3.1.5 Criterion E

The inert gas should be chosen with due regard to the needs of the LMFBF Program.

Justification: This criterion is a secondary objective of the FFTF,² to promote LMFBF technology where possible with minimum disturbance to design of FFTF systems.

1. Refer to References, Appendix A, Item 1, page 3-17.

2. Refer to References, Appendix A, Item 18.

3.1.6 Criterion F

The inert gas should be chosen to take advantage of proven technology and components, inasmuch as is possible.

Justification: This criterion is part of the primary objective of the FFTF¹ to provide a reliable testing facility without incurring unnecessary development risks or costs.

3.1.7 Criterion G

The inert gas should be chosen with due regard to cost.

Justification: This criterion is imposed by good engineering practice. If a design choice is offered, the choice involving the least cost should be made, other things being equal.

3.1.8 Criterion H

The inert gas chosen must provide an atmosphere suitable for operation of electrical and mechanical equipment.

Justification: This criterion pertains to atmospheres in inert cells in which electrical equipment is required to operate. The cell atmosphere must permit such operation.

3.1.9 Criterion I

The inert gas should be chosen to minimize activation from irradiation by neutrons.

Justification: This criterion is imposed by good engineering practice. If a design choice is offered, the choice involving the least potential for gaseous activation by neutrons should be made, other things being equal.

1. Refer to References, Appendix A, Items 1 (page 2-2) and 18.

3.1.10 Criterion J

The inert gas must facilitate cooling of equipment as required.

Justification: This is one of the fundamental requirements for the inert gas system inasmuch as gas cooling is the only practical method of temperature control in many applications.

SECTION 4.0 EVALUATION OF CRITERIA AND SELECTION OF INERT GASES FOR FFTF APPLICATIONS

The criteria are discussed in this section, and the selections are made for the various applications. This section is divided into two main sections: sodium cover gas selection and inert atmosphere selection.

4.1 SODIUM COVER GAS SELECTION

Helium, argon, and nitrogen are the only gases which have been used as cover gas for sodium cooled reactor applications.¹

The applications for which evaluation and selection are made in this section are listed in Table D-1.

4.1.1 Reactor Primary Transport System

This system comprised the reactor vessel and the primary heat transport system, including the pumps, the overflow loop seals, the intermediate heat exchanger and the associated piping. The cover gas chosen for this system must satisfy the seven criteria listed below in the order of their importance; the ranking is based on judgment of what is most important to overall FFTF objectives.

- The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.

1. Refer to Table D-2, Page D-62.

TABLE D-1. Summary of Gas Selection Evaluation

APPLICATION	Criterion A Prevent Chemical Reactions	Criterion B Control Fission Product Gases	Criterion C Control of Material Damaging Impurities	Criterion D Control of Undesirable Interface Conditions with Other Systems	Criterion E Compatibility with LMFBR Needs	Criterion F Conform to Proven Technology and Components	Criterion G Economic Design and Operation	Criterion H Compatible with Electrical Equipment Operations	Criterion I Minimizes Neutron Activation of Gases	Criterion J Facilitates Cooling of Equipment Gas Choice	Leading Reason for Choice	Reference Section (Page Number)	
Reactor Primary Heat Transport System	X	X	X	X	X	X	X	N/A	X	N/A	Argon	1	D-5
Reactor Primary Sodium Receiving and Processing System	X	X	X	X	X	X	X	N/A	N/A	N/A	Argon	Compatibility	D-24
Closed Loop Primary Heat Transport System	X	X	X	X	X	X	X	N/A	N/A	N/A	Argon	3	D-24
Closed Loop Primary Sodium Receiving and Processing System	X	X	X	X	X	X	X	N/A	N/A	N/A	Argon	Compatibility	D-27
Reactor Secondary Heat Transport System	X	N/A	X	X	X	X	X	N/A	N/A	N/A	Argon	4	D-27
Reactor Secondary Sodium Receiving and Processing System	X	N/A	X	X	X	X	X	N/A	N/A	N/A	Argon	Compatibility	D-28
Closed Loop Secondary Heat Transport System	X	N/A	X	X	X	X	X	N/A	N/A	N/A	Argon	4	D-28
Closed Loop Secondary Sodium Receiving and Processing System	X	N/A	X	X	X	X	X	N/A	N/A	N/A	Argon	Compatibility	D-29
Fresh Sodium Storage	X	N/A	X	X	X	X	X	N/A	N/A	N/A	Argon	Leakage, Cost	D-29
Contaminated Sodium Storage	X	X	X	X	X	X	X	N/A	N/A	N/A	Argon	6	D-29
Interim Fuel Decay Storage	X	X	X	X	X	X	X	N/A	N/A	N/A	Argon	Compatibility	D-30
Closed Loop Cell Atmosphere	X	N/A	X	X	N/A	X	X	X	N/A	X	5	Cost	D-31
Reactor Primary Sodium Purification and Storage Cell Atmosphere	X	N/A	X	X	N/A	X	X	X	N/A	X	5	Cost	D-37
Reactor Primary Heat Transport Equipment Cell Atmosphere	X	N/A	X	X	N/A	X	X	X	N/A	X	5	Cost Activation	D-38
Contaminated Sodium Processing Cell Atmosphere	X	N/A	X	X	N/A	X	X	X	N/A	X	5	Cost	D-40
Radioactive Maintenance Cell	X	N/A	X	X	N/A	X	X	X	N/A	X	5	Cost	D-40
Fuel Transfer and Examination Cell	X	X	X	X	N/A	X	X	X	N/A	X	Argon	2	D-40
Fuel Handling Machine (tentative)	X	X	X	X	X	X	X	N/A	N/A	X	Argon	Compatibility	D-45
Optional Atmosphere in Refueling Hot Cell	X	N/A	N/A	X	N/A	X	X	X	N/A	X	5	Cost	D-50
Reactor Access Space	X	X	X	X	N/A	X	X	N/A	N/A	X		Nitrogen	D-51

1. Solubility, leakage, backup reactor, cost, blanketing
 2. Elimination of Nitriding Potential, Cost
 3. Solubility, leakage, cost
 4. Solubility, leakage, blanketing, cost
 5. Nitrogen
 6. Leakage, cost, compatibility with served systems
- N/A = Not applicable

- The inert gas must facilitate control of fission product gases which may be present from reactor fuels.
 - The inert gas must facilitate control of material damaging impurities, and must not itself damage materials.
 - The inert gas should take advantage of proven technology and components.
 - The inert gas must not cause unnecessary effects in the design and operation of interfacing systems.
 - The inert gas should be chosen to minimize activation from irradiation by neutrons.
 - The inert gas should be chosen with due regard to the needs of the LMFBR Program.
 - The inert gas should be chosen with due regard to cost.
- These criteria are discussed below in order to compare the gases in meeting the criteria for this application.

4.1.1.1 Criterion A

The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.

This criterion must be operative when the sodium systems are in their normal closed configuration, and when the sodium systems are open for maintenance. Basically, this criterion simply requires that serious chemical reactions be prevented in situations which would have grave consequences. Nitrogen, argon, and helium all satisfactorily fulfill this criterion in themselves, inasmuch as they do not normally react with sodium. The key requirement is that contamination of the cover gas with reactive impurities such as oxygen and water must be kept sufficiently low to preclude grave consequences. A discussion of the impact of this key requirement on gas selection is given in Section 4.1.1.3 below.

4.1.1.2 Criterion B

The inert gas must facilitate control of fission product gases which may be present from reactor fuels.

Fission product gases can be considered to consist of noble gas isotopes, halogens, and volatile solids, all of which are produced in the nuclear processes. The source of these fission gases is primarily from the fission process and incidentally from decay of irradiated fuels. Control of these gases is necessary to minimize the radiological hazard attending the leakage of contaminated cover gas into inhabited areas of the facility. Control of these gases can be considered to consist of (1) controlled release of isotopes to the atmosphere where possible, and (2) segregation and/or confinement of isotopes until natural decay reduces the activity levels to a point where controlled release is possible.

The volatile solids consist chiefly of the alkali metals sodium, cesium, and rubidium. Other volatiles such as the halogens, sodium iodide, tellurium, and strontium are present but in much lower concentrations in the cover gas than is cesium for example.¹ For all such volatiles, the control method is to confine them to the point of origin as much as possible. Sodium vapor traps will routinely remove nearly all such contaminants because their vapor pressure is quite low at the temperatures that vapor traps are operated. Consequently, the volatile solids tend to be precipitated in the vapor traps.

One of the main criteria for designing vapor traps is to provide sufficient heat transfer surface area to cool the

1. Refer to References, Appendix A, Items 19 and 20 (page 73).

vapor laden carrier gas to a selected temperature. In principle helium would be the preferable gas from this standpoint, with nitrogen and argon being next in order of descending preference; this ranking stems from the heat transport properties of the gas. However, in practice, sufficient heat transfer area can be provided in the vapor traps to compensate for differences in heat transport properties. Vapor traps have been designed, built, and operated for nitrogen at DFR, argon at EBR-II and Fermi, and helium at SRE and Hallam. Thus, there is no significant preference between the candidate gases for control of volatile solids or halogens.

The noble gases, xenon and krypton, are not affected by sodium vapor traps and, therefore, must be controlled by other methods. Both routine, and nonroutine release of fission gases from fuels must be considered. The routine release of fission gases is the condition that occurs when vented fuels are used. The nonroutine release of fission gases is the condition that occurs upon cladding failure of nonvented fuel. The two conditions are quite different and impose different requirements on a cover gas system that must handle the noble fission gases.

In themselves, the kryptons and xenons are quite harmless to sodium systems. However, when cover gas contaminated with radioactive xenon and krypton leaks into inhabited areas in the reactor plant, the resultant radioactivity is a hazard to personnel. This must be considered in the design of the inert gas system, the reactor vessel and other components where gas leakage is possible.

Present and past sodium reactors controlled xenon and krypton chiefly by the use of radioactive gas holdup tanks. Those

reactors have a normally static cover gas, with flow into or out of the reactor during barometric or temperature transients. Fission gases released to the cover gas remained confined there or were stored in radioactive gas storage tanks until radioactive decay had reduced the activity to a level that would permit release to the uncontrolled atmosphere. This is a satisfactory solution for a reactor designed for nonvented fuels or a small number of fuel pin failures, because the quantities of fission gases released are small and the activity level is manageable. For this situation, the equilibrium activity of fission gases in the cover gas can be maintained low enough in relation to cover gas leakage to pose no serious problems by the use of purging and radioactive gas storage tanks. An example of this is worked out in Section 6.3 of this Appendix.

This example shows that under some simplifying assumptions the cover gas would have to be purged every one to four days of continuous full power operation when operating with 10 failed fuel pins if the cover gas activity were to be limited by leakage considerations to 600 $\mu\text{Ci/cc}$. Since it appears the cover gas space in the reactor will be on the order of 100 cubic feet, two or three volume purges every three or four days will not impose a great load on the radioactive gas holdup system. However, the calculations in Section 6.3 indicate that the cover gas would have to be purged much more often if the noble gases from a whole sub-assembly were continuously released or if relatively large cladding failures occurred in the fuel pins. This would require a nearly continuous purge flow and could result in a prohibitively large radioactive gas holdup system.

It is unlikely that the reactor would be operated with failed fuel pins because fission products and fissionable material could be washed into the sodium coolant during such operation. A serious contamination of the reactor and heat transport systems with long lived fission products could result; these radioactive materials would be difficult to remove from the system. Therefore, the fission product release problem can be considered to be limited to the vented fuel case, and to the situation with a very small number of failures of nonvented fuel.

For initial FFTF operation, vented fuels will not be used in open test or driver positions.¹ Further, it is expected that very conservative reactor operation will prevail initially, and that the reactor will be shut down upon detection of fuel pin failures. Therefore, the cover gas choice will be made on the basis of very limited noncontinuous fission gas releases.

As indicated above, periodic cover gas purging can be used to handle the situation with a limited number of fuel pin failures. The use of cover gas would be small, perhaps a few hundred cubic feet per week, and this could be easily handled by the radioactive gas holdup system. For such an approach, either argon or helium will satisfactorily serve as the cover gas.

4.1.1.3 Criterion C

The inert gas chosen must facilitate control of material damaging impurities, and must not itself damage materials.

Nitriding of austenitic stainless steel and other materials will occur in sodium systems under a nitrogen cover gas

1. Refer to References, Appendix A, Item 1, page 3-24.

when the sodium temperatures are above 900 °F.¹ The gross effect of nitriding is to embrittle materials. Thus, nitrogen is a material damaging gas under expected FFTF reactor conditions if used as a cover gas. For this reason it cannot be considered as a candidate for the FFTF reactor cover gas application. Nitrogen was initially used as cover gas for the Dounreay reactor, but was replaced with argon because of potential nitriding of fuel materials.

Cover gas impurities considered to be material damaging are nitrogen, methane, hydrogen, oxygen, carbon dioxide, and carbon monoxide. These impurities appear in sodium cover gas systems from diffusional inleakage, and from reduction of lubricants and reactor materials. These impurities can potentially damage reactor materials or increase sodium plugging temperature. The impurities reported² for Fermi and EBR-II are listed below:

<u>Item</u>	<u>Fermi, ppm</u>	<u>EBR-II</u>
H ₂	0-10	20
O ₂	10	Not Available
CH ₄	0-10	Not Available
Co	0-50	Not Available
N ₂ (average)	3000-4000	3000-17000
Max. Sodium Temp. °F	900	900

It is not known what impurity levels will be ultimately permitted for the FFTF. Tests³ are being performed to make this determination.

1. Refer to References, Appendix A, Item 10, page 11.
2. Refer to References, Appendix A, Item 10, pp. 6 and 8.
3. Refer to Support Information Requirements, Appendix B, Item 1.

No nitriding damage has been reported from Fermi, EBR-II, or DFR which have nitrogen as an impurity in their cover gases. However, the final judgment as to the ultimately allowable nitrogen levels in the FFTF cover gas will have to await the completion of the cited tests, since experience with other reactors is limited to 900 °F sodium temperature.

Inasmuch as reactor sodium temperatures are ultimately expected to reach 1200 °F, it seems likely that at least the nitrogen levels will have to be reduced to minimize the possibility of nitriding of the reactor materials.

There are several methods of removing nitrogen from either helium or argon. Cryogenic stripping or fractionation, "gettering" with high temperature titanium (1500 °F), calcium (1100 °F), lithium (400 °F) or other metals, or low temperature adsorption methods have been used for this purpose.¹ The cryogenic fractionation or absorption methods involve liquefaction or near liquefaction of the incoming impure argon and fractional distillation or cryogenic stripping. The output nitrogen impurity content claimed for these various methods ranges from zero to 25 ppm. These methods would appear to be adequate for the purpose considering that the present nitrogen levels in sodium reactors is 3000-17000 ppm.

"Gettering" or chemisorption methods, which work equally well with helium or argon, involve metal reaction beds operating at high temperatures. However, the getter beds cannot be regenerated and must be replaced when saturated; this is a disadvantage inasmuch as the beds would be radioactive. The other impurities (oxygen, water, methane, and hydrogen) can be readily removed from either argon or helium by chemical or refrigerative techniques as reported in the above references.

1. Refer to References, Appendix A, Items 21 through 28

In summary, there are methods available to remove these material damaging impurities when necessary from either argon or helium. As a result the choice of cover gas then is not strongly influenced by this criterion.

4.1.1.4 Criterion F

The inert gas should be chosen to take advantage of proven technology and components.

For sodium reactor operation, both helium and argon have been successfully used as sodium cover gases.¹ Initial FFTF operating conditions will not differ from or exceed the operating conditions of those reactors. Therefore, a choice of either helium or argon is in accordance with proven technology.

4.1.1.5 Criterion D

The cover gas choice should not cause unnecessary effects on the design or operation of interfacing systems. There are several aspects to this criterion.

From the point of view of cover gas solubility in sodium, argon is less soluble than helium. Basic solubility data² indicate that helium is more soluble in sodium than is argon by factors of two to three orders of magnitude. The brief parametric study in the cited reference indicates that, as a result of the solubility difference, it could take one hour to accumulate a given size bubble of helium in a portion of the cold leg of a sodium system, while it would take nearly 1000 hours to produce the same effect with argon. The period spikes that occurred in the SRE reactor are postulated to have been caused by gas bubbles in sodium passing through the core.³ It has been recently postulated

1. Refer to Table D-2, page D-62.

2. Refer to References, Appendix A, Item 29.

3. Refer to References, Appendix A, Item 30, page 4.

that these bubbles were the result of cover gas solubility effects.¹ Direct experiments determined that argon can be transferred by solubility effects from the hot portion of a NaK circuit to the cold portion.² This experimental confirmation of the effect of solubility verifies the theoretical studies. Gas entrainment has been experienced at DFR, BR-5, and Hallam but it was attributed to vortexing in sodium pumps³ or to piping design.⁴ This type of gas problem then is not dependent on gas solubility.

Inasmuch as helium is more soluble in liquid metals than is argon, the effects of solubility would affect the design of the heat transport system to a greater degree with a helium cover gas than with an argon cover gas. For example, it may be shown that with a sodium flow rate of 45000 gpm entering the various IHX's at 900 °F and leaving at 600 °F, approximately 700 cc/min of argon or 190,000 cc/min of helium would be released as a 600 °F gas in the IHX's due to the solubility change accompanying the cooldown. This assumes that the sodium entering the IHX is saturated with gas in either case. While this saturation is not likely to be realized in practice, the numbers indicate the potential magnitude of the problem. Clearly, argon is preferable to helium as a cover gas from the solubility aspect, inasmuch as it would cause the least disturbance to the design of the heat transport system.

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1. Refer to References, Appendix A, Item 31.
 2. Refer to References, Appendix A, Item 32, page 39.
 3. Refer to References, Appendix A, Item 33, page 10.
 4. Refer to References, Appendix A, Item 34.

