70-1113

→ Ref to 6 Thorpe 546-SS

GENERAL ELECTRIC

WILMINGTON MANUFACTURING DEPARTMENT
GENERAL ELECTRIC COMPANY • P.O. BOX 780 • WILMINGTON, NORTH CAROLINA 28402

December 10, 1984

Director
Office of Nuclear Material Safety & Safeguards
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

'84 DEC 11 P2:54

Attention: Mr. W. T. Crow, Section Leader
Uranium Process Licensing Section
M/C 396-SS

Gentlemen:

References: (1) NRC License SNM-1097, Docket #70-1113
(2) Letter, CM Vaughan to WT Crow, 6/1/84
(3) Letter, GH Bidinger to CM Vaughan, 9/11/84

Subject: REQUEST FOR WITHDRAWAL OF PROPRIETARY INFORMATION FROM PUBLIC DISCLOSURE

On June 1, 1984, General Electric Company submitted an application to the NRC requesting authorization to operate equipment and processes known as UPMP (Uranium Process Management Project). That submittal included two versions of the application - one with proprietary information included and one for release to the NRC Public Document Room with proprietary information deleted.

During a recent review of the 6/1/84 application, it was discovered that several pages in the nonproprietary submittal inadvertently contained proprietary information. Therefore, General Electric requests that this information be withdrawn from the Public Document Room(s) and returned to GE.

In order to facilitate withdrawal and replacement, a complete copy of the 6/1/84 non-proprietary submittal is attached which incorporates revised pages. All information deleted from these revised pages was designated as proprietary by the affidavit accompanying the submittal (J. A. Long, 6/4/84) and confirmed by the NRC (Reference 3). Attachment 1 contains a list of the effected pages.

General Electric Company requests that this letter and Attachment 1 be withheld from public disclosure until such time as the proprietary information is removed from the PDR(s).

24536

GENERAL ELECTRIC

General Electric Company personnel would be pleased to discuss this matter with you and members of your staff as you may deem necessary.

Very truly yours,

GENERAL ELECTRIC COMPANY

Charles M. Vaughan

Charles M. Vaughan, Acting Manager
Regulatory Compliance
M/C J26

CMV:bsd
NSD/SGD-L
Attachment

GENERAL ELECTRIC

Director - ONMSS
December 10, 1984

ATTACHMENT 1

The following pages in the 6/1/84 non-proprietary submittal for the UPMP project have been revised to delete proprietary information:

2.1-13
2.2-15
2.2-17
2.3-19
2.4-27
2.4-29
2.5-12
4-27
4-29
4-30
4-47
4-48

CM Vaughan
:bsd

DOCKET NO. 70-1113
CONTROL NO. 24536
DATE OF DOC. 12/10/84
DATE RCVD. 12/11/84
FCUF ✓ PDR ✓ 11/27/85
FCAF ____ LPDR ____
WM ____ I&E REF. ✓
WMUR ____ SAFEGUARDS ✓
FCTC ____ OTHER ____

DESCRIPTION:

request for withdrawal of proprietary information from public disclosure

12/12/84 INITIAL Cre

GENERAL ELECTRIC COMPANY

AFFIDAVIT

I, James A. Long, being duly sworn, depose and state as follows:

1. I am General Manager, Wilmington Manufacturing Department, General Electric Company, and have been delegated the function of reviewing the information described in paragraph 2 which is sought to be withheld and have been authorized to apply for its withholding.

2. The information to be withheld is identified portions of the Uranium Process Management Project (UPMP) licensing demonstration document dated June 1, 1984, supporting Application Amendment N-18/S-32, NRC License SNM-1097, Docket #70-1113. This licensing action was first noticed with the Nuclear Regulatory Commission 14 December 1982.

3. In designating material as proprietary, General Electric utilizes the definition of proprietary information and trade secrets set forth in the American Law Institute's Restatement Of Torts, Section 757. This definition provides:

> "A trade secret may consist of any formula, pattern, device or compilation of information which is used in one's business and which gives him an opportunity to obtain an advantage over competitors who do not know or use it.... A substantial element of secrecy must exist, so that, except by the use of improper means, there would be difficulty in acquiring information.... Some factors to be considered in determining whether given information is one's trade secret are: (1) the extent to which the information is known outside of his business; (2) the extent to which it is known by employees and others involved in his business; (3) the extent of measures taken by him to guard the secrecy of the information; (4) the value of the information to him and to his competitors; (5) the amount of effort or money expended by him in developing the information; (6) the ease or difficulty with which the information could be properly acquired or duplicated by others."

4. Some examples of categories of information which fit into the definition of proprietary information are:

   a. Information that discloses a process, method or apparatus where prevention of its use by General Electric's competitors without license from General Electric constitutes a competitive economic advantage over other companies;

b. Information consisting of supporting data and analyses, including test data, relative to a process, method or apparatus, the application of which provide a competitive economic advantage, e.g., by optimization or improved marketability;

c. Information which if used by a competitor, would reduce his expenditure of resources or improve his competitive position in the design, manufacture, shipment, installation, assurance of quality or licensing of a similar product;

d. Information which reveals cost or price information, production capacities, budget levels or commercial strategies of General Electric, its customers or suppliers;

e. Information which reveals aspects of past, present or future General electric customer-funded development plans and programs of potential commercial value to General Electric;

f. Information which discloses patentable subject matter for which it may be desirable to obtain patent protection;

g. Information which General Electric must treat as proprietary according to agreements with other parties.

5. In addition to proprietary treatment given to material meeting the standards enumerated above, General Electric customarily maintains in confidence preliminary and draft material which has not been subject to complete proprietary, technical and editorial review. This practice is based on the fact that draft documents often do not appropriately reflect all aspects of a problem, may contain tentative conclusions and may contain errors that can be corrected during normal review and approval procedures. Also, until the final document is completed it may not be possible to make any definitive determination as to its proprietary nature. General Electric is not generally willing to release such a document to the general public in such a preliminary form. Such documents are however, on occasion furnished to the NRC staff on a confidential basis because it is General Electric's belief that is is in the public interest for the staff to be promptly furnished with significant or potentially significant information. Furnishing the document on a confidential basis pending completion of General Electric's internal review permits early acquaintance of the staff with the information while protecting General Electric's potential proprietary position and permitting General Electric to insure the public documents are technically accurate and correct.

6. Initial approval of proprietary treatment of a document is made by the Subsection Manager of the originating component, the man most likely to be acquainted with the value and sensitivity of the information in relation to industry knowledge. Access to such documents within the Company is limited on a "need to know" basis and such documents at all times are clearly identified as proprietary.

7. The procedure for approval of external release of such a document is reviewed by the Section Manager, Project Manager, Principal Scientist or other equivalent authority, by the Section Manager of the cognizant Marketing fuction (or his delegate) and by the Legal Operation for technical content, competitive effect and determination of the accuracy of the proprietary designation in accordance with the standards enumerated above. Disclosures outside General Electric are generally limited to regulatory bodies, customers and potential customers and their agents, suppliers and licensees only in accordance with appropriate regulatory provisions or proprietary agreements.

8. The document mentioned in paragraph 2 above has been evaluated in accordance with the above criteria and procedures and has been found to contain information which is proprietary and which is customarily held in confidence by General Electric.

9. The document mentioned in paragraph 2 above, its appendices and replacement pages contain process engineering details and drawings developed by General Electric which will result in significantly reduced process losses and environmental impact, a General Electric developed proprietary ammonium based uranyl nitrate conversion process, patentable applications of plasma emission spectrometry and density-refractometry; and the design, application and supporting criticality safety analysis for special neutron absorber panels used as a primary means of criticality control.

10. The information in that document, to the best of my knowledge and belief, has consistently been held in confidence by the General Electric Company, no public disclosure has been made, and it is not available in public sources. All disclosures to third parties have been made pursuant to regulatory provisions of proprietary agreements which provide for maintenance of the information in confidence.

11. Public disclosure of the information sought to be withheld is likely to cause substantial harm to the competitive position of the General Electric Company and deprive or reduce the availability of profit-making opportunities because:

a. Such information is a significant part of a program which was developed with the expenditure of resources exceeding 9 million dollars.

b. Public availability of this information would deprive General Electric of the ability to seek reimbursement to the substantial financial and competitive disadvantage of General Electric.

c. Public availability of the information would allow foreign competitors, including competing BWR suppliers, to obtain information at no cost which General Electric developed at substantial cost. Use of this information by foreign competitors would give them a competitive advantage over General Electric by allowing them to develop the same or nearly similar methodology at lower cost than General Electric.

STATE OF NORTH CAROLINA

ss:

COUNTY OF NEW HANOVER

James A. Long, being duly sworn, deposes and says:

That he has read the foregoing affidavit and the matters stated therein are true and correct to the best of his knowledge, information, and belief.

Executed at Wilmington, North Carolina, this 4 day of June 1984

James A. Long

James A. Long
GENERAL ELECTRIC COMPANY

Subscribed and sworn before me this 4 day of June 1984 in New Hanover County.

Rhoda M Rowles

NOTARY PUBLIC, STATE OF NORTH CAROLINA

My Commission Expires 3-12-88

TABLE OF CONTENTS

Reference: SNM-1097

TABLE OF CONTENTS

Reference: SNM-1097

TABLE OF CONTENTS

CHAPTER 4 - CRITICALITY SAFETY ANALYSES FOR EQUIPMENT & OPERATIONS

Reference: SNM-1097

TABLE OF CONTENTS

TABLE OF CONTENTS

Reference: SNM-1097

TABLE OF CONTENTS

Reference: SNM-1097

TABLE OF CONTENTS

TABLE OF CONTENTS

Reference: SNM-1097

CHAPTER 1.0
INTRODUCTION

This document provides a process description and demonstration of safety for the Uranium Process Management Project (UPMP) facility expansion at the General Electric Company, Wilmington Manufacturing Department, Wilmington, North Carolina. This new facility will be operated under Special Nuclear Material License SNM-1097 and will become an integral part of nuclear fuel production at the Wilmington site.

1.1 PURPOSE

The purpose of UPMP is to establish the recovery and recycle of uranium from waste streams and on-site uranium scrap recovery as normal processes within the current fuel fabrication operation.

1.2 GENERAL PROJECT DESCRIPTION

1.2.1 Project Scope

The UPMP includes six basic process and control segments which have been synergistically integrated to recover uranium from off-line material streams and to convert the recovered uranium to uranium dioxide powder for use in standard nuclear fuel products. The project also includes chemical and other related support systems and building modifications.

The basic UPMP segments include:

1.2.1.1 Fluoride Waste Treatment

A treatment process to remove low concentrations of uranium from the ammonium fluoride liquid waste stream which results from the chemical conversion of uranium hexafluoride to uranium dioxide.

1.2.1.2 Rad Waste Treatment

A lime treatment and solids separation process to remove low concentrations of uranium from a waste stream composed of laundry water, decontamination wash water, floor mop water, incinerator scrubber water and laboratory drain discharges.

1.2.1.3 Nitrate Waste Treatment

A two part process consisting of (1) a primary lime treatment and uranium solids separation system for the ammonium nitrate liquid waste stream generated in the conversion to uranium dioxide from uranyl nitrate and (2) a secondary lime treatment and solids separation system to handle the nitrate waste treatment effluent and the waste stream from the UPMP solvent extraction system. The combined nitrate liquid wastes will be neutralized, treated for removal of metals and ultimately released to the existing site nitrate lagoon. Contaminated solids will be packaged for shipment to licensed offsite burial facilities.

1.2.1.4 Scrap Processing

A uranium scrap pre-treatment, (primarily oxidation), nitric acid dissolution and solvent extraction process to recover uranium from scrap materials and sludges. This process will produce a pure uranyl nitrate product suitable for conversion to nuclear reactor grade uranium dioxide.

1.2.1.5 Uranyl Nitrate Conversion

A uranyl nitrate conversion (to uranium dioxide) process. This process will replace the existing batch hydrogen peroxide precipitation process.

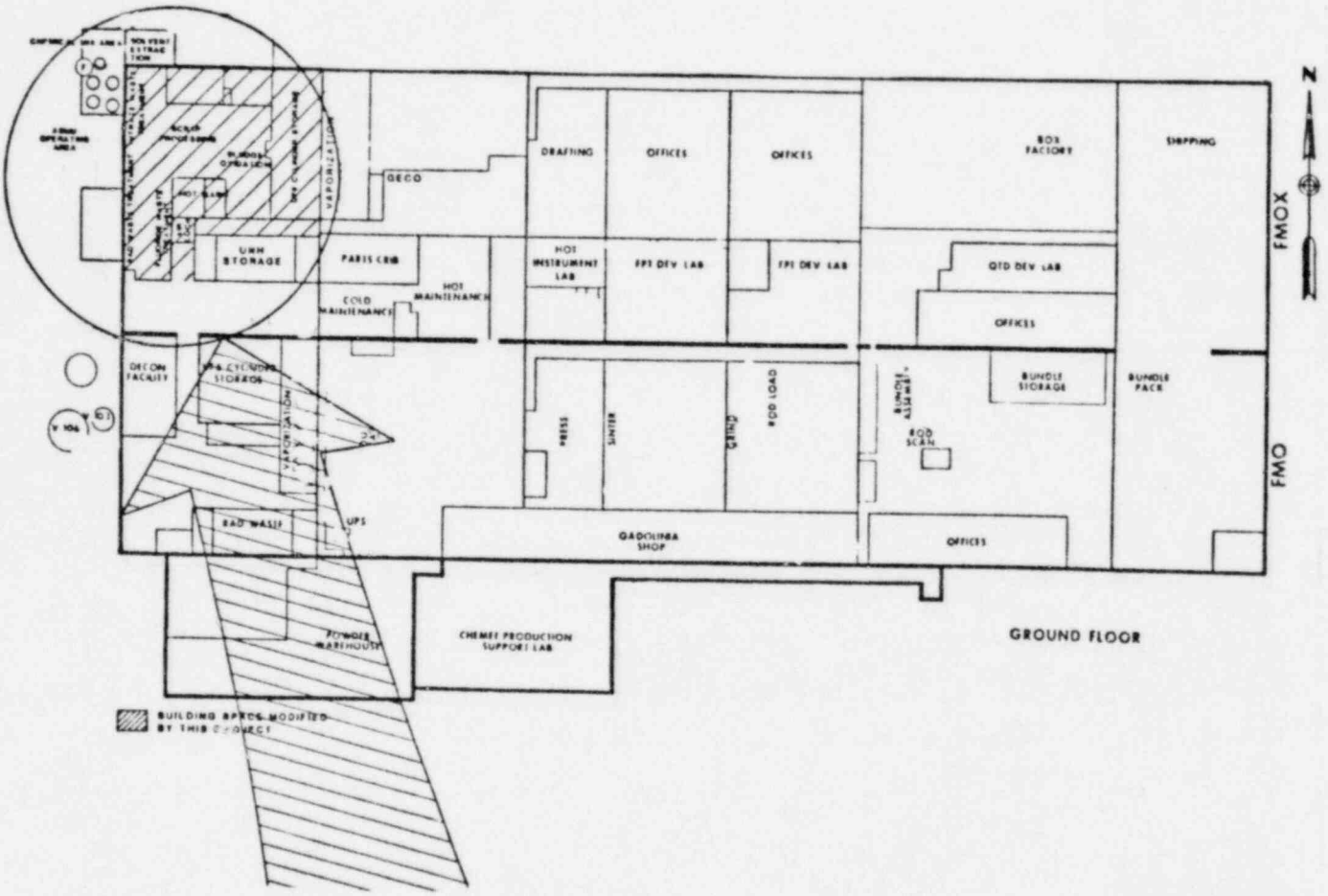
1.2.1.6 Process Control Systems

The UPMP process control system is a distributed system with dual consoles. Each console will monitor one-half of the UPMP process while providing backup for the other half. Power is provided via an interruptible power supply with battery backup.

1.2.2 Facility Description

As shown in Figure 1-1, the UPMP facility is located in the northwest corner of the existing high bay FMO-X building and in three new contiguous building additions

FIGURE 1-1
UPMP FACILITY



Reference: SNM-1097

to the north and west. The total UPMP process and support floor area is approximately 29,200 square feet. Modifications to the existing building consist of the addition of a second floor and a mezzanine level for the control room, computer room, and process laboratory. The three new buildings are a three story solvent extraction building, a solvent and chemical makeup building, and a single level structure for weather protection of the electrical substation and uninterruptible power supply system (see Figures 1-2 through 1-4).

1.2.3 Integration with Existing Manufacturing Facilities

Figure 1-5 schematically presents the current fluoride, nitrate and rad waste systems. Figure 1-6 indicates how the new UPMP facility will fit into the current waste handling systems. As illustrated in this Figure, the new UPMP facility will provide integral pre-treatment and in-line waste treatment systems to reduce the waste stream uranium content and to increase subsequent uranium recovery.

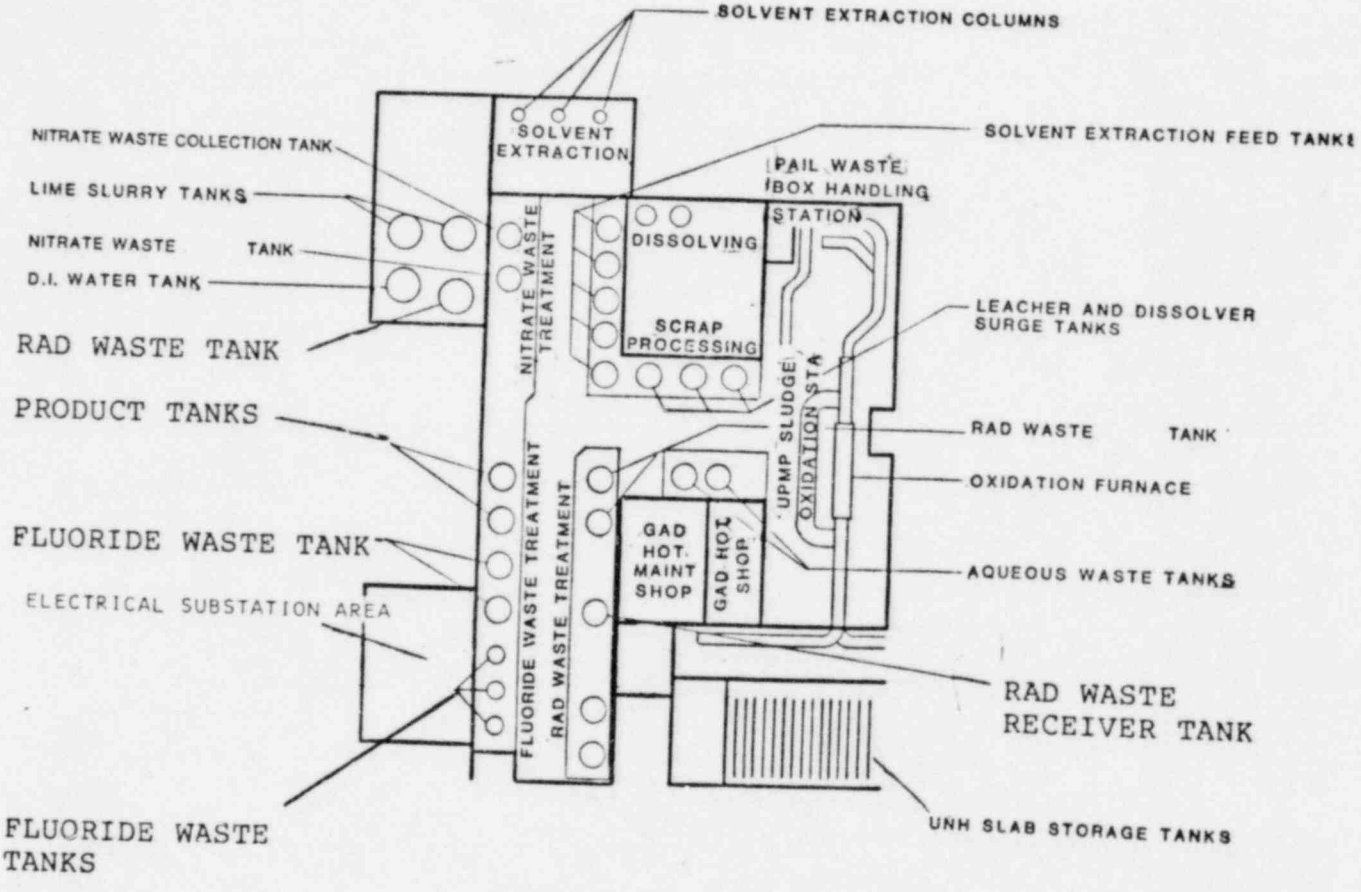
Selected utilities and services will be supplied from or connected to existing FMO-X systems. These include electrical power, fire detection and sprinkler systems, steam, chilled water, potable water, compressed air, instrument air, process gases, storm sewers and process sewers. In addition, UPMP nuclear safety systems (e.g., criticality alarms and air sampling) will be connected to existing facilities.

1.2.4 New Processes and Technological Features

The UPMP is a extensive combination of industrial processes and technological features. Several are new in WMD operations and are of specific note in this license amendment application; as indicated below, several are also considered proprietary to GE.

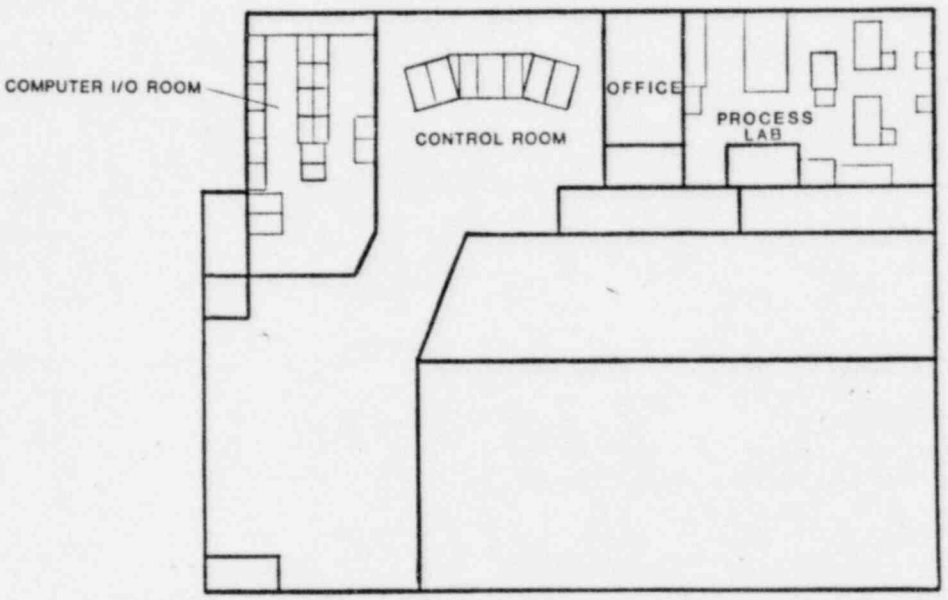
- o A system for fluoride waste treatment (trade secret)
- o A solvent extraction system for uranium recovery and purification
- o An uranyl nitrate conversion process (patent to be applied for)

FIGURE 1-2
UPMP EQUIPMENT LAYOUT - GROUND FLOOR



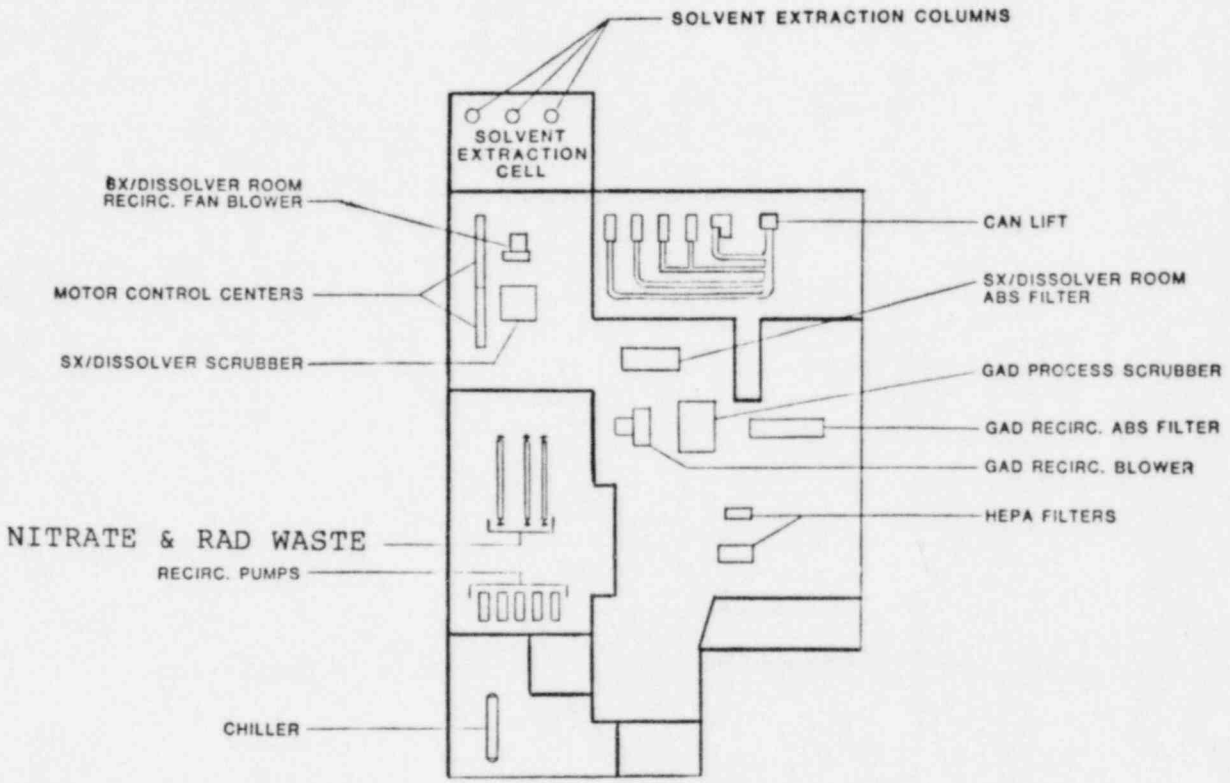
Reference: SNM-1097

FIGURE 1-3
UPMP EQUIPMENT LAYOUT - MEZZANINE



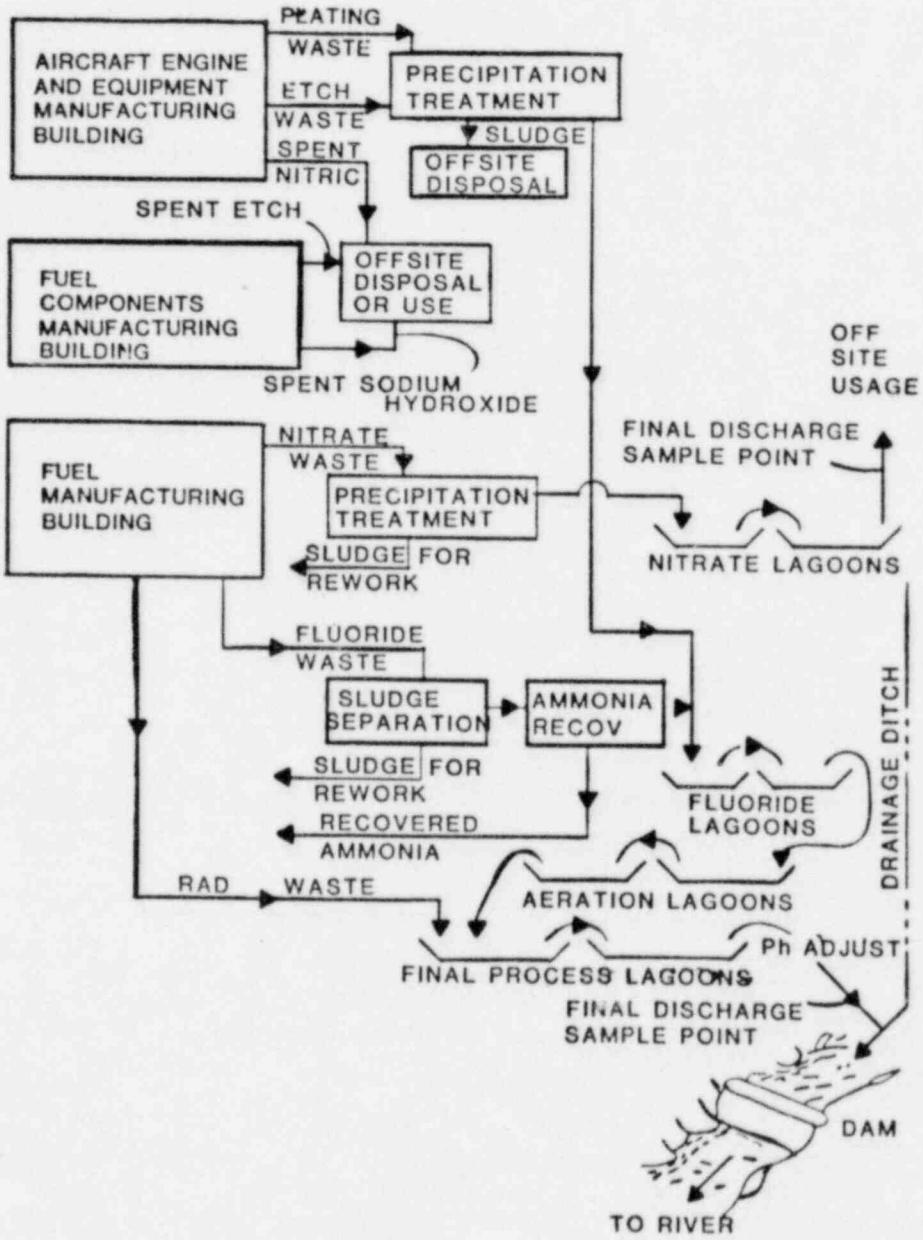
Reference: SNM-1097

FIGURE 1-4
UPMP EQUIPMENT LAYOUT - SECOND FLOOR



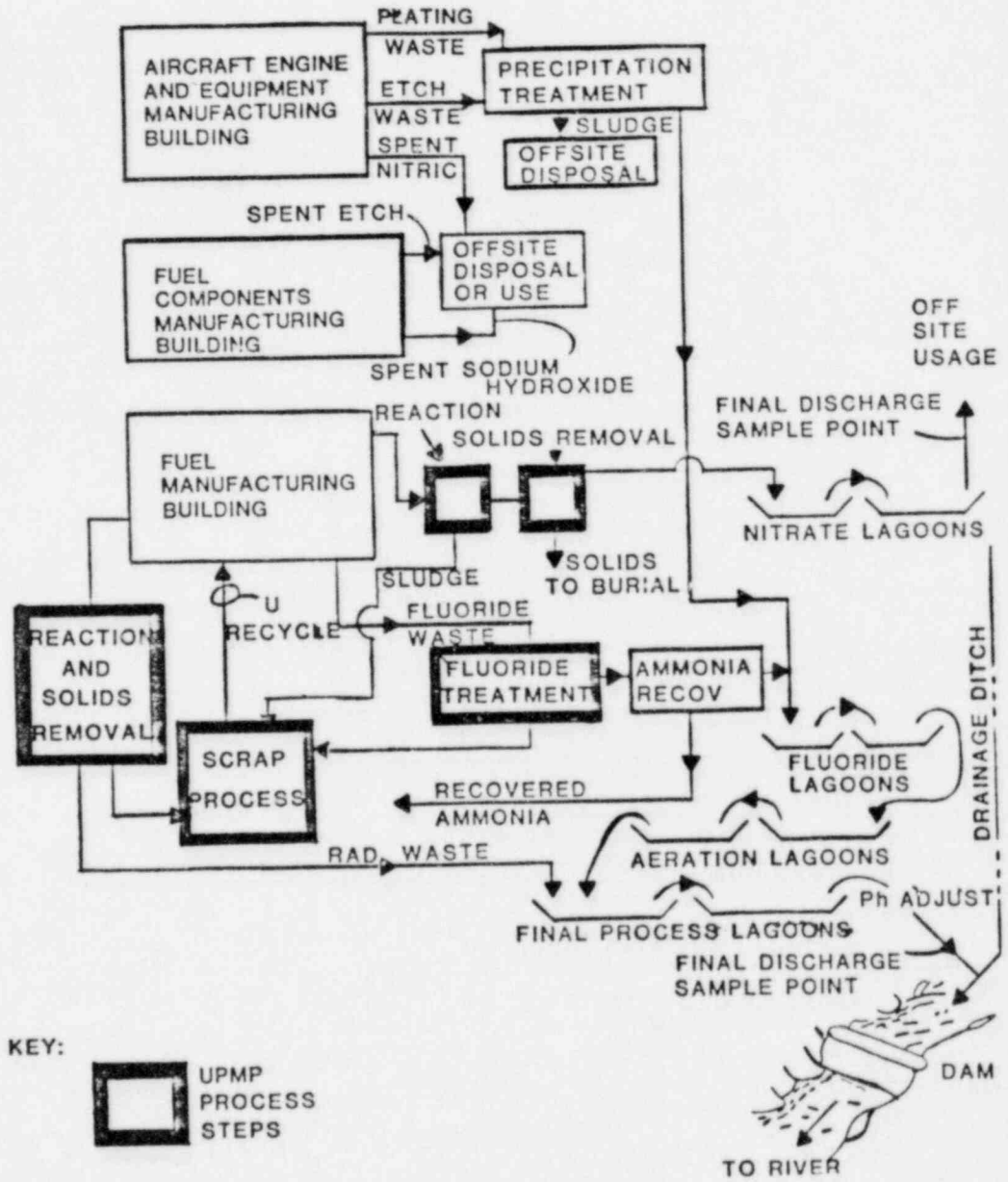
Reference: SNM-1097

FIGURE 1-5
EXISTING FLUORIDE, NITRATE & RAD WASTE SYSTEMS



Reference: SNM-1097

FIGURE 1-6
UPMP FLUORIDE, NITRATE & RAD WASTE SYSTEMS



Reference: SNM-1097

- A scrap dissolving process for low grade sludges and incinerator ash
- Lime precipitation and solids removal in rad waste treatment (details of the process are a trade secret)
- Lime precipitation and solids removal in nitrate waste treatment (details of the process are a trade secret)
- Geometrically safe vessels and scrap dissolvers utilizing neutron absorber panels (trade secret) †
- Automated mechanical filters for solids removal
- A distributed process control system
- A dedicated process laboratory which includes †

  for process analytical measurements (patentable applications) †
- Bubble cap tray design absorption column for removal of oxides of nitrogen from dissolver offgas
- Tandem instrumentation for in-line uranium and acid measurement

The following chapters in this document present a detailed description of the processes and features listed above and highlight not only the process designs but also the criticality, radiological and environmental safety considerations.

Included as an appendix to this document is a package of facility and equipment drawings. These drawings are particularly useful in detailed reviews of information in Chapters 2-5 of the demonstration since the equipment numbers defined in the text are consistent with the numbering on the drawings.

1.3 PROJECT BENEFITS

UPMP processes have been extensively tested and, as a result of these development efforts, success in achieving the predicted project benefits is assured. Operation of UPMP will have significant positive environmental impacts and reduced safety risks.

1.3.1 Improved Radiological Environmental Protection

The quantity of uranium in radioactive liquids (fluoride, rad waste, and nitrates) discharged from the manufacturing operation will be reduced approximately %. †

The uranium concentration in calcium fluoride sludge will be reduced sufficiently to consider disposal of the sludge under Options 1 and 2 of SECY 81-576 or for chemical use in non-nuclear operations.

The quantity of nuclear material to be disposed of for site decommissioning will be reduced.

1.3.2 Improved Non-radiological Environmental Protection

UPMP reduces generation of calcium fluoride sludge from rad waste by % . Therefore, not only is the uranium † concentration in the sludge reduced, but also the quantity of this by-product material is minimized.

The facility design extensively treats process effluents prior to their discharge to the atmosphere. Although the atmospheric discharge from the WMD site will be increased insignificantly as a result of the additional material being processed, the overall discharge to the atmosphere, when the current offsite reprocessing operations are considered, will be reduced. The net result will be a favorable environmental impact for the Fuel Cycle.

The UPMP process designs have focused on resource conservation. Solutions in solvent extraction are processed so as to permit recycling through the operations thus reducing the quantity of waste chemicals and the need for their disposal.

1.3.3 Reduction of Risks

Currently scrap material is shipped over-the-road for off-site reprocessing; UNH solutions are returned to Wilmington. Since UPMP implements in-house scrap reprocessing, external shipments of these nuclear materials will no longer be needed. This eliminates the risk of potential nuclear releases to the environment during accidents on the highway.

Reference: SNM-1097

A new conversion process eliminates the use of hydrogen peroxide, thus avoiding a potentially hazardous industrial safety condition.

1.3.4 Contribution to Site Decommissioning

Complete removal from the site of all contaminated sludges is a commitment in the Closure and Decommissioning Plan approved by the NRC in December, 1981. Approximately cubic feet of uranium-bearing calcium fluoride sludge have been accumulated and stored on site since the plant started up.

Thus UPMP is, in essence, the first step in completing the decommissioning activity.

Reference: SNM-1097

CHAPTER 2.0
PROCESS DESCRIPTION

2.1 FLUORIDE WASTE TREATMENT SYSTEM

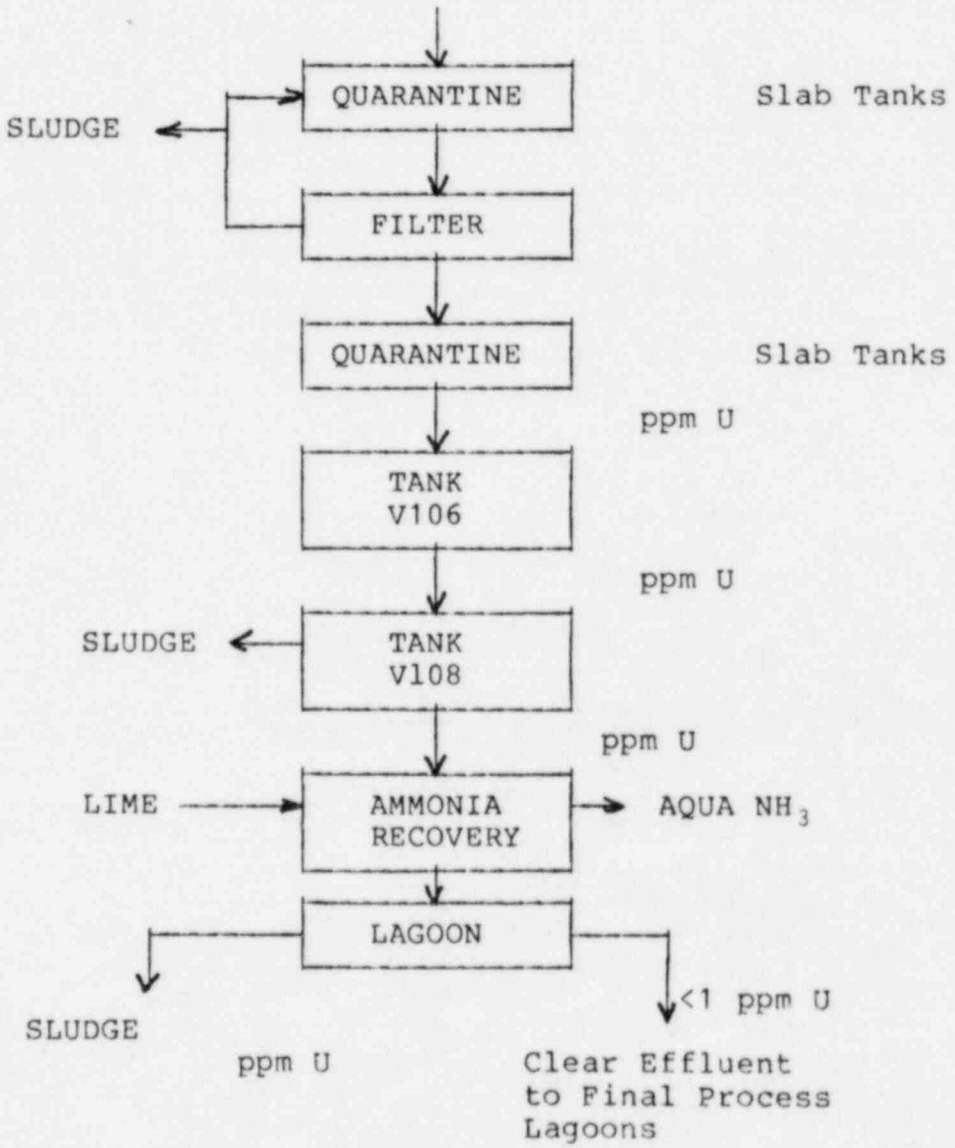
2.1.1 Current Operation

In the conversion of uranium hexafluoride to uranium dioxide, an ammonium fluoride waste stream is generated which contains a very low concentration of uranium.

The fluoride waste liquids resulting from the Fuel Manufacturing Operation (FMO) conversion processes are currently accumulated in quarantine tanks and are circulated through a filtration system to take out the uranium solids. (See Figure 2.1-1.) The clear liquid from the system is accumulated in the quarantine tanks and is sampled for uranium concentration. If the uranium concentration does not exceed the release limits for liquid transferred, it is released from the quarantine tanks to the accumulation tank located outside of the building. The sludge is accumulated in five gallon pails, transferred to the REDCAP drying furnace in FMO and is subsequently recycled through an existing batch uranyl nitrate conversion process (UPS).

The fluoride waste stream is batch pumped from the V-106 tank to a 100,000 gallon settling tank, (V-108), at the process Waste Treatment Facility. Any uranium solids that settle to the bottom of the V-108 tank are removed by centrifuging. This wet sludge is packaged in five gallon plastic pails and is transported to the REDCAP furnace area to be dried. The clear supernate from V-108 is decanted and is treated with lime to precipitate calcium fluoride and uranium. The stream is steam stripped of ammonia and pumped into a lined lagoon where the calcium fluoride and uranium solids settle to the bottom. The supernate from the lagoon, which is nearly free of fluoride, ammonia and uranium, is discharged to the final process lagoons.

FIGURE 2.1-1
FLUORIDE WASTE FLOW - PRESENT PROCESS



Reference: SNM-1097

A side stream of fluoride waste, is diverted from tank V-106 to the existing GECO rundown tanks. These two tanks contain about 2500 gallons of waste water. A very high volume is recirculated from these tanks through high capacity ejectors then back into the tanks. The purpose of this system is to develop a vacuum for the GECO conversion process and to scrub the process gasses. A liquid flow equal to the input flow is returned to tank V-106. The operation of the rundown tanks is controlled by the GECO process control system.

2.1.2 UPMP Fluoride Waste Treatment System

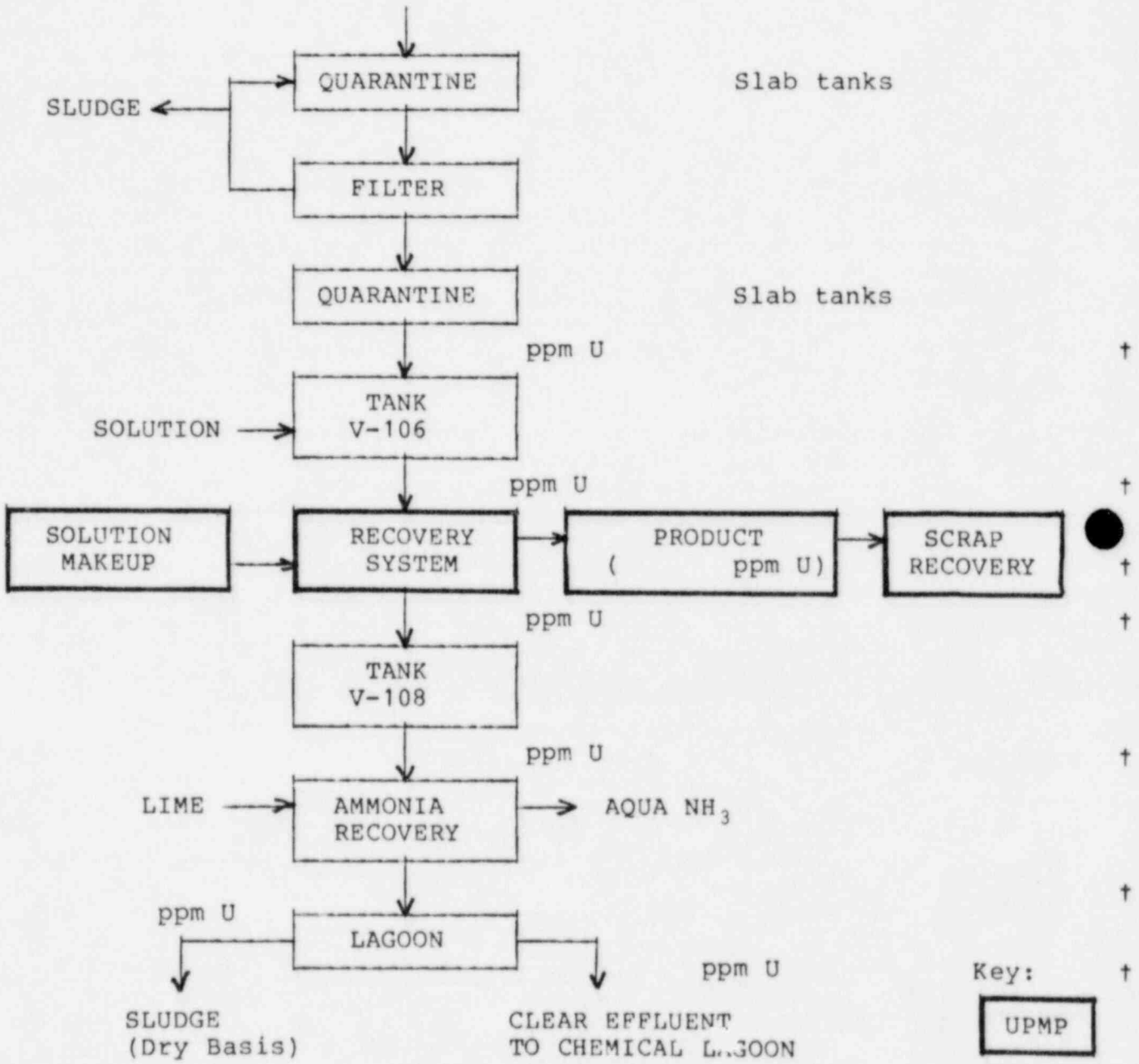
To further reclaim uranium from the fluoride stream, (mostly soluble or colloidal), and to minimize the uranium concentration in the calcium fluoride sludge, a system will be installed between existing tanks V-106 and V-108 for processing the fluoride waste. (See Figure 2.1-2.) This new process is described as follows:

2.1.2.1 Surge Tank - Existing Tank V-106

The clarified fluoride waste liquid from the FMO quarantine tanks will be accumulated in the surge tank V-106 which serves as the feed tank for the fluoride waste treatment system. The process line from the quarantine tanks to V-106 will not be changed from the existing system and transfers to tank V-106 will be based on the existing release limit controls. One difference, however, will be that the density of the liquid in V-106 will be monitored by the UPMP process control system and concentrations of greater than grams of uranium per liter will result in a cut off of the feed from the FMO quarantine tanks. †

The waste liquor in the surge tank will contain compounds such as ammonium fluoride, ammonium hydroxide, insoluble and colloidal uranium compounds and trace quantities of nitrates and † Before this solution can be processed through the fluoride waste treatment system, the insoluble and colloidal uranium compounds must be dissolved. The waste liquor in V-106 will be kept in †

FIGURE 2.1-2
FLUORIDE WASTE FLOW - UPMP PROCESS



Reference: SNM-1097

constant circulation by a dedicated high volume pump. This will prevent the insoluble uranium compounds from settling. This circulating stream flows through a venturi type gas scrubber on the top of V-106 which is used to mix the tank contents.