Another aspect of this criterion is the effect of cover gas choice or the fuel handling machine (FHM). As discussed in Section 4.2.7, both argon and helium are acceptable technical choices for the FHM proper. There are three possible choices for the conceptual design of the FHM: (1) a sodium-cooled machine; (2) an argon-cooled machine, and (3) a helium cooled machine. Any of the three concepts may be chosen.

It would be desirable to choose the reactor cover gas to be the same as the FHM gas to avoid gas incompatibilities at this interface. If different gases were chosen for each application, it would probably be necessary to temporarily change the reactor cover gas to be the same as the FHM gas during the fuel handling operations, as discussed in Section 4.2.7.4. The design and operational complexities necessary to accomplish this change should be avoided if possible. Therefore, argon would be preferable as cover gas for a FHM using argon and helium would be preferable as cover gas for a FHM using helium.

Another aspect of this criterion is cover gas leakage through seals. Seal leakage can be considered to be the result of laminar or molecular flow through minute leak paths, since the gas pressure in the reactor will be only a few inches of water above ambient pressure.¹ Analysis of relative leakage tendencies² shows that, for a cover gas temperature of 800 °F, helium will leak approximately 1.2 times more than argon through the same leak passage for the laminar flow regime. When leak passages are very small, comparable to mean free path lengths for the gas molecules, helium will leak about 3.4 times more than argon. This may

1. Refer to References, Appendix A, Item 3, page 2-5.

2. Refer to Appendix D, Section 6.2.

be a significant difference, considering that leakage will be a problem that will have to be aggressively attacked during design and before the ultimate use of vented fuels can be implemented. On a basis of leakage, then, argon is preferable to helium.

Another possible leak source is the rotating seal for the sodium pumps. Presently, oil-filled face type seals and buffered gas seals are under consideration for this application.

Informal contact¹ with people familiar with pump seals indicates that, in their opinion, there is no real difference in the pump seals for either argon or helium. This seems reasonable, since both are essentially buffered seals with no direct leak path through the rotating seal. The higher diffusion of helium could have a small effect, although a properly designed seal should not be so marginal that diffusion should make a difference. Oil and water buffered seals have been developed for gas-cooled reactors.² These seals prevent shaft leakage from helium gas circulators with 300 psi and 400 to 600 °F suction conditions; these conditions are more severe than is expected for the FFTF. Seal materials capable of being used as dry face seals in very dry helium and argon have been found as part of this work.³ In this regard, the data pertains primarily to

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1. Refer to References, Appendix A, Items 35 through 39.
 2. Refer to References, Appendix A, Item 40, pp. 15 and 40.
 3. Refer to References, Appendix A, Item 41, p. 106.

helium since the poor heat transport properties of argon exclude it from use in gas-cooled reactors. Shaft seals are always a difficult matter, but it would appear that there are no significant technical differences in this area. Thus, it appears that a choice of either argon or helium would have little effect on the amount of sodium pump seal development required.

Another aspect of this criterion is the choice of reactor configuration, and the attendant reactor refueling hot cell interface. The two reactor configurations that must be considered are the reference concept and the backup design. For the reference reactor, refueling takes place through nozzles and it is rarely necessary to open the reactor to the hot cell. Consequently, the normal atmosphere in the refueling hot cell is air.¹ For this reactor a choice of either argon or helium would not impose unnecessary requirements on the hot cell interface.

Other reactor configurations such as the backup design² are open to the reactor hot cell during refueling. This choice of reactor configuration would favor argon over helium inasmuch as the greater density of argon would cause it to blanket the sodium more efficiently in the open reactor. Helium on the other hand would quickly rise from the sodium surface, allowing a heavier cell atmosphere to reach the molten sodium surface. However, the refueling hot cell for this reactor type would be required to have a high purity inert atmosphere, so that refueling could be accomplished without unacceptable reactions of sodium with atmospheric contaminants. With a high purity inert refueling hot cell,

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1. Refer to References, Appendix A, Item 42, page 1.
 2. Refer to References, Appendix A, Item 43.

the buoyancy of helium is not a serious matter inasmuch as a heavier inert cell atmosphere will prevent serious oxidation processes as well as the helium, which it would displace. It would be preferable to have argon as the cover gas because of its favorable blanketing properties, but helium is not ruled out because the hot cell atmosphere will by necessity be of very high purity. Thus, the consequences of allowing a heavier inert gas to spill into the open reactor are acceptable. The relatively small quantity of helium allowed to contaminate the hot cell atmosphere is not expected to affect the equipment in the hot cell.

In summary, argon is preferable as primary cover gas to helium when considering: (1) cover gas solubility effects, (2) gas leakage, (3) the possibility of accommodating argon-cooled fuel handling machines, and (4) the possibility of accommodating the backup reactor design. Helium is preferable to argon as cover gas when considering the possibility of accommodating a helium-cooled FHM. The gases are equally satisfactory when considering shaft seals.

4.1.1.6 Criterion I

The inert gas should be chosen to minimize activation from neutron irradiation.

Calculations¹ indicate that operation of the FFTF Reactor at 400 MWt with an argon cover gas would result in an equilibrium activity level of 0.03 $\mu\text{Ci/cc}$ of argon-41 in the cover gas if the sodium pool depth was 15 feet over the reactor core. The potassium impurity in the sodium would result in an argon-39 concentration of 0.023 $\mu\text{Ci/cc}$ in the cover gas as a result of the N,P reaction of neutrons with the potassium.

1. Refer to References, Appendix A, Item 44.

A brief analysis was performed to examine the effect of leakage of activated argon directly into a routinely occupied reactor refueling hot cell.¹ The analysis was based on equilibrium concentrations of radionuclides in a hot cell of 450,000 cubic feet with a ventilation rate of 10,000 cfm. The possible presence of other radioactive gases from fuel failures was not considered. The maximum permissible concentration of argon-41 is 2×10^{-5} $\mu\text{Ci/cc}$, as stated in AECM-0524, for adult persons in controlled areas. The maximum permissible concentration of argon-39 is 1.3×10^{-5} $\mu\text{Ci/cc}$ as calculated by the recommended method.² The results show that for argon activities as above, a leakage of 1150 ft³/day of argon cover gas into the hot cell would result in the maximum permissible combined concentration of argon-41 and argon-39 in the hot cell.

A similar analysis³ was performed to examine the effect of leakage of activated argon into a normally occupied work area of a reactor containment that does not have a reactor refueling hot cell. The results of this analysis are given below. A containment of 150 ft diameter, with a 70 foot high cylindrical work area capped by a hemisphere has a volume of about 2.1×10^6 ft³

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1. Refer to Appendix D, Section 6.5.
 2. Refer to References, Appendix A, Item 45, page 22.
 3. Refer to Appendix A, Section 6.5.

This leakage figure is far greater than leakage figures reported for other reactors: 18 to 48 scfd at Fermi,¹ 71 scfd at Hallam,² and 0.09 scfd at Dounreay.³ Consequently, the use of argon as a cover gas would impose no exceptional design requirements on reactor sealing provisions or on the ventilating system of the hot cell.

For the backup reactor, the hot cell atmosphere will be inert. In such a situation there would be no significant ventilation of the hot cell because of the cost of inert gas. Therefore, any leakage of activated argon into the hot cell will result in continuous radioactive contamination of the hot cell atmosphere. Analysis of this situation⁴ shows that the equilibrium activity in the hot cell atmosphere due to argon-41 would be about 0.38 MPC's if the cover gas activity was 0.03 $\mu\text{Ci/cc}$. The cover gas leakage rate assumed was 100 cubic feet per day. At these levels, the hot cell could be entered at will.

From the above discussion, it may be concluded that neutron activation of the cover gas would pose no particular problem

1. Refer to References, Appendix A, Item 46, page 27.
2. Refer to References, Appendix A, Item 47, page 115.
3. Refer to References, Appendix A, Item 48, page 12.
4. Refer to Appendix D, Section 6.5.

if argon were chosen as cover gas. Since the activation of helium would be less than that of argon, the problem would be of even less concern for helium. Therefore, both argon and helium fulfill this criterion, although helium is preferable from an activation viewpoint.

4.1.1.7 Criterion E

The inert gas should be chosen with due regard to the needs of the LMFBR Program.

From the viewpoint of the LMFBR Office,¹ there are no overriding technical factors which demand either argon or helium as cover gases. Industry seems to favor argon inasmuch as all the major sodium-cooled reactors with the exception of SRE and Hallam have used argon.² From the point of view of power-producing reactors, argon seems preferable inasmuch as it is produced by commercial sources from the atmosphere, while helium is produced from government sources and is considered a natural resource. However, there is no LMFBR programmatic direction in this regard.¹

The vented fuel concept is being favorably considered for future reactors. The resultant fission gas problem can be solved by high integrity sealing of reactors, or by gas purification, or by both. The use of helium in the FFTF would advance sealing technology inasmuch as helium is harder to contain than argon; a seal that would contain helium would certainly contain argon. The use of argon might result in a development of economical methods of purification of argon which would be necessary to permit the ultimate

1. Refer to References, Appendix A, Item 49.
2. Refer to Table D-2, page D-62.

use of vented fuel with an argon cover gas. Thus, there is no identifiable choice between helium or argon from the LMFBF Program standpoint.

4.1.1.8 Creterion G

The inert gas should be chosen with due regard to cost. The basic cost¹ of the candidate gases at the present time at Hanford is:

Helium:	4.3¢/scf
Argon:	1.6¢/scf
Nitrogen:	0.16¢/scf

A complete cost comparison of using these gases for the cover gas applications is not possible at this time. Some preliminary cost comparisons based on certain assumptions can be made as follows:

- A. Usage: Argon was used as the sole cover gas in Fermi. Argon usage at Fermi, in calendar year 1966 was 147,000 scf per month when averaged over the calendar year.² Helium was used as cover gas and reactor cavity atmosphere at Hallam. The average helium usage during Hallam operation was about 1000 scf per day or about 30,000 scf per month.³ No usage rate can be postulated for FFTF at this time. However, if it is assumed that 50,000 scf per month will be the usage of cover gas for all applications, the cost of using helium would be \$2,150 per month and \$800 per month with argon. On this basis, argon would be preferable to helium.
- B. System Cost: No solid basis is available for comparing system costs of using helium or argon. If it is assumed that the cover gas would be the only application

1. Refer to References, Appendix A, Item 50.
2. Refer to References, Appendix A, Item 51, page 20.
3. Refer to References, Appendix A, Item 47, page 113.

for either argon or helium in the containment, the system costs should not be greatly different because the piping should be nearly identical. Due to their different densities, the main difference in piping would be that argon would be introduced into the bottom of a gas space and removed from the top, and helium would be introduced into the top and removed from the bottom. This should have little bearing on cost. The other cost difference would be in the storage facility. If argon is chosen, the storage vessels can be obtained from the vendor as part of the cryogenic supply contract. Thus there is no material cost involved. If helium is chosen, the storage vessels would have to be purchased. It is estimated that these storage vessels would cost about \$30,000. This is a small cost when amortized over FFTF life.

In summary, it appears that argon would be preferable on a cost basis to helium although the cost differences appear relatively small.

4.1.1.9 Selection of Reactor Primary Heat Transport System Cover Gas

From the discussion of the criteria, it was determined that nitrogen was unacceptable because of potential nitriding of reactor materials. Helium and argon are equally acceptable when the following factors are considered:

- The basic inerting function of the cover gas
- Control of fission gases during initial FFTF operating conditions
- Control of material damaging impurities
- The effects of cover gas activation
- Application of proven technology
- Application to the needs of the LMFBR Program.

Argon is chosen over helium for the reactor primary cover gas because:

- It is less soluble in sodium than is helium. This will result in less potential for transference of cover gas from hot to cold portions of the heat transport system and will lessen the possibility of passing gas bubbles through the core. Consequently, the magnitude of a potential design problem in the heat transport system and nuclear control system is thereby reduced.
- Argon is easier to contain than is helium. Consequently, it will be somewhat easier to design the gas seals in the reactor vessel and heat transport systems.
- It is the better choice when considering the possibility of implementation of the backup reactor.
- It is the better choice when considering cost.

4.1.2 Reactor Primary Sodium Receiving and Processing System

This system comprises the reactor primary sodium storage tanks, the reactor primary sodium surge tank, the sodium cold traps, and the associated piping.

Argon is chosen as the cover gas for this system because this system is intimately connected to the reactor primary heat transport system. The gas space of the sodium surge tank in this system breathes directly into the cover gas system. Therefore, the same cover gas must be used as is used in the reactor primary system.

4.1.3 Closed Loop Primary Heat Transport System

This system comprises the sodium pumps, the surge tanks, and the intermediate heat exchanger of each closed loop. The closed loops are separate circuits so that no cover gas or

sodium can be transferred from one closed loop to another. The cover gas chosen for the closed loop primary system must satisfy the seven criteria listed in Section 4.1.1 of this appendix.

The main differences between the gas system requirements for the reactor primary and the closed loop primary are that the closed loops must be capable of operating at 1200 °F sodium temperature initially,¹ and that vented and failed fuel operation in the closed loop must be considered as probable during initial FFTF operation.² The effects of these testing requirements is that: (1) closer control of material damaging impurities in the cover gas may be necessary, and (2) the fission gases routinely released by vented or failed fuels must be accommodated.

From the discussion of control methods for material damaging impurities given in Section 4.1.1.3 of this appendix, it was concluded that adequate means of providing such control can be applied to either argon or helium. Nitrogen is precluded for this application because of potential nitriding of the closed loop materials.

Accommodation of vented and failed fuels in the closed loops can be effected by the use of radioactive gas holdup tanks. The closed loop systems will contain a relatively small gas volume. This can result in very high activity levels because of the unfavorable dilution factor. Fission gas released will be on the order of 5 scc per day for 90 pin vented fuel tests. The closed loops are expected to contain on the order of 20 cubic feet of gas. Analysis³ indicates that this may result in gas activities on the order of 80000 $\mu\text{Ci/cc}$

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1. Refer to References, Appendix A, Item 52, page 2-6.
 2. Refer to References, Appendix A, Item 52, page 2-25 and Item 1, page 2-7.
 3. Refer to Appendix D, Section 6.4.

closed loop system if the cover gas is not continuously purged. Such activity levels would require a zero leak cover gas system. Since it is unlikely that zero leakage can be maintained, this high activity cannot be permitted in the closed loops. However, because the closed loop systems will be relatively small piping systems, it will be possible to hold leakage to very minimal levels by the use of welded joints wherever possible and by high integrity seals where necessary. With system leak levels on the order of 0.1% per day, the cover gas activity can be fairly high, on the order of 100 to 1000 $\mu\text{Ci/cc}$ for 1 to 3% cell leak rates. The purge rate necessary to hold the activity to this level is 10 to 100 volume changes per day or 0.15 to 1.5 cfm. At gas flow rates on this order the radioactive gas holdup tankage requirements while not minimal at least are not unreasonable. For a storage condition of 150 psig and 100 °F, approximately 50 cubic feet of tankage would be needed per day to accommodate vented fuel tests for each closed loop at leak rates of 0.1% per day. Assuming a required holdup time of 21 days, and two simultaneous vented fuel tests the total tankage volume would be about 2400 cubic feet, to handle approximately 33,000 scf per month of contaminated cover gas. Considering that Fermi was designed to handle 9800 scf per month of contaminated gas¹ the gas handling rate is not unreasonable.

The amount of holdup tankage required is a direct function of the leakage rate permitted for the Closed Loop System. A well designed and constructed system will reduce the holdup tankage requirements to minimum levels. A leaky system will increase the purging requirements greatly, and consequently the tankage requirements. However, because of the nature of

1. Refer to References, Appendix A, Item 53, page 113.1.

the closed loop systems, it should be possible to minimize leakage. Therefore, it is expected that radioactive fission gas control can be exercised by the use of holdup tanks.

4.1.3.1 Selection of Cover Gas for Closed Loop Primary Heat Transport System

Argon is selected as the normal cover gas for this system. Since impurity control can be applied to either helium or argon, even at the higher requirements expected in the closed loops, both gases are acceptable under this criterion. Since control of fission gases can be effected by radioactive gas holdup or tankage, both gases are acceptable under this criterion. Argon is chosen for this application because

- It satisfies all the criteria
- It offers advantages over helium in regard to solubility in sodium, leakage tendency, and cost.

4.1.4 Closed Loop Primary Sodium Receiving and Processing System

This system comprises the sodium storage tank, the sodium purification equipment, and the associated piping.

Argon is selected for this system to maintain compatibility since this system is connected to the closed loop primary system which uses argon as cover gas.

4.1.5 Reactor Secondary Heat Transport System

This system comprises the intermediate heat exchangers, the sodium pumps, the sodium surge tanks, and the associated piping.

The cover gas for this system must satisfy the criteria listed below:

- A. The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.
- B. The inert gas must facilitate control of material damaging impurities, and must not itself damage materials.
- C. The inert gas should take advantage of proven technology and components.
- D. The inert gas must not cause unnecessary effects in the design and operation of interfacing systems.
- E. The inert gas should be chosen with due regard to the needs of the LMFBP Program.
- F. The inert gas should be chosen with due regard to cost.

Argon satisfies the criteria above as discussed under Section 4.1.1. Argon is chosen as cover gas for this application because:

- 1. Argon is proven for sodium cover gas applications.
- 2. The methods available to purify argon of material damaging impurities are adequate, and pose no special maintenance problems in the absence of radioactivity.
- 3. The gas pressure in this system will be higher than that of the primary. This will enhance the leakage potential. Since argon has less tendency to leak, argon is preferable from this aspect.
- 4. The use of argon will permit taking advantage of the lesser solubility in sodium and greater density features of argon.
- 5. Argon is cheaper than helium.

4.1.6 Reactor Secondary Sodium Receiving and Processing System

This system comprises the reactor secondary sodium storage tanks, the sodium cold traps, and the associated piping.

Argon is chosen as cover gas for this system because argon satisfies the criteria for secondary sodium systems and because this system is intimately connected to the reactor secondary heat transport system which uses argon as the cover gas.