A separate pumping system which utilizes parallel pumps, will be used to transfer the fluoride waste solution from the surge tank to the system, through the filters and, ultimately, to tank V-108 at the Waste Treatment Facility.

At the design flow rate, the parallel pump system relied on for transfer will not have sufficient head to overcome the total pressure drop through the system. To assure adequate, stable operation, a booster pump has been added to the feed system. The booster pump will increase the pressure of the feed to compensate for the pressure drop across the system. Uranium is either collected or caught in the filter. The effluent filter also prevents any solids from passing through to tank V-108.

2.1.2.2 Recovery System

The process will be a system, operating with a The operation and of the will be controlled by the UPMP process control system. One complete cycle includes the following sequences: (See Figure 2.1-3.)

2.1.2.2.1

2.1.2.2.1.1

Reference: SNM-1097

FIGURE 2.1-3
FLUORIDE WASTE TREATMENT PROCESS FLOW

Reference: SNM-1097

2.1.2.2.1.2

2.1.2.2.1.3

2.1.2.2.2

2.1.2.2.2.1

2.1.2.2.2.2

2.1.2.2.3

2.1.2.3 Product Adjustment

The product, as it is being received into the product vessel, will be mixed with nitric acid at a controlled rate. The rate of acid addition will be automatically controlled to maintain the mixture at the proper pH.

The nitric acid will be supplied from a nitric acid break tank which will be a critically safe pipe tank that serves to isolate the acid from the uranium bearing process.

The product, after it is acidified, is circulated in the vessels to mix the solution thoroughly and will be sampled and chemically analyzed.

The aluminum nitrate will be supplied from a critically safe aluminum nitrate break tank. This tank will isolate the supply system from the uranium bearing process.

The product, which contains about kgs of uranium, will be either used in the scrap processing dissolvers

and leachers or, if the dissolver/leachers are not operating, will be processed through the nitrate waste treatment process.

2.1.2.4 Process Control

The system is controlled by the UPMP process control system. (The UPMP process control system is described in Section 2.6.)

The determination of uranium † will be made from grab † samples which will be analyzed in the UPMP process control laboratory. The control room operator will be notified of the results and, when † will direct the control system † † †

Periodic sampling and analysis of the product will be made to insure that the process is operating within the limits. The limit of the † effluent is † ppm uranium. If the concentration is above ppm uranium, the UPMP process control system will automatically switch flow to the surge tank V-106 until the < ppm uranium is achieved. †

† † † † † †

A proportional sampling system in the † effluent line will measure the total volume transferred to waste treatment tank V-108 and will provide a representative sample of the liquid transferred.

2.1.2.5 GECO Rundown System

The source of fluoride waste for the existing GECO rundown tanks will be relocated from the existing surge tank discharge pump to a location downstream of the

process system. A controlled side stream of fluoride waste will be diverted from the pipe line to tank V-108, then to the GECO rundown tanks A and B. The return from this system goes back into the transfer line to V-108. This provides the rundown tanks with fluoride waste that has less than ppm uranium. †

2.1.2.6 Storage Tank - Existing Tank V-108

The treatment of the fluoride waste at the Waste Treatment Facility will not change significantly as a result of the process system, except that uranium bearing sludge will no longer be settled and centrifuged. The reason for this is that the uranium concentration in the product is decreased by a factor of or more from that in V-108 prior to the † implementation of the UPMP process.

The lime treatment of this fluoride waste to precipitate fluoride and recover ammonia will not change, however, the uranium concentration in the calcium fluoride sludge that settles in the fluoride lagoons will change. Before implementation of fluoride waste treatment, the uranium concentration in the dry calcium fluoride sludge has been about ppm. With the † implementation of the treatment process, the concentration in the dry calcium fluoride sludge will be about ppm or less and will make disposal of this † material under SECY 81-576 an attractive option.

2.1.3 Criticality Safety Considerations

As noted in Section 2.1.1, the fluoride waste system will be designed to process an ammonium fluoride liquid waste stream containing a very low concentration of uranium. Prior to the implementation of UPMP, this low concentration has been in the range of ppm U in † the liquid stream and ppm U in the calcium † fluoride sludge in the final process lagoons. These values are factors of or more below the † minimum critical concentration for a homogeneous mixture of UO_2 and water. As indicated by the results in Section 4.1.9.1, the Kinf = 1.0 value is approximately 200,000 ppm U or, equivalently, about 250 grams U/liter.

The implementation of the UPMP system † between the existing fluoride waste system process tanks V-106 and V-108 will favorably impact the fluoride waste system concentration control as shown in Table 2.1-1. As indicated, no concentrations in the UPMP fluoride waste system will approach within less than a factor of the 250 gm U/liter minimum critical $UO_2 + H_2O$ † concentration and only the concentrations in the product and in the † will be higher than those in the fluoride † waste system operation prior to UPMP.

The following sections describe the specific controls implemented in the UPMP fluoride waste system to assure criticality safety. These controls include not only those existing prior to UPMP which assured concentration control in V-106 and V-108 operations, but also the process and chemistry considerations which limit achievable uranium concentrations and the extensive use of geometry control in new UPMP fluoride waste equipment. A final section addresses the criticality safety of fluoride waste system under normal and accident conditions.

2.1.3.1 Density Control in UPMP Surge Tank - Existing V-106

Surge tank V-106 is a geometrically unsafe 65,000 gallon tank located immediately outside of the Fuel Manufacturing Operations building. Tank V-106 is used as an accumulation tank for liquids from the fluoride quarantine tanks prior to their treatment by the UPMP system. Criticality safety of the tank is based upon the uranium dump limit control of the quarantine tanks (in FMO) and adequate mixing of the contents of V-106 by a high volume liquid recirculation line. The fluoride quarantine tank dump limits and V-106 mixing will not be changed from those used by operations prior to UPMP. In addition, it will be assured that not only are the specified concentrations not exceeded, but also that tank V-106 does not contain at any one time more than 75% of a minimum critical mass. (For 4.0% enriched UO_2 and considering the volume of tank V-106, this latter guideline is equivalent to a dump limit to V-106 of no more than ppm U in each gallons released †

Reference: SNM-1097

TABLE 2.1-1

FLUORIDE WASTE SYSTEM
URANIUM CONCENTRATION CONTROL

System	Uranium Concentration Range Prior to UPMP (ppm U)	After UPMP (ppm U)	Overall Effect
Tank V-106			Unchanged
GECO Rundown Tanks			Improved
			Recovery*
			Recovery*
Tank V-108			Improved
Liquid Discharge			Improved
Calcium Fluoride Sludge			Improved

*

Reference: SNM-1097

from the quarantine tanks.) In addition, dissolution and the density monitoring feature will be added specifically for the UPMP operation. The dissolution of uranium and the density monitoring in tank V-106 in the UPMP operation will be predominately for process control, but will also serve to enhance the safety in V-106. The former (dissolution) will be an enhancement because it improves the mixing of the contents of V-106 in conjunction with the high volume recirculation line. The latter (density monitoring) will provide additional safety because a maximum density limit equivalent to grams U/liter will be interlocked via † the UPMP process control system with the inlet valves to V-106. If this value (which is well below the minimum critical value for homogeneous $UO_2 + H_2O$) is reached, the process control system will close the V-106 inlet valves and not permit additional dumps from the fluoride quarantine tanks.

2.1.3.2 Chemistry and Process Control

Chemistry †

The basic chemistry of the process is † illustrated in Figure 2.1-4. The chemistry is divided into two cycles, †

2.1.3.2.1 †

Fluoride liquid waste contains about pm † fluoride, ppm nitrate and ppm uranium. †

Reference: SNM-1097

FIGURE 2.1-4
BASIC CHEMISTRY

Reference: SNM-1097

2.1.3.2.2

2.1.3.2.3 Process Control

The process is monitored and controlled by the UPMP process control system in conjunction with the UPMP process laboratory. This laboratory is located adjacent to the UPMP control room and contains spectrographic, titration and specific ion electrode instruments. (Reference Figure 1-3.) A grab sample from the process will be analyzed for uranium and the data logged in the control room. The periodic grab sample of the process feed solution will be analyzed in the laboratory for both soluble and insoluble uranium.

Reference: SNM-1097

FIGURE 2.1-5

Reference: SNM-1097

FIGURE 2.1-6

Reference: SNM-1097

FIGURE 2.1-7

Reference: SNM-1097

This will determine if process adjustment are necessary for the dissolving of the uranium in surge tank V-106.

The UPMP process control system will modify process flows and chemistry when the process control samples indicate the predefined control limits have been reached. Control room operators will be aware of the system status.

The lab system will analyze the effluent from the process to insure that the uranium concentration is less than ppm. This system will provide automatic † sampling and analysis as well as manual capabilities and will be coupled with the process control system.

For the treatment system, a measurement greater than ppm uranium will result in the process control † system sounding an alarm and automatically diverting the effluent stream back into surge tank. The entire system will remain in this recirculating mode until the discharge is determined to be below the ppm uranium † level, at which time the process control system will re-establish the flow to V-108.

A proportional sampling system will be located in the effluent discharge line from the treatment system to tank V-108. This system will measure the flow rate and total volume discharged to tank V-108 and obtain a representative sample of the liquid flowing through the pipe line. The sample will be analyzed daily by the Chemet laboratory for the uranium concentration and the results will be used for uranium accountability of the operation.

2.1.3.3 Geometry Control in the Fluoride Waste System

In addition to the uranium density control described in the preceding sections, the UPMP fluoride waste system also makes significant use of geometry control for equipment in the treatment system. In summary, the fluoride waste system consists of the following:

(1) geometrically safe cylindrical tanks. †

(2) geometrically safe vessels. †

(3) geometrically unsafe tanks. †

(4) geometrically safe pumps. †

(5) geometrically safe diaphragm pump. †

(6) critically safe floor basin. †

(7) Associated geometrically safe process piping

Table 2.1-2 is a listing of the process equipment in the fluoride waste system and briefly describes the geometry and corresponding criticality safety designation. (HVAC equipment is not included in this list but is generically discussed in Section 5).

2.1.3.4 Normal and Accident Conditions in the Fluoride Waste System

As noted previously, the maximum uranium concentration present in the fluoride waste system is grams per liter. From Table 4-4 in Chapter 4, the Kinf for a full density homogeneous mixture of UO_2 and H_2O with a U density no greater than this is in the range of 0.30-0.50. It can therefore be concluded that under normal conditions, the Keff for any piece of equipment in the fluoride waste system is well below a value of 0.90. †

In the evaluation of fluoride waste system accident conditions, four significant conditions have been identified. These are:

2.1.3.4.1 Failure of Concentration Control in Existing Tank V-106

In order for a significant failure of concentration control in existing surge tank V-106 to occur, at least

three independent system failures must occur upsteam prior to dumping from the fluoride quarantine tanks.

(1) Failure of manufacturing process equipment with a subsequent high carry over of uranium into the fluoride liquid waste system.

(2) Failure of fluoride quarantine tank process controls (most notably the filter and centrifuge systems) to remove the high concentration of uranium from the stream prior to transfer to the quarantine tanks.

(3) Failure of the U monitor or SPEC 20 measurement systems to detect the high level of uranium prior to dumping of the quarantine tank to the surge tank.

Given these failures and the following assumptions about credible conditions, an assessment of the criticality safety of tank V-106 has been made.

- Assume a single 1000 gallon quarantine transfer containing as much as 100 kg of uranium is dumped to V-106.

- Assume that prior to this dump, tank V-106 contained 20,000 gallons of liquid (approximately 1/3 full) with approximately ppm U. †

- Assume the mixing, dissolving and density controls on tank V-106 are fully operable and monitored by the UPMP process control system.

Based upon these conditions, it can be seen that after the kg U per gallon quarantine transfer is † dumped to tank V-106, the surge tank will contain kg U and gallons of liquid/mixture. † This mixture will be adequately dissolved and mixed by process controls, and the resulting uranium concentration will be no more than grams of † uranium per liter. Since quarantine tank dumps are only made approximately every 30 minutes, continued releases to V-106 at this level for more than a few times are not credible. Nonetheless, if such releases were to occur over a period of 24 hours, the resulting slow increase

Reference: SNM-1097

in uranium content in V-106 would eventually be detected by the surge tank density controls and further input from the quarantine tanks halted by the process control system. (At least such dumps would be required to † reach this point since the V-106 density limit is set at † grams U/liter).

Because at least four independent and multiple failures must occur to exceed this critically safe condition, this system complies with the double contingency policy defined in Chapter 4.

2.1.3.4.2 Failure of Concentration Control in the System

Except as noted in Table 2.1-2, all process equipment in the treatment system is geometrically safe. Failure of concentration control in this area will therefore not result in a critically unsafe condition without the coincident and unrelated failure of such a geometry control.

Conversely, failure of geometry control in the treatment system will not result in a critically unsafe condition without the coincident and unrelated failure of the fluoride waste system concentration controls.

2.1.3.4.3 Back Flow of Uranium Into the DI Water Supply Tank or Make-up Tank

Since the treatment system is operated under † lbs positive pressure, prevention of backflow of uranium into the unsafe geometry DI H_2O supply tank and make-up-tank is achieved by process controls (monitoring devices) and automatic double block and bleed valves. The double block and bleed valve operation is shown in Figure 2.1-8.

If the process control and double block and bleed valve systems do fail, however, criticality safety will still be assured by the fluoride waste system concentration controls. Not only will the uranium concentration backflowing into the DI water supply tank and the make-up tank be further diluted from the value in the fluoride waste system, but also the maximum volumes of

TABLE 2.1-2
UPMP FLUORIDE WASTE SYSTEM EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Treatment Equipment	Yes		Geometrically Safe with Neutron Absorber Panels
	Filters	Yes		Geometrically Safe Cylinders
	Filters	No, ppm U		Geometrically Safe Cylinders
	Filters	Yes		Geometrically Safe Cylinders
	Venturi Gas Scrubber	Yes		Geometrically Unsafe Tank but part of T-500 Operation
	Pump	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pump	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pump	No		Geometrically Safe Slab and Volume
	Seal Pot	Yes		Geometrically Safe Cylinder
	Seal Pot	Yes		Geometrically Safe Cylinder
	FW Sump	No		Geometrically Safe Cylinder (with Concrete Reflection)
	Break Tank	No		Geometrically Safe Cylinder
	Break Tank	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Unsafe
	Tank	Yes		Geometrically Safe Cylinders
	DI Water Supply Tank	No		Geometrically Unsafe Back-flow prevented by Double Block & Bleed Valves

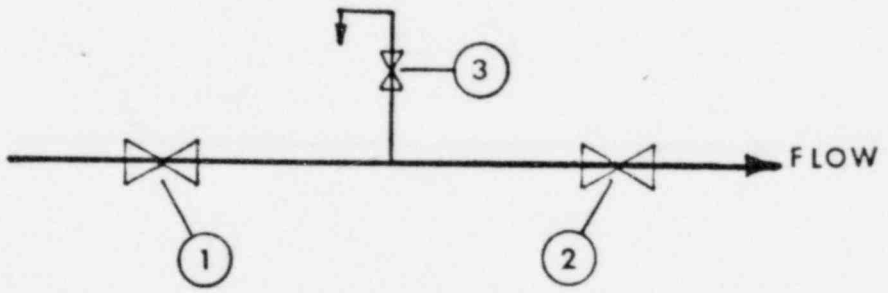
Reference: SNM-1097

TABLE 2.1-2
UPMP FLUORIDE WASTE SYSTEM EQUIPMENT LIST
(CONTINUED)

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Tank	No		Geometrically Unsafe Back-flow prevented by Double Block & Bleed Valve
	Tanks	No, ppm U		Geometrically Unsafe
	Tank	No, ppm U		Unsafe Geometry
	Vessels	Yes		Geometrically Safe with Neutron Absorber Panels
	Vessels	Yes		Geometrically Safe with Neutron Absorber Panels
	Process Piping	Yes	1",2", 3" and up to 6" diameter piping	Geometrically Safe Cylindrical and Slab Geometries
	FW Floor Basin	No	3.5" Thick Slab	Critically Safe Slab with Concrete Reflection

Reference: SNM-1097

FIGURE 2.1-8
BLOCK & BLEED VALVE SYSTEM



The system is controlled by a sequence controller that is activated by an OPEN or CLOSE signal.

NORMAL FLOW POSITIONS

Block Valve #1 is OPEN
Block Valve #2 is OPEN
Bleed Valve #3 is CLOSED

VALVE OPERATION

CLOSE:

To stop the flow, the CLOSE signal is activated. The valves operate in sequence. That is, when block valve #1 closes, then block valve #2 closes, then bleed valve #3 opens. If either block valve #1 or 2 should leak, the liquid will flow out through the bleed valve #3 onto the floor.

OPEN:

To open the valves, to start the flow, the OPEN signal is activated. The valves operate in sequence. That is, when bleed valve #3 closes, then block valve #2 opens, then block valve #1 opens.

Reference: SNM-1097

these tanks assures that the amount of uranium contained in either of the tanks will be less than a safe batch (as tabulated in Table 4-7).

2.1.3.4.4 Failure of Concentration Control in V-108

Failure of concentration control in tank V-108 will require as a minimum the following independent, unrelated conditions:

(1) Failure of fluoride quarantine tank dump limit controls.

(2) Failure of treatment process controls to remove uranium.

(3) Failure of the UPMP measurement system to detect high (ppm U) uranium concentrations. †

Since tank V-108 is itself equipped with concentration controls and a solids removal system, failure of concentration control will not violate the requirements of the double contingency policy.

2.2 RAD WASTE TREATMENT

2.2.1 Current Operation

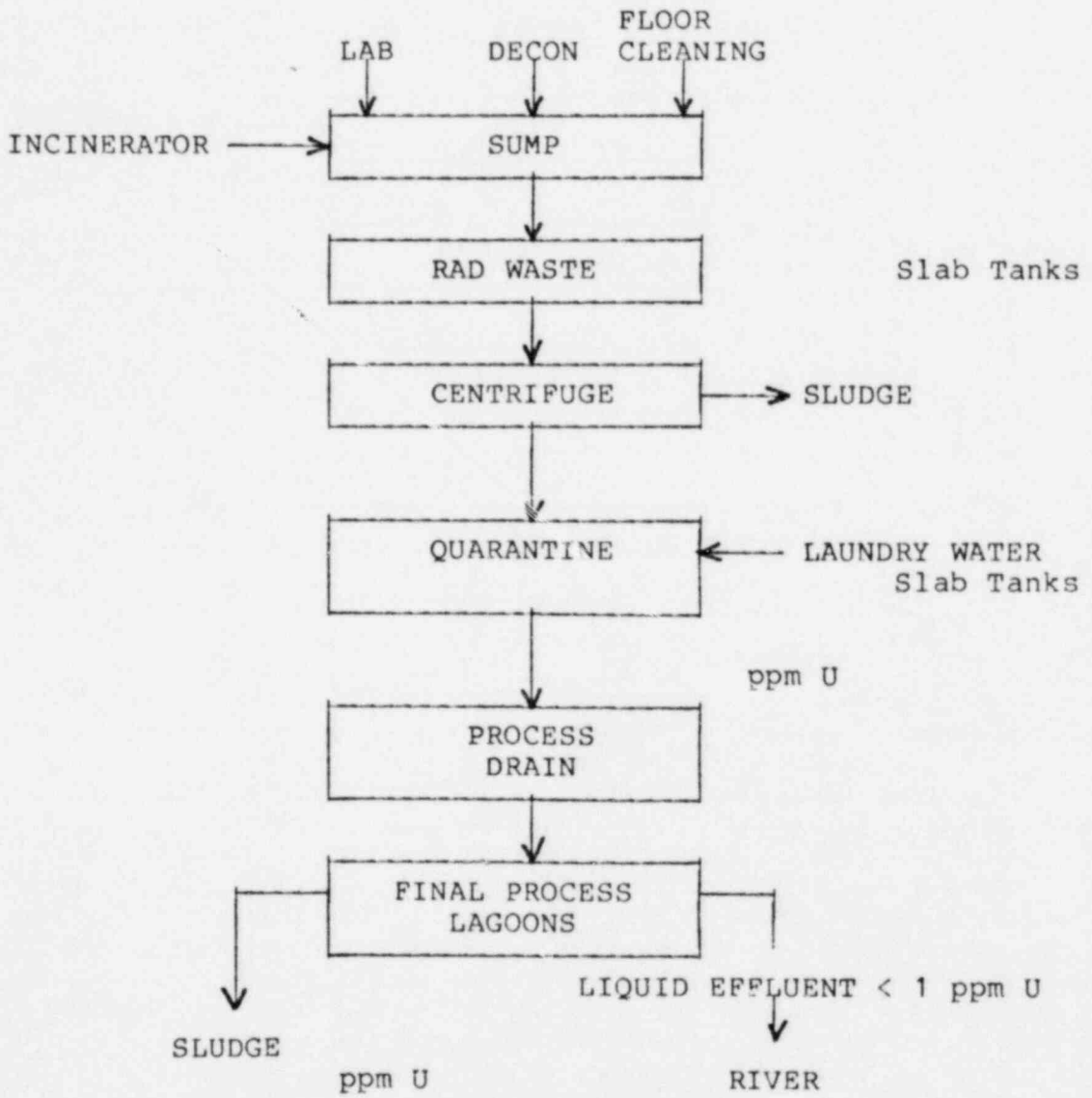
The rad waste system is an accumulation of various low level radioactive waste streams that are generated in the fuel manufacturing operation. These streams, as shown in Figure 2.2-1, are collected from the Chemet laboratory, the decon facility, the incinerator, equipment cleaning for maintenance and general housecleaning liquids. These liquids are collected in the existing FMO rad waste accumulation tanks #1 and #2 which are located in the FMO rad waste complex. The pH is frequently adjusted by the operator to reduce the soluble uranium content of the rad waste. The liquids are circulated through an existing clarifier to continuously remove suspended uranium and other particulate.

The solids removed by the clarifier are backflushed to an accumulator tank. The slurry is desludged using a dewatering, bowl-type centrifuge. The solids are loaded into containers, transported to the REDCAP area for drying and subsequently shipped off-site for processing. The reprocessed material is returned to WMD as UNH solution.