4.1.7 Closed Loop Secondary Heat Transport System

This system comprises the intermediate heat exchangers, the sodium pumps, the sodium surge tanks, and the associated piping.

Argon is chosen as cover gas for this system for the reasons given in Section 4.1.5.

4.1.8 Closed Loop Secondary Sodium Receiving and Processing System

This system comprises the sodium storage tanks, the sodium purification system, and the associated piping.

Argon has been chosen as cover gas for this system because argon satisfies the criteria for secondary sodium systems as discussed in Section 4.1.5. Additionally, this system is intimately connected to the closed loop secondary system; the use of the same gas will prevent mixing of different cover gases.

4.1.9 Fresh Sodium Storage System

Fresh sodium will be supplied to all user systems by this system. Argon is chosen for this system because, (1) it is a satisfactory cover gas; (2) it is cheaper than helium; and (3) it has a lesser tendency to leak. Nitrogen is an acceptable alternate. However, argon is chosen to preclude the possibility of contaminating the cover gas of other sodium systems with nitrogen.

4.1.10 Contaminated Sodium Storage

In the event that gross fuel failure occurs in the closed loop it is expected that highly contaminated sodium will be dumped into the contaminated sodium dump tank. Some amounts of fission gases will thereby be introduced into this tank. However, the fission gas quantities will be very small since most of the fission gases will be released into the closed loops during the fuel failure. Consequently, the fission gas problem should be less severe in this tank than in the closed loop proper. Further, it is expected that the sodium temperature will be low, on the order of 300 to 400 °F. Therefore, no requirements in regard to material damaging impurities are expected. From these considerations and from consideration of the other criteria discussed in Section 4.1, it is evident that helium, argon, or nitrogen could be used for this application.

Argon is selected for this application because:

1. It satisfies all the criteria.
2. It offers advantages over helium in regard to leakage and cost.
3. The use of argon will prevent inadvertent admission of nitrogen into the closed loop systems, such as could occur by operational error.

4.1.11 Interim Fuel Decay Storage

Interim Fuel Decay Storage is simply a temperature controlled sodium pool in which decaying fuel is stored temporarily. Argon is chosen for the cover gas over the sodium because argon satisfies the cover gas criteria, and because the gas used in the reactor, fuel handling machine, and the Fuel Transfer Cell is argon. Thus, the choice of argon for this application is totally compatible with the other gas applications in the fuel handling sequence.

4.2 INERT CELL ATMOSPHERE SELECTION

Inert atmospheres will be provided for cells in the containment which contain radioactive sodium, for the Fuel Handling machine, for fuel transfer and examination cells external to the containment, and for maintenance and decontamination cells external to the containment.

Helium, argon, and nitrogen may be used as inert atmospheres. There are a number of criteria which must be examined to permit a reasoned choice among these candidates. The applications for which evaluation and selection are made are listed in Table D-1.

4.2.1 Closed Loop Cell Atmosphere

These cells contain the closed loop sodium systems which will have the highly radioactive and occasionally, contaminated sodium in them. The atmosphere in this cell must satisfy the criteria listed below in the order of their importance.

- The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.
- The inert gas must facilitate control of material damaging impurities, and must not itself damage materials or equipment.
- The inert gas must provide adequate cooling of equipment as required.
- The inert gas must not cause unnecessary effects in the design and operation of other systems.
- The inert gas should be chosen with due regard to cost.
- The inert gas should be chosen to take advantage of proven technology and components.
- The inert gas must provide an atmosphere suitable for operation of electrical equipment.

There is no significant neutron environment in these cells and therefore activation need not be considered as a criterion.

These criteria are discussed below in order to compare the gases in meeting the criteria for this application.

4.2.1.1 Criterion A

The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.

This criterion applies chiefly when and if a sodium system leaks or ruptures, allowing sodium to escape into the cell.

Sodium will not react with either argon, helium or nitrogen as far as is known. Atmospheres of less than four percent oxygen in the lower ranges of humidity do not permit serious sodium-oxygen or sodium-water reactions to occur.¹ On this basis then, there is no strong technical reason to choose any of the three gases for the cell atmospheres, since oxygen and water content may be controlled equally in all three.

4.2.1.2 Criterion C

The inert gas must facilitate control of material damaging impurities, and must not itself damage materials or equipment.

For the inert cell atmospheres, nitrogen, argon, and helium are the candidate gases. As indicated in the discussion in Section 4.1.1.3 the control of material damaging impurities in either argon or helium is technically feasible by purification or by purging. Argon or helium will not damage equipment or materials insofar as is known. Nitriding of high

1. Refer to References, Appendix A, Item 9, page 19.

temperature stainless steels is prevented by small percentages of oxygen.¹ Inasmuch as some oxygen will be present in the cells, it appears that this potential problem is not serious. Laboratory tests are being performed to verify this assessment.²

The presence of oxygen and nitrogen in a neutron field leads to the formation of oxides of nitrogen³ which form nitric acid in the presence of moisture. These nitrogeneous oxides have been detected in the primary shield tank at Fermi.⁴ The possibility of material damage from this effect was considered at Fermi and Sefor but was not considered to be significant enough to preclude the use of nitrogen for cell atmospheres. There are no reports of damage to materials due to the use of nitrogen as an inert cell atmosphere. Therefore, helium, nitrogen and argon can be considered equal candidates for inert cell atmospheres under this criterion.

4.2.1.3 Criterion J

The inert gas must provide adequate cooling of equipment as required.

For the cells, all three candidate gases were compared to determine what effect the heat transport properties had on cooling. The heat transfer properties of argon are inferior to those of nitrogen. The result of this is that, (1) the surface temperatures of cooled components is higher with argon than it is for nitrogen, and (2) the heat exchanger

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1. Refer to References, Appendix A, Item 10, page 13.
 2. Refer to Support Information Requirements, Appendix B, Item 1.
 3. Refer to References, Appendix A, Item 54.
 4. Refer to References, Appendix A, Item 46.

cores are larger for the same pressure drop for argon than for nitrogen. The surface temperature difference is of no great concern, being about 10 °F higher on horizontal pipes for the same insulation. The heat exchanger cores are approximately 45 percent larger for the same gas side pressure drop¹ and Reynold's number and the blowers must move more argon to achieve the same cooling.

The heat transfer properties of helium are superior to those of nitrogen. The result of this is that: (1) the surface temperature of cooled components is slightly lower in helium than for nitrogen, and (2) the heat exchanger cores are smaller for the same pressure drop for helium than for nitrogen. The heat exchanger cores for helium are significantly smaller than cores for nitrogen. However, the method used in Section 6.6 to provide a numerical comparison cannot be used because it depends on an approximate parity of heat transfer properties. Since helium heat transfer properties are so much better than either nitrogen or argon, such parity does not exist. However, a significantly smaller heat exchanger would be necessary to provide equal cooling. Helium best fulfills this criterion, with nitrogen and argon as the next preference, in that order.

4.2.1.4 Criterion H

The inert gas must provide an atmosphere suitable for operation of electrical and mechanical equipment.

The electrical insulating values and heat transfer properties of argon are such that electrical motors should be derated approximately 70 percent and ac voltages should be limited to 220 Vac rms to avoid trouble.² The low dielectric of

1. Refer to Appendix D, Section 6.6.

2. Refer to References, Appendix A, Item 55.

argon permits arcing and corona at much lower voltages than in air. The poor heat transfer properties of argon cause the motor coil temperatures to be higher than in air. These are reasons for the above-mentioned limitations.

The electrical insulating value of helium is such that voltages should be limited to 220 Vac rms¹ to avoid arcing, although the cited reference pertains to lower radiation levels than are expected in this application. Direct current applications are not affected by the gas dielectric properties because the electrical field in a D.C. conductor is confined to the wire itself. The heat transfer properties of helium are good, and therefore derating would not be necessary to hold coil temperatures down.

The electrical insulating value and heat transfer properties of nitrogen are essentially the same as air. Therefore, the equipment need not be derated nor do voltages have to be limited for operation in nitrogen. Therefore, the use of argon or helium as inert cell atmospheres imposes some limitations on the use of electrical equipment while nitrogen imposes the least.

Applying equally to argon, helium, and nitrogen is the fact that operation of brush type motors in atmospheres containing less than 40 ppm water (-57 °F dewpoint) and low oxygen content, results in extremely rapid brush wear.² However, if the moisture content is greater than 40 ppm (-57 °F dewpoint), off-the-shelf brush-type electrical motors can be used in nitrogen-filled cells, if the brushes are impregnated with molybdenum disulphide.²

Tests and confirming literature surveys indicate that oil, grease, or dry lubricated bearings perform similarly in

1. Refer to References, Appendix A, Item 56.

2. Refer to References, Appendix A, Item 57, pages 1 and 10.

helium, nitrogen, hydrogen or air when the moisture content of the gases is the same.¹ Argon should be no different. The bearing problem is engendered by a lack of moisture in the atmosphere rather than by a choice of gas. Therefore, argon, nitrogen and helium atmospheres pose no intrinsic problem for bearings.

In general nitrogen best fulfills this criterion, with helium and argon being next in order of preference.

4.2.1.5 Criterion G

The inert gas should be chosen with due regard to cost. A study² was made to compare the costs of nitrogen, argon, and helium usage for various inert cells. The results are summarized below:

Location	Estimated Volume, ft ³	Annual Cost in Dollars		
		Argon	Nitrogen	Helium
Fuel Examination and Transfer	42,240	4,079	421	11,200
Closed Loop Cells	108,590	37,220	3,840	102,500
Primary Heat Transfer and Sodium Storage	182,000			
Reactor Cavity	33,225			

A cost estimate was prepared to compare the cost of an inert gas system equipment comprising twelve inert cells and a cryogenic supply with nitrogen or argon as the gas. The cost of the nitrogen system was \$105,000 and the cost of the same system with argon was \$123,000. The difference in costs stemmed from the larger derated blowers necessary to circulate the argon, and the larger heat exchanger cores. Helium was not considered because the usage study² results above indicated that helium was too expensive to consider as atmosphere in the cells, unless other requirements were to demand it.

1. Refer to References, Appendix A, Item 58, page 1.
2. Refer to References, Appendix A, Item 50.

In summary, nitrogen is clearly preferable from a cost consideration, with argon and helium next in order of preference.

4.2.1.6 Criterion F

The inert gas should be chosen to take advantage of proven technology and components.

All three candidate gases have been used as glove box atmospheres. The experience at the Fuel Cycle Facility at EBR-II and the irradiated fuel inspection facility at Dounreay constitutes proof of technology for use of argon in large cells. The experience at Hallam, SRE, and Fermi constitutes proof of technology for use of nitrogen in large cells. Helium was used as the atmosphere in the reactor cavity at Hallam but apparently this is the only relatively large cell that has been operated with a helium atmosphere. Therefore, argon and nitrogen both meet this criterion adequately, with helium meeting it less adequately.

4.2.1.7 Criterion D

The inert gas must not cause unnecessary effects in the design and operation of other systems.

The choice of cell atmosphere has little direct effect on the systems and equipment within the cells except from the viewpoint of electrical equipment operation which is discussed under 4.2.1.4.

4.2.1.8 Selection of Atmosphere for Closed Loop Cells

Nitrogen is chosen as the atmosphere for these cells because nitrogen will satisfy the technical requirements at least cost. The use of nitrogen will provide adequate cooling capability in an atmosphere conducive to the operation of

off-the-shelf electrical equipment. The total of usage and system components is least for nitrogen. Therefore nitrogen is chosen because it satisfies the criteria at least cost.

4.2.2 Reactor Primary Sodium Purification and Storage Cell Atmosphere

These cells contain the reactor sodium and purification equipment located in the containment. The atmosphere in these cells must satisfy the criteria used in the selection of the closed cells.

Nitrogen is chosen as the atmosphere for these cells for the same reasons given for the selection of nitrogen for the closed loop cells.

4.2.3 Reactor Primary Heat Transport Equipment Cell Atmosphere

These cells contain the reactor primary heat transport equipment, and connect with the reactor cavity cell. A portion of the atmosphere in these cells is used to cool the external reactor neutron shield. As such, it is subject to neutron irradiation. The atmosphere in these cells must satisfy the criteria listed below in the order of preference.

- The inert gas must prevent serious sodium oxygen reactions which could occur if air came in contact with molten sodium.
- The inert gas must facilitate control of material damaging impurities and must not itself damage materials or equipment.
- The inert gas must provide adequate cooling of equipment as required.
- The inert gas must provide an atmosphere suitable for operation of electrical equipment.

- The inert gas should be chosen to minimize activation from neutron irradiation.
- The inert gas should be chosen with due regard to cost.
- The inert gas should be chosen to take advantage of proven technology and components.
- The inert gas must not cause unnecessary effects in the design and operation of other systems.

The discussion of the criteria is the same for this application as for the closed loop cells except for neutron activation which can be expected in the reactor cavity.

4.2.3.1 Criterion I

The inert atmosphere should be chosen to minimize activation from neutron irradiation.

This criterion applies only to the gas spaces immediately adjacent to the reactor vessel, inasmuch as the neutron flux will not be significant in other locations. A brief screening analysis was performed to analyze the results of using nitrogen or argon as the reactor cavity gas.¹ In recent concepts, this gas is used to maintain an inert atmosphere in the cavity and to cool the neutron shield. The analysis assumed a pure argon atmosphere on the one hand, and a nitrogen atmosphere containing 300 ppm of argon as an impurity as the other case. Total gaseous activities reported are: 16 $\mu\text{Ci/cc}$ for the pure argon atmosphere, and 0.003303 $\mu\text{Ci/cc}$ for the nitrogen atmosphere of which 0.0033 $\mu\text{Ci/cc}$ was the contribution of the argon impurity. A person standing two feet away from an unshielded infinitely long duct 2 feet by 2 feet in cross-section that contained gas of an activity of 16 $\mu\text{Ci/cc}$ would receive about 10 r/hr radiation.² If the gaseous activity was 0.0033 $\mu\text{Ci/cc}$, the

1. Refer to References, Appendix A, Item 59, page 3.34.
2. Refer to References, Appendix A, Item 60.

person would receive only 2 mr/hr. In addition the predominant activation product of argon is argon 41 which has a half life of 1.83 hours; the predominant activation product of nitrogen is nitrogen-16 which has a half life of only 7.1 seconds. Therefore, leakage of activated argon would pose problems that leakage of activated nitrogen would not. The cross-section of helium is smaller than that of nitrogen. Therefore activations would be less of a problem than with nitrogen. Therefore, both nitrogen and helium adequately fulfill this criterion, while argon does not.

4.2.3.2 Selection of Atmosphere for Reactor Primary Heat Transport Equipment Cells

Nitrogen is chosen for this application because nitrogen will satisfy requirements at least cost. The use of argon would be very undesirable because of the neutron environment in this area. The resulting activation would require special design provisions and operating procedures. The use of helium would result in an unnecessary cost penalty. Therefore, nitrogen is the best choice technically and economically.

4.2.4 Contaminated Sodium Processing Cell Atmosphere

This cell contains only the contaminated sodium storage and processing equipment. Inasmuch as there will be no significant neutron flux in this cell, the selection criteria used for the closed loop cells apply.

Nitrogen is chosen for this application for the reasons given for selection of nitrogen for the closed loop cell atmosphere.

4.2.5 Radioactive Maintenance Cell Atmosphere

This cell is used for remote maintenance of sodium system components. The selection criteria for this application are the same as for the closed loop cells.

Nitrogen is chosen for this application for the same reasons given for selection of nitrogen of the closed loops cells.

4.2.6 Fuel Transfer and Examination Cells Atmosphere

These cells are located outside of the containment and have a common atmosphere supply. Irradiated driver fuels, test fuels, and materials test specimen are moved, cleaned, examined, and disassembled in these cells. The fuels and materials specimen in these cells will be radioactive and contaminated with sodium residuals. The atmosphere in these cells must satisfy the criteria listed below in the order of their importance.

- The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.
- The inert gas must facilitate control of material damaging impurities, and must not itself damage materials or equipment.
- The inert gas must provide adequate cooling of equipment as required.
- The inert gas must provide an atmosphere suitable for operation of electrical equipment.
- The inert gas should be chosen to take advantage of proven technology and components.
- The inert gas must not cause unnecessary effects in the design and operation of other systems.

- The inert gas must facilitate control of fission gases which may be present from reactor fuels.
- The inert gas should be chosen with due regard for cost.

Neutron irradiation is not considered for this selection because the neutron environment is insignificant in these cells.

4.2.6.1 Criterion A

The inert gas must prevent serious chemical reactions which could occur if air came into contact with molten sodium.

As discussed in Section 4.2.1.1 all three candidate gases will satisfy this criterion.

4.2.6.2 Criterion B

The inert gas must facilitate control of material damaging impurities, and must not itself damage materials or equipment.

The FFTF is a coordinated facility for investigation into the behavior of fuels and structural materials subjected to high fast neutron flux prototypical of fast reactor environments. The fuel examination facility is crucial in this investigation in that the fuels and materials tested in the FFTF will be examined for effects of the nuclear environment. The atmosphere in the fuel exam facility must be such that no significant changes in the sample occur as a result of the necessary exposure for examination. Since there is insufficient information available about the effect of nitrogen on macro- and microstructures of candidate materials and fuels, nitrogen must be rejected because test data may be jeopardized if it were used.

Argon and helium will not damage materials or equipment insofar as is known. As discussed in Section 4.1.1.3 there are a number of methods of controlling material damaging impurities in either argon or helium. Therefore, argon and helium are acceptable under this criterion but nitrogen is unacceptable.

4.2.6.3 Criterion J

The inert gas must provide adequate cooling of equipment as required.

The atmosphere in these cells will be used to cool all the equipment and fuels in the cells. As discussed in Section 4.2.1.3 helium is the best from this aspect, with nitrogen and argon being next in order of preference.

4.2.6.4 Criterion H

The inert gas must provide an atmosphere suitable for operation of electrical equipment.