The clarified rad waste is transferred to the existing FMO rad waste slab tanks 4 and 5. Laundry water is also transferred from its collection point in the existing FMO-X rad waste slab tanks to FMO rad waste slab tanks. The composite liquids in the tanks are circulated, sampled, and analyzed for uranium. If the uranium concentration is less than the release limits of ppm U, the liquid is discharged to the existing † industrial sewer. The discharge line is equipped with a continuous proportional sampler for uranium accountability. The uranium in the rad waste is precipitated and is settled in the existing final process lagoons after it mixes with the other waste streams in the industrial sewer. The uranium concentration of this dried sludge ranges from † ppm. †

Reference: SNM-1097

FIGURE 2.2-1
RAD WASTE - PRESENT



Reference: SNM-1097

2.2.2 UPMP Radwaste Treatment System

The UPMP rad waste treatment system will be implemented to improve the uranium recovery by:

- Providing a controlled lime treatment process.
- Providing a filtration system for liquid and solids separation.

The results will be a substantial reduction of uranium concentration in the sludge settled in the final process lagoons.

2.2.2.1 Rad Waste Accumulation

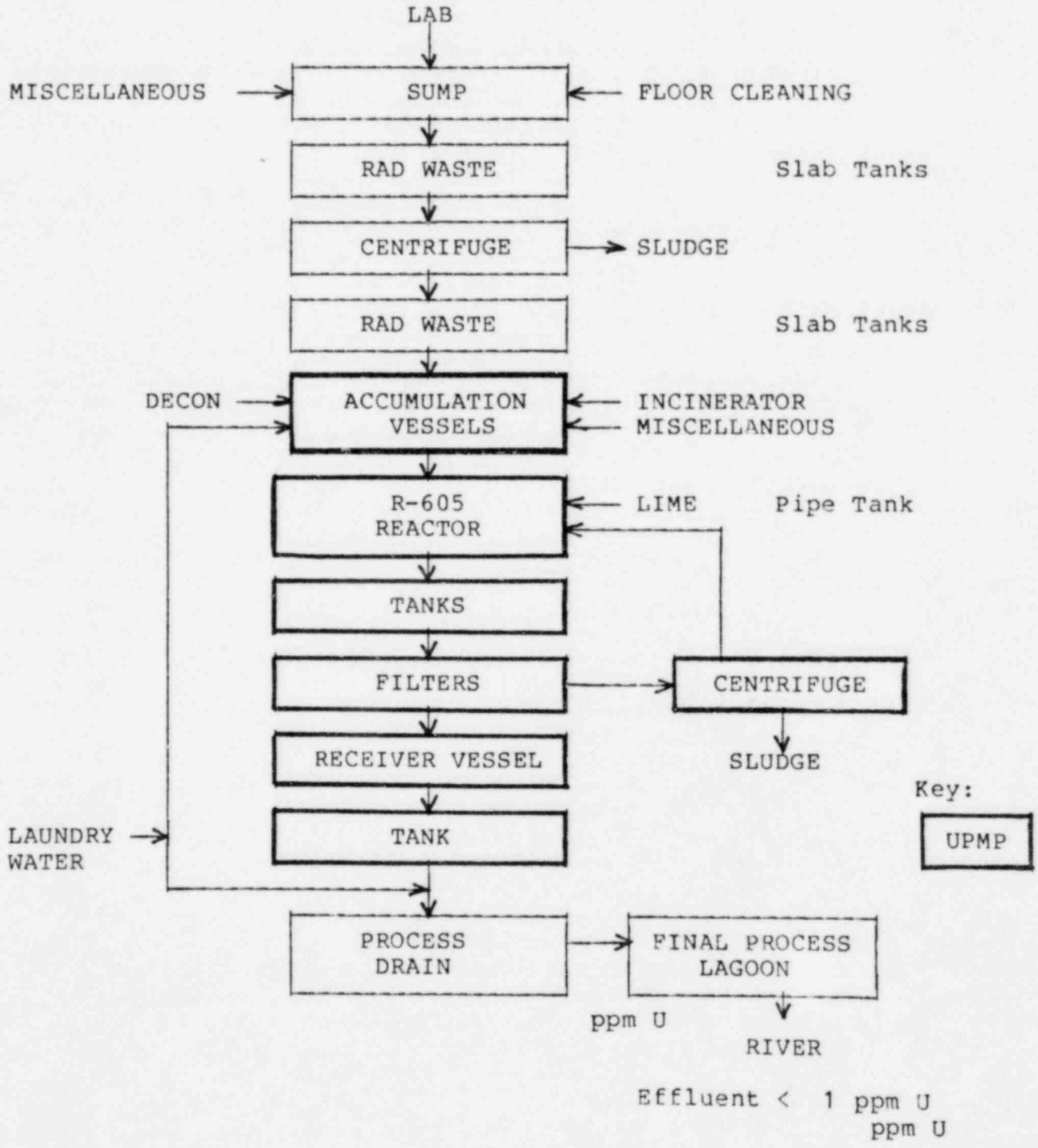
In a concept similar to the UPMP fluoride waste system, the UPMP rad waste system will be situated between the existing rad waste quarantine system and the current discharge point to the final process lagoons. (See Figure 2.2-2) Several of the waste streams presently being collected in the existing FMO rad waste accumulation tank will be diverted to the UPMP rad waste accumulation vessels. The only waste streams that will be collected in the present FMO rad waste accumulation slab tanks will be the laboratory waste water, equipment cleaning water and housecleaning liquids. These waste liquids will continue to be treated by the present process, accumulated in the FMO rad waste slab tanks, analyzed, released, and pumped to the UPMP accumulation vessels. The existing release limits of ppm † uranium will still be in effect.

2.2.2.2 Laundry Water

The laundry water will continue to be collected in the existing FMO-X slab tanks. When one tank is full, the input water will be diverted to the second tank. The water in the full first tank will be circulated for mixing, pumped through the sample loop to UPMP laboratory, and sampled and analyzed for uranium by the UPMP lab measurement system. The results will be transmitted to the UPMP process control system which will automatically control the dispositon of the laundry

Reference: SNM-1097

FIGURE 2.2-2
RAD WASTE - UPMP



Reference: SNM-1097

FIGURE 2.2-2
RAD WASTE - UPMP
(CONTINUED)

Reference: SNM-1097

water. If the uranium concentration is less than a preset value (ppm), the water will by-pass the treatment facility and be pumped to the rad waste discharge point. If the uranium concentration is above the preset value it will be pumped to the accumulation vessels for normal treatment. †

2.2.2.3 Rad Waste Accumulation Vessels

The waste water in the accumulation vessels will be kept in constant circulation. A controlled side stream will be diverted to the tank where it will be continuously mixed with a % lime slurry to a pH of and then overflow into the holding tanks. † †

The lime addition will precipitate fluorides, uranium and other ions as calcium compounds.

The % lime slurry will be supplied to the UPMP facility from a gallon storage tank which is located outside the west end of the building in the aqueous and solvent make up area. The lime slurry will be made up on a batch basis, by diluting % lime slurry from a gallon storage tank with rad waste from the the rad waste holding tank. † † † † †

2.2.2.4 Rad Waste Tanks †

The lime treated water solution will be a dilute slurry as it enters the tanks. Thorough mixing by circulation will prevent settling of any sludge in the vessels. The dilute slurry will be pumped from the rad waste vessels into the filter system. †

2.2.2.5 †

† † † † † † †

Reference: SNM-1097

FIGURE 2.2-3

Reference: SNM-1097

2.2.2.6

2.2.2.7

2.2.2.8

2.2.2.9 Rad Waste

The product, flowing by gravity into the receiver vessel, will be clear and contain less than ppm uranium. The receiver vessel will be kept in constant circulation and a small side stream will be diverted through a constant flowing sample loop to the process control laboratory. There a sample from the loop will be withdrawn and analyzed for uranium by the UPMP lab system. The results will be transmitted to the UPMP process control system.

If the uranium is less than ppm, the product will be continuously discharged to a gallon holding tank located outside the west end of the building. If the uranium is greater than ppm, an alarm will be sounded in the control room and the product will be automatically diverted by the UPMP process control

system, back to rad waste collecting vessels for reprocessing.

The product collected in the holding tank will be discharged by gravity through a proportional sampler to the process drain. The level in the holding tank will be maintained at about 50% to provide dilution water to make up % lime slurry from % lime slurry. †

2.2.3 Criticality Safety Considerations

The rad waste system is designed to process rad waste liquids containing low concentration of uranium, as noted in Section 2.2.2. Prior to the implementation of UPMP, the uranium concentration in this rad waste stream has been low, (ppm or less). The sludge that is † removed from the rad waste stream prior to discharge has a uranium concentration of ppm. † These sludges are collected in five gallon pails, dried and stored for off-site processing. The sludge that is precipitated in the final process lagoons has a low uranium concentration of ppm. These † values are a factor of or more below the † minimum critical concentration for a homogeneous mixture of pure UO_2 and water. As indicated by the results in Section 4.1.9.1, the Kinf = 1.0 value is approximately 200,000 ppm U or equivalent to 250 grams uranium/liter.

The implementation of the UPMP rad waste system between the rad waste quarantine tanks and the discharge to the final process lagoons will favorably impact the rad waste system concentration control as shown in Table 2.2-1. The major impact will be reduction of uranium concentration in the liquid discharge by a factor of † or more. †

The following sections describe the specific controls implemented in the UPMP rad waste treatment system to assure criticality safety. These controls include not only those existing prior to UPMP, but also the process considerations which limit achievable uranium concentrations. Also, extensive use of geometry in the

TABLE 2.2-1
RAD WASTE SYSTEM URANIUM CONCENTRATION CONTROL

System	Uranium Concentration Range, ppm U: Prior to UPMP	Uranium Concentration Range, ppm U: After UPMP	Overall Effect	
Discharge from Rad Waste Quarantine Tank			Unchanged	†
Vortex Clarifier Sludge			Unchanged	† †
Rad Waste Accumulation Tank			Surge Capacity*	†
Rad Waste Tanks			Pre-Treatment*	† †
Filters			Recovery*	† †
Centrifugal Sludge			Recovery*	† †
Rad Waste Product			Improved	†
Discharge to Final Process Lagoons			Improved	†
Sludge in Final Process Lagoons			Improved	† †

*Provides for direct recovery and internal recycle of the uranium.

Reference: SNM-1097

UPMP rad waste treatment equipment assures criticality safety. A final Section 2.2.3.4 is included which discusses the criticality safety of the rad waste system under normal and accident conditions.

2.2.3.1 Concentration Control in UPMP Rad Waste Accumulation Vessels

The operation of the rad waste accumulation vessels is detailed in Section 2.2.2. These vessels are in design with a and are † geometrically safe by virtue of † neutron absorber panels. †

After the implementation of the UPMP rad waste treatment system, several of the lowest uranium concentration waste streams will be diverted from the FMO rad waste quarantine tank directly to the UPMP rad waste accumulation tanks. The waste stream that is the major contributor of uranium (equipment cleaning for maintenance), will remain in the FMO rad waste quarantine system. This waste stream will continue to be processed through a clarifier desludging operation prior to accumulation in the existing rad waste quarantine slab tanks. The existing rad waste quarantine tank dump limits are unchanged and the uranium concentration will be verified by a SPEC 20 measurement to be below ppm. This measurement † will assure that the uranium sludge is removed before the rad waste is transferred to UPMP accumulation vessels.

Laundry water will not normally be routed to the rad waste accumulation vessels. It will normally by-pass the treatment system and be discharged through the proportional sampler to the industrial sewer. The laundry water will be accumulated in the existing slab tanks, circulated and analyzed by the UPMP laboratory systems. The uranium content in the laundry water very seldom reaches as high as ppm. If the uranium † content is below ppm, the water will be by- † passed around the treatment system. Consequently, when laundry water is routed through accumulation vessels, it will actually cause additional dilution of the uranium.

Reference: SNM-1097

In addition to these concentration controls, the rad waste accumulation vessels have also been instrumented with density monitors interfaced to the UPMP process control system. If these density monitors detect values higher than the equivalent of grams uranium/liter, † the process control system will automatically close all process inlet valves and sound an alarm to notify the control room operator of the condition.

2.2.3.2 Rad Waste Treatment Chemistry and Process Control

2.2.3.2.1 Process Chemistry

The rad waste accumulated in vessels V-600 and V-601 will contain soluble uranium, carbonates, fluorides and numerous metal ions. A controlled stream of rad waste flows from the accumulation vessels to the tank. The liquid in the tank will be thoroughly mixed with an agitator. A % lime slurry will be added to † the tank to adjust the pH to about This lime † will precipitate the uranium, carbonates and fluorides as calcium compounds and the metal ions as hydroxides. The pH of the rad waste stream is measured before and after the tank, for control of the addition of % † lime slurry to attain the proper pH. The treated rad waste from the tank will flow into the rad waste vessels to stabilize the reaction. †

2.2.3.2.2 Process Control

The UPMP rad waste treatment system will be controlled by the UPMP process control system. The flow rate through the process will be controlled by the liquid level in the radwaste accumulation vessels. This level is dependent on the liquid input from the various sources of rad waste. † † † † † † † † †

Reference: SNM-1097

The pH of the product in the pipe line header will be monitored by the UPMP process controller. Any change in product pH will be noted by the controller. A pH condition outside the operating parameter range will sound an alarm.

The product in the receiver vessel will be circulated and the discharge rate from the system controlled by the liquid level in the vessel. A small side stream will be diverted through a constant flowing sample loop to the UPMP control laboratory. There a sample will be withdrawn from the sample loop and analyzed for uranium by the UPMP analytical system. The results will be transmitted to the UPMP process controller. If the uranium is less than ppm, the product will be continuously discharged to the gallon holding tank. If the uranium is above ppm, an alarm will be sounded and the product automatically diverted back to the radwaste accumulation vessels for reprocessing.

The density of the product will be monitored by a density meter in the receiver recirculation system. If this density should exceed the equivalent of grams uranium per liter, an alarm will be sounded and the product stream automatically diverted back to receiver vessels for reprocessing.

Water that is discharged from the laundry facility will be collected in existing geometrically safe slab tanks, circulated, sampled and analyzed for uranium by the UPMP laboratory system and the results transmitted to the UPMP process controller. If the uranium concentration

Reference: SNM-1097

is ppm or less, the laundry water will by-pass † the rad waste treatment and be discharged through the proportional sampler, to the process drain.

If the uranium concentration is above the preset value, the laundry water will be discharged to the rad waste accumulation vessels to be treated.

The product from the rad waste product receiver vessel will be discharged into the product holding tank located outside the west end of the building. The liquid level in this tank is maintained at about 50% to provide dilution water for the % lime slurry make-up. †

Any liquid above the 50% level will be discharged through a proportional sampler to the process drain. The proportional sampler will measure the volume discharged and obtain a representative sample of the liquid for uranium analysis by the WMD Chemet laboratory.

2.2.3.3 Geometry Control of the Rad Waste Treatment System

The rad waste treatment system makes significant use of geometry control as well as the use of uranium concentration control described in the preceding sections. In summary, the rad waste treatment system consists of the following:

(1) geometrically safe cylindrical tanks. †

(2) geometrically safe vessels. †

(3) geometrically unsafe tanks. †

(4) existing geometrically safe slab tanks. †

(5) geometrically safe filters. †

(6) geometrically safe cylindrical centrifuges. †

(7) geometrically safe pumps.

(8) geometrically safe diaphragm pumps. †

(9) One (1) critically safe floor basin for liquid spills.

(10) Associated geometrically safe process piping.

(11) Material handling equipment in compliance with geometrically safe designs: five (5) gallon pails.

Table 2.2-2 summarizes the process equipment along with a brief description of the geometry and the corresponding criticality safety designation. (HVAC is not included in this listing but is generically discussed in Chapter 5).

2.2.3.4 Normal and Accident Conditions in the Rad Waste System

As noted previously, the maximum uranium concentration normally present in the UPMP rad waste system is less than grams/liter. From Table 4-4 (in Chapter 4), † the Kinf for a full density homogeneous mixture of UO_2 and H_2O with a U density no greater than this is in the range of 0.30-0.50. It can, therefore, be inferred that under normal conditions, the Keff for any piece of equipment in the rad waste system will be well below a value of 0.90.

In the evaluation of the rad waste system accident conditions, the following three significant conditions have been identified:

2.2.3.4.1 Failure of Concentration Control in the Rad Waste System

As noted in Table 2.2-2, almost all process equipment in the UPMP rad waste system is geometrically safe and failure of rad waste system concentration control will not result in a critically unsafe system. The only exceptions to this are product holdup tanks and the lime storage tanks. The latter two of these are large geometric process support vessels not designed to

TABLE 2.2-2
UPMP RAD WASTE SYSTEM EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Centrifuges	Yes		Geometrically Safe Cylinder
	Filters	Yes		Geometrically Safe
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Volume
	Pumps	No, ppm U		Geometrically Safe Slab and Volume
	Pump	No, ppm U		Geometrically Safe Slab & Volume
	Pump	No, ppm U		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Tank	Yes		Geometrically Safe Cylinder
	Seal Pots	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder
	Tanks	Yes		Geometrically Safe Slab
	Tank	No, ppm U		Geometrically Unsafe
	Tanks	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Unsafe
	Tank	No		Geometrically Unsafe

Reference: SNM-1097

TABLE 2.2-2
UPMP RAD WASTE SYSTEM EQUIPMENT LIST
(CONTINUED)

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Vessels	Yes		Geometrically Safe with Neutron Absorber Panels †
	Vessels	Yes		Geometrically Safe with Neutron Absorber Panels †
	Vessel	No, ppm U		Geometrically Safe with Neutron Absorber Panels †
	Process Piping	Yes	1",2",3",4",6",8" Pipe	Geometrically Safe Cylinders & Slabs
	Rad Waste Floor Basin	No	3.5" Thick Slab	Critically Safe Slab with Concrete and 1" Water Reflection
	Five Gallon Pails at CEN-644 & 646 Discharge	Yes	11-1/4" ID, 13-1/2" High, 22 Liters	Geometrically Safe Volume

Reference: SNM-1097

contain uranium and are discussed further in Section 2.2.3.4.3.

Failure of concentration control in hold-up tank requires the following independent and coincident conditions:

(1) Failure of concentration control in the rad waste quarantine tank system including not only failure to restrict high level uranium streams from the system but also failure to detect the high U content via the SPEC 20 colorimeter.

(2) Failure of the UPMP (geometrically safe) rad waste treatment process especially the precipitation and filtration steps to remove the high level of uranium in the stream.

(3) Failure of the UPMP process control system to detect the increase of the turbidity in the product from the filters; failure of the density monitors on the product receiver vessel; and failure of the process laboratory system to detect the high uranium concentration, and the failure of the pH control system.

For an unsafe condition to arise, all three of the independent cases must occur at the same time. It is therefore concluded that the criticality safety of the product hold-up tank is fully in compliance with the double contingency policy.

2.2.3.4.2 Failure of Geometry Control in the Rad Waste System

Failure of geometry control in the rad waste system will not result in a critically unsafe condition without the coincident and unrelated failure of the rad waste concentration controls.

2.2.3.4.3 Backflow of Uranium into the Lime Slurry Tanks

Backflow of uranium into the lime slurry tanks from the rad waste system is prevented by the use of a positive

air break in the process piping from the lime slurry tanks to the rad waste system. This is achieved by piping the lime slurry solution into the top of the rad waste reactor tank which is vented to the atmosphere at a point above the solution level in the tank.

If this air break backflow prevention fails, however, the lime slurry tanks will still be critically safe because of the rad waste system concentration control.

Reference: SNM-1097

2.3 NITRATE WASTE TREATMENT

2.3.1 Current Operation

Nitrate waste is an accumulation of radioactive waste streams that are generated from the existing Uranium Purification Process (UPS), from acid flushing of the existing ADU conversion lines and from acid cleaning of equipment for maintenance. The UPS conversion waste stream is collected in the FMO nitrate waste quarantine tanks, analyzed and transferred to accumulation tank V-103 if the uranium concentration is ppm or less. † If the uranium concentration is between † ppm, the quarantine tanks may be dumped to V-103 with authorization by the foreman. If the quarantine tank concentration is greater than ppm, the material † must be recirculated/reworked until it is within limits. Figure 2.3-1 outlines the treatment process.

2.3.1.1 Nitrate Waste Quarantine

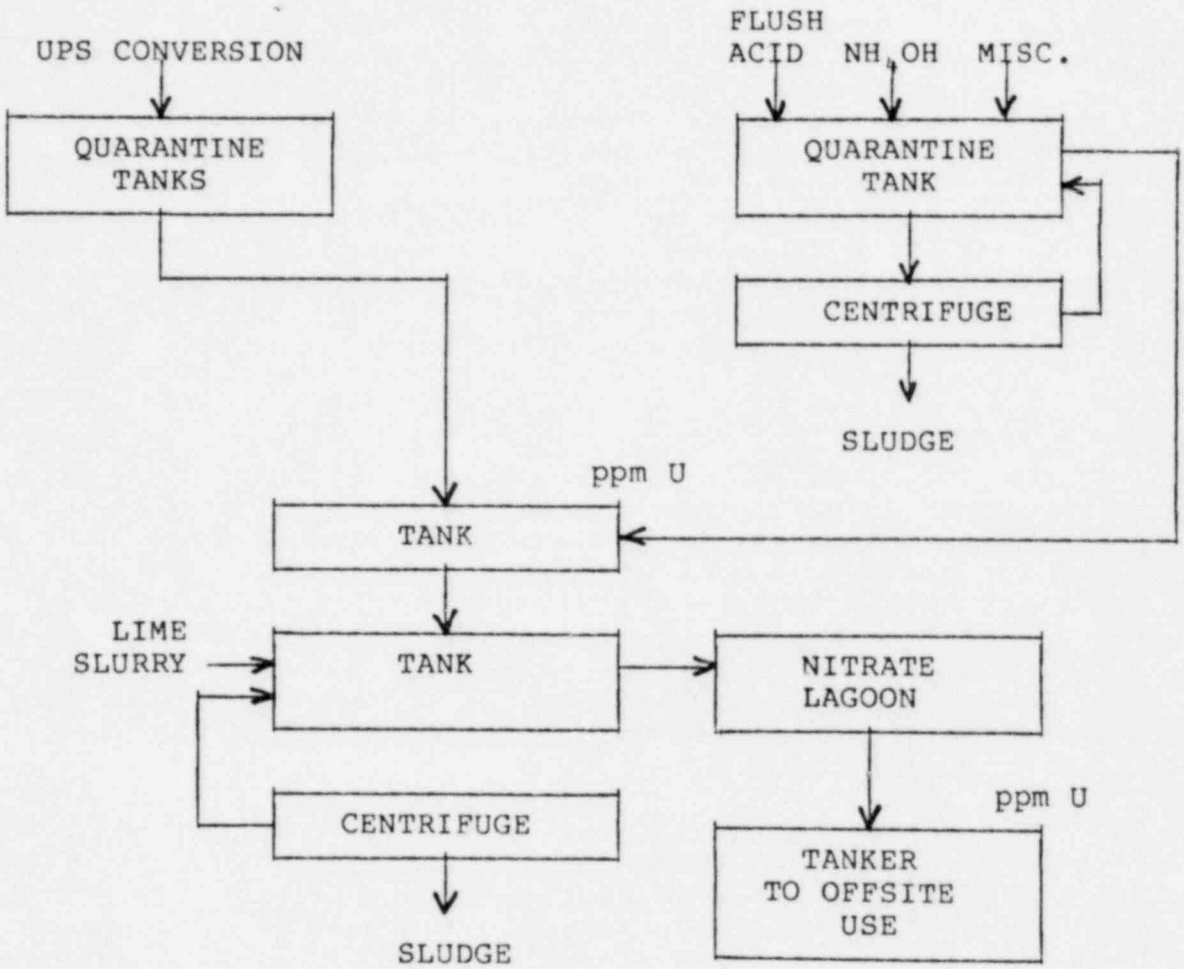
The waste stream from the acid flushing and cleaning operation is collected in FMO nitrate waste C quarantine tank. When full, the liquid is circulated by a pump, ammonium hydroxide is added to precipitate any soluble uranium and the liquid is passed through a centrifuge to remove the solids. When the uranium concentration in the quarantine tank is ppm or less, the contents † are transferred to accumulation tank V-103. The sludge removed by the centrifuge is placed in five gallon pails to be dried and shipped off-site for processing. The uranium concentration of the wet sludge is † ppm. †

The liquid in tank V-103 is kept in constant circulation by a pump to prevent settling of uranium. A circulating stream is monitored for density and if the density exceeds a value equivalent to grams uranium liter † in the waste stream, an alarm is sounded in the control room and the nitrate waste inlet valves are closed.