This cell will contain several varieties of electrical equipment such as, manipulators, machine tools and hoists. As discussed in Section 4.2.1.4, nitrogen is preferable from this aspect with helium and argon being next in order of preference.

4.2.6.5 Criterion F

The inert gas should be chosen to take advantage of proven technology.

As discussed in Section 4.2.1.5, argon and nitrogen both meet this criterion adequately with helium meeting it less adequately.

4.2.6.6 Criterion D

The inert gas must not cause unnecessary effects in the design and operation of other systems.

The major interfacing system with this facility is the fuel handling machine (FHM). The concept for the FHM has not been selected. If a gas-cooled FHM is selected it would be desirable to have the same gas in this facility as is used in the FHM to avoid gas mixing problems. If argon is chosen as the FHM gas, an argon choice for this facility would be compatible.

If the FHM gas choice were helium, and argon were chosen for this facility, some helium contamination of the atmosphere can be expected. The level of helium contamination should not be excessive in such a case because the greater density of argon would tend to keep it from rising into the FHM and the lesser density of helium would tend to keep it from descending into this facility. Contamination of the Fuel Transfer Cell atmosphere should not be critical if the electrical equipment in this facility were designed to accommodate such contamination. The argon contamination of the helium in the FHM, however, would interfere to some degree with the operation of the FHM cooling system because of the significant differences in heat transport properties between helium and argon. Therefore, it is undesirable to allow a gas incompatibility to exist.

Based on the discussion above, it would seem that if a gas cooled FHM concept is selected using a gas different from the atmosphere in the Fuel Transfer Cell, a gas transfer lock would be necessary to avoid the effects of the

incompatible gases in the FHM atmosphere. This would be an undesirable complexity that can be avoided by using the same gas throughout the fuel handling sequence.

4.2.6.7 Criterion G

The inert gas should be chosen with due regard to cost.

As discussed in Section 4.2.1.5 nitrogen is most preferable, with argon and helium being next in that order of preference.

4.2.6.8 Criterion B

The inert gas must facilitate control of fission product gases which may be present from failed or vented fuels.

Failed and vented fuels will ultimately be transferred into these cells, and will be examined in the examination cell. However, the quantities of fission gases that will be released to the cell atmosphere will be small because the fuels will be sufficiently "old" so the majority of the radioactive gases will be decayed away or will have escaped elsewhere. No fission gas will be produced in these cells because criticality will be precluded. Therefore, control of fission gases can be effected by (a) allowing the radioactive gases to decay in the cell atmosphere or (b) purging the cell to the gas holdup system if necessary. It is unlikely that alternative 2 would be necessary except following an unidentified emergency.

4.2.6.9 Selection of Inert Atmosphere for the Fuel Transfer and Examination Cells

Argon is selected for this application because it generally meets the criteria. Nitrogen is disallowed from the viewpoint of potential nitriding of test specimens. Helium is more

expensive than argon. There are no cogent reasons for using helium inasmuch as the conditions expected for this facility will be generally similar to those for the EBR-II Fuel Cycle Facility. Since argon has been successfully used at that facility, there is no incentive to use helium. Therefore, argon will be used as the atmosphere in this facility.

4.2.7 Fuel Handling Machine Gas

The choice of gas for this application must satisfy the following criteria.

- The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.
- The inert gas must facilitate control of material damaging impurities, and must not itself damage materials or equipment.
- The inert gas must provide adequate cooling of equipment as required.
- The inert gas must not cause unnecessary effects in the design and operation of other systems.
- The inert gas should be chosen with due regard to cost.
- The inert gas should be chosen to take advantage of proven technology and components.

These criteria are discussed below:

4.2.7.1 Criterion A

The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium. As discussed in Section 4.1.1.1 helium, argon and nitrogen satisfy this criteria equally well.

4.2.7.2 Criterion C

The inert gas must facilitate control of material damaging impurities, and must not itself damage material or equipment. The FHM will be moving fuels at high heat liberation rates which will potentially result in high fuel cladding temperatures. As discussed in Section 4.2.6.2 nitrogen must be rejected for this application because of potential nitriding of fuel cladding and consequent loss of test data. Neither helium nor argon will normally react with materials. Further, as discussed in Section 4.1.1.3 control of reactive impurities may be exercised in either gas. Therefore, both helium and argon meet this criteria while nitrogen does not.

4.2.7.3 Criterion J

The inert gas must provide adequate cooling of equipment as required. At the present time, the Fuel Handling Machine (FHM) concept has not been selected. There are two possible choices for the conceptual design of the FHM: (1) a sodium-cooled machine; (2) a gas cooled machine.

If a sodium cooled machine is selected, the gas in the FHM would be simply a sodium cover gas with no cooling function. As discussed in Section 4.1, both helium and argon fulfill the cover gas criteria. Inasmuch as argon has been selected as the gas for other cover gas applications, argon would be used for the sodium-cooled FHM to avoid interface or logistics complication to the FFTF that would attend the choice of helium for the FHM.

There are two possible approaches to the gas-cooled FHM: continuous or noncontinuous cooling. In the continuous cooling concept, gas cooling of a fuel subassembly begins before the fuel section is removed from the reactor sodium. The

cooling gas enters the subassembly at the top, passes through the subassembly, and bubbles through the reactor sodium to the cover gas region. Studies¹ have shown that both argon or helium are equally acceptable from technical considerations, and no unacceptable operating penalties will result from either choice. Therefore, either argon or helium may be used as coolant in the continuously cooled gas FHM.

In the noncontinuous gas cooling concept, the fuel is lifted into the FHM proper before cooling is begun. This approach eliminates the problem that may result from bubbling large quantities of gas through the reactor sodium. Time studies² have shown that approximately three minutes is required to lift the fuel into the FHM and to begin gas cooling. Heat transfer studies have shown that, with helium as the FHM cooling gas, fuel subassemblies decaying at a rate of 34 kwt could be lifted into the FHM in the three minute period. These studies assumed that the initial cladding temperature was 450 °F, and that the cladding temperature was allowed to rise to the maximum³ of 1200 °F during the three minute lift period. If argon was used as the FHM gas, the studies indicate that fuel subassemblies decaying at a rate of 26.6 kwt could be lifted into the FHM for the same cladding temperature conditions. According to present estimates⁴ the average driver fuel will decay at a rate of 34 kwt approximately 10 hours after shutdown, and 27 kwt about 20 hours after shutdown.

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1. Refer to References, Appendix A, Item 61, page 8.
 2. Refer to References, Appendix A, Item 62.
 3. Refer to References, Appendix A, Item 63.
 4. Refer to References, Appendix A, Item 64, page 10.

Fuel handling operations, however, will not be commenced for 24 hours after reactor shutdown.¹ Therefore, both argon and helium fulfill this criterion since neither limits the initiation of fuel handling operations for sodium-cooled FHM, or for either variety of gas cooled FHM's.

4.2.7.4 Criterion D

The inert gas must not cause unnecessary effects in the design and operation of other systems. If a helium cooled FHM concept were selected, helium would be the better choice for cover gas to maintain gas compatibility between the FHM and the reactor. If an argon cooled FHM concept were selected, argon would be the better choice for cover gas for the same reason.

If helium were used in the noncontinuous gas cooled FHM, and argon were used as reactor cover gas, gas mixing would occur when the lower valve was opened chiefly from diffusional effects. However, the gas displacement caused by subsequent movement of the grapple and the fuel subassembly would cause a high degree of mixing of reactor and FHM gas in that case. For the continuous cooling approach the gases would be strongly mixed by the flow of cooling gases back and forth from the FHM and the reactor.

The heat transfer properties of argon and helium are quite different, and it would be difficult to design the FHM gas cooling system accommodate pure argon, pure helium and any mixture of the two. Thus, it would be undesirable from the FHM to initiate fuel handling operations with different gases in the FHM and the reactor or in the FHM and the Fuel Transfer Cell. The most desirable situation

1. Refer to References, Appendix A, Item 65.

would be to have the same gas throughout the fuel handling sequence. Since argon has been selected for the reactor, and for the Fuel Transfer Cell atmosphere, argon would be the better choice than helium for the FHM to maintain gas compatibility throughout. A choice of helium for the FHM would necessitate changing the reactor cover gas for fuel handling operations, and would provide helium contamination of the Fuel Transfer Cell atmosphere each time fuel was moved. While these problems are not insurmountable, an incremental design and operational complexity would result from the helium choice. Therefore, argon fulfills this criteria better than does helium.

4.2.7.5 Criterion G

The inert gas should be chosen with due regard to cost.

As discussed previously, the cost of helium at Hanford is 4.3¢/scf and argon is 1.6¢/scf. From this aspect, argon is preferable to helium. No other cost comparisons can be made at this time because no concept has been chosen for the FHM. If a sodium cooled machine is chosen, the cost contribution from the gas will be minimal.

A study is necessary to determine the comparative cost penalties involved in choosing argon or helium for the gas cooled FHM. The use of helium would result in smaller components than would the use of argon. However, helium circulators would be more sophisticated than argon circulators, and therefore would probably be more costly. Because of the uncertainties in the concept, no cost comparisons can be made at this time.

4.2.7.6 Criterion F

The inert gas should be chosen to take advantage of proven technology. If a sodium-cooled FHM is chosen, both argon or helium fulfill this criterion inasmuch as the gas is simply a sodium cover gas.

If a gas cooled FHM is chosen, both argon and helium fulfill this criterion to the same degree because EBR-II uses an argon cooled FHM and Hallam used a helium cooled FHM. These reactors however, moved fuel at lower heat liberation rates than is projected for the FFTF. However, based on past usage, both argon and helium fulfill this criteria to the same extent.

4.2.7.7 Selection of Gas for the Fuel Handling Machine

From the foregoing discussion, nitrogen was rejected for this application because of the potential nitriding of fuel elements. Helium and argon were found to be equally acceptable from the viewpoints of

1. Basic Inerting
2. Impurity Control
3. Cooling
4. Proven Technology.

Argon is tentatively chosen for this application because argon is most compatible with the reactor cover gas and Fuel Transfer Cell atmosphere. The use of helium would introduce design and operational complexities to FFTF systems which are neither desirable nor necessary. This choice will be confirmed upon completion of conceptual design studies to select a fuel handling concept. The gas choice for the FHM will be baselined in the Conceptual System Design Description for the Reactor Refueling System.

4.2.8 Machinery Dome Atmosphere

The machinery dome is located above the reactor vessel head and acts as a buffer between the reactor cover and the work area. Normally the atmosphere under the dome is air. However, an inert atmosphere is desired as an option to this normal. The inert gas chosen for this option must satisfy the following criteria:

- The inert gas must prevent serious chemical reactions which could occur if air came in contact with molten sodium.
- The inert gas must provide adequate cooling of equipment as required.
- The inert gas must not cause unnecessary effects in the design and operation of other systems.
- The inert gas must be chosen with due regard to cost.
- The inert gas must facilitate control of radioactive gases which may be present from reactor leakage.
- The inert gas must facilitate control of material damaging impurities, and must not itself damage materials and equipment.
- The inert gas should be chosen to take advantage of proven technology and components.

The purpose of providing an inert atmosphere in this location is to preclude sodium fires in case sodium gets on the reactor cover. As discussed throughout this section nitrogen is a preferable choice over argon because of the cost factor. The only reason to use argon as a cell atmosphere is to preclude nitriding of hot stainless steels. The pressure under the machinery dome will be less than the hot cell pressure because of the necessity of controlling radioactive gases that will leak through the reactor vessel cover into the access space. Inasmuch

as the machinery dome upper surface seals are exposed to the air atmosphere of the reactor refueling hot cell, it can be expected that as a result air will leak into the reactor access space. The air inleakage will assure that oxygen will be present to prevent serious nitriding of the reactor cover and nozzles. Therefore, nitriding should not be a problem in this location. Nitrogen is therefore selected as the atmosphere for the reactor access space because it satisfies the criteria at least cost.

5.0 SINGLE GAS CONCEPT FOR THE FFTF

Inert gases were selected for specific FFTF applications in Sections 4.1 and 4.2 of this appendix. The results are that argon was chosen for all sodium cover gas applications for initial operation for the Fuel Handling Machine, and for the Fuel Transfer and Examination Facilities. Nitrogen was chosen as the atmosphere for the remaining inert cells. Generally, nitrogen was chosen on the basis of cost. Consideration was given to the use of argon for all inert gas applications in the FFTF to determine if any net advantages would accrue from such a variation.

Summary

The use of argon for all FFTF inert gas applications results in a cost disadvantage, additional problems and requirements with radioactive gases, additional constraints on maintenance procedure or air purge vent design, and merely reduces but does not eliminate the possibility of cover gas contamination by diffusional inleakage of nitrogen.

5.1 COST EFFECTS OF UNIVERSAL APPLICATION OF ARGON

There are two broad categories of inert gas system cost that can be considered: system cost and usage cost.

5.1.1 System Cost

From available cost estimates, the system costs of the nitrogen and argon systems are as follows:

<u>System</u>	<u>Labor and Material Dollars</u>
Argon Sodium Cover Gas System	\$ 226,000
Argon System for Fuel Transfer and Examination	182,000
Nitrogen System for Inert Cells	<u>105,000</u>
Total:	\$ 513,000

If an all argon system was used in the FFTF, the systems costs would be as follows:

<u>System</u>	<u>Labor and Material Dollars</u>
Argon Sodium Cover Gas System	\$ 226,000
Argon System for Fuel Transfer and Examination	182,000
Argon System for Inert Cells	<u>123,000</u>
Total:	\$ 531,000

Review of the system considerations in evaluating the use of one or two gases indicates that the advantages potentially gained by reducing the number of gases are confined primarily to:

1. Reducing the number of sources of supply
2. Reducing the quantity of valves and piping up to the supply manifolding required for furnishing any gas.
3. Possible reduction in the amount of instrumentation.

The tankage and vaporizers for argon and nitrogen are customarily provided by a vendor as part of a supply contract and thus do not represent an added cost to the project.

Thus the economic advantages must be keyed to reduction in the second and third items above. Item 2 pertains to conventional equipment, and represents limited cost. Item 3, has not been sufficiently defined in FFTF to make quantitative comparisons, but it does not appear that differences in instrumentation could conceivably compensate for the gas usage cost differences outlined below.

5.1.2 Cost of Expendable Gases

A study¹ was made to compare the estimated operating costs of using nitrogen and/or argon as cell atmosphere. This comparison was made under the assumption that 0.3% cell volume would be lost per day because of barometric variation, makeup for inleakage, and airlock usage. Additionally it was assumed that each closed loop cell would require dumping three times annually, and the primary sodium storage and heat transfer cells would require dumping once annually. On this basis, the annual usage cost of expendable gases for the inert cells is as follows:

- a. Nitrogen and Argon in various FFTF cells \$ 7919.00
- b. Argon only in FFTF cells \$41279.00

5.2 DESIGN AND OPERATIONAL EFFECTS OF UNIVERSAL APPLICATION OF ARGON

There are several interface effects on the FFTF that would be engendered by the universal use of argon in the FFTF. These are discussed below.

5.2.1 Effects of Use of Argon in Neutron Flux Areas

As discussed in Section 4.2.3.1 the use of argon in the reactor cavity will result in activation of the argon to an

1. Refer to References, Appendix A, Item 50.

average level of 16 $\mu\text{Ci/cc}$. Since this is significantly higher than the MPC level of 2×10^{-6} $\mu\text{Ci/cc}$ exceptional care would be required to insure that leakage would not hamper normal operation of the FFTF. Since the activity of the cavity gas would be higher than the activity of the reactor cover gas proper (see Section 4.1.1.6) the emphasis of control would shift from reactor leakage to reactor cavity leakage.

The normal means of confinement of radioactivity in cell atmospheres is by pressure differential. Cell pressure levels are set so that leakage is from zones of low contamination to zones of high contamination. For control of such high activity gas, a pressure differential would be essential. This control method is quite satisfactory for air cells but is less desirable for inert cells. For example, consider that the relationship of pressures and seals was such that air leaked into the reactor cavity at a rate equal to 1% of the cavity volume per day, or 330 cfd. In order to maintain the oxygen content at a safe level of 4%, pure argon would also have to be added to the reactor cavity atmosphere. For the 4% oxygen level this dilution flow for steady state would be:

$$\begin{aligned} 0.04 &= \frac{V_{O_2}}{V_{\text{argon}}} = \frac{V_{\text{air}}}{5(V_{\text{argon}})} \\ V_{\text{argon}} &= \frac{V_{\text{air}}}{5(0.04)} = 5 V_{\text{air}} = 5(330 \text{ cfd}) \\ &= 1650 \text{ cfd} \end{aligned}$$

This inflow would have to be greater if lower oxygen levels were desired. In order to maintain the negative pressure in the reactor cavity, a total of $330 + 1650 = 1980$ cubic feet

of gas per day would have to be removed by a compressor and put into radioactive gas holdup tankage. Holdup tankage would be required because the total activity and quantity of the gas removed from the cavity would exceed the allowable release.

A trade study would be necessary to determine if the gas removed daily from the reactor could be reused after radioactive decay eliminated the activity. For a 75% availability factor, the annual cost of argon to serve the reactor cavity would be $0.75 \times 365 \text{ day/year} \times 1650 \text{ ft}^3/\text{day} \times \$0.016 = \$5400$ if it was vented when the activity levels permitted. This cost would have to be compared to the cost of providing equipment to remove oxygen and nitrogen from the stored gases since the stored gas would be 4% oxygen and 16% nitrogen. The required holdup time would have to be determined to provide a basis on which to estimate the radioactive gas tankage required. This tankage would be greater than that required for the simpler hold-for-vent system since reuse would probably require lower activity than that permitted for release.

If nitrogen were used in the reactor cavity for the same conditions, again approximately 1980 cfd would have to be removed from the reactor cavity. However, the annual usage cost for simple venting would be about \$540 because nitrogen is cheaper. The total activity would be only about 1.4 curies per day which could be released directly. Additionally, since the cavity gas activity would be only 0.003 $\mu\text{Ci/cc}$ (See Section 4.2.3.1) leakage would not be such a severe problem. With activity at that level, it might be possible to operate the reactor cavity at a pressure slightly higher than that of the surrounding areas. If this situation

developed, even the minimal cost of controlling reactor cavity gas purity would be eliminated because air would not leak significantly into the reactor cavity against the adverse pressure gradient.

In summary, it can be seen that the use of argon in neutron flux areas in the inerted cells would result in serious problems stemming from activation. Much less severe conditions would ensue if nitrogen were used for this application. Therefore nitrogen is preferable from this standpoint.

5.2.2 Effects of Use of Argon in Cells not in Neutron Flux

For cells such as the closed loop or primary sodium storage cells, the use of argon instead of nitrogen would engender a potential hazard to maintenance personnel. This potential hazard stems from the density of argon, an advantage for sodium cover gas applications, but a disadvantage for use in inert cells.

Since argon is more dense than air, considerable care would have to be exercised in providing an air atmosphere for cells previously filled with argon. Argon would tend to pool in low areas in such cells during air purging unless special attention were given to this problem during design. If argon pools were left in low areas such as pipe galleries and the like, it would be possible that maintenance people could be overcome with anoxia if they entered such spaces. Since argon is odorless and tasteless, oxygen level detectors would become normal maintenance equipment as well as radiation detectors.

A method of circumventing this hazard would be to have the exhaust vents of the purging system at the bottom of the low

areas in the cells. Such low vents may collect and become plugged with radioactive sodium in the event of a failure of a sodium system. This would prevent the use of the vent system until the vents were cleared.

If nitrogen were used as the cell atmosphere, this potential hazard would not exist. If it were elected to purge a nitrogen filled cell with air, the air would mix freely with the nitrogen during purging, since there is very little difference in density. As a result, the possibility of having anoxic conditions in low areas of the cells would be much reduced. The exhaust vents of the cells could be located well above the levels likely to be flooded with molten sodium in event of a piping failure.

In summary, it is evident that the use of argon in cells not exposed to neutron flux will pose an unnecessary potential hazard to maintenance personnel and would impose unnecessary requirements on the location of the exhaust vents of the air purging system. Therefore, nitrogen is preferable to argon from this standpoint.

5.2.3 Effects of Use of Argon Atmospheres on the Sodium Cover Gas Systems

One of the reasons advanced for the use of argon in the inert cells, is that it would eliminate nitrogen entry by diffusional inleakage into the sodium heat transport systems. However, it would merely reduce rather than eliminate it. Since these cells will probably be held at a pressure lower than the surrounding areas because of radiological considerations, some air inleakage can be expected.

Consideration of fire hazards associated with sodium requires that the oxygen level be no greater than about 4%

of these cells. This oxygen would come from inleakage of air. Since air is about 80% nitrogen, holding the cell atmospheres to 4% oxygen would result in 16% nitrogen in the cell atmospheres. Thus, diffusional inleakage of nitrogen could still be expected, although to a lesser degree than if argon were used.

From experience with sodium reactors to date, nitrogen levels in the cover gas resulting from diffusional inleakage has not been a problem (See Section 4.1.1.3) Since initial FFTF conditions will be quite similar to the conditions reached by existing sodium reactors, it is not expected that the FFTF will have any particular nitrogen problems that may stem from diffusional inleakage of nitrogen from inert cells.

Should it develop that much lower nitrogen levels are required in the reactor cover gas to meet future conditions, the argon cover gas may be purified at that time using the available methods. (See Section 4.1.1.3) Initial closed loop requirements are such that nitrogen control may be necessary. However, since fission gas control will also be necessary, the purge and holdup method suggested will control nitrogen as well. Additionally the high system integrity demanded from consideration of fission gases will tend to reduce the inleakage potential.

In summary, it can be seen that the use of argon as the inert cell atmospheres would reduce but not eliminate any diffusional inleakage into sodium systems. This is an advantage but there are other methods of coping with this problem.

SECTION 6.0 SUPPORTING INFORMATION

6.1 STATE-OF-THE-ART COMPARISON FOR SODIUM REACTORS

A brief literature survey was performed to provide material for comparison of various aspects of sodium-cooled reactors. This information is presented in Table D-2.

6.2 COMPARISON OF LEAKAGE TENDENCY OF HELIUM AND ARGON

Helium gas is more difficult to contain than the heavier gases. Helium system leakage is commonly controlled by welding where possible and using high integrity seals where welding is not possible. A brief analysis was made to compare the leakage tendency of helium and argon. It was assumed that the leakage of a gas system is the sum of many minute leaks. The analysis considered one such leak as a cylindrical capillary. The volumetric flow of helium and argon were compared through such a passage assuming the gas temperature in either case was 800 °F, and the differential pressure across the passage was 10 inches of water with the reactor total pressure 10 inches of water above atmospheric. The flow passage was assumed to be two inches long, and the diameter was parameterized in the range 10^{-8} inches to 10^{-1} inches. For the viscous flow regime, the volumetric flow expression is the Hagen-Poiseuille law:

$$\frac{dv}{dt} = \frac{(\Delta P)}{(\Delta L)} \frac{(\pi D^4)}{(128\eta)}$$

Where the symbols are defined in the Glossary Section 6.7 this appendix.

The upper limit of this flow regime occurs when the flow is such that the Reynolds number is 2000. For the assumed conditions this occurs at flow passage diameters of 0.147 inches and 0.057 inches for helium and argon respectively.

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TABLE D-2. Data on Liquid-Metal-Cooled Reactor Plants

Fuel Element Cladding	SRE	MNPF	EBR-I	EBR-II	EFAPP	LAMPRE-I	DFR	BR-5	Rapsodie
Power, MW(t)	20	240	1.4	62.5	430	1	72	5	20
Turbine steam conditions: temp, °F/pressure, psig	825/600	825/800	529/390	840/1250	780/900	Air heat dump	555/185	Air heat dump	Air heat dump initially
Coolant	Na	Na	NaK (22.5-77.5)	Primary System Na	Na	Na	NaK (70-30)	Na	Na
Reactor Inlet temp, °F	500	602	442	700	600	750	392	707	840
Reactor Outlet temp, °F	960	945	600	884	900	950	662	842	1000
Pipe and Vessel materials	304 SS	304 SS	347 SS	304 SS	304 SS	316 SS 316L SS	347 SS	321 SS	316 SS
Other materials in contact with coolant:									
Fuel-element	304 SS	304 SS	Mark I and II, 347 SS Mark III and IV, Zircaloy-2	304 L SS	Core, Zr Blanket, 304 SS	Ta	Cladding, Nb and V End fitting, 347 SS	321 SS	316 SS
Fuel							Mark I, U Mark II, U-0.5% Cr Mark IIIA, U-20% Mo		
Moderator cladding	Zr	304 SS			Neutron-Source cladding, Ta Spring, Inconel X				
Control-rod thimble	Zr	Zircaloy-2; replaced with 304 SS							
Coolant flow #/hr	0.61 x 10 ⁶	8.4 x 10 ⁶		3.8 x 10 ⁶	15.9 x 10 ⁶				1.4 x 10 ⁶
Hard-facing	Stellite			Cr, 18-4-1 Stellite, and Colmonoy	Stellite 6, Colmonoy 6, Colmonoy 4, and nitrided 304 SS				
Cover gas, ΔP	+5 psi, max + 1/2 psi operation	+1 in. H ₂ O		-3 in. H ₂ O	+4 in. H ₂ O				
Cover gas	Helium	Helium	Argon	Argon	Argon	Helium	Argon (originally nitrogen)	Argon	Argon
Other Materials	Bellows, 321 SS Pump Rot. El., 316 SS	Bellows 321 SS Cold trap, carbon steel	Intermediate heat exchanger, "A" nickel		Structure: 347 SS 316 SS and 321 SS Pump housing, 2 1/4 Cr-1 Mo	Structure: 430 SS 17-4 PH SS and 304 SS Diluent plug, Armco iron	Hot-trap getter, Zr (not used)		
	Cold trap carbon steel Fill tank, carbon steel Oxygen getter, Zr Carbon getter, 304L SS	Fill tank, carbon steel				Catch pot, Ta Hot-trap getter, Zr			
Inert gas for process and fuel exam. cells	Nitrogen in piping galleries and over kerosene cleaner, @+5 psi max.	Helium in reactor cavity @ 2 1/2 psig N ₂ used in Cold traps HX cells, pump cells, maint. cells +5 psi max. Normal 1-6" H ₂ O		FCF uses argon & air Nitrogen used in Na transfer Disassembly cell gas is argon @-2" H ₂ O and 200 cfm	Argon used for liquid metal transfer and remote maint. operations Air depleted to 5% O ₂ 90 °F in 130 °F out @30,000 cfm in below the floor system Normal air in above the floor system				

The lower limit of this expression occurs when the flow passage diameter is about 200 mean free paths of the gas molecules concerned.¹ From the expression for mean free path developed in the cited reference, the paths are

$$\begin{aligned} L &= 8.6 \frac{n}{P} \frac{T}{M} \\ &= 1.95 \times 10^{-5} \text{ inches for helium} \\ &= 7.75 \times 10^{-6} \text{ inches for argon} \end{aligned}$$

For flow passages less than two mean free paths in diameter, molecular collisions with the walls of the passage occur much more frequently than intra-gas molecule collisions. The flow equation for this molecular flow regime, according to the cited reference is:

$$\frac{dv}{dt} = \frac{\Delta P}{P} \cdot \frac{2\pi}{3L} \cdot \frac{D^3}{2} \cdot v_a$$

The results of this comparison are shown on Figure D-3. For the viscous flow regime, helium will escape 1.21 times the rate of argon through the same passage. For the molecular flow regime, helium will escape 3.4 times the rate of argon through the same passage.

6.3 NOBLE GAS RELEASE TO REACTOR PRIMARY COVER GAS

In order to provide an indication of the effects of noble fission gas release to the cover gas the following analysis was performed.

The following assumptions are made:

1. Ten pins are failed, and release fission gases to the cover gas region which is a volume of 100 cubic feet.

1. Refer to References, Appendix A, Item 66, page 81.

Figure D-3

2. Failure occurs 115 days after reactor startup.
3. After the failure the reactor continues to operate.
4. The failure is such that a period of time elapses between the continuing formation of the isotopes and the release to the cover gas.

Analysis of failures require that a failure be specified. For the first case assume that the failure is a pin-hole leak. Assume that the location of the leak is such that, following the initial release of stored gases, a period of 5 days elapses between the formation of noble gas isotopes, and the arrival of the isotopes in the cover gas. This reduces the release essentially to xenon 133.

The inventory of noble gases in each pin after 115 days operation is 12000 curies.¹ The initial release for the ten pin failure causes an immediate rise in activity. Assuming a 60% burst release fraction, as did the cited reference, the peak activity following the release is

$$G = \frac{(10 \text{ pins}) (0.6 \times 12000 \text{ curies})(\text{pin}) (10^6 \text{ } \mu\text{Ci/cc})}{(2.8 \times 10^4 \text{ cc/ft}^3) (10^2 \text{ ft}^3)} = 26000 \frac{\mu\text{Ci}}{\text{cc}}$$

This burst of activity would trigger alarms, and the cover gas space would be thoroughly purged. Assume that purging was continued until cover gas activity was reduced to 100 $\mu\text{Ci/cc}$. The contaminated cover gas from purging would be put into holdup tanks until release to the uncontrolled atmosphere was possible.

1. Refer to References, Appendix A, Item 67, page 13.

The rate of introduction of xenon 133 to the cover gas for the whole core under the assumptions would be 3.44×10^{17} atoms/sec.¹ For the ten fuel pin failure, the injection of xenon 133 into the cover gas would be

$$j = (3.44 \times 10^{17}) (0.8) \left(\frac{10}{17000}\right) = 1.6 \times 10^{14} \text{ atoms/sec.}$$

This is based on a core of 77 fuel subassemblies,² each with 217 pins.³ This is a core of approximately 17000 pins with an assumed release fraction of 0.8.⁴

For a static cover gas system, the rate of accumulation of xenon 133 in the cover gas is

$$\frac{dN}{dt} = j - \lambda N$$

λ = decay constant

j = injection rate

N = atoms of xenon in cover gas at time t

t = time

$N(0)$ = atoms of xenon in cover gas at time zero

solving,

$$N = N(0) \exp(-\lambda t) - \frac{j}{\lambda} [1 - \exp(-\lambda t)]$$

Converting this to specific activity, assuming a 100 cubic foot cover gas space,

$$\begin{aligned} G \frac{\mu Ci}{cc} &= \frac{N\lambda}{3.7 \times 10^4 \times 2.83 \times 10^6} \\ &= \frac{N(0) \lambda [\exp(-\lambda t) + j (1 - \exp(-\lambda t))]}{1.05 \times 10^{11}} \end{aligned}$$

1. Refer to References, Appendix A, Item 68, page 10.
2. Refer to References, Appendix A, Item 69.
3. Refer to References, Appendix A, Item 70.
4. Refer to References, Appendix A, Item 71, pages 4-1.

The allowable cover gas activity is a function of the leakage of cover gas into occupied areas. Assuming that the allowable activity is approximately 600 $\mu\text{Ci/cc}$ for the design leakage, as was the case for HNPF,¹ it would take approximately 3.7 days after the 10 pin failure to reach this level, under the assumptions. If a purge was then initiated to transfer the contaminated cover gas to storage tanks, the process could be repeated a number of times. The frequency of this purge is a direct function of the rate of introduction of the radioactive species into the cover gas. If a 217 pin failure were postulated, the purge frequency would drop to approximately three hours. Thus it can be seen that a reactor that must be able to accommodate vented and failed fuel must be able to handle significant quantities of contaminated cover gas.

To consider the effect of more probable failures, it was assumed that 10 pins were failed such that each was leaking 10% of the noble gas produced. Shorter holdup times were considered. The analysis was similar to that above, except the equations were solved for each significant isotope, and the individual activities were summed to give the total activity. The analysis assumed as above that purging would be initiated at a total cover gas activity of 600 $\mu\text{Ci/cc}$ and would be continued until the activity was reduced to 100 $\mu\text{Ci/cc}$. For a ten second holdup time in the fuel pins, the purge frequency would be about every 2 minutes, which would mean continuous purging. For a three hour holdup in the fuel pins, the purge frequency would be about 28 hours.

1. Refer to References, Appendix A, Item 72, pages 4-8. D-68

Obviously, the fission gas problem for failed fuels is highly dependent on type of failure. However, releases involving very short holdup times imply relatively large cladding failures which would cause reactor shutdown. The longer release time failures imply small leaks which can be considered to be more conducive to continued reactor operation. These longer release time failures then could be part of the design conditions for the inert gas system.

6.4 CLOSED LOOP PRIMARY COVER GAS SYSTEM FISSION GAS CONSIDERATIONS

The following analysis was performed to provide a basis for estimation of the effects of fission gas releases to the closed loop cover gas. For purposes of analysis, it was assumed that: (1) the closed loop in-pile tube contained 90 fuel pins; (2) the total gas volume in each closed loop system was 20 cubic feet; and (3) the closed loop gas leakage is into the closed loop cell, which is at positive pressure with respect to the adjacent areas.

Assuming a vented fuel test which releases noble fission gases to the coolant, the fission gases must escape from the fuel and find their way to the cover gas space. For purposes of analysis, assume that 100% of the noble fission gases formed are released but that it takes five days for them to find the way to the cover gas region. The greater part of this delay would be in the fuel pin proper.

For such a situation, the radioisotope of major concern is Xenon-133. The release of Xenon-133 to the cover gas in the closed loop is 1.8×10^{15} atom/sec based on 90 pins. This amounts to a Xenon-133 release of 6400 curies per day. If

the Xenon-133 is allowed to come into equilibrium by decay, the specific activity of the cover gas will rise to the value calculated below

$$G_{\text{equilibrium}} = \frac{1.8 \times 10^{15} \text{ atom/sec}}{3.7 \times 10^4 \frac{\text{dis/sec}}{\mu\text{c}} \times 20 \text{ ft}^3 \times 2.83 \times 10^4 \frac{\text{cc}}{\text{ft}^3}}$$

$$= 86000 \frac{\mu\text{Ci}}{\text{cc}}$$

The closed loop systems can be expected to leak gas into the closed loop cells. If the closed loop system leaks 5% of the gas per day, this alone would reduce the cover gas activity in the closed loop to

$$G_{5\%} = \frac{A_{\text{equil}} \lambda}{\lambda + \frac{F}{V}}$$

$$= \frac{(86000)(0.131)}{0.131 + 0.05} = 62000 \mu\text{Ci/cc}$$

Assuming a closed loop cell volume of 18000 cubic feet, the 5% leakage would result in the Xenon-133 level in the cell atmosphere calculated below, assuming no cell purging or leakage.

$$G_{\text{cell}} = \frac{(A_{\text{cg}})(dv/dt)_{\text{cg}}}{V_{\text{cell}} \lambda}$$

$$G_{\text{cell}} = \frac{(62000 \mu\text{Ci/cc})(20 \text{ ft}^3)(0.05)/\text{day}}{(18000 \text{ ft}^3)(0.131/\text{day})} = 26.2 \mu\text{Ci/cc}$$

If 5% per day of the contaminated closed loop cell atmosphere leaks into the operating area above the closed loop cell, the contamination of the air in the operating area would be as follows, assuming that the volume of the operating area is 300,000 cubic feet and it is supplied with 30 air changes per day.

$$\frac{G_{\text{op area}}}{G_{\text{cell}}} = \frac{(18000 \times 0.05 \text{ ft}^3/\text{day})}{(3 \times 10^5 \text{ ft}^3)(0.131/\text{day} + 30/\text{day})} = 10^{-4}$$

$$G_{\text{cell}} = \frac{(62000 \text{ } \mu\text{Ci/cc})(20 \times 0.05 \text{ ft}^3/\text{day})}{18000 \text{ ft}^3 (0.131 + 0.05)/\text{day}} = 19 \text{ } \mu\text{Ci/cc}$$

and $G_{\text{op}} = 19 \times 10^{-4} = 190$ MPC's of Xenon-133 in the operating areas. By reducing both leakages to 1% per day, the closed loop cell atmosphere activity would be reduced to about 7 $\mu\text{Ci/cc}$, and the activity in the atmosphere in the operating areas would be about 13 MPC's. Thus it can be seen that even small leakages of closed loop cover gas will produce radiological problems in the FFTF.