Reference: SNM-1097

FIGURE 2.3-1
NITRATE WASTE TREATMENT

PRESENT



Reference: SNM-1097

2.3.1.2 Nitrate Waste Treatment

The liquids that have been accumulated in tank V-103 are pumped, on demand, to treatment tank V-104 located at the Waste Treatment Facility. The liquid is batch treated with lime to adjust the pH. Uranium and other metal ions are precipitated. The batch is allowed to settle for hours, in order to decompose the † hydrogen peroxide used in the UPS conversion process.

After the solids are settled, the clear liquor is decanted to the nitrate lagoon. The sludge is removed from the bottom of the tank V-104 and centrifuged to remove the solids. The solids are placed in five gallon pails, dried and shipped off-site for processing. The uranium concentration of this wet sludge is † ppm. The centrate is returned to tank † V-104. When the sludge removal is finished, the treatment cycle is complete and ready to receive the next batch from tank V-103.

The decant pipe line from tank V-104 to the nitrate lagoon is equipped with a proportional sampler for uranium accountability. The uranium concentration in the clear nitrate waste solution in the lagoons is about ppm and in the nitrate waste sludge is † ppm. †

2.3.2 UPMP Nitrate Waste Treatment

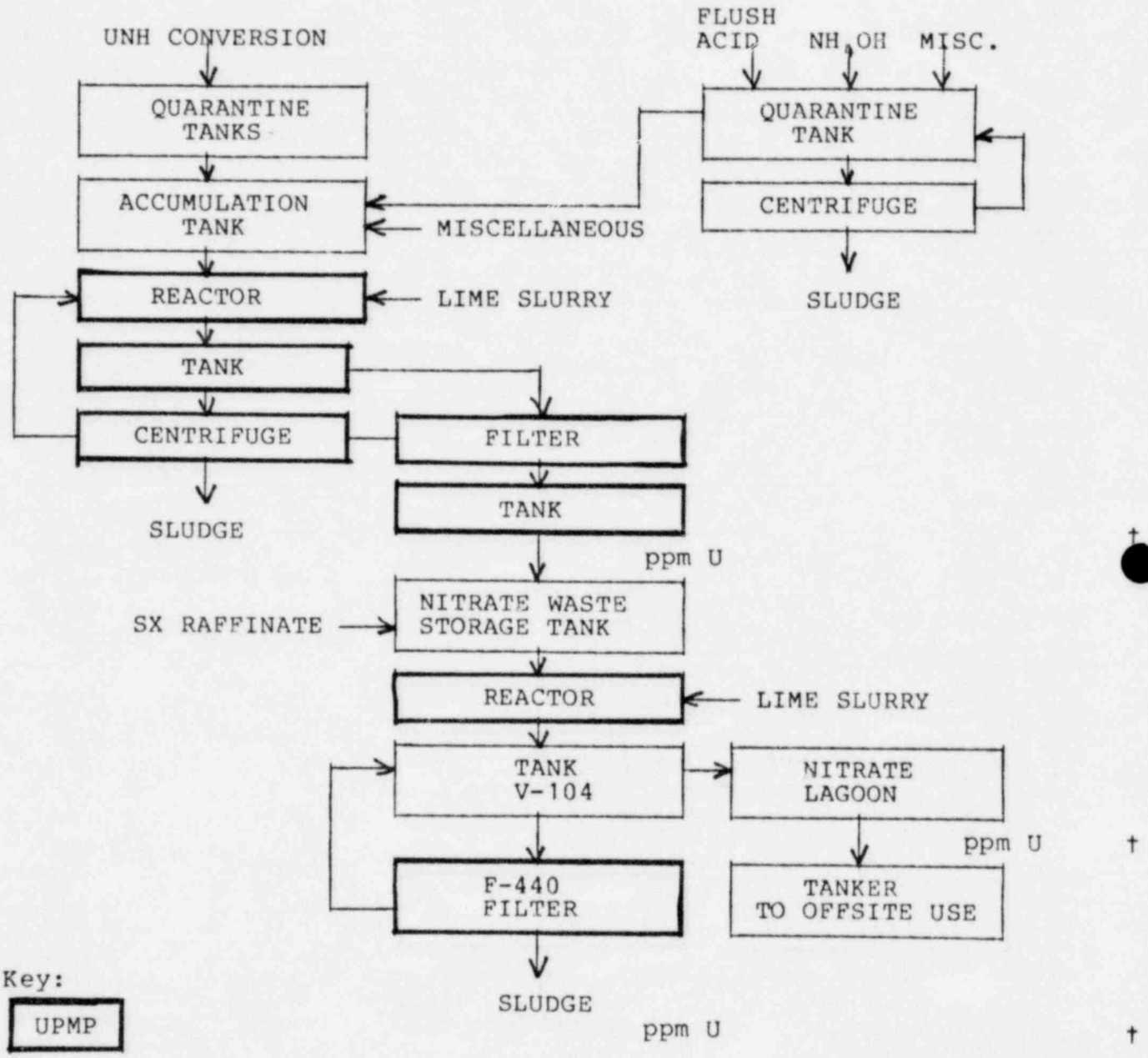
Because of the installation of solvent extraction with UPMP and the modification of the UNH conversion process (old UPS conversion), the use of hydrogen peroxide will no longer be required. Thus, the nitrate waste treatment system can be changed. This waste treatment system will be installed between the existing quarantine tanks and the existing Waste Treatment Facility. Figure 2.3-2 outlines the treatment process.

The treatment of the nitrate waste discharged from the various processes in UPMP and UNH conversion will be segregated into two steps. The first step, primary treatment, will treat all waste liquids except the aqueous waste (AW or Raffinate) from solvent extraction and will be very similiar in form to the rad waste

Reference: SNM-1097

FIGURE 2.3-2
NITRATE WASTE TREATMENT

UPMP



Reference: SNM-1097

FIGURE 2.3-2
NITRATE WASTE TREATMENT
(CONTINUED)

Reference: SNM-1097

operation. The second step, secondary treatment, will treat the aqueous waste (AW) from the solvent extraction process in addition to the primary nitrate waste product stream. The aqueous waste (AW) waste stream will contain all the metal impurities rejected by the solvent extraction process and will contain trace levels of uranium (ppm). †

The treated waste stream from the primary treatment system and the aqueous waste (AW) will be blended in the existing nitrate waste storage tank V-103 and then treated in the secondary nitrate waste treatment located at the Waste Treatment Facility. The effluent from this treatment will be discharged to the nitrate lagoon and the solids shipped to an approved off-site waste burial facility.

2.3.2.1 Primary Nitrate Waste Treatment

2.3.2.1.1 Nitrate Waste Collection Tank

The nitrate waste from UNH conversion quarantine tanks, A and B, located in FMO, will be pumped to the collection vessel. Other nitrate waste liquors generated in the UPMP facility, except the aqueous waste, will also be collected in this vessel. The liquid in this tank will be kept in constant circulation by the nitrate waste transfer pump to thoroughly mix and prevent settling of solids. This solution will have a density of gms/ml and a uranium concentration of † about ppm. If the fluoride waste product is also † being treated, the uranium concentration of the solution can be as high as ppm. †

2.3.2.1.2 Nitrate Waste Treatment

A controlled stream of nitrate waste is diverted from the recirculation of the nitrate waste collecting vessel to nitrate waste reactor. In the reactor, a controlled volume of % lime slurry is added and mixed with the † nitrate waste to maintain a pH of about The † treated solution, a dilute slurry, will flow into a vessel. This solution will be circulated by the filter pumps and thoroughly mixed to insure completion of the precipitation reaction.

Reference: SNM-1097

2.3.2.1.3

2.3.2.1.4

FIGURE 2.3-3

(Duplicate of Figure 2.2-3)

Reference: SNM-1097

2.3.2.1.5

2.3.2.1.6 Nitrate Waste Product

The product from the treatment system will flow by gravity into the product receiver tanks. These are diameter Schedule cylindrical tanks, high. The liquid in these tanks will be kept in constant circulation by a product pump. A small side stream will be diverted through a constant flowing sample loop to the UPMP process control laboratory. There, a sample from the loop will be automatically withdrawn and analyzed for uranium. The results will be transmitted to the UPMP process control system. If the uranium is ppm, the product will be continuously discharged to nitrate waste storage tank V-103 located outside of the building. If the uranium is greater than ppm, an alarm will be sounded and the product will

be automatically diverted by the UPMP process control system, back to nitrate waste collecting vessel for reprocessing.

2.3.2.1.7 Nitrate Waste Storage Tank - Existing V-103

V-103 is an existing 20,000 gallon PVC lined tank which is located outside of the FMO building. This tank will receive the treated product from the primary nitrate waste treatment system and the AW waste from the solvent extraction system. The liquid in the tank will be kept in constant circulation by a pump. The circulation stream will be monitored for density and if the density of the solution increases above a set point equivalent to a maximum uranium concentration of grams per liter, an alarm will be sounded in the control room and the double block and bleed valves on the inlet streams will automatically close. (Double block and bleed valve operation is illustrated in Figure 2.3-4.) A controlled stream will go to the Waste Treatment Facility for further treatment. †

2.3.2.2 Secondary Nitrate Waste Treatment

2.3.2.2.1 Reaction Tank

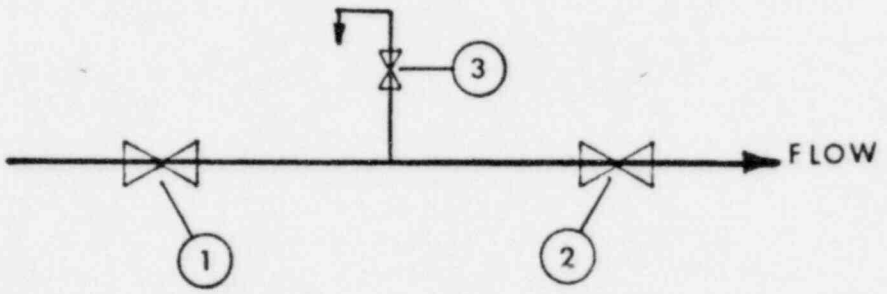
A controlled stream of nitrate waste from tank V-103 will be received into the reaction tank located at the Waste Treatment Facility. This stream will be mixed with a lime slurry to adjust the pH to This will precipitate the metal ions and uranium that is in the aqueous waste liquid from solvent extraction. †

The treated solution, a dilute slurry, will flow by gravity into the existing settling tank V-104.

2.3.2.2.2 Settling Tank - Existing V-104

The dilute slurry from the reaction tank will flow into the draft tube of the settling tank. A may be added to enhance the settling of the solids. The clear effluent will be drawn off the top of the liquid in the tank and discharged to the nitrate lagoons. The †

FIGURE 2.3-4
BLOCK & BLEED VALVE SYSTEM



The system is controlled by a sequence controller that is activated by an OPEN or CLOSE signal.

NORMAL FLOW POSITIONS

Block Valve #1 is OPEN
Block Valve #2 is OPEN
Bleed Valve #3 is CLOSED

VALVE OPERATION

CLOSE:

To stop the flow, the CLOSE signal is activated. The valves operate in sequence. That is, when block valve #1 closes, then block valve #2 closes, then bleed valve #3 opens. If either block valve #1 or 2 should leak, the liquid will flow out through the bleed valve #3 onto the floor.

OPEN:

To open the valves, to start the flow, the OPEN signal is activated. The valves operate in sequence. That is, when bleed valve #3 closes, then block valve #2 opens, then block valve #1 opens.

(Duplicate of Figure 2.1-8)

concentrated sludge will be removed out of the bottom tank outlet for filtering.

The concentration of uranium and solids in this system will be as follows:

- The feed to the reaction tank should have a density of grams/cc, with a uranium concentration of about ppm. †
- The lime treated solution from the reactor tank will have a density of grams/cc, with about ppm uranium and about solids. †
- The clear effluent from the settling tank should have a density of grams/cc with about ppm uranium. †
- The concentrated sludge removed from the bottom of the settling tank will have density of about grams/ml with about ppm uranium and about % solids. †

2.3.2.2.3 Filtration

The sludge from the bottom of the settling tank will be pumped into the secondary nitrate waste sludge filter for solids removal. The filtrate will be returned to the tank and the solids will be discharged into five gallon pails. The filter cake collected in the five gallon pails will have about ppm uranium and about % solids. †

2.3.3 Criticality Safety Considerations

The nitrate waste system is designed to process nitrate waste liquids containing low concentrations of uranium, as noted in Section 2.3.2. Prior to the implementation of UPMP, the uranium concentration in this nitrate waste stream has been low, ppm or less. The sludge that is removed from the nitrate waste stream prior to discharge to tank V-103, has a uranium concentration of ppm. The sludge that is removed †

from tank V-104 at the waste treatment facility has a uranium concentration of ppm. These † sludges are collected in five gallon pails, dried and stored for off-site processing. The uranium concentration in the nitrate waste system liquids are a factor of or more below the minimum critical † concentration for a homogeneous mixture of pure UO_2 and water. As indicated by the results in Section 4.1.9.1 the Kinf = 1.0 value is approximately 200,000 ppm U or equivalent to 250 grams uranium/liter.

The implementation of the UPMP nitrate waste system between nitrate waste quarantine tanks and the discharge to the existing waste treatment settling tank V-104 will impact the nitrate waste system concentration control as shown in Table 2.3-1. The major impact will be the reduction of uranium concentration in the liquid discharge to the nitrate lagoon by a factor of † or more. †

The following sections describe the specific controls implemented in the UPMP nitrate waste treatment system to assure criticality safety. These controls include not only those existing prior to UPMP, but also the process considerations which limit achievable uranium concentrations. Also, extensive use of geometry in the UPMP nitrate waste treatment equipment assures criticality safety. A final Section 2.3.3.4 is included which discusses the criticality safety of the nitrate waste system under normal and accident conditions.

2.3.3.1 Uranium Concentration Control in UPMP Nitrate Waste Collecting Vessel

After the implementation of UPMP Nitrate waste treatment system, the operation of the FMO nitrate waste quarantine tanks will not change except that they will discharge to the nitrate waste collecting vessel instead of the storage tank. The nitrate waste quarantine tank dump limits will not change prior to UPMP implementation and the uranium concentration is verified by a SPEC 20 measurement to be below ppm. This insures that † the uranium sludge is removed before the nitrate waste is transferred to UPMP collection vessel.

Reference: SNM-1097

TABLE 2.3-1
NITRATE WASTE URANIUM CONCENTRATION CONTROL

System	Uranium Concentration Range (ppm U) Prior to UPMP	After UPMP	Overall Effect	
Discharge from Nitrate Waste Quarantine Tanks			Unchanged	†
Sludge from Nitrate Centrifuge			Unchanged	† †
Nitrate Waste Collecting Vessel	---		Surge Capacity*	†
Nitrate Waste Vessel	---		Pre-Treatment*	† †
Filters	---		Recovery*	†
Centrifuge Sludge	---		Recovery*	† †
Nitrate Waste Product	---		Improved	†
Aqueous Waste to Existing V-103	---		None	†
Transfer to Existing V-104			Improved	†
Effluent to Nitrate Lagoon			Improved	†
Filter Cake from V-104			Improved	† †
Nitrate Lagoon Discharge			Unchanged	†

*Provides direct recovery and internal recycle of the uranium.

Reference: SNM-1097

The operation of the nitrate waste collecting vessel is detailed in Section 2.3.2.

In addition to this, the nitrate waste collecting vessel will be instrumented with density monitors interfaced with the UPMP process control system. If these density monitors detect values higher than the equivalent of grams uranium/liter, the process control system will automatically close all process inlet valves and sound an alarm to notify the control room operator of the condition. †

2.3.3.2 Nitrate Waste Treatment Chemistry and Process Control

2.3.3.2.1 Chemistry

The nitrate waste accumulated in the collection vessel will contain soluble uranium, carbonates, fluorides and numerous metal ions. A controlled stream of nitrate waste will flow from the collecting vessel to the tank. The liquid in the tank will be thoroughly mixed with an agitator. A % lime slurry will be added to the tank to adjust the pH to about † This lime will precipitate the uranium, carbonates and fluorides as calcium compounds and at the pH of the metal ions will precipitate as hydroxides. The pH of the nitrate waste stream is measured before and after the tank. This controls the addition of % lime slurry to attain the proper pH. The treated nitrate waste from the tank flows into the vessel to stabilize the reaction. † † † † † †

2.3.3.2.2 Process Control

The UPMP nitrate waste treatment system will be controlled by the UPMP process control system. The flow rate through the process will be controlled by the liquid level in the collecting vessel. This level will be dependent on the liquid input from the various sources of nitrate waste.

Reference: SNM-1097

The product in the tanks will be circulated and the discharge rate from the system will be controlled by the liquid level in the tanks. A small side stream will be diverted through a constant flowing sample loop to the UPMP control laboratory where a sample will be withdrawn from the sample loop and analyzed for uranium. The results will be transmitted to the UPMP process controller. If the uranium is less than ppm, the product will be continuously discharged to nitrate waste storage tank V-103. If the uranium is above ppm, an alarm will be sounded and the product will be automatically diverted back to the collecting vessel for reprocessing.

The density of the product will be monitored in the storage tank. If this should exceed a density which is equivalent to an upper limit of grams uranium per liter, an alarm will be sounded and the product stream automatically diverted back to the collecting vessel for reprocessing.

The product from the tanks will be discharged into nitrate waste storage tank V-103 located outside the west end of the building. The aqueous waste stream from the aqueous waste vessels, acid raffinate from solvent extraction, will also be discharged into V-103. The liquid in the tank will be recirculated for thorough mixing and the level will be maintained by diverting a controlled side stream to the secondary nitrate waste tank located at the Waste Treatment Facility. This stream will be monitored for density and, if it exceeds a set point equivalent to grams of uranium † per liter, the alarm will be sounded and the inlet valves will be closed.

A proportional sampler will be located in the pipe line between the product tanks and storage tank. The sampler will measure the volume discharged and obtain a representative sample of the liquid for uranium analysis by the Chemet laboratory.

The nitrate waste stream flowing into secondary nitrate waste reaction tank will be mixed with a controlled volume of % lime slurry to adjust the pH to † approximately This treated stream will flow by † gravity into the settling tank V-104. The pH of the inlet and discharge streams of the tank will be monitored by the control system to adjust the lime slurry flow to maintain a pH. †

The lime in the tank will precipitate the uranium and the metal ions that were added to the nitrate waste stream by the aqueous waste. The solid will settle to the cone bottom of the settling tank V-104 and the clear liquid will be decanted from the top.

2.3.3.3 Geometry Control of Nitrate Waste Treatment System

The UPMP nitrate waste treatment system will be implemented with extensive use of geometry control in equipment design, summarized as follows:

(1) geometrically safe cylindrical † tanks

(2) geometrically safe vessels †

(3) geometrically unsafe tanks †

(4) geometrically safe filters †

(5) geometrically safe cylindrical centrifuge †

(6) geometrically safe filter †

(7) Geometrically safe pumps

(8) geometrically safe diaphragm pumps †

(9) One (1) critically safe floor basin for liquid spills.

(10) Associated geometrically safe process piping.

(11) Material handling equipment in compliance with geometrically safe designs

Table 2.3-2 contains a listing of UPMP nitrate waste equipment.

2.3.3.4 Normal and Accident Conditions in the Nitrate Waste System

As noted previously, the maximum uranium density normally present in the UPMP nitrate waste system will be less than grams/liter. From Table 4-4 in † Chapter 4, the Kinf for a full density homogeneous mixture of UO_2 and H_2O with a U density no greater than this will be in the range of 0.30-0.50. It can therefore be inferred that under normal conditions, the Kinf for any piece of equipment in the nitrate waste system will be well below a value of 0.90.

In the evaluation of nitrate waste system accident conditions, three significant conditions have been identified. These are:

TABLE 2.3-2
UPMP NITRATE WASTE EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Centrifuge	Yes		Geometrically Safe Cylinder
	Filters	Yes		Geometrically Safe
	Filter	Yes		Geometrically Safe Slab
	Transfer Pumps	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Slab & Volume
	Pumps	Yes		Geometrically Safe Slab & Volume
	Pump	Yes		Geometrically Safe Slab & Volume
	Transfer Pump	Yes		Geometrically Safe Slab & Volume
	Pumps	No, ppm U		Geometrically Safe Slab & Volume
	Pump	No, ppm U		Geometrically Safe Slab & Volume
	Pump	Yes		Geometrically Safe
	Pump	Yes		Geometrically Safe Slab & Volume
	Pump	No		Geometrically Safe Slab & Volume
	Tank	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Seal Pots	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	No, ppm U		Geometrically Safe Cylinder

Reference: SNM-1097

TABLE 2.3-2
UPMP NITRATE WASTE EQUIPMENT LIST
(CONTINUED)

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Tank	Yes		Geometrically Unsafe
	Tank	Yes		Geometrically Unsafe
	Tank	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Unsafe
	Tank	No		Geometrically Unsafe
	Tank	Yes		Geometrically Safe with Neutron Absorber Panels
	Tank	Yes		Geometrically Safe with Neutron Absorbe Panels
	Process Piping	Yes	1",2",3",4",6" Pipe	Geometrically Safe Cylinders and Slabs
	Floor Basin	No	3.5" Thick Slab	Critially Safe Slab with Concrete and 1" Water Reflection
	Five Gallon Pails	Yes	11-1/4" ID, 13-1/2" High, 22 Liters	Geometrically Safe Cylinder

Reference: SNM-1097

2.3.3.4.1 Failure of Concentration Control in Nitrate Waste System

As noted in Table 2.3-2 almost all process equipment in the UPMP nitrate waste system will be geometrically safe and failure of nitrate waste system density control will not result in a critically unsafe system. The only exceptions to this are the existing V-103 nitrate waste storage tank and the lime storage tanks. The lime † storage tanks are large geometric process support vessels not designed to contain uranium and are discussed further in Section 2.3.3.4.3. Failure of concentration control in V-103 requires the following independent and coincident conditions:

(1) Failure of concentration control in the nitrate waste quarantine tank system including not only failure to restrict high level uranium streams from the system, but also failure to detect the high U content via the SPEC 20 monitor.