In order to control the fission gases, it will be necessary to purge the closed loop cover gas to keep its activity low enough to permit realistic leakages. Assuming it was desired to limit the activity in the operating areas to 0.01 MPC levels with the 5% leakage rates previously assumed, the closed loop cover gas activity would have to be reduced to about 3 $\mu\text{Ci/cc}$. This would only be accomplished by purging, and would require about 3700 cover gas volume changes per day. For the six closed loops each with 20 cubic feet gas volume this would result in a daily accumulation of $6 \times 20 \times 3700 = 450,000$ cubic feet per day. Assuming the gas was cooled from 1000 to 100 °F and compressed to ten atmospheres into the radioactive gas holdup tanks, the tankage required per day would be about 17000 cubic feet per day. Clearly this is not practical.

Alternatively if it is assumed that the closed loop system leaks only 1% of the cover gas per day, and the closed loop cell leaks 1% per day into the operating areas, the closed loop cover gas activity could be about 60 $\mu\text{Ci/cc}$ for an

activity of 0.01 MPC in the operating areas. Reduction of the activity to 60 $\mu\text{Ci/cc}$ would require about 180 cover gas volumes per day. For the 6 closed loops, this would result in an accumulation of $6 \times 20 \times 180 = 21600$ cubic feet per day. Assuming the cooling and compression as above, the daily tankage requirement would drop to about 830 cubic feet per day. This is not out of reason but is still fairly large considering that the gas for each day's accumulation will have to be held for at least two to three weeks before it could be vented to the uncontrolled atmosphere.

In summary, it can be seen that testing of vented fuels in the closed loops will demand high integrity sealing of the closed loop system proper, and of the closed loop cells themselves. If this can be achieved, then the radioactive gas holdup tankage requirements are not out of reason, and fission gas control can be realized by the use of radioactive gas holdup tanks. Since the closed loops are relatively small piping systems, low leakage should be achievable with reasonable care in design and construction. Should it develop that low leakage rates cannot be achieved, then some form of cover gas purification will be required inasmuch as the cost involved in supplying radioactive gas holdup tankage would be excessive.

For tests involving failed fuels, the conclusions will be the same. Shorter lived isotopes are released from failed fuel than are released from vented fuel. As a result, the radioactive noble gas problem is potentially more severe for failed fuels. However, it is unlikely that a failed fuel test would involve 90 fuel pins because of the possibility of serious closed loop contamination. Therefore, the higher release potential of failed fuel will be

somewhat compensated by the fewer number of fuel pins involved. The effect of failed fuel on the closed loop design will be different from the vented fuel effect only by degree, not kind from the standpoint of noble gas release.

6.5 LEAKAGE OF ACTIVATED ARGON INTO REACTOR REFUELING HOT CELL

The following analysis to determine the effect of leakage of activated argon cover gas into the reactor refueling hot cell. This analysis is conservative in that the presence of the reactor access space was not considered. It is assumed that the cover gas leaked directly into the hot cell and that steady state conditions have been reached. For this situation the concentration of argon 41 in the hot cell atmosphere is C_{hc}

$$C_{hc} = \frac{(dv/dt)_{12} C_c}{V_{hc} (\lambda + F/v)}$$

where,

C_{hc} = argon 41 concentration in $\mu\text{Ci/cc}$.

C_c = argon 41 concentration in reactor cover gas $\mu\text{Ci/cc}$.

$\frac{(dv)}{(dt)}_{12}$ = leakage of cover gas into hot cell ft^3/day .

V_{hc} = hot cell volume ft^3

λ = decay constant of argon 41 = $\frac{9.1}{\text{days}}$

$\frac{F}{V}$ = purge constant of hot cell.

= $\frac{\text{ventilation rate}}{\text{hot cell volume}}$

Substituting the numerical data (See Page D-21) into the equation and making the appropriate conversions, we find

$$C_{hc} = \frac{(C_c)(dv/dt)_{12}}{1.89 \times 10^7}$$

The allowable concentration of argon-41 in the hot cell in the presence of argon-39 is calculated by the following. According to 10 CFR 20 the sum of concentrations divided by the MPC's must not exceed unity.

$$\frac{C_{Ar-41}}{MPC_{A-41}} + \frac{C_{Ar-39}}{MPC_{A-39}} = 1$$

Using the available data, $C_{A-41} = 0.03 \frac{\mu Ci}{cc}$ and $C_{A-39} = 0.023 \frac{\mu Ci}{cc}$

$$\frac{C_{Ar-41}}{C_{Ar-39}} = \frac{0.03}{0.023} = 1.3$$

Substituting and using the MPC's stated on page D-21, we find

$$C_{Ar-41} = C_{hc} = 1.82 \times 10^{-6} \mu Ci/cc$$

Then

$$\begin{aligned} (C_c) \left(\frac{dv}{dt} \right)_{12} &= 1.89 \times 10^7 \times 1.82 \times 10^{-6} \\ &= 34.5 \frac{ft^3}{day} \mu Ci/cc \end{aligned}$$

For an argon cover gas concentration of $0.03 \mu Ci/cc$ a leakage of $1150 \frac{ft^3}{day}$ would be allowable.

The same expression can be used to determine the activity of a normally inerted hot cell. For this case $F/V = 0$.

For a cover gas leakage of 100 cubic feet per day, the activity level in the hot cell for a $0.03 \mu\text{Ci/cc}$ cover gas activity is $7.5 \times 10^{-7} \mu\text{Ci/cc}$ or about 0.38 MPC's.

For a reactor plant without a reactor refueling hot cell, activated argon will leak directly into the normally occupied work area. Using the expression given on page D-73, and assuming 32 air changes per day in the work area and the radionuclide concentrations on the previous page, it can be shown that

$$\begin{aligned} (dv/dt)_{12} &= \frac{(C_{hc})(V_{hc})(\lambda + F/v)}{C_c} \\ &= (V_{hc})(2.5 \times 10^{-3}) \end{aligned}$$

or for 10 air changes per day,

$$(dv/dt)_{12} = (V_{hc})(1.15 \times 10^{-3})$$

6.6 COMPARISON OF HEAT EXCHANGER SIZES FOR NITROGEN, ARGON, AND HELIUM

To roughly compare the heat exchanger sizes for argon and nitrogen cooling of cells, several simplifying assumptions were made: (1) that a fin tube heat exchanger was to be used and the fin efficiency was unity for either case; (2) the liquid side coefficients were very large and the thermal resistance of the tubes was insignificant; (3) the Reynolds number and gas side pressure drop would be identical; and (4) the heat load and ΔT would be the same for either gas. Under these assumptions the overall heat transfer coefficient equals the gas side convective coefficient. The problem then reduces to determining the relative sizes of the convective coefficients, since under the assumptions

$$(hA_t)_{N_2} = (hA_t)_{\text{argon}}$$

or

$$\frac{A_{at}}{A_{nt}} = \frac{h_n}{h_a}$$

Under the assumption that Reynolds number is identical for either gas, and using the Reynolds number definition of Item 73, Appendix A.

$$R = \left(\frac{4r_h w}{A_f \eta} \right)_n = \left(\frac{4r_h w}{A_f \eta} \right)_a$$

Since the hydraulic diameter is a constant factor for the same heat exchanger surface

$$\frac{(W/A_f)_a}{(W/A_f)_n} = \frac{\eta_a}{\eta_n} \quad \text{or} \quad \frac{A_{a-f}}{A_{n-f}} = \frac{w_a}{w_n} \frac{\eta_n}{\eta_a}$$

Remembering that $w = \frac{Q}{cp\Delta T}$ and using data from Reference 74, Appendix A

$$\frac{A_{a-f}}{A_{n-f}} = \frac{cp_n}{cp_a} \frac{\eta_n}{\eta_a} = \frac{0.248}{0.125} \cdot \frac{0.01744}{0.02210} = 1.57$$

Under the further assumption that the gas side pressure drop is identical for either gas, the heat exchanger depths may be compared as follows. Considering only core pressure drop

$$\left(\frac{(W/A_f)^2}{2g\rho} f \frac{d}{r_h} \right)_{\text{argon}} = \left(\frac{(W/A_f)^2}{2g\rho} f \frac{d}{r_h} \right)_{\text{nitrogen}}$$

rearranging, and cancelling identical terms

$$\frac{L_a}{L_n} = \left[\frac{\rho_a}{\rho_n} \frac{(W/A_f)_n^2}{(W/A_f)_a^2} \left(\frac{\eta_r}{\eta_a} \right) \right] = 0.9 \text{ for } 70^\circ \text{F}$$

Then the heat exchanger core volume comparison for argon and nitrogen is as follows, recognizing that the face area of a heat exchanger core is directly proportional to the flow area

$$\frac{V_{hxa}}{V_{hxn}} = \frac{L_a}{L_n} \cdot \frac{A_{a-f}}{A_{n-f}} = 0.9 \times 1.57 = 1.4$$

Thus heat exchanger cores for argon are about 40% larger than one for nitrogen for the same Reynolds number and pressure drop.

Heat transfer performance is often shown for certain heat exchanger surfaces as data plots of Colburn heat transfer versus Reynolds number.¹ Under the assumption that Reynolds number is identical for either argon or nitrogen,

$$\left(\frac{h}{C_p} \frac{W}{A_f} Pr^{2/3} \right)_a = \left(\frac{h}{C_p} \frac{W}{A_f} Pr^{2/3} \right)_n$$

Rearranging, and substituting $\frac{WC_p}{A_f} = \frac{Q}{\Delta T A_f}$

$$\frac{h_n}{h_a} \frac{A_{a-f}}{A_{n-f}} \left(\frac{Pr_a}{Pr_n} \right)^{2/3} = 0.975 \frac{A_{a-f}}{A_{n-f}} \text{ for } 70^\circ \text{F}$$

But flow area is directly proportional to face area for a given heat exchanger surface. Making this transformation, and remembering $V_{hx} = (A) (L)$

$$\frac{h_n}{h_a} = 0.975 \frac{V_{hxa}}{V_{hxn}} \frac{L_n}{L_a}$$

Remembering that heat transfer area is directly proportional to core volume for a given heat transfer area

1. Refer to References, Appendix A, Item 73.

$$\frac{h_n}{h_a} = 0.975 \frac{A_{at}}{A_{nt}} \cdot \frac{L_n}{L_a} \text{ or } \frac{(hAt)_n}{(hAt)_a}$$

$$= (0.975) (0.9)^{-1} = 1.08$$

The conclusion is that a heat exchanger sized for argon is about 40% larger than one for nitrogen for the same flow conditions but has only about 92% of the performance. Therefore, the heat exchanger core should be about 45% larger than nitrogen for the same heat load and ΔT ; the Reynolds number and pressure drop would be close but not identical.

As a practical matter, conceptual heat loads were used to provide a basis for estimating the cost of the Nitrogen Receiving and Distribution System. A new estimate was then prepared using heat exchangers about 45% larger than the ones used in the nitrogen estimate, and blowers sized larger to compensate for the poorer heat transport properties of argon.

6.7 GLOSSARY

TERMS

- A = area
- Cp = specific heat
- f = friction factor
- g = gravitational constant
- W/A_f = mass velocity
- h = heat transfer coefficient
- d = heat exchanger depth
- Pr = Prandtl number
- j = injection rate of atoms to cover gas
- Q = heat load

λ = radioactive decay constant
 r_h = hydraulic radius
 ΔT = gas temperature drop across heat exchanger
 V = volume
 G = cover gas activity $\mu\text{Ci/cc}$
 w = mass flow rate
 ρ = density
 η = gas viscosity
 ΔP = differential pressure
 dv/dt = volumetric flow rate
 D = diameter
 ΔL = flow passage length = 2 inches
 L = mean free path of gas molecule
 T = absolute temperature
 M = molecular weight of gas
 M = weight
 R = gas constant
 P = absolute pressure
 γ = arithmetical average molecular velocity
 F = purge volumetric flow rate
 c = concentration of xenon and krypton in the
cover gas

SUBSCRIPTS

a = argon
 f = flow
 n = nitrogen
 t = heat transfer
 i = individual
 cg = cover gas
 hx = heat exchanger core
 hc = hot cell

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APPENDIX E

SUPPORTING INFORMATION

SECTION 1.0 INERT GAS SYSTEM EQUIPMENT SIZING

Preliminary estimates of the size of major components of the Inert Gas System are developed in this section. These estimates are at best the first iteration in the design of the system. The results of these estimates are summarized below. The number of units do not consider the redundancy necessary from reliability considerations. The procedure used in the estimation is given in the discussion following. The equipment sizes will change as better information becomes available during preliminary design.

<u>Item</u>	<u>Envelope Size</u>
Liquid Nitrogen Supply	4 dewars, 16 feet high × 6 feet in diameter
Nitrogen Cell Coolers	Contained unit 4 feet × 3 feet × 6 1/2 feet
Reactor Cavity Cooling Heat Exchanger Cores (2) Blowers (2)	6.5 feet × 6.5 feet × 1 foot 54 inches × 85 inches × 95 inches
Liquid Argon Supply	1 dewar, 16 feet high × 8 feet in diameter
Fuel Examination and Transfer Cell Equipment	
Main Heat Exchangers	14 feet × 12 feet × 1 foot deep
Main Blower	106 inches × 106 inches × 118 in.
Expansion Duct	14 feet long, 12' × 14' one end, 6' × 6' other end
Compressed Argon Supply	42 inches × 76 inches × 85 inches
Recirculating Argon Cover Gas Holdup Tank	5 feet diameter × 26 feet long
Compressor	6.5 feet × 5.5 feet × 3.5 feet

Item	Envelope Size
Suction Tank	5 feet diameter × 26 feet long
Vapor Trap	13.5 feet tall × 3.5 feet diameter
Radioactive Gas Decay System	
Helper Blowers	13 inches × 15 inches × 16 inches
Main Compressor	3 feet × 5.5 feet × 13.75 feet
Small Compressor	1.75 feet × 3 feet × 7 feet
Radioactive Gas Storage Tanks	20 tanks, 5 feet diameter × 16 1/2 feet long 6 tanks 7 feet diameter × 31 feet long

1.1 LIQUID NITROGEN SUPPLIES

The liquid nitrogen requirements are developed below under the following assumptions:

1. A thirty day makeup for leakage must be stored on site
2. Nitrogen cell pressures are negative and in-leakage of air is 1% cell volume per day
3. Sufficient nitrogen to purge the inert atmosphere cells must be available to permit air purging and re-inerting in event of major maintenance

The total volume of the nitrogen filled cells is about 324,000 ft³.¹ Assuming it is desired to hold the oxygen level in those cells to 4%, the total daily usage of fresh nitrogen would be

$$(\text{dv}/\text{dt})_n = \frac{(3.24 \times 10^5 \text{ ft}^3)(0.01/\text{day})(0.21)}{0.04} = 17000 \text{ ft}^3/\text{day}$$

or about 520,000 ft³/month, assuming 1% of the cells volume inleakage per day.

In order to purge these cells, once they had been provided with an air atmosphere for maintenance, approximately 1.65 volume purges will be necessary to bring the oxygen level down from air to 4%. This would require $V_{N_2} = 1.65 (324,000 \text{ ft}^3) = 534,000 \text{ ft}^3$ of nitrogen.

¹ Refer to References, Appendix A, Item 50

The total nitrogen that must be stored is 520,000 + 534,000 = $1.05 \times 10^6 \text{ ft}^3$. This stored quantity may seem overly large in view of the ready availability of gases from plants in Portland or Seattle. However, the reserve will also act as backup for the Plant Fire Protection System No. 26. For standard conditions the density of nitrogen is 0.072 lb/ft^3 . Assume the nitrogen is stored as a saturated liquid at 115 psia. Therefore, the volume of liquid that must be stored is

$$V = \frac{1.05 \times 10^6 \text{ ft}^3 \times 0.072 \text{ lb/ft}^3}{44 \text{ lb/ft}^3} \times 7.48 \frac{\text{gal}}{\text{ft}^3} = 12,800 \text{ gallons.}$$

The liquid nitrogen supply then could consist of about four 3000 gallon dewars, each of which would be about 16 feet high and 8 feet in diameter according to manufacturers' catalogs. This tankage quantity can be reduced about 30% if the cell pressures were positive rather than negative. Standard vaporizers, accessories to these tanks will each vaporize 5000 cfh, so that a total of 20,000 cfh could be provided. However, larger capacity vaporizers can be provided if necessary.¹

1.2 NITROGEN CELL COOLER UNITS

Preliminary heat load estimates for the nitrogen atmosphere cells are tabulated in Section 2.2.2.6. Assuming a 20 °F temperature rise in the circulating nitrogen and a liquid coolant in the heat exchanger, the required volumetric flow rate was calculated and is listed in Section 2.2.2.6. Blower horsepower was preliminarily estimated by assuming 4 inches of water pressure drop through a system fed by a 70% efficient fan. For the reactor cavity, a 100 °F gas temperature rise across this heat load was assumed.

1. Refer to Support Information Requirements, Appendix B, Item 10.

1.3 LIQUID ARGON SUPPLY

The liquid argon requirements are developed below under the following assumptions:

1. The cover gas system uses 1000 scfd, and a thirty day reserve must be stored on site.
2. One purge of the Fuel Examination and Transfer Cells must be stored on site.
3. The purge of these cells must reduce contaminant level by a factor of 15; this requires a 2.7 cell volume purge to accomplish.