(2) Failure of the UPMP (geometrically safe) nitrate waste treatment process, especially the precipitation and filtration steps, to remove the high level of uranium in the stream.

(3) Failure of the UPMP process control system to detect the increase of the turbidity in the output from the filters, failure of the density monitor on storage tank V-103, and failure of the process laboratory to detect the high uranium concentration, and the failure of the pH control system.

For an unsafe condition to arise, all three of these independent cases must occur at the same time. It is therefore concluded that the criticality safety of tank V-103 is fully in compliance with the double contingency policy.

2.3.3.4.2 Failure of Geometry Control in the Nitrate Waste System

Failure of geometry control in the nitrate waste system will not result in a critically unsafe condition without the coincident and unrelated failure of the nitrate waste concentration controls.

2.3.3.4.3 Backflow of Uranium into Unsafe Geometry Vessels

Backflow of uranium into the lime slurry tanks from the nitrate waste system will be prevented by use of a positive air break in the process piping from the lime slurry tanks to the nitrate waste system. This will be achieved by piping the lime slurry solution into the top of nitrate waste tank which will be vented to the atmosphere at a point above the solution level in the tank.

If this air break backflow prevention fails, however, the lime slurry tanks will still be critically safe because of the nitrate waste system concentration control.

2.4 SCRAP PROCESSING

2.4.1 Current Scrap Processing Operation

High grade uranium bearing scrap generated during fuel manufacturing is currently oxidized in the REDCAP furnace and processed through the Uranium Purification System (UPS) digesting and conversion facilities located in the FMO building.

Low grade uranium bearing scrap generated by the waste treatment operation and the decon facility, and high grade gadolinia bearing uranium scrap generated in the Gad shop are placed in five gallon pails and shipped off-site for vendor processing. The purified uranyl nitrate is returned via tank truck and unloaded into the FMO-X slab storage tanks for subsequent UPS conversion.

The new scrap processing facility will replace the existing REDCAP furnace and UPS digest facilities as well as the off-site processing requirements.

2.4.2 UPMP Scrap Processing

Uranium-bearing scrap will be processed for uranium recovery, purification and recycle to the fuel conversion process. Scrap processing unit operations include:

- Oxidation and drying of sludge and scrap,
- High grade scrap dissolving and dissolver solution filtration,
- Low grade scrap leaching and leacher solution filtration,
- Feed adjustment,
- Solvent extraction recovery and purification,
- Uranyl nitrate product concentration and storage,
- Solvent treatment.

High grade scrap dissolution will be accomplished in scrap dissolvers designed for a maximum of kg UO_2 † equivalent per batch. Low grade scrap will be dissolved in safe geometry pipe dissolvers. Release of both high grade and low grade scrap materials to dissolution will be based on enrichment lots in order to minimize downgrading of enrichments and yet meeting production requirements.

Reference: SNM-1097

2.4.2.1 Scrap Processing Material Handling - Scrap Input

2.4.2.1.1 Input Materials to the scrap processing system are generated from multiple sources as follows:

2.4.2.1.1.1 Wet Sludges

- Wet sludges from Fuel Manufacturing Operation (FMO) conversion area

  - Rad waste sludge
  - Fluoride (ADU) sludge
  - Nitrate waste sludge
  - Wet powder

- Wet sludges from the decon facility

- Wet sludges internally generated in the UPMP area (Gd-contaminated):

  - Rad waste lime sludge
  - Nitrate waste lime sludge

Wet sludges will be packaged in five gallon plastic pails having a polyethylene bag as an inner liner and closed. The pail lid will be sealed. The maximum weight of a five gallon pail of wet sludge will not exceed 35 kg. All plastic pails generated in the FMO conversion area will be recycled to that area. All other pails will be recycled only within the UPMP area.

2.4.2.1.1.2 Non-Gd Powder and Pellets

- Dirty powder generated in the FMO conversion and fabrication areas

- Non-recyclable pellet hard and green scrap dispositioned from an outside storage area or the fabrication area

- Dry filter knock-out powder from the decon facility

The pellet scrap and dry filter knock-out powder will be packaged in polyethylene bags closed and placed in three and five gallon metal pails, respectively. The maximum weight per pail may not exceed 35 kg for either type.

2.4.2.1.1.3 Gd-Bearing Scrap

- Dirty Gd powder
- Non-recyclable Gd green pellet scrap
- Non-recyclable Gd hard pellet scrap
- Incinerator ash
- Incinerated HEPA filter media

The pellet scrap and Gd-bearing sludges are packaged in three and five gallon metal pails, respectively. The maximum weight per pail may not exceed 35 kg.

2.4.2.1.2 Output Solid Materials from the scrap processing facility will be:

- Insoluble filter cake containing very low levels of uranium which, after being washed, will be assayed, accountability weighed, tampersafe sealed and packaged in three or five gallon pails and placed in 4'x4'x3-1/2' metal boxes for off-site burial.

- Non-combustible solids such as worn-out equipment, furnace muffles, piping, etc., which will be cut into pieces small enough to fit inside a 4'x4'x3-1/2' metal box, scanned and then transported to the decon facility for resorting and repackaging prior to final disposition.

- Combustible waste packaged inside 4'x4'x3-1/2' wooden or cardboard boxes, scanned and transferred to the decon facility for re-sorting and repackaging prior to incineration.

2.4.2.2 Scrap Processing Material Handling - Process Considerations

The following constraints have been applied in the design of the scrap processing facility:

2.4.2.2.1 With the exception of incinerator ash, all sludges (both wet and dry) will be oxidized in the muffle furnace prior to dissolution. Oxidation is essential to remove all organics (oils, greases, binders), volatile

Reference: SNM-1097

salts (NH_4F, NH_3, HNO_3, SiF_4, NaCl) and all combustibles such as wood, paper, and plastics. The wet sludges are assumed to contain 50 weight percent water (nominal).

2.4.2.2.2 All scrap material and product movements into and out of this facility will be entered on the computerized Manufacturing Information Control System (MICS) and a traveler (MICS) card will be attached to each container of material.

2.4.2.2.3 High grade scrap powder and sludges will be processed in three or five gallon pails. High grade pellet hard and green scrap will be processed in three gallon pails.

2.4.2.2.4 All oxidized materials will be processed through a size reduction step, homogeneously blended within each pail, isotopically scanned for percent U_{235}, accountability weighed, tampersafe sealed, entered on MICS, and placed inside a sealed polyethylene bag. Interim queuing of all pails of oxidized material will be provided by existing outside storage pads.

2.4.2.2.5 The production control function will retrieve oxidized materials from the pads for dissolution and recovery by specified enrichment band in a minimum lot size of kg UO_2 equivalent. †

2.4.2.3 Scrap Processing Material Handling - Sludge Transfer

The process feed for scrap processing will be routed in and out of the UPMP building through the following areas:

- Sludge oxidation furnace input queue conveyors
- Oxidation furnace discharge queue conveyor
- Gd scrap queue conveyor
- Dissolver feed queue for oxidized sludge and incinerator ash

Reference: SNM-1097

2.4.2.3.1 Sludge Queueing

Pellet scrap in three gallon pails and sludge in five gallon pails (each with a maximum weight of 35 kg/pail), generated in FMO conversion and fabrication, will be transported to the FMO-X corridor queue conveyor outside the oxidation area. The operator delivering the sludge will make a MICS entry transaction for each pail of sludge at the MICS terminal located in the corridor. The operator will place a spacer skid on the storage conveyor and then place a pail on each spacer skid. Wet sludge will be packaged in five gallon plastic pails lined with a plastic bag sealed with a twist lock. Dry powder and pellet scrap will be packaged in the same manner except the external container will be a three or five gallon pail.

The pail conveyors are located 14" above the floor and can each store up to 30 three or five gallon pails of sludge (on spacer skids). As required by the process control plan, the operator will manually transfer cans in batch quantities from the storage conveyor (located on the south wall of the corridor) to spacer skids on the oxidation furnace queue conveyor located on the north side of the corridor. A single pail of scrap or sludge will be processed in the oxidation station at a time. When a pail is needed, the operator at the enclosure will activate the powered conveyor and transfer it, still on its skid, to the bottom entrance door of the enclosed bucket lift. (See Figure 2.4-1.) The pail and skid will be transferred automatically via the pail lift to the siphon station within the enclosure.

2.4.2.3.2 Boat Loading

When a pail of scrap or sludge arrives at the siphon station, the operator, working through openings in the enclosure, will remove the pail lid and set it aside. If the material is wet sludge, the twist lock is removed from the plastic bag. If there is free standing liquid over the sludge, the operator will open the plastic bag and use the siphon wand to siphon off the excess liquid. (The removal of the siphon wand from its hanger will automatically activate a pump and associated valving.

FIGURE 2.4-1

Reference: SNM-1097

Replacing the wand on the hanger will stop the pump.) The operator will then seal the plastic bag with the same plastic twist lock and move the pail of scrap or sludge to the skid stop where the pail is mechanically lifted from the spacer skid and pushed to the pail dump station. At the pail dump station, the pail will be tilted and the operator, working through openings in the enclosure, will pull the plastic bag with sludge or dump the pail contents, if scrap, into the inclined chute and slide it into the oxidation boat below. A ram pushes downward on the plastic bag both piercing it and assuring no pile up of material in the center of the deep rectangular boat. Only the contents of a single pail will be dumped into each oxidation boat.

The operator will insert a card into the MICS terminal and activate the "ENTER MICS" button to record the transfer of material to this station.

2.4.2.3.3 Pail Rinse Operation

The operator will manually move the empty pail to the rinse station. At the rinse station, the operator, working through openings in the enclosure, will use the DI water rinse wand to clean the interior of the bucket and the siphon wand to remove the rinse water. The rinse water plus decant liquid will be transferred directly to the rad waste accumulator tank. The lid to the pail will be clamped on and the operator will then place the empty pail with the lid back onto its spacer skid. The pail will be returned to the conveyor via the bucket lift after which the operator will dispatch the next incoming bucket of sludge.

2.4.2.3.4 Gadolinium (Gd) Fabrication and UPMP Generated Sludge Handling

Gd-bearing sludges generated within the UPMP facility and the Gd fabrication area will be queued on skids on the conveyor feeding the Gd dump station. (See Figure 2.4-2.) The operator will manually transfer one three or five gallon pail of sludge or pellet scrap at a time from the cart to the conveyor. Receipt of each pail of sludge at this station will be accountability weighed and an entry made on a MICS terminal.

The sludges generated in the UPMP rad waste and nitrate waste systems will be collected at the centrifuge hoppers in three or five gallon pails, weighed, and the data entered into the MICS system. The pails will then be placed on a cart and transferred to the second pail dump station queue conveyor.

The transfer of the sludges at the Gd pail dump station will be the same as that discussed in paragraph 2.4.2.3.2.

2.4.2.3.5 Oxidative Furnace Stoking and Boat Dumping

The oxidizing furnace is a gas tight muffle type furnace which has an Inconel, "D" shaped section with guide rods on the inside to guide the boats through the furnace and prevent boat jamming. The maximum furnace operating temperature will be C (F) and the † maximum furnace input production capacity will be kg/hour of wet (% water) scrap. Each † furnace boat will hold one 35 kg (gross) pail of scrap. The boats will pass through the furnace in a string pushed by the timed pusher mechanism. The nominal rate is feet per hour. (The furnace muffle is sized for † boats, each inches high by inches † wide by inches long.)

A swinging overhead hinged door at either end of the muffle will allow one boat to be pushed in and one out when the pusher is activated. The furnace ends are enclosed and vented to the exhaust scrubbing system. The muffle extends out of the furnace and has a " † long cooling jacket section on both ends to protect the enclosure and to cool a boat of oxidized sludge.

Air flow through the furnace will be in the laminar to slightly turbulent range and controllable. The furnace offgas scrubber will use water as the scrubbing medium and is sized for a Btu/hr heat load at † scfm flow rate. The offgas from the scrubber is † saturated with water and will go to the vessel offgas system. The scrub water will go to the nitrate waste accumulation tanks.

FIGURE 2.4-2

Reference: SNM-1097

The operator will start the sequence to feed a loaded boat in the furnace by activating the furnace "STOKE" button. (The stoking ram will not activate until the preset stoking time cycle has elasped.)

2.4.2.3.6 Oxidation Furnace Discharge Operations

At the end of the furnace, oxidized sludge will be dumped from each boat and will fall by gravity into a inch thick by inch hopper † feeding a roll crusher below. Pneumatic vibrators installed on the hopper feeding the roll crusher will minimize powder buildup.

The crushed oxide will flow through a inch † diameter rotary feed valve via a inch † diameter transition chute into a three or five gallon metal pail. A load cell will be used below each pail to limit the maximum gross weight of the pail to 35 kg. If the weight limit is reached, a wafer valve will automatically close and halt powder flow. As in the case of the oxidation feed operation, oxidized pellet hard or green scrap will be restricted to three gallon pails. The feed hopper is vented through a pre-filter unit and a HEPA filter housing to maintain dust control in the enclosure.

An empty pail cannot be introduced to the can fill station until the pail just loaded is conveyed to the blend station. (See Figure 2.4-3) At the blend station, the operator will physically load and clamp the pail to the blender mechanism. The clamp on top of the blender is designed such that it facilitates homogenous blending. After blending, the pails will be conveyed through an airlock to an isotopic scanning station. After isotopic scanning, the pail will be accurately weighed on a suspended load cell, tampersafe sealed and then slipped inside a polyethylene bag. The tampersafe seal number and can weight will be entered on MICS and a card attached to the pail. The pail is then conveyed to the queueing conveyors inside the pail/waste box handling station. At this station, the pail will be accountability weighed and a second MICS entry made.

FIGURE 2.4-3
SCRAP PROCESSING PROCESS FLOW

Reference: SNM-1097

2.4.2.3.7 Handling, Staging and Transfer

After the second MICS entry is made, the pails will be placed on the pail holding conveyor to await transport to the storage pads. Three and five gallon pails of oxidized sludge or scrap will be routed to and from the existing outside storage pads via a forklift truck. All pail movements to and from the area will be entered on a MICS terminal.

A pallet with pail separators will be used for the safe transport to and from the pads. Incoming pails of oxidized sludge released for dissolution will be routed to specific dissolver conveyor queues upstairs.

2.4.2.4 Scrap Dissolver Operations

The dissolver input dump hoods and batch queueing conveyors are located on the northwest mezzanine floor level of the facility. (Figure 2.4-4).

A schematic representation of the entire scrap processing flow is shown in Figure 2.4-5, page one, with product concentration shown on page two of the figure.

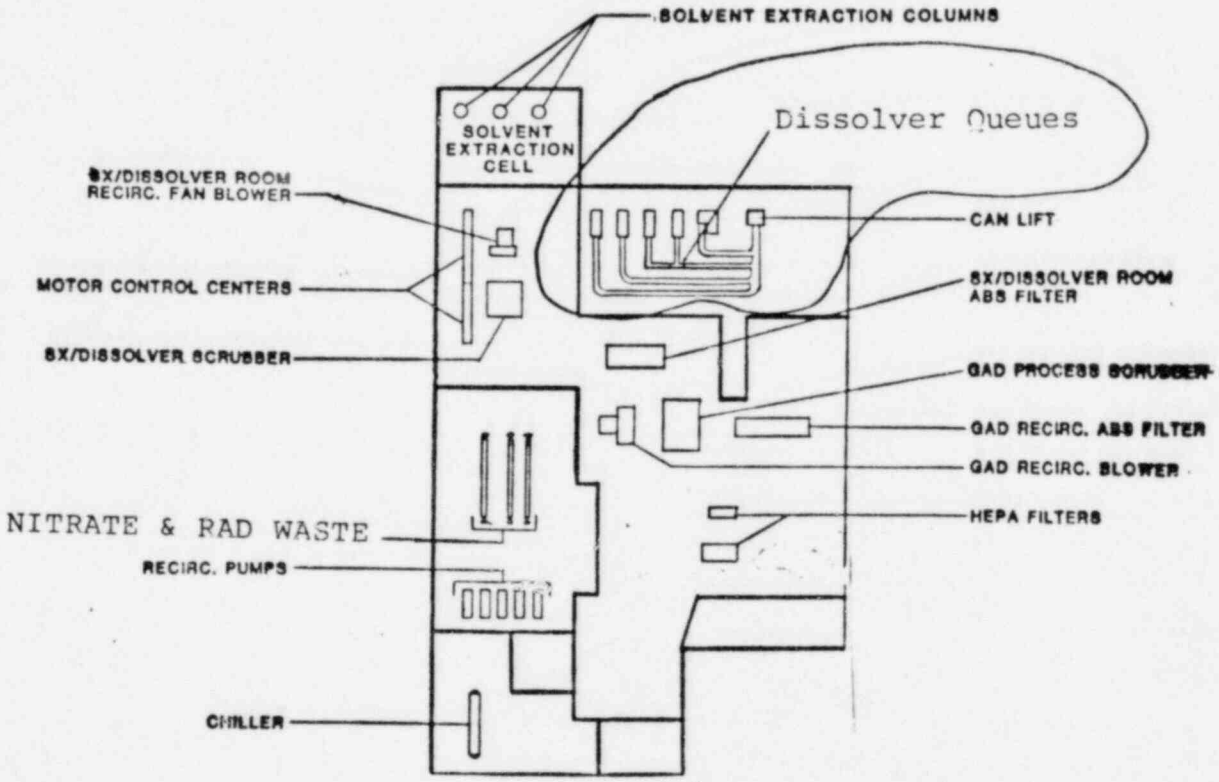
2.4.2.4.1 Queueing

Pails of scrap material, as released by the production control function in $\geq$ kg UO_2 equivalent lots, and will be routed to the mezzanine floor queue area via a pail lift from the pail entry area below. The operator will select the conveyor queue and will route each pail of scrap to the appropriate queuing conveyor feeding each dissolver or leacher. Each of the charging hoods has an automated pail dump mechanism. The dissolving/leaching operation will be done in three unit types: †

- high grade scrap dissolvers †
- low grade scrap leachers †
- low grade leacher †

Each pail will be moved into the pail dump enclosure and authorized for dumping at that station. The tampersafe

FIGURE 2.4-4
PROPOSED EQUIPMENT LAYOUT - SECOND FLOOR



Reference: SNM-1097

FIGURE 2-4.5
SCRAP PROCESSING PROCESS FLOW

Reference: SNM-1097

FIGURE 2-4.5
SCRAP PROCESSING PROCESS FLOW
(CONTINUED)

Reference: SNM-1097

seal will be removed and the seal number entered on MICS.

The dump rate to each dissolver will be dependent upon the dissolver feed rate as specified in the Production Requirement Operations Document (PROD) and will vary according to the type of scrap being processed and the unit type being used. The high grade scrap will be dumped to the feed hopper. Pulsed air actuated bridge breakers will be used to prevent bridging and holdup of oxidized scrap.

2.4.2.4.2 Dissolution

2.4.2.4.2.1 High Grade Scrap Dissolving/Filtration

High grade scrap will be processed in kg UO_2 † equivalent batches per dissolver. Each batch dissolver cycle includes the following steps:

- Fill/heat-up
- Dissolving
- Empty/filtration/rinse

During the dissolving sequence, nitric acid and aluminum nitrate will first be charged to the dissolver. The liquid in the dissolver will be heated by steam injection and recirculated until the proper reaction temperature is reached. The control system will then permit operation of the dissolver feed system. The scrap will be fed to the dissolver from the feed hopper at a uniform rate via inch rotary feed valves. † A flow indicating device connected to the process control system will be used to assure that feed is flowing to the dissolver. The dissolver will be operated at a negative pressure with respect to the dissolver hood.

During the dissolving cycle, dilute fluoride waste treatment product or DI water will be sprayed into the dissolver to minimize particulate entrainment and solids accumulation on the wall of the dissolver. The dissolver solution will be circulated through a heat

exchanger to remove the heat of reaction. Moist air and oxides of nitrogen will exit the dissolver via a † inch cylindrical de-entrainment pad and a † inch diameter reflux condenser. The resulting condensate will be returned to the dissolver. The non-condensable gases from both dissolvers will be combined in the dissolver off-gas header and routed to the NO_x absorber.

The process control system will monitor and control the number of pails entering the dissolver and will compare this with the preset pail count for the batch. After the last pail of scrap is charged to the hopper, the process control system will prevent further dumping. The process control system will set a delay timer to assure complete dissolution. Digestion will be continued until the density of the dissolver solution stabilizes. At the end of the dissolving cycle, the dissolver solution will be at approximately † gm U/l with a specific gravity of approximately †

At the end of digestion, the dissolver solution will be pumped from the dissolver through the † inch diameter filter, through the † inch diameter product cooler, and into the dissolver surge tank. (The filtration rate will change as the solids loading changes the flow resistance of the filter cake). If the solids loading is high, increasing the pressure drop across the filter and decreasing the filtration rate, the flow will be automatically directed by the process control system to the alternate filter.

When the dissolver is empty, flush solution will be added via the dissolver spray and pumped through the system into the dissolver surge tank. The flush volume will be approximately † filter hold-up volumes. When the rinse sequence is complete, the filter(s) will be back-pulsed with air motivated filtrate to dislodge the filter cake, and the slurry subsequently back-flushed to one of the pipe leachers for a second digest cycle.

2.4.2.4.2.2 Low Grade Scrap Processing

The low grade scrap material is characterized by a relatively low uranium content and a high weight percent of insoluble solids. This material will normally be

Reference: SNM-1097

stored in three or five gallon pails and contain less than a safe batch of uranium.

Low grade scrap leaching is a batch controlled process that is limited to one pail of dry feed per batch.

2.4.2.4.2.2.1 Leaching

The leaching operation will be done in either of `long, inch diameter leachers. The leachers can be run simultaneously depending on processing needs. The feed to the leachers will be limited by the process control system to one five gallon pail of material (≤ 1 safe batch) in each leacher batch. Oxidized low grade scrap containing up to weight percent uranium will be batch charged to the leacher.

Prior to charging of the scrap material aluminum nitrate and dilution water will be fed to the leacher and the its associated recirculation tanks. Circulation between the tanks will then be started. The feed entering the top of the leacher will form a wet slurry. After the initial heat-up to a preset temperature, concentrated nitric acid addition will be started. The slurry will be recirculated between the tanks as the digest process goes to completion.

The leacher off-gas will exit the leacher via a inch diameter de-entrainment pad. The condensables (H_2O and HNO_3 vapor) will be recycled to the leacher and the non-condensable gasses will be combined with the dissolver off-gas and routed to the NO_x absorber.

2.4.2.4.2.2.2 Leacher Solution Filtration

When the dissolution is complete, the leacher slurry containing ≤ grams of uranium per liter in solution will be pumped by the leacher slurry pump from the leacher to a filter. The filtration rate through the filter is determined by the pump parameters and/or the solids loading on the filter. The filter is sized such that with a nominal single batch the cake thickness will be thick.

Reference: SNM-1097

Prior to filtered solids discharge, the filter will be air pressurized to blow all residual feed through the cake and out to the inch diameter filtrate † collection tank. The solids will be rinsed with either fluoride waste treatment product or DI water to displace interstitial liquor held up in the filter cake. The filtrate will be routed from the filter to the filtrate collection tank. A turbidity meter in the recirculation line on this tank detects bleed through and provides an input to the control system which determines whether the current filtrate stream is to be recycled to the leacher or pumped through the inch diameter leacher † product cooler to the leacher surge tank.

At the end of the rinse sequence, a final extended air blowdown will remove interstitial liquor in the cake. The filter cake will be funneled into a five gallon pail. The insoluble solids will be weighed, sampled and a MICS transaction will be made for material accountability. Total uranium losses with this burial material (undissolved plus interstitial) are estimated to range from % to % of the uranium in the † leacher feed or typically grams uranium/pail. †

2.4.2.4.2.2.3 Residue Leacher

An inch diameter utility leacher is provided for † processing miscellaneous scrap materials and/or "hard to handle" low grade scrap such as HEPA filter media, HEPA filter ash and insoluble solids rework. Due to process considerations, this material operation will be limited to $\leq$ one safe batch and will be controlled by the process control system.

The leacher tank and its associated inch † diameter recirculation tank will be charged with a pre-determined amount of dilution water. A single pail containing no more than kg of material with a † variable uranium content will be charged directly into the in the leacher tank. Hot nitric acid will be

Reference: SNM-1097

metered into the tank and the reaction temperature monitored by the process control system.

If the reaction temperature exceeds a pre-set level, the acid addition will be terminated automatically. After acid addition is complete, the tank will be circulated for hours depending on the material † type. At the completion of the digest step, the leach solution will be either pumped to the inch leacher † recirculation tanks as dilution water or processed through the leacher filter. The action to be taken will depend on the original uranium content of the scrap being processed (e.g., very low uranium concentration scrap digest material will be used for leacher dilution water).

The leacher containing the insoluble solids will be rinsed, allowed to drip dry and removed from the vessel using the hoist. The basket will be positioned above the basket dump station. The pinned bottom plate of the basket will be dropped and the solids will be discharged directly to a five gallon pail. The pail will then be routed to solid waste handling for interim storage, assayed, and ultimately sent offsite for burial.

2.4.2.5 Feed Adjustment

The surge tanks for the dissolver and the leachers will contain the filtered products of the respective operations. The uranium concentration in the dissolver surge tanks will be ≤ gm U/l and that of the † leacher will be ≤ gm U/l. The target feed † concentration for the solvent extraction process is † gm U/l to gm U/l. Each vessel is provided with † density measuring devices which are tied into the UPMP process control system.

The required final adjustment of the feed solution composition for the solvent extraction process will be carried out in the feed adjustment vessels. † vessels are provided so that receipt of † solutions, sampling and adjustment of the uranium concentration and acidity can occur while simultaneously

Reference: SNM-1097

holding or transferring adjusted feed to the solvent extraction feed metering vessel.

The solvent extraction process controls employed for uranium recovery and purification are designed for a range of uranium concentrations in the feed depending upon the blend of solutions being processed. Dissolver solution will be sufficiently high in uranium concentration that it may be blended with low grade solution. The anticipated range of uranium concentration in the solvent extraction feed will allow the processing of up to kg U/hr through a " † extraction column with a resulting dilute product concentration up to gm U/l. †

Preparation of solvent extraction feed will be accomplished by blending together various amounts of process solution, material for rework and reagents. Process solutions are drawn from the dissolver and leacher surge tanks and the rework material from the UNH rework tank. The blended volumes depend upon the uranium concentration and enrichment in the various component streams and the desired concentration and enrichment for solvent extraction processing. Primary enrichment control is accomplished at the outside storage where scrap is segregated into enrichment bands based on measurements of the material. Acid and DI water may be required for adjustment of the acidity and uranium concentration, and aluminum nitrate for final adjustment of the Al/F ratio for corrosion control and/or to prevent formation of non-extractable uranium fluoride complexes. A sample stream from these feed adjustment tanks will be routed to the UPMP process laboratory where free fluoride will be monitored. Uranium concentration and acidity will be obtained from inline instrumentation.

The adjusted feed material will be filtered through a final filter prior to solvent extraction to remove post-precipitated material that arises from solution cooling and aging.

2.4.2.6 Solvent Extraction

Solvent extraction technology will be employed to recover and purify uranium from the blended feed

solution. Separation of the uranium from soluble contaminants in the solution will be accomplished by preferential transfer of the uranyl nitrate to an organic phase, scrubbing of the organic phase to remove trace contaminants, and stripping of the purified uranyl nitrate from the organic using slightly acidified, warm water.

The organic phase utilized in the process will be a mixture of tri-butyl phosphate and a normal paraffin hydrocarbon diluent (N-dodecane). The diluent affects the density and interfacial tension of the organic to values that permit practical operation of the solvent extraction columns. Extraction of the uranyl nitrate by the organic results from the formation of non-ionic complexes between uranyl nitrate and the organic in a molar ratio of The transfer † equilibrium is strongly affected by the presence of high concentrations of common ions (NO_3^-) in the aqueous phase. The reverse transfer is facilitated by the absence of the common ions (NO_3^-). Extraction of nitric acid and contaminants into the organic phase is a function of the organic phase solvent saturation.

The solvent extraction process will employ standard techniques for contacting the aqueous and organic phases. These columns consist of vertical cylindrical vessels (pipes) through which the aqueous and organic phases are passed. The heavier, aqueous phase will be introduced at the top of each column and the lighter organic phase at the bottom. Thorough mixing of the two phases will be accomplished within the columns.

The solvent extraction system employs extraction † columns, inch diameter columns and a † inch diameter column, to perform the three operations of extraction/scrubbing/stripping. The uranyl nitrate feed stream will be pumped into the top of the column and pass downward. The ratio of organic to aqueous will be controlled to achieve proper uraninum saturation of the

Reference: SNM-1097

organic (gm U/l physical limit) thus inhibiting † extraction of trace contaminants into the organic phase and simultaneously controlling uranium losses to a target of less than gm U/l. †

The AW leaving the column will pass through a inch † diameter decanter for removal of entrained organic and will then flow to the inch diameter † aqueous waste recirculation tank.

A sample stream will be continuously pumped to the UPMP laboratory where it will be periodically measured. This process control measurement provides near real time knowledge of the loss to the aqueous waste stream.

The AW stream will overflow to either of † quarantine tanks where it will be recirculated and again sampled for uranium content by the UPMP laboratory. If the uranium content is greater than ppm (the † current dump limit to V-103), the batch volume will be recycled to the process for rework. If the aqueous waste stream is within the uranium target level, batch disposal will take place through the gallon † existing nitrate waste tank (V-103) for further treatment at the secondary nitrate waste treatment facility.

The organic phase leaving the of the column will † pass through the inch diameter product surge tank to † become the feed (uranium-rich) stream for the next process stage.

Reference: SNM-1097

The uranium laden solvent leaving the column will be pumped from the inch diameter product surge tank to † the next process step where the uranium will be stripped back into the aqueous phase. Dilute uranyl nitrate product from the process column will be passed through a inch diameter product decanter to remove any † entrained organic, and then overflow to the inch † diameter product feed tank.

Geometrically-safe disengaging sections are provided at the ends of each solvent extraction column for entrained phase separation. Each disengaging section will provide the necessary cross-sectional area to reduce the flow velocity to a level at which phase separation will occur. Particulate impurities that enter the solvent extraction columns will tend to accumulate at the controlled aqueous/organic interface.

2.4.2.7 Product Concentration

During start-up of the solvent extraction process, the dilute product will be recycled from the product decanter to the UNH rework tank until sample analysis by the UPMP laboratory system indicates an acceptable product quality (i.e., trace metal impurities). The dilute product will then be routed to the inch † diameter product concentration feed tank or during enrichment changeover, the product will be collected in an UNH dilute product surge tank. The dilute product will be pumped from either tank to the foot long † inch diameter product concentrator reboiler. † The overhead from the reboiler will enter the † tall inch product concentrator. †

The uranium concentration will be increased from ≤ gm U/l in the feed to between gm U/l in the bottoms (target gm U/l). The maximum allowable concentration is gm U/l. Overheads from the concentrator (water vapor and trace HNO_3) will be condensed in the inch diameter product concentrator condenser supplemented with DI water make-up, and recycled to the column as warm strip water from the strip water make-up tanks.

The concentrator product under density control will flow by gravity through the product cooler into product accountability tanks. The full tanks will be recirculated and sampled for product quality in the UPMP process laboratory. Uranium concentration control will be accomplished using in-line measurements A MICS transaction will be made and the entire solution volume will be transferred to interim product slab storage tanks located in FMO-X. Storage tank selection will be based on enrichment. The tank will be flushed forward with an appropriate volume of nitric acid or DI water to purge the transfer line, and attain the end-point concentration of gm U/l as nominal feed to the UNH conversion process.

2.4.3 Criticality Safety Considerations

As in the case of the fluoride waste, rad waste and nitrate waste systems, criticality safety of the UPMP scrap process operation is assured by a combination of operational/process controls, chemistry limitations, uranium mass limits and geometry control. The use of geometry control is especially emphasized because of the higher uranium concentrations and throughput rates present in this system as compared to the process waste streams.

The next section gives a brief summary of criticality safety limits and parameters which are applicable to the controls implemented in the scrap processing operation. These are based on the in-depth discussions presented in Chapter 4. After this summary, a discussion is

presented of the application of these limits and parameters to the criticality safety considerations for the scrap processing operation. Following this, a final section is included which covers normal operations and accident conditions.

2.4.3.1 Criticality Safety Limits and Parameters Applicable to Scrap Processing Operations

As described in Section 2.4.2, the UPMP scrap processing operation consists of four basic systems: scrap oxidation, scrap dissolving, solvent extraction, and uranyl nitrate product concentration and storage. The uranium processing equipment in these four systems is of eight types:

- Three and five gallon pails
- Oxidation furnace boats
- Dissolvers
- Vessels
- Leachers
- Solvent extraction columns
- Nitrate waste tank V-103
- Miscellaneous types of critically safe equipment (such as pumps, filters, seal pots, sumps, floor basins, etc.)

With the exception of the nitrate waste tank, equipment in each of these categories is critically safe primarily because of geometry and materials of construction and secondarily because of mass, concentration or moderation control. Criticality safety of tank V-103 is based on concentration and process/chemistry controls. Before a more in-depth discussion, however, a summary of the criticality safety parameters applicable to this equipment has been tabulated based on the discussions in Chapter 4. These are presented in Tables 2.4-1 through 2.4-9.

Table 2.4-1 lists critically safe geometric dimensions for equipment containing mixtures of UO_2 and water which have simple geometries or small volumes. Tables 2.4-2 through 2.4-6 summarize key Monte Carlo keff calculations for three and five gallon pails, dissolvers, leachers, tanks and solvent extraction columns.

TABLE 2.4-1
GEOMETRICALLY SAFE PARAMETERS
FOR UO_2 + H_2O MIXTURES

A. Safe Geometry Parameters

	Homogeneous Mixtures	Heterogeneous Mixtures
Safe Cylindrical Diameter	9.5 Inches	8.3 Inches
Safe Slab Thickness	4.45 Inches	3.6 Inches
Safe Volume	24 Liters	13 Liters

B. Geometrically Safe* Dimensions for Inch (Inch OD) †
Infinite Cylinders with Homogeneous UO_2 + H_2O Mixtures

Wall Material	Pipe Schedule	Wall Thickness (Inches)	Inner Diameter (Inches)	
PVC		0.165		†
Stainless Steel 304		0.250		†
Carbon Steel		0.365		†

* GEKENO Keff + 3σ - bias $\leq$ 0.97

Reference: SNM-1097

TABLE 2.4-2
NEUTRON MULTIPLICATION FACTORS (Keffs)
FOR THREE & FIVE GALLON PAILS

		W/F Volume Ratio	GEKENO Keff ± σ	
A.	Three Gallon Pails with Heterogeneous $UO_2 + H_2O$ Mixtures	1.0		†
		2.0		†
		3.0		†
		4.0		†
		5.0		†
		6.0		†

		WF H_2O	GEKENO Keff ± σ	
B.	Five Gallon Pails with Homogeneous $UO_2 + H_2O$ Mixtures	0.10		†
		0.1573		†
		0.2183		†
		0.2711		†
		0.3172		†
		0.3486		†
		0.35		†
		0.40		†
		0.45		†
		0.50		†

NOTE: WF = Weight Fraction
W/F = Water to Fuel

Reference: SNM-1097

TABLE 2.4-3
Neutron Multiplication Factors (Keffs)
for Dissolvers with Neutron Absorber Panels †
(Heterogeneous UO_2 + H_2O Mixtures)

W/F Volume Ratio	GEKENO Keff	±	σ	
1.0				†
2.0				†
3.0				†
4.0				†
5.0				†
6.0				†

TABLE 2.4-4
Neutron Multiplication Factors (Keffs) For
Cylindrical Inch Schedule Pipe Tank Leachers* †
(Heterogeneous U + H_2O Mixtures)

W/F Volume Ratio	GEKENO Keff	±	σ	
1.0				†
2.0				†
3.0				†
4.0				†
5.0				†
6.0				†
8.0				†
10.0				†

* Infinitely Tall

Reference: SNM-1097

TABLE 2.4-5
Neutron Multiplication Factors (Keffs) For
Vessels with Neutron Absorber Panels †
(Homogeneous UO_2 + H_2O Mixtures)

WF H_2O	GEKENO Keff ± σ	
0.8972 (100 gm U/liter)		†
0.7745 (250 gm U/liter)		†
0.6787 (400 gm U/liter)		†
0.5202 (750 gm U/liter)		†
0.10		†
0.20		†
0.25		†
0.30		†
0.40		†
0.50		†

TABLE 2.4-6
Neutron Multiplication Factors (Keffs) For
Solvent Extraction Columns
(Homogeneous UO_2 + H_2O Mixtures)

WF H_2O	GEKENO Keff ± σ	
0.10		†
0.20		†
0.25		†
0.30		†
0.40		†
0.50		†

Reference: SNM-1097

TABLE 2.4-7
SAFE BATCH LIMITS

	Mass, kg U		
Uncontrolled Geometry (Homogeneous UO_2 + H_2O Mixtures)	16	(18.1 kg UO_2)	
Uncontrolled Geometry (Heterogeneous UO_2 + H_2O Mixtures)	16	(18.1 kg UO_2)	
Vessels* (Homogeneous UO_2 + H_2O Mixtures)	315		†
Dissolvers * (Heterogeneous UO_2 + H_2O Mixtures)	400		†

* 45% of minimum critical mass assuming failure of neutron absorber panels but integrity of vessels †

TABLE 2-4.8
UO_2 + H_2O Kinf VALUES
(Homogeneous Mixtures)

WF H_2O	GEKENO Kinf ± σ	
0.0		†
0.005		†
0.05		†
0.10		†
0.20		†
0.25		†
0.30		†
0.40		†
0.50		†
0.75		†
0.7745 (250 gms U/liter)		†
0.8972 (100 gm U/liter)		†

Reference: SNM-1097

TABLE 2.4-9
UO_2 + H_2O Kinf VALUES
HETEROGENEOUS MIXTURES

W/F Volume Ratio	GEMER Kinf	±	σ
1.0			
2.0			
3.0			
4.0			
5.0			
6.0			
8.0			
10.0			

Reference: SNM-1097

Safe batch limits are tabulated in Table 2.4-7 both for uncontrolled geometries and for vessels and dissolvers with the assumption that the neutron absorber panels have failed. †

Finally, Tables 2.4-8 and 2.4-9 contain Monte Carlo infinite neutron multiplication factors for homogeneous and heterogeneous UO_2 + H_2O mixtures over a range which includes optimum moderation. Table 2.4-8 also includes Kinfs for dry (moderation control) and dilute (density control) mixtures. Table 2.4-9 for heterogeneous mixtures is included for comparison with the homogeneous case.

2.4.3.2 Scrap Processing Operations Criticality Safety

As noted in Section 2.4.3, the use of geometry control in the UPMP scrap processing operation has been especially emphasized as a primary control because of uranium concentrations and throughput rates which are significantly higher than those in the three UPMP liquid waste streams. In conformance with the double contingency policy, however, scrap processing equipment criticality safety is also assured by secondary (and in some cases tertiary) controls such as geometry, uranium concentration, uranium mass, or moderation. These secondary (and tertiary) controls are usually the same type for individual pieces of equipment in each of the eight basic categories defined in the previous section. Table 2.4-10 summarizes this, subject to the following considerations:

2.4.3.2.1 Three and five gallon pails are used for the handling and storage of high and low grade scrap and sludges. Three gallon pails are used for "heterogeneous" pellets and hard scrap and five gallon pails are used for powder and sludges (materials which form "homogeneous" mixtures with water). This distinction is important since as indicated in Table 2.4-2, the three gallon pail is geometrically safe for heterogeneous UO_2 and water mixtures by virtue of its diameter and height whereas the five gallon pail is not. (The five gallon pail is geometrically safe for heterogeneous $U(4.0)O_2$ and water mixtures and may be used in operations with uranium scrap with enrichments no greater than this). With geometry as the primary control, three and five gallon

TABLE 2.4-10
SCRAP PROCESSING OPERATIONS CRITICALITY SAFETY SUMMARY

Type of Equipment	Contents	Controls		
		Primary	Secondary	Other
1A. Five Gallon Pail	High Grade Scrap Powder	Geometry (Ref. Table 2.4-2)	Volume (Ref. Table 2.4-1)	Mass/Moderation Control
	Wet & Low Grade Scrap	Geometry (Ref. Table 2.4-2)	Volume (Ref Table 2.4-1)	Safe Batch (Ref Table 2.4-7)
B. Three Gallon Pail	Pellet Hard or Green Scrap	Geometry (Ref. Table 2.4-2)	Mass/Moderation Control (Ref. Table 2.4-8)	
2. Oxidation Furnace Boats	High and Low Grade Scrap and Sludge	Geometry (Ref. Table 2.4-1)	Volume (Ref. Table 2.4-1)	Mass Control
3. Dissolvers	High Grade Scrap Batches	Geometry (Ref. Table 2.4-3)	Mass (Ref. Table 2.4-7)	
4. Vessels	Scrap Dissolving and Solvent Extraction Process Liquids	Geometry (Ref. Table 2.4-5)	Mass Control (Ref. Table 2.4-7)	Density Control (Ref. Table 2.4-8)
5. Leachers	Low Grade Scrap	Geometry (Ref. Table 2.4-4)	Mass Control (Ref. Table 2.4-8)	
6. Solvent Extraction	Organic and Aqueous Liquid	Geometry (Ref. Table 2.4-6)	Density Control (Ref. Table 2.4-8)	
7. Waste Tank	Aqueous and Nitrate Wastes	Density Control Solvent Extraction Process	Density Control ICAP	Density Control V-103
8. Miscellaneous Equipment	Process Liquids and Scrap	Geometry (Ref. Table 2.4-11)	Mass, Density as Applicable	

Reference: SNM-1097

pails have identified secondary controls depending on the contents. These are as follows:

Three gallon pails of pellets or hard scrap are critically safe because of mass/moderation control: Mass control because 35 kg is less than 90% of a minimum critical mass, and moderation control because hard scrap (pressed and sintered) contains significantly less than 0.5% by weight of water. (As shown in Table 2.4-8, the Kinf for UO_2 powder and 0.5% by weight of water is less than 1.0. Heterogeneous effects are unimportant at this level of water.) For green scrap (i.e., unsintered pellets) the moderation content can be higher (as much as 5% equivalent water by weight) but green scrap occupies at least twice the volume of hard scrap.

Five gallon pails with UO_2 powder, wet sludges or low grade scrap are critically safe by virtue of volume. The volume of a five gallon pail is about 22 liters which is less than the 24 liter safe geometry volume for homogeneous UO_2 and water mixtures. This is a different form of control from the geometrical safety discussed above because in the event of most failures of the pails geometry (diameter or height), the contents will still not exceed a safe volume. In those cases in which the safe volume may be compromised, the five gallon pail will still be critically safe because of tertiary control (mass/moderation control for pails of high grade powder and safe batch control for wet and low grade scrap). Mass/moderation control is based upon a combination of mass (35 kg UO_2 is less than 90% of a minimum critical mass for 5.0% enriched UO_2 powder) and moderation control (UO_2 powder with powder preparation additives contains less than 5.0% by weight of moderator equivalent to water). Wet and low grade scrap is critically safe by safe batch control because wet sludge is nominally 50% by weight of water (50% X 35 kg = 17.5 kg) and pails of low grade scrap such as incinerator ash contain less than 17.5 kg of uranium. (As noted in Table 2.4-7, the safe batch limit for UO_2 powder is 18.1 kg).

2.4.3.2.2 Oxidation furnace boats are used for the oxidation of high and low grade scrap and sludges originally contained in three or five gallon pails. Individual boats are filled one-for-one from individual pails so

that the secondary (and tertiary) controls for three and five gallon pails apply in the same way to the furnace boats. The primary control is different, however, in that the thick by inch wide by inch † long furnace boats are geometrically safe for both homogeneous and heterogeneous UO_2 and water mixtures. (Geometric safety for heterogeneous mixtures is evident since the buckling for a inch by inch x † inch slab, assuming an extrapolation length of 6.64 cm, is 0.0252 cm^2 and is greater than the value of 0.0196 cm^2 for a inch thick safe geometry infinite † slab.)

2.4.3.2.3 Each dissolver processes kg UO_2 equivalent † batches of oxidized high grade scrap (typically U_3O_8 powder). Table 2.4-3 illustrates that these vessels are geometrically safe with a Keff less than 0.90 for heterogeneous UO_2 and water mixtures. The key features of the dissolver geometry are the dimensions of the vessel and neutron absorber panels. This is the basis for the secondary control for the dissolvers. Failure of the primary control can occur in two ways: failure of the vessel, or failure of the neutron absorber panels. In the case of the former, the failure will result in leakage of the dissolver solution on the floor into a safe slab configuration. If the neutron absorber panels fail, however, the dissolver will be critically safe because of the batch size. The kg batch size † is less than the dissolver safe batch as tabulated in Table 2.4-7. It can also be noted that the uranium concentration in the dissolver after complete dissolution of the kg batch is 350 grams U/liter. † From a comparison of Tables 2.4-3 and 4-4, it can be seen that the keff of an unfailed dissolver is less than 0.83 (since 350 grams U/liter is equivalent to a fuel mixture with a W/F volume ratio of greater than 6.0).

2.4.3.2.4 Vessels (as opposed to dissolvers) in the scrap process operation are used as holding or treatment vessels for uranyl nitrate from the dissolving or solvent extraction operations. As indicated by Table 2.4-3 the primary criticality control is geometry (again based upon the radial dimensions of the tank and neutron † absorber panels). The secondary control for these vessels is either mass (reference Table 2.4-3 or

concentration density (less than 250 grams U/liter, reference Table 2.4-5).