Under these assumptions the total volume of gaseous argon is then:

$$V = 1,000 \frac{\text{ft}^3}{\text{day}} \times 30 \text{ day} + 1 \text{ purge} \times 2.7 \frac{\text{Vol}}{\text{purge}} \\ \times 10^5 \frac{\text{ft}^3}{\text{vol}} = 3 \times 10^5 \text{ ft}^3.$$

The density of liquid argon at 150 psia is $73 \frac{\text{lb}}{\text{ft}^3}$ and the density of argon gas at standard condition is 0.103 lb/ft^3 . The total gallonage of liquid argon that must be stored is:

$$V = \frac{3 \times 10^5 \text{ ft}^3 \times 0.103 \text{ lb/ft}^3}{73 \text{ lb/ft}^3} \times 7.48 \frac{\text{gal}}{\text{ft}^3} \\ = 3160 \text{ gallons}$$

The liquid argon supply then could consist of about one 3000 gallon dewar, about 16 feet high and 6 feet in diameter.

1.4 COOLER UNITS FOR FUEL EXAMINATION AND TRANSFER CELLS

It is estimated that the heat load for these cells is 1.43×10^6 Btuh. Assuming a 25 °F temperature rise in the circulating argon approximately 70,000 cfm of argon to provide

the cooling. The blower horsepower was estimated assuming 70% fan efficiency and 3.5 inches of water pressure drop through the circuit.

1.5 COMPRESSED ARGON REQUIREMENTS FOR PNEUMATIC TOOLS

The compressed argon supply for the Fuel Transfer and Examination Cells will consist of a compressor, after cooler, and receiver. A complete 220 cfm supply will supply roughly 10 pneumatic implements simultaneously and will fit in an envelope 42 inches × 76 inches × 85 inches according to a manufacturers catalog.

1.6 MECHANICAL EQUIPMENT FOR THE RECIRCULATING ARGON COVER GAS SUPPLY

This equipment consists of a holdup tank, a compressor, a suction tank, and a vapor trap. Assuming a design flow of 50 scfm, the equipment envelope sizes would be approximately as follows, based on comparable equipment in the Fermi reactor.¹ The system pressure will be 40 psig.

<u>Item</u>	<u>Envelope Size</u>
Holdup Tank	5' diameter × 26' long (500 ft ³)
Compressor, Diaphragm Type	6.5 feet × 5.5 feet × 3.5 feet
Suction Tank	5' diameter × 26 feet long (500 ft ³)
Vapor Trap	13.5 feet tall × 3.5 feet diameter

1.7 RADIOACTIVE GAS DECAY AND DISPOSAL SYSTEM

The major mechanical equipment in this system consists of the decay storage tanks, the compressors, and the blowers.

The blowers assist in passing gas vented to the Radioactive Gas system to the main ventilation exhaust stack of the

1. Refer to References, Appendix A, Item 53.

Heating and Ventilating System. These blowers may or may not be necessary, depending on the pressure level in that portion of the heating and ventilating system that the radioactive gas system discharges to. These blowers are 350 cfm leak tight blowers based on the need to be able to handle flow rates near the total capacity of the vaporizers attached to the liquid nitrogen supplies. Each will fit in an envelope 13 inches by 16 inches by 15 inches according to a manufacturers catalog. The compressors consist of one large and two small.

The compressors consist of one large and two small. The large compressor will handle approximately 350 actual cfm, as based on the total capacity of the vaporizers on the liquid nitrogen storage units. The envelope size of this compressor is about 3 feet by 5.5 feet by 13.75 feet. The small compressors will handle about 45 actual cfm, suitable for a cover gas purge operation or for the fuel cleaning vessel purge. The envelope size for this compressor is about 1.75 feet by 3 feet by 7 feet. These compressors will compress the gas to 150 psig.

The radioactive gas storage capacity is based on the following assumptions: (1) simultaneous vented fuel tests must be accommodated in two closed loops, and the required purge rate for these closed loops is 1 cfm with a gas temperature of 900 °F, (2) the closed loops leak 0.1% system volume per day to the closed loop cells which are held at negative pressure; (3) air inleakage into the closed loop cells is 1% cell volume per day; (4) one complete closed loop cell purge must be accommodated per month; (5) two complete reactor primary cover gas purges must be accommodated per day because of failed fuels; (6) the tank storage conditions are 70 °F and 150 psig.

For the closed loops proper, the activity level of the cover gas is about 160 $\mu\text{Ci/cc}$, assuming vented fuel tests which release 5 day old xenon-133. This activity was calculated assuming a 90 pin vented fuel test, a 1 cfm purge flow, and available fission gas release data.¹ The exhaust ventilation flow rate will be on the order of 2×10^5 cfm.² A rule of thumb is that stack activities of about 1,000 times the offsite exposure limit are permissible. This of course depends on the stack height and a number of other factors. However, assume that this rule of thumb is applicable. The offsite MPC for xenon-133 is 3×10^{-7} $\mu\text{Ci/cc}$ and the exposure limit is one-third of this value. The stack release constant therefore is:

$$\begin{aligned} K &= (\text{stack flow})(\text{offsite exposure limit}) (1000) \\ &= (2 \times 10^5) \left(\frac{3 \times 10^{-7}}{3} \right) (10^3) = 20 (\mu\text{Ci/cc}) (\text{ft}^3/\text{min}) \end{aligned}$$

If the two closed loop cover gas purge flows were continuously vented the contribution to this stack constant would be:

$$\begin{aligned} K_i &= (160 \mu\text{Ci/cc}) (2 \text{ Loops}) (1 \text{ ft}^3/\text{min}/\text{loop}) \left(\frac{530^\circ\text{R}}{1360^\circ\text{R}} \right) \\ &= 125 \text{ ft}^3 \mu\text{Ci/cc min.} \end{aligned}$$

Obviously the purge gas must be tanked. For a total release rate of $2 \text{ ft}^3/\text{min}$, the allowable released activity level would obviously be 10 $\mu\text{Ci/cc}$.

The closed loop cover gas would have to be held approximately 21 days for decay processes to reduce the activity from 160 $\mu\text{Ci/cc}$ to 10 $\mu\text{Ci/cc}$. Therefore, under the assumed

1. Refer to References, Appendix A, Item 68.
2. Refer to References, Appendix A, Item 2.

storage conditions, approximately 2,400 cubic feet of tankage must be provided for the holdup of the purge gas from the two closed loops.

For the closed loop cells, the 1% air inleakage per day will result in a total cell purge of about 1,100 ft³/day per cell to hold the oxygen level to 4%. This combined with the cover gas leakage into the cell will cause activity levels of

$$g = \frac{(160 \text{ } \mu\text{Ci/cc})(0.02 \text{ ft}^3/\text{day})}{(18,000 \text{ ft}^3)(0.13/\text{day} - 1100/18,000)} = 9 \times 10^{-4} \frac{\mu\text{Ci}}{\text{cc}}$$

The contribution of this to the stack release constant is

$$\begin{aligned} K_i &= (9 \times 10^{-4} \text{ } \mu\text{Ci/cc})(2 \text{ cells})\left(\frac{1100 \text{ ft}^3/\text{day}}{1440 \text{ min/day}}\right) \\ &= 0.00137 \text{ } \mu\text{Ci ft}^3/\text{cc min.} \end{aligned}$$

This could be released directly. Therefore, no tankage allotment would have to be provided for that gas flow. For the closed loop cell purge, assume a purge of 4 cell volumes such as might be necessary to reduce atmospheric activity to tolerable levels following an accident. The tankage requirement for this condition is 7200 cubic feet under the assumed storage conditions.

For the reactor cover gas purge, assume the gases must be held 20 days before they may be released. The daily accumulation is 2000 scf or about 200 ft³ of tankage. A total of 4000 ft³ of tankage would have to be provided for this purpose.

In summary, a total of 13,600 cubic feet of tankage will serve as holdup, assuming that weather conditions permit release at all times. Assuming it is desired to hold one day's accumulation of closed loop cover gas purge

and reactor cover gas purge in one tank, the tanks would be about 325 cubic feet each. This would result in 20 tanks each 5 feet in diameter by 16 1/2 feet long. The remaining volume could be handled by six tanks of 1200 cubic feet each which could be 7 feet in diameter by 31 feet long. Inasmuch as these larger tanks are for post-emergency conditions, and would rarely be used, a portion of this tankage could be used in event that weather conditions were such that normal radionuclide release could not be made. Inasmuch as some release is expected to be possible every day, no serious restraints are expected.

1.8 ARGON PURIFICATION EQUIPMENT

The argon atmosphere in the Fuel Transfer and Examination Facilities will be held to about 25 ppm of water and oxygen.¹ Assuming an inleakage of air of 0.3 cfh as is the case with the Fuel Cycle Facility² of the EBR-II reactor plant, the required flow rate through the purification equipment can be calculated as follows:

$$25 \times 10^{-6} = \frac{(0.3 \text{ ft}^3/\text{hr}) (0.21)}{F}$$

$F = 2520 \text{ ft}^3/\text{hr}$, assuming complete removal of oxygen from the circulating stream. The removal equipment then should be capable of handling twice this flow, so that the equipment need run only one-half of the time. This will permit maintenance without allowing an excessive buildup of oxygen or water in the cell atmosphere during the time the equipment is shut down.

-
1. Refer to References, Appendix A, Item 8.
 2. Refer to References, Appendix A, Item 75.

SECTION 2.0 DETERMINATION OF VACUUM LEVEL REQUIRED FOR
FILLING SODIUM SYSTEMS

The use of vacuum is desirable in preparing sodium systems for initial filling. Purging with inert gas is satisfactory in principle but such an approach in practice does not preclude the possibility of having air pockets trapped in portions of the system. Evacuation does preclude such air pockets. Further, some outgassing of the sodium system would be desirable to reduce the amount of gases that are sorbed on the steel surfaces of the piping. Therefore, evacuation of the sodium systems is the selected method of preparing the sodium systems for filling.

The vacuum system conceived in the main body of this document consists of portable vacuum pumps and the appropriate piping and connectors. Manufacturers' data indicates that portable mechanical vacuum pumps with speeds up to 50 cfm are readily available at reasonable prices. The capacity of these pumps is relatively constant over a wide range but decreases rapidly below 10^{-3} to 10^{-4} mm of mercury.

The following analysis was performed to determine a tolerable vacuum level that could satisfactorily remove excess oxygen and nitrogen from the unfilled sodium system. It was assumed that the system piping was heated to 350 °F and was in steady state. For purposes of analysis, it was assumed that the total volume V of the sodium system was to be 90% filled with sodium, leaving 10% of the system as the cover gas volume. The symbols listed in the glossary are used below.

The system will be evacuated to some pressure P and the system will then be refilled with pure argon. After this

operation, the total pressure in the system is atmospheric and the gas temperature is 350 °F. Under this condition, the weight of oxygen left in the system is:

$$M_1 = \frac{PV}{RT} = \frac{(2116 \text{ lb/ft}^2)(V\phi)}{(48.2 \frac{\text{Ft}}{^\circ\text{R}})(810 \text{ }^\circ\text{R})} = 0.05 V\phi \text{ where } \phi = \text{volume}$$

percent of O_2 in the argon.

After sodium is introduced into the system, it will getter the oxygen. The resulting contamination of the sodium with oxygen is

$$\frac{M_o}{M_{na}} = \frac{0.05 V\phi \times 10^6}{(0.9 V)(57 \text{ lb Na/ft}^3)} = 975\phi \text{ (assuming the}$$

system is 90% filled with sodium)

Sodium cold trapping can bring oxygen levels in sodium down to about 8 ppm. Therefore, there is no reason to reduce the cover gas oxygen level below about 0.8% which corresponds to about 8 ppm in the equation above. This corresponds to an oxygen partial pressure of $P_o = (760)(0.008) = 6.1 \text{ mm Hg}$ which could be reached with a vacuum pump if the system were evacuated to $P = 6.1/0.21 = 29 \text{ mm of mercury}$. If the above reasoning is followed in regard to nitrogen, it will be found that, if a system is evacuated to 1 mm of mercury and is subsequently filled with pure argon, the nitrogen contamination of the cover gas is about 1,000 ppm which is tolerable according to available experience in other sodium reactors. The corresponding oxygen contamination of the sodium amounts to about 0.3 ppm. Thus, evacuation to about 1 mm of mercury will very satisfactorily remove both oxygen and nitrogen from the system to the degree required to avoid serious contamination of the

sodium with oxygen, or the cover gas with nitrogen. Practice in other reactors¹ is to evacuate to about 0.5 mm of mercury. Therefore, mechanical vacuum pumps which have an effective bottom limit of 10^{-3} to 10^{-4} mm of mercury are quite adequate for preparation of sodium systems for filling.

1. Refer to References, Appendix A, Item 74, page 148.

SECTION 3.0 ESTIMATION OF HEAT LOAD FROM SODIUM PIPING
SYSTEM DURING STANDBY OPERATION

This study is undertaken to estimate the heat load on the inert gas cell units during standby operation of the sodium systems. Assume that the cell outlet temperature is 100 °F with an inlet temperature of 80 °F. From page 2-16 of this document, the nitrogen flow is 5000 cfm and the blower motor power is 5 horsepower. Assuming that during standby the cell will be illuminated to permit operation of TV cameras. With 100 fc illumination on a working plane 17 feet by 42 feet, the lighting power would be approximately 3 kW.

During normal operation at 1200 °F, the closed loop system will be insulated so that the surface temperature of the insulation is no greater than 150 °F. It can be shown from this that the heat load from the sodium piping during standby will be 25 to 30% of that at high temperature operation. During high temperature operation, the heat load on the cell coolers is estimated to be 100,000 BtuH. The net load from the sodium piping is $100,000 - 5(2545) = 87,275$ BtuH, allowing for the blower motor assuming 25% of this for standby operation the net standby load is as follows:

Blower Motor	12,725 BtuH
Lights @ 3 kW	10,239
Sodium Piping	<u>21,819</u>
Total	44,783 BtuH

Thus, the standby heat load is about 45% of the normal heat load. It is obvious that no cell atmosphere heaters will be required for the inert cells during standby operation since the turndown is well within the range of commercially available cooler units.

SECTION 4.0 STORAGE OF GASEOUS EXPENDABLES

Argon and nitrogen expendables may be stored either as a liquid or a gas. There are advantages and disadvantages to either storage mode. The choice of liquid versus gaseous storage is strongly influenced by the usage and by the inventory requirements. The discussion below is predicated on (1) utilizing 500,000 cubic feet of nitrogen per month, and having storage for that 1,000,000 cubic feet on site, and (2) utilizing 30,000 cubic feet per month of argon, and having storage for about 300,000 cubic feet on site, as assumed in Sections 1.1 and 1.3 of Appendix E of this document. Liquid storage is characterized by low storage pressure (100-150 psi), and minimal storage facility requirements, and is the method most used today to store atmospheric constituent gases. In order to produce gas from liquid, heat must be added to vaporize the liquid and heat the vapor to ambient temperatures. It takes approximately 11.5 Btu to produce one cubic foot of argon gas at standard conditions from liquid, and about 12.5 Btu per cubic foot of nitrogen. This heat may be supplied either from earth's atmosphere or from artificial sources depending on the required rate of gas evolution.

Gaseous storage is characterized by high storage pressure, and more extensive storage facility requirements. Although heat must be added to compressed gas to maintain the storage temperature during a blowdown, the heat capacity of the storage vessels and the heat entering the uninsulated storage vessels from the atmosphere normally satisfies this requirement for all but high blowdown rates over relatively long time spans.

For liquid storage, the dewars and controls* are often rented as part of the gas supply contract; this is the present practice at Hanford. Thus there is an avoidable capital cost involved by this option although the dewars and controls may be purchased if desired. Gaseous storage, however, would require the purchase of the tankage and controls.

The commercial sources of argon and nitrogen closest to Hanford are located in Portland, Oregon and Seattle, Washington. Liquid oxygen is widely used commercially in many places in the Pacific Northwest, and the nitrogen and argon is a byproduct of oxygen recovery from the atmosphere. Liquified oxygen, nitrogen, and argon are routinely trucked to customer bulk stations on delivery routes thus there is no problem in acquiring these products on short notice. Gaseous nitrogen and argon is generally shipped in the man-sized bottles containing about 250 scf of gas at 2200 psig. It is not shipped in quantity because of transportation economics, since a much larger quantity of gas can be shipped in liquified form for the same shipping weight.

Cost Comparison

The storage requirements for gas versus liquid may be compared as follows:

Liquid Storage

Page E-3 of this document shows that the assumed storage volume for nitrogen can be contained in four 3000 gallon liquid storage units, each about 8 feet in diameter and 16 feet high. Page E-4 of this document shows that the argon storage can be satisfied by one 3000 gallon dewar of the same size. These units need cost nothing since they

could be rented. However, the cost would be about \$75,000 if it were desired to purchase them.

Gaseous Storage

Assume that the desired storage pressure is 1000 psig, and that the tankage will be of ASTM-53 Grade B steel pipe. The required tankage volume is

$$V_{N_2} = \frac{10^6 \text{ ft}^3 \times 15 \text{ psia}}{1015 \text{ psia}} = 14,800 \text{ ft}^3$$

$$V_{\text{argon}} = \frac{3 \times 10^5 \text{ ft}^3 \times 15 \text{ psia}}{1015 \text{ psia}} = 4500 \text{ ft}^3$$

The allowable stress for the selected steel is 15,000 psi according to the ASME Pressure Vessel Code Section VIII. Using the hoops hoop stress formula and solving for R/t

$$\frac{R}{t} = \frac{S}{P} = \frac{10,000}{1000} = 15$$

where

R = mean radius of the vessel

t = the wall thickness

For this choice, the tankage stock could be 14 in. OD pipe with a 0.5 in. wall thickness and weighing 72 pounds per foot. The inside area of this pipe is

$$A = \frac{\pi}{4} \left(\frac{13}{12}\right)^2 = 0.92 \text{ ft}^2$$

The approximate pipe length to contain the gases would be

$$L_{N_2} = \frac{V}{A} = \frac{14,800}{0.92} = 16,100 \text{ feet}$$

$$L_{\text{argon}} = \frac{4500}{0.92} = 4900 \text{ feet}$$

Using the given weight of pipe and assuming a net cost installed of \$0.50 per pound, the cost of the tankage would be

$$\begin{aligned}\text{Tankage Cost (nitrogen)} &= (16,100 \text{ ft}) \left(72 \frac{\text{lb}}{\text{ft}^3}\right) (0.50 \text{ \$/lb}) \\ &= \$578,000\end{aligned}$$

$$\begin{aligned}\text{Tankage Cost (Argon)} &= (4900 \text{ ft}) \left(72 \frac{\text{lb}}{\text{ft}^3}\right) (0.50 \text{ \$/lb}) \\ &= \$176,000\end{aligned}$$

The cost figures would be \$239,000 and \$71,500 for 500 psi storage computed on the same basis. The purpose of this analysis is to provide a feeling for cost rather than to make a firm estimate. The cost of gaseous storage is clearly higher than the cost of liquid storage especially since the liquid storage units could be rented. Even if it were desired to purchase the liquid units, the total cost would be in the neighborhood of \$75,000 since the units in the 3000 gallon size run around \$15,000 each.