An exception to this is the secondary control applicable to the dissolver surge tank and SX feed adjustment tanks. The uranium concentration in these vessels can reach a maximum of 350 grams uranium per liter (the maximum value for the dissolvers) and the vessels can contain as much as two dissolver batches (i.e., kg). Secondary control of criticality safety is therefore based upon the form of the material (uranyl nitrate) and a consideration of credible accident conditions. The worst case of these accident conditions are failure of the tank (such that the uranyl nitrate is discharged into the dissolver area basin and sump) and failure of the neutron absorber panels. Criticality safety under either of these conditions is demonstrated by the applicable parts of Chapter 4. †

2.4.3.2.5 Residue leachers are inch schedule stainless steel 304 cylindrical tanks which are used in dissolving single three or five gallon pails of low grade scrap. These tanks are geometrically safe for heterogeneous UO_2 and water mixtures (reference Table 2.4-4) which is the primary control, and are controlled secondarily by mass (one five gallon pail of low grade scrap contains less than one safe batch). A tertiary control is density since the concentration after dissolution is less than the minimum critical value for UO_2 and water. †

2.4.3.2.6 Solvent extraction columns are geometrically safe (reference Table 2.4-6) - the primary control - and are controlled by concentration - the secondary control. As noted in Section 2.4.2.6, the maximum concentration accommodated by the organic phase in the solvent extraction columns is 125-130 gram U/liter which is less than the 250 gm U/liter value for UO_2 and water which corresponds to Kinf = 1. In addition, the aqueous phase (feed) concentration at the feed adjustment tanks is controlled to gm U/l. †

2.4.3.2.7 The nitrate waste tank V-103 is used to hold dilute effluent ($\leq$ ppm U) from primary nitrate waste and spent solvent extraction aqueous waste containing less than ppm U. The primary criticality control for †

this tank is the concentration control based on the solvent extraction process and process control system. The secondary control is also concentration, in this case provided by the UPMP lab measurement of the uranium in the solvent extraction aqueous waste at the aqueous waste recirculating and surge tanks. The lab measurements are provided to the process control system. A tertiary density control is also present in the nitrate waste tank in the form of density probes and tank recirculation. As in the case of the fluoride waste system surge tank V-106, the nitrate waste tank density probes are directly interfaced to the process control system and are set to close off inlet streams if the tank bulk density exceeds a value equivalent to 250 grams U/liter. This value is higher than the corresponding control in the fluoride waste system since densities in V-103 are significantly affected by metals and other impurities resulting from the solvent extraction operations.

2.4.3.2.8 Other miscellaneous equipment in the scrap processing operation are listed in Table 2.4-11. In this table, the primary geometry control is described and the secondary controls are either mass or concentration controls as applicable to the system to which the component belongs.

2.4.3.3 Geometry Control of the Scrap Processing System

The scrap processing system was designed using geometry control as a guideline for the entire process. The equipment used in scrap processing can be summarized by the following:

(1) geometrically safe vessels †

(2) geometrically safe tanks †

(3) geometrically safe pumps †

(4) geometrically safe heat exchangers †

(5) geometrically safe filters †

Reference: SNM-1097

(6) geometrically safe feed hoppers †

(7) geometrically safe feed valves †

(8) geometrically safe cooler †

(9) geometrically safe slab filter †

(10) existing critically safe tanks †

(11) geometrically safe process columns †

(12) critically safe venturi eductor †

(13) Material handling equipment geometrically designed for criticality safety

(14) geometrically unsafe tank †

(15) Criticality safe floor basins for liquid spills

(16) Associated geometrically safe process piping

Reference: SNM-1097

This scrap processing system equipment is delineated in Table 2.4-11.

2.4.3.4 Normal and Accident Conditions in the Scrap Processing Operations

As noted in the previous section, uranium processing equipment in the UPMP scrap processing operation have been designed to assure criticality safety under ununsual and extremely unlikely conditions and are usually significantly less reactive (from a criticality safety viewpoint) than the optimum conditions. An example of this is that while most scrap processing operation equipment is designed to be geometrically safe (which implies optimum moderation UO_2 equivalent densities of 2.0 to 3.0 grams/cc), the maximum credible concentration in most operations is 350 grams U/liter = 0.4 grams UO_2/cc. Table 2.4-12 presents a further criticality safety evaluation of the normal operations for the eight scrap processing operation categories discussed in the previous sections. This table summarizes the normal conditions applicable to the category and indicates an "upper limit" Keff $\pm 3\sigma$ value which can be assigned based upon the indicated reference. The upper limit so indicated is not necessarily the factor which applies to the normal condition but is a value which by inference is greater than the actual value. These normal case Keffs are less than 0.90.

In the evaluation of the scrap processing operations accident conditions, four significant conditions have been identified. These are:

2.4.3.4.1 Failure of Geometry Control in Scrap Process Operations

Criticality safety in the event of failure of geometry control in scrap process operations has been addressed in Section 2.4.3.2 and especially by Table 2.4-10. The secondary controls assure criticality safety when the primary geometry control fails.

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Tank	Yes		Geometrically Safe Cylinder
	Column	Yes		Geometrically Safe Cylinder
	Column	Yes		Geometrically Safe Cylinder
	Column	Yes		Geometrically Safe Cylinder
	Filter	Yes		Critically Safe Slab
	Dissolvers	Yes		Geometrically Safe w/ Neutron Absorber Panels
	Leachers	Yes		Critically Safe Cylinder
	Leacher	Yes		Geometrically Safey Cylinder
	Furnace Scrubber	Yes		Geometrically Safe Cylinder
	Condenser	No		Geometrically Safe Cylinders
	Cooler	Yes		Geometrically Safe Cylinder
	Cooler	Yes		Geometrically Safe Cylinder
	Condenser	No		Geometrically Safe Cylinder
	Cooler	Yes		Geometrically Safe Cylinder
	Heater	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST
Page 2

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Concentrator	No		Geometrically Safe Cylinder
	Concentrator	Yes		Geometrically Safe Slab and Volume
	Concentrator	No		Geometrically Safe Cylinder
	Concentrator	Yes		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Filter	Yes		Geometrically Safe Cylinder
	Dust Collectors	Yes		Geometrically Safe Cylinder
	Filter	Yes		Geometrically Safe Cylinder
	Filter	Yes		Geometrically Safe Slab
	Filter	Yes		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Strainer	Yes		Geometrically Safe Cylinder
	Filter	Yes		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Filter	No		Geometrically Safe Cylinder
	Furnace	Yes		Administrative Control
	Boats	Yes		Geometrically Safe Slab and Volume
	Skids	Yes		Physical Design Maintains Center-to-Center 25" Pail Spacing
	Transfer Dolly	Yes		Physical Design Maintains 25" Center-to-Center Pail Spacing
	Scrubber Eductor	Yes		Geometrically Safe Cylinder
	Pump	Yes		Geometrically Safe Cylinder

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST
Page 3

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Volume
	Pumps	Yes		Geometrically Safe Slab and Volume
	Pumps	Yes		Geometrically Safe Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pumps	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Cylinder
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST
Page 4

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geomtrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	Yes		Geometrically Safe Volume
	Pump	No		Geometrically Safe Volume
	Pulsers	Yes		Geometrically Safe Volume
	Pulser	Yes		Geometrically Safety Volume
	Rotary Valve	Yes		Geometrically Safe Cylinder
	Rotary Valves	Yes		Geometrically Safe Cylinder and Volume
	Seal Pots	No		Geometrically Safe Cylinder
	Seal Pot	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder
	Sump	No		Geometrically Safe Cylinder

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST
Page 5

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Sump	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Unsafe
	Hopper	Yes		Geometrically Safe Slab
	Hoppers	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Demisters	Yes		Geometrically Safe Cylinder
	Demisters	Yes		Geometrically Safe Cylinder
	Tanks	Yes		Critically Safe Vessel
	Demister	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tanks (Existing)	Yes		Geometrically Safe Slab
	Tank	No		Geometrically Safe Cylinder
	Tank	No		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Decanter	Yes		Geometrically Safe Cylinder
	Tanks	Yes		Geometrically Safe Cylinder

Reference: SNM-1097

TABLE 2.4-11
SCRAP PROCESSING SYSTEM EQUIPMENT LIST
Page 6

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Decanter	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tank	Yes		Geometricall Safe W/ Neutron Absorber Panels
	Tank	Yes		Geometrically Safe w/ Neutron Absorber Panels
	Tank	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tanks	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tank	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tank	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tanks	Yes		Geometrically Safe W/ Neutron Absorber Panels
	Tanks	Yes		Geometrically Safe w/ Neutron Absorber Panels
	Five (5) Gallon Pails at Furnace Discharge	Yes	11-1/4" ID, 13-1/2" High 22 Liters	Geometrically Safe Volume
	Floor Basins	No	Max. 3-3/4" Thick Slab	Geometrically Safe Slab With Concrete and 1" Water Reflection
	Process Lines	Yes	1/2" to 4" Range	Geometrically Safe Cylinders and Slabs
	Three (3) Gallon Pails at Furnace Discharge	Yes	11-1/4" ID, 8-13/16" High 17.8 Liters	Geometrically Safe Volume

Reference: SNM-1097

TABLE 2.4-12
SCRAP PROCESS OPERATIONS NORMAL CONDITIONS

Equipment Category	Normal Conditions	Upper Limit Keff ± σ		Reference	
1. Pails - Five Gallon	High or Low Grade Scrap (< 10% H_2O)	0.8672	0.0041	Table 2.4-2	
	Wet Sludge (≥ 50% H_2O)	0.8485	0.0044	Table 2.4-2	
- Three Gallon	Dry Hard Scrap or Pellets (> W/F Ratio of 1.0)	0.8362	0.0033	Table 2.4-2	
2. Oxidation Furnace	UO_2 Powder or Sludge Safe Geometry-3-3/4" Slab	0.84*	--	Table 2.4-1	
	Dry Hard Scrap or Pellets (< W/F Ratio of 1.0)	0.84	--	Table 4-38	
3. Dissolvers	≤ 350 grams U/Liter (or W/F Ratio >> 6.0) or 250 Kg U Mass Limit			Table 2.4-3	†
4. Vessels	≤ 350 grams U/Liter			Table 2.4-5	†
5. Leachers	Safe Batch or < 100 grams U/liter			Table 2.4-4	†
6. Solvent Extraction	≤ 350 grams U/Liter (>> 50% H_2O)			Table 2.4-6	†
7. Nitrate Waste Tank	≤ 100 ppm U			Table 2.4-8	†
8. Miscellaneous Types Critically Safe Equipment	Safe Geometry	--		Table 2.4-1	
	Density Control	See Chapter 4.0			
	Mass Control	See Chapter 4.0			

*From the Reactivity Formula and ARH-600 Kinf, M^2 and λ Data.

Reference: SNM-1097

2.4.3.4.2 Double Batching in Scrap Process Operations

In scrap process operations, batch (or mass) control is only applicable to geometrically safe equipment (three and five gallon pails, oxidation furnace boats, leachers and various miscellaneous items). Therefore, double batching or failure of mass controls will not by itself result in a critically unsafe condition.

2.4.3.4.3 Failure of Concentration Control in Nitrate Waste Tank V-103

Since failure of concentration control in tank V-103 requires at least three unrelated, simultaneous incidents criticality safety of this vessel complies with the double contingency policy. As discussed in Section 2.4.3.2.7, all of the following are required for failure of concentration control in V-103:

- Failure of solvent extraction process controls (which normally limit the uranium content in the aqueous waste stream to ppm). †
- Failure of the UPMP lab measurement system and UPMP process control system (which restricts dumps to V-103 from the nitrate waste system to no more than ppm U and from solvent extraction to no more than ppm U). † †
- Failure of V-103 density probes and controls (which close all inlet valves if tank bulk densities equivalent to greater than grams U/liter are detected). †

2.4.3.4.4 Uranium Backflow to Geometrically Unsafe Process Vessels

The process chemical demand in the facility is at a level which cannot be accommodated by the volume contained in 10" diameter and smaller tanks without requiring unreasonable tank heights. Geometrically unsafe standard chemical make-up tanks are used to provide the required process chemicals.

Reference: SNM-1097

2.4.3.4.4.1 General Backflow Prevention Techniques

In the facility design described in this document, three basic concepts (break tanks, air breaks and double block and bleed valving systems) have been utilized either individually or in combination to prevent backflow of process liquids to the geometrically unsafe tanks.

2.4.3.4.4.1.1 Break Tanks

As used in this design, break tanks are geometrically safe 10" diameter, Schedule 80 pipe tanks or smaller. The inlet supply nozzles from the geometrically unsafe chemical tank are located in the top of the break tank, well above the break tank overflow. This assures that there is always an air gap between the liquid level and the inlet supply nozzle. The feed to the process vessel is from the bottom of the tank and the liquid level is controlled by a level switch interlocked with the chemical supply pump.

2.4.3.4.4.1.2 Air Break

The air break is standard throughout this facility. It is used either alone or in conjunction with the other back flow prevention schemes. In the air break design, the inlet nozzle of the process vessel is positioned in the top of the vessel six to twelve inches above the vessel overflow nozzle. This positioning technique assures that an air gap always exists between the liquid in the process vessel and the supply line from the chemical supply tank (which at times is a break tank).

2.4.3.4.4.1.3 Double Block and Bleed Valving System

The double block and bleed system was previously described in Section 2.1.3.4.3 and in Figure 2.1-8. This concept is used where positive system pressures make the provision for an air gap either in the break tank or the process vessel unattainable. The general concept, as described in Figure 2.1-8, is to always have the supply tank isolated from the process by valve seats. This is accomplished by providing a drain path between the valves for unintentional flow from either the process chemical tank or the process vessel itself.

2.4.3.4.4.2 Scrap Processing Operation Backflow Prevention

In the scrap processing operation, break tanks and air breaks are used to prevent process backflow. The specific process chemical streams are:

(1) Nitric Acid

All nitric acid supply to the dissolvers and leachers are via the nitric acid supply pump through the 8" diameter, Schedule 40, nitric acid break tank to the process vessel. The supply input in each dissolver/leacher is accomplished across an air break arrangement.

(2) De-Ionized Water

De-ionized water is supplied to the system by the DI water supply pump through the 10" diameter, Schedule 80, DI water break tank into the process vessels using the air break feature on each dissolver/leacher.

(3) Aluminum Nitrate

Aluminum nitrate is fed to the system by the aluminum nitrate supply pump through the 10" diameter, Schedule 80, aluminum nitrate break tank, into the process vessels which incorporate the air break design feature.

(4) Solvent

The fresh solvent is supplied from the solvent make-up tanks, which are not geometrically safe. When a complete solvent replacement is required by the process, the solvent is pumped via the solvent transfer pump through an inter-tie pipe which requires administrative approval prior to connection to the solvent feed tank. This input is made through the top of the vessel using an air break for back flow prevention. Additions are made in this fashion infrequently, and only when batch solvent concentration changes are required.

During normal day to day operations, solvent make-up is from the geometrically unsafe solvent mix tank via the solvent transfer pump into the geometrically safe metering tank (break tank). This tank is located six (6) feet above the solvent surge tank which it feeds by gravity flow. The input to the surge tank is through a nozzle located in the top of the tank, six inches above the tank overflow thereby forming the air break.

2.4.3.4.4.2.5 Aqua Ammonia

Aqua ammonia is transferred to the 8" diameter SX neutralization tank from the main header through the top of the tank air break.

2.5 URANYL NITRATE CONVERSION

2.5.1 Current Conversion Process

The current Uranium Purification Process (UPS) is designed to process discrepant uranium powder with low impurity concentration. The system processes the powder through digest, precipitation, centrifugation and calcination steps to produce a uranium oxide powder. Refer to Figure 2.5-1.

2.5.1.1 Digest

A weighed quantity of discrepant uranium powder (about kg) is dissolved in a controlled volume of † N nitric acid and then diluted with DI water to † attain a uranium concentration of about grams/ † liter. The digester is a inch diameter cylindrical † tank. The solution is transferred, through filters to the slab storage (LEM) tank which are gallon, † inch slab tanks. There is a bank of LEM † tanks which are used for in-process storage of UNH solution ahead of the precipitation step.

2.5.1.2 Cooling and Precipitation

A controlled volume of UNH is batch transferred from a LEM tank to a inch diameter cylindrical cooling † tank. The solution is cooled by recirculating through a heat exchanger. Ammonium hydroxide is added to obtain a predetermined pH level. When the solution is cooled to the desired temperature, it is transferred to a inch diameter cylindrical tank where hydrogen † peroxide is added to precipitate the uranium as a tetroxide. The uranium is precipitated at a controlled pH as a tetroxide to prevent co-precipitation of iron and other metal impurities. The slurry is transferred to a inch diameter cylindrical tank which is the † feed for the centrifuge.

2.5.1.3 Centrifuge

The dilute slurry flows from the feed tank through the scroll type horizontal centrifuge. Here the uranium

Reference: SNM-1097

FIGURE 2.5-1
UPS PROCESS - SCHEMATIC FLOW DIAGRAM

Reference: SNM-1097

precipitate is separated from the liquid phase. This is discharged into a slab type hopper as a thick paste.

The liquid phase is discharged into a second clarifier type centrifuge to remove the last trace of uranium precipitate. The liquid phase centrate is discharged to the nitrate quarantine tanks. The solid phase, which is a slurry, is pumped back into the process through the centrifuge feed tank.

2.5.1.4 Calcination

The slurry that is collected in the centrifuge hopper is pumped at a controlled rate into the calciner. The calciner is a rotating, gas heated inch diameter † tube through which the uranium slurry is processed. The slurry is dried and reacted at elevated temperatures with a counter current flow of hydrogen-nitrogen gas mixture. The product is UO_2 powder. The reacting gasses are withdrawn from the calciner, scrubbed with water to remove ammonia and nitrates and discharged into the plant process venting system.

The water from the gas scrubber is recirculated through a supply tank, cooled and reused in the scrubber. A controlled side stream is diverted to the centrifuge feed tank and blended with the process stream.

2.5.1.5 Quarantine

The process water (nitrate waste, from the clarifier centrifuge) is alternately collected in gallon, † inch quarantine slab tanks. Each tank is filled, circulated for mixing and sampled for uranium concentration. If the uranium concentration is ppm or less, it is released to the † gallon storage tank, V-103, located outside the FMO building. If the uranium concentration is too high in the quarantine tank, the contents are recycled.

Another quarantine tank is used to collect acid flushing and rinsing of the ADU conversion lines. This waste solution is very acid since molar nitric acid †

is used to flush and clean the various process pipe lines and equipment. Ammonium hydroxide is added to the tank and recirculated for mixing to precipitate the uranium. The contents of this tank are circulated through a double centrifuge arrangement to remove the uranium solids until the concentration in the tank is ppm uranium or less, as determined by a SPEC 20 Colorimeter. The tank contents are released and pumped to the nitrate waste storage tank V-103. †

2.5.2 UPMP CONVERSION PROCESS

With the implementation of solvent extraction, the uranyl nitrate solution will be a pure product. Therefore the existing UPS conversion process can be modified to provide a † system. The conversion process can be † divided into the following steps: precipitation, centrifugation and calcination. Figure 2.5-2 outlines the process. The conversion process will be controlled by a central process control system similar to the one used for the other UPMP processes.

2.5.2.1 Precipitation

The UNH solution which will be the product from the solvent extraction process, contains grams † uranium per liter and about molar of free nitric † acid. This product, which will be the feed solution for UNH conversion will be stored in existing † gallon, inch slab tanks in the UPMP area. Upon † demand, the contents of one of the slab tanks will be transferred to the existing gallon LEM tanks, † located in the FMO area. The precipitation will take place as shown in Figure 2.5-2.

2.5.2.2 Centrifuge

The solid bowl scroll type dewatering centrifuge will be an existing unit that was used for the UPS system. This unit separates the ammonium diuranate solids from the liquid. The solids will be discharged into a †

FIGURE 2.5-2
UNH CONVERSION PROCESS - UPMP

Reference: SNM-1097

inch thick slab hopper as a pasty sludge containing about % solids and will be pumped by the slurry pump into the calciner. †

2.5.2.3 Calcination

Calcination will be accomplished in the same manner as current facility operations. The thick pasty sludge from the dewatering centrifuge will be pumped into the existing calciner. This sludge contains about % solids and will be equivalent to about % uranium concentration. The calciner will be an existing, rotating, gas fired 10 inch diameter tube, through which the uranium sludge will be processed. † †

2.5.2.4 Quarantine

The process water from the clarifier overflow tank will be pumped to the existing 230 gallon quarantine tanks as nitrate waste. When a tank is full, the liquid will be mixed by recirculation quarantine discharge, sampled and analyzed for uranium using a SPEC 20 Colorimeter. If the uranium concentration is less than the discharge limit of ppm, the tank contents will be released and pumped to the UPMP nitrate waste collecting vessel for further treatment. (See Section 2.3). †

The operation of the C nitrate quarantine tank, as described in Section 2.5.1.5, will not change except that the contents will be transferred to the UPMP nitrate waste collecting vessel.

2.5.3 Criticality Safety Considerations

The uranyl nitrate conversion system, because of relatively high uranium concentrations, uses geometry control, operational process control, and chemistry limitations. A brief summary of criticality safety limits and parameters which are applicable to the controls implemented in the UNH conversion process, are presented in Section 2.5.3.1. This includes a discussion of the application of these limits and parameters to the criticality safety considerations for

the process as based on the in-depth discussions presented in Chapter 4. A final section is included which covers normal operations and accident conditions.

A major portion of the uranyl nitrate conversion equipment was originally used for the UPS conversion process. This includes the UNH storage tanks, the LEM and UPS quarantine tanks, the dewatering and clarification centrifuges, and the calciner. This equipment is currently approved for processing 4% enriched uranium in the same density ranges required for UNH conversion and will be appropriately reanalyzed and modified, if necessary, prior to operations with enrichments above this value.

2.5.3.1 Concentration Control of the Uranyl Nitrate for the Conversion Process

The uranium concentration of the feed to UNH conversion will be controlled by the solvent extraction product concentration as defined in Section 2.4.2.7. The uranium concentration in each UNH storage tank will be known and verified by separate sampling and analysis by the Chemet laboratory and released by documentation from the Quality Control and Production Control functions. Table 2.5-1 summarizes these concentrations at key points in the conversion process and compares them with corresponding values for the UPS System. The chemistry and process controls, which assure these concentrations, are described in the following section.

2.5.3.2 Uranyl Nitrate Conversion Chemistry and Process Control

2.5.3.2.1 Chemistry

The uranium concentration and the free nitric acid concentration for the UNH in each storage tank will be known. These values are introduced into the process control system by the operator. Precipitation will be controlled. Conversion will take place in a reducing atmosphere to product UO_2.

2.5.3.2.2 Process Control

The UNH conversion process is controlled by a process control system. The control system will regulate the

TABLE 2.5-1
UNH CONVERSION CONCENTRATION RANGE

System	U Concentration Range Prior to UPMP	U Concentration Range After UPMP	Overall Effect
Digest Tank		---	
UNH			Recovery
LEM Tanks			Intermediate Process
Intermediate Process		---	N/A
Intermediate Process			Intermediate Process
Intermediate Process	---		Intermediate Process
Intermediate Process	---		Intermediate Process
Centrifuge Feed			Improved
Sludge			Unchanged
Centrate			Improved
Centrate			Improved
Slurry			Unchanged
Scrubber Water			Unchanged
Quarantine Tanks			Improved

process flows, temperatures and pressures to produce the desired quality of UO_2 powder.

2.5.3.3 Geometry Control of the Uranyl Nitrate Conversion System

UNH Conversion will be implemented with extensive use of geometry control in the design of the equipment. This equipment is summarized as follows:

(1) Critically Safe Slab Tanks (existing) †

(2) Geometrically Safe Slab Tanks (existing) †

(3) Geometrically Safe Heat Exchangers †

(4) Geometrically Safe Tanks †

(5) Existing Critically Safe Centrifuges †

(6) Critically Safe Slab Tank †

(7) Existing Critically Safe Cylindrical Calciner †

(8) Critically Safe Heat Exchanger †

(9) Geometrically Safe Pumps †

(10) One (1) Critically Safe Floor Basin for Liquid Spills

(11) Associated Geometrically Safe Process Piping