Technical and Reliability Comparison

Liquid storage units are subject to failure of the control valving and loss of vacuum in the insulation of the vessel. The loss of vacuum would not result in failure of the gas supply since its only effect would be to increase the heat leak from the atmosphere to the cryogenic liquid. This would result in an increased boil-off rate and possible venting of surplus vapor, but not large loss of gas. Vacuum repairs are readily made in-site without interruption of gas service. Failure of control valving is a possibility but this failure pertains to both gaseous and liquid supplies since controls are required for both. Sufficient redundancy can be employed in either case to provide the required reliability. Extensive use of liquid storage in the space programs and by commercial businesses demonstrates its acceptable reliability.

As discussed in the foreport of this section, heat must be applied to liquid gas to produce gaseous gas. Vaporizers are available to perform this function. Individual vaporizers using the earths atmosphere as the heat source range in size from 2000 to 5000 cubic feet per hour gas production rate. These units may be paralleled as necessary to vaporize larger quantities of gas. If it was acceptable to purge all the nitrogen cells from air to 4% oxygen over a two day period, the required flow rate would be

$$\dot{V} = \frac{(1.65)(324,000 \text{ ft}^3)}{(24 \frac{\text{hr}}{\text{day}})(2 \text{ day})} = 11,150 \frac{\text{ft}^3}{\text{hr}}$$

This is well within the 20,000 cfh capability indicated in Section 1.1 of Appendix E of this report, and is well within the capability of any high pressure gas storage system. Therefore, gas and liquid storage are adequate from a reliability and technical viewpoint.

In conclusion, liquid storage is chosen for the nitrogen and argon supplies basically because of the cost advantage.

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APPENDIX F

PERTINENT INSTRUMENTATION DRAWINGS

SK-3-14538 Sheets 1 & 2

13	12	11	10	9	8	7	6	5	4	3								
LOCATION	REFERENCE DRAWING	VENTILATION ZONE	NORMAL ATMOSPHERE	CONTROLLING SYSTEM	MEASURED VARIABLE	PURPOSE OF MEASUREMENT	CONTROLLED ELEMENT	SENSOR	NO. OF SENSORS	SUPPORT INFORMATION	DESIRED VALUE	RANGE	ACCURACY	SCHEMATIC NO.	ALARM	LOCATION OF DISPLAY	TYPE OF DISPLAY AND RECORDING	COMMENTS
P9 WARY SODIUM STORAGE AND EQUIPMENT	SK-3-12963 ELEV. 0'-0" SK-3-12783	1A	NITROGEN	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION		C/A SHEATHED T/C		CS0093 APPENDIX B ITEM 20	100°F	60-100°F	2% OF RANGE	1	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE	OPERATING, MONITORING AND CONTROL	INERT GAS FEED AND BLEED VALVE	DIFFERENTIAL PRESSURE CELL		CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-1 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD	2% OF RANGE	2	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	PRESSURE CELL LOCATED INSIDE CONTAINMENT AND WILL BE SUBJECT TO PRESSURES DEVELOPED DURING CONTAINMENT LEAKAGE TESTS.
					PRESSURE DROP ACROSS FILTER	DETERMINES WHEN FILTER REQUIRES CHANGING		DIFFERENTIAL PRESSURE CELL		CS0093 APPENDIX B ITEM 20	1/4 INCH	0-1.5 INCH	2% OF RANGE	3	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
					OUTLET TEMPERATURE OF RECIRCULATED ATMOSPHERE	CONTROL	VALVE TO CONTROL COOLANT FLOW TO COIL	C/A SHEATHED T/C	1	CS0093 APPENDIX B ITEM 20	100°F	80-120°F	2% OF RANGE			CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
P9 WARY SODIUM PUMPS AND HEAT EXCHANGER #1 AREA	SK-3-12968 ELEV. 0'-0" SK-3-12783	1A	NITROGEN	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION		C/A SHEATHED T/C		CS0093 APPENDIX B ITEM 20	SUMMER(MAX): 85° WINTER(MIN): 70°	TBD	2% OF RANGE	1	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE	OPERATING, MONITORING AND CONTROL	INERT GAS FEED VALVE & REACTOR CAVITY BLEED VALVE	DIFFERENTIAL PRESSURE CELL		CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-1 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD	2% OF RANGE	2	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	NO FILTER. CELL EXHAUSTS INTO REACTOR CAVITY. PRESSURE CELL LOCATED INSIDE CONTAINMENT & WILL BE SUBJECT TO PRESSURE DEVELOPED DURING CONTAINMENT LEAKAGE TESTS.
					OUTLET TEMPERATURE OF RECIRCULATED ATMOSPHERE	CONTROL	VALVE TO CONTROL COOLANT FLOW TO COIL	C/A SHEATHED T/C	1	CS0093 APPENDIX B ITEM 20	TBD	TBD	2% OF RANGE			CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
P9 WARY SODIUM PUMPS AND HEAT EXCHANGER #2 AREA	SEE ITEM 2 ABOVE FOR MEASURED VARIABLES																	
REACTOR CAVITY	SK-3-12969 ELEV. -20' SK-3-12783	1A	NITROGEN	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION		C/A SHEATHED T/C	6	CS0093 APPENDIX B ITEM 20	150°F	100-400°F	2% OF RANGE			CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	THIS AREA IS HEATED PRIOR TO FILLING VESSEL AND COOLED DURING REACTOR OPERATION.
					PRESSURE	OPERATING AND MONITORING INFORMATION		DIFFERENTIAL PRESSURE CELL	1	CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-1 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD	2% OF RANGE	2	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE DROP ACROSS FILTER	DETERMINES WHEN FILTER REQUIRES CHANGING		DIFFERENTIAL PRESSURE CELL	1	CS0093 APPENDIX B ITEM 20	1/4 INCH	0-1.5 INCH	2% OF RANGE	3	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
					OUTLET TEMPERATURE OF RECIRCULATED ATMOSPHERE	OPERATING, MONITORING AND CONTROL INFORMATION	1) VALVE TO CONTROL COOLANT FLOW TO COIL 2) CONTROL ELEMENT FOR ELECT. HEATING	C/A SHEATHED T/C	1	CS0093 APPENDIX B ITEM 20	TBD	TBD	TBD		HIGH/LOW		COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	THIS AREA IS HEATED PRIOR TO FILLING VESSEL AND COOLED DURING REACTOR OPERATION.
FUEL DECAY STORAGE	SK-3-12968 ELEV. +18' SK-3-12795	1A	ARGON	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION		C/A SHEATHED T/C		CS0093 APPENDIX B ITEM 20	100°F	200-500°F	2% OF RANGE	1	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE	OPERATING AND MONITORING INFORMATION		DIFFERENTIAL PRESSURE CELL	1	CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-1 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD						
CLOSED LOOP CELL #1	SK-3-12973	1A	NITROGEN	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION		C/A SHEATHED T/C	1	CS0093 APPENDIX B ITEM 20	100°F	80-150°F	2% OF RANGE	1	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE	OPERATING, MONITORING AND CONTROL INFORMATION	FEED AND BLEED VALVES	DIFFERENTIAL PRESSURE CELL	1	CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-1 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD	2% OF RANGE	2	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	
					PRESSURE DROP ACROSS FILTER	DETERMINES WHEN FILTER REQUIRES CHANGING		DIFFERENTIAL PRESSURE CELL	1	CS0093 APPENDIX B ITEM 20	1/4 INCH	0-1.5 INCH	2% OF RANGE	3	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
					OUTLET TEMPERATURE OF RECIRCULATED ATMOSPHERE	OPERATING, MONITORING AND CONTROL INFORMATION	CONTROLS INERT GAS FEED AND BLEED VALVES	C/A SHEATHED T/C	1	CS0093 APPENDIX B ITEM 20	TBD	TBD	2% OF RANGE		HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION.	
CLOSED LOOP CELL #2	SEE ITEM 6 ABOVE FOR MEASURED VARIABLES																	
CLOSED LOOP CELL #3	SEE ITEM 6 ABOVE FOR MEASURED VARIABLES																	
CLOSED LOOP CELL #4	SEE ITEM 6 ABOVE FOR MEASURED VARIABLES																	
CLOSED LOOP CELL #5	SEE ITEM 6 ABOVE FOR MEASURED VARIABLES																	
CLOSED LOOP CELL #6	SEE ITEM 6 ABOVE FOR MEASURED VARIABLES																	
FUEL TRANSFER CELL	SK-3-12969 ELEV. -20' SK-3-12785	1B	ARGON	82	TEMPERATURE	OPERATING AND MONITORING INFORMATION	CONTROLS CELL COOLING SYSTEM	C/A SHEATHED T/C		CS0093 APPENDIX B ITEM 20	90°F	70-120°F	2% OF RANGE	1	HIGH	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	TEMPERATURE IS LOWERED TO MAINTAIN CELL PRESSURE AND CONSERVE ARGON
					PRESSURE	OPERATING AND MONITORING INFORMATION	CONTROLS INERT GAS FEED AND BLEED VALVES	DIFFERENTIAL PRESSURE CELL		CS0093 APPENDIX B ITEM 20 CS0025 APPENDIX B ITEM 3	-2 INCH OF H ₂ O WITH RESPECT TO ATMOSPHERE	TBD	2% OF RANGE	1	HIGH/LOW	CONTROL ROOM	COMPUTER DISPLAY AND RECORDING. SWITCH PROVIDED FOR ANALOG INDICATION AND RECORDING.	FUEL IS TRANSFERRED FROM THE FUEL HANDLING MACHINE INTO THIS CELL. FEED AND BLEED VALVES ARE OPERATED WHEN COOLING CONTAINED ARGON CANNOT CONTROL PRESSURE.

- NOTES:
- REFER TO INTERFACES, APPENDIX C, ITEM 1. TEMPERATURE, PRESSURES AND VENTILATION ZONES ARE DEFINED IN THE CONCEPTUAL DESIGN DESCRIPTION FOR THE HEATING AND VENTILATION SYSTEM.
 - THE FOLLOWING LIST OF VARIABLES ARE MEASURED AND CONTROLLED DURING PURIFICATION OF THE ATMOSPHERE. MEASUREMENT METHODS AND LOCATION OF MEASUREMENTS ARE TO BE DETERMINED BY A SUPPORT INFORMATION STUDY LISTED IN APPENDIX C, ITEM 5 IN THE CONCEPTUAL DESIGN DESCRIPTION OF THE INERT GAS PROCESSING AND RECEIVING SYSTEM.
VARIABLE	COMMENT
OXYGEN CONTENT IN INERT GAS ATMOSPHERE	MAINTAIN AT LESS THAN 4%
INERT GAS CONTENT AFTER AIR PURGE	
NITROGEN	
HYDROGEN	
LIGHT HYDROCARBON	
WATER VAPOR	40 TO 60 PPM
CARBON MONOXIDE	
SODIUM VAPOR	
RELATIVE HUMIDITY	50% RH @ 80°F d.b.

U.S. ATOMIC ENERGY COMMISSION
RICHLAND OPERATIONS OFFICE
PACIFIC NORTHWEST LABORATORY
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MEASUREMENT LIST
OF ATMOSPHERIC VARIABLES
FFTF BUILDING PLAN XVIII

DATE: 12-16-68
BY: M. D. Roush
CHECKED: M. D. Roush
SCALE: 1/8" = 1'-0"

CLASSIFICATION: NONE
DRAWING STATUS: NEXT USED ON: 12-16-68

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1	12-16-68	ISSUED FOR CONSTRUCTION

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APPENDIX G

DRAWINGS

SK-3-12783
SK-3-12784
SK-3-12785
SK-3-12786
SK-3-12787

CONCEPTUAL

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**SYSTEM SCHEMATIC
 NITROGEN RECEIVING
 AND DISTRIBUTION**

FAST FLUX TEST FACILITY

3.0-GEN 7001.01

SK-3-12783

1.3TH ISSUE 2-12-69
 1.2TH ISSUE 7-12-68
 1.1TH ISSUE 6-27-68
 1.0TH ISSUE 7-12-67
 0.9TH ISSUE 5-18-67

REV	DATE	DESCRIPTION
1	7-12-67	1.0TH ISSUE
2	5-18-67	0.9TH ISSUE
3	6-27-68	1.1TH ISSUE
4	7-12-68	1.2TH ISSUE
5	2-12-69	1.3TH ISSUE

LEGEND			
INSTRUMENT SYMBOLS			
PRINCIPAL FLOW			
AUXILIARY FLOW			
REFERENCE LINE			
BLOCK VALVE			
CHECK VALVE			
BUTTERFLY VALVE			
PRESSURE CONTROL VALVE			
HIGH EFFICIENCY FILTER			
HOSE CONN. FOR COOLING			
PNEUMATIC TOOL DISCONNECT			
BLIND FLANGE			
NO NORMALLY OPEN			
NC NORMALLY CLOSED			
CONNECTION TO PROCESS			
PNEUMATIC SIGNAL			
ELECTRICAL SIGNAL			
LOCALLY MOUNTED			
PANEL MOUNTED			
POSITION IDENTIFICATION			
LETTER	FIRST	SECOND	THIRD
A		ALARM	
C			CONTROLLER
E		ELEMENT	
F	FLOW		
H			HI
I		INDICATOR	
L			LO
P	PRESSURE		
R		RECORDER	
T	TEMP.		
D	DIFFERENTIAL		

ARGON SYSTEM - FUEL TRANSFER AND FUEL EXAMINATION CELLS

NOTES:
 1. SYSTEM ITEM NUMBERS ARE CONTINUED FROM ARGON RECEIVING AND DISTRIBUTION DWG SK-3-12784.
 2. REFER TO APPENDIX C, ITEM 6

CONCEPTUAL

U.S. ATOMIC ENERGY COMMISSION
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SYSTEM SCHEMATIC
 ARGON FOR FUEL TRANSFER
 & FUEL EXAMINATION CELLS

FAST FLUX TEST FACILITY

300 GEN 7001.01

SK3-12785

ISSUE 2-12-69
 4TH ISSUE 7-12-68
 3RD ISSUE (REDRAWN) 6-27-68

APPROVED FOR CONFORMANCE
 DATE 8/10/68
 SCALE NONE
 CLASSIFICATION NONE

REVISIONS

NO.	DATE	DESCRIPTION
1	8/10/68	ISSUED FOR CONSTRUCTION

LEGEND				
PRINCIPAL FLOW				
AUXILIARY FLOW				
BLOCK VALVE				
CHECK VALVE				
MODULATING VALVE				
NO NORMALLY OPEN				
NC NORMALLY CLOSED				
E.I. ELECTRICAL INTERLOCK				
INSTRUMENT SYMBOLS				
CONNECTION TO PROCESS				
PNEUMATIC SIGNAL				
ELECTRIC SIGNAL				
LOCALLY MOUNTED				
PANEL MOUNTED				
POSITION IDENTIFICATION				
LETTER	FIRST	SECOND	THIRD	
E		ELEMENT		
I		INDICATOR		
P	PRESSURE			
F	FLOW			
C		CONTROL		
D	DIVERTING			
V	VALVE		VALVE	

RADIOACTIVE GAS DECAY AND DISPOSAL SYSTEM NO. 82-3

NOTES
1. REFER TO INTERFACES APPENDIX C, ITEM NO. 8

CONCEPTUAL		U. S. ATOMIC ENERGY COMMISSION RICHLAND OPERATIONS OFFICE PACIFIC NORTHWEST LABORATORY OPERATED BY BATTTELLE MEMORIAL INSTITUTE	
SYSTEM SCHEMATIC RADIOACTIVE GAS DECAY AND DISPOSAL FAST FLUX TEST FACILITY		300 GEN. 7001 01	
SK-3-12786		7-12-68	

REV	DATE	BY	CHKD	DESCRIPTION
1	7-12-68	W. J. B.		INITIAL DESIGN
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S. O. Arneson

J. M. Batch

A. L. Bement

R. G. Baumgartel

R. A. Bennett

C. L. Boyd

D. C. Boyd

W. L. Bunch

J. R. Carrell

W. L. Chase

J. C. Cochran

D. L. Condotta

R. R. Cone

D. R. Doman

R. V. Dulin

E. A. Evans

L. M. Finch

C. J. Foley

E. E. Garrett

J. P. Hale

R. A. Harvey

R. J. Hennig

C. W. Higby

P. L. Hofmann

E. M. Johnston

H. D. Lenkersdorfer

C. E. Love

D. Marinos

W. B. McDonald

J. S. McMahon

J. W. Mitchell

C. A. Munro

C. R. Nash

C. N. Orsborn

M. G. Patrick

R. E. Peterson

O. W. Priebe

F. H. Shadel

D. W. Shannon (2)

D. E. Simpson

C. R. F. Smith

R. J. Squires

D. D. Stepnewski

G. H. Strong

C. D. Swanson

K. G. Toyoda

M. A. Vogel

R. C. Walker

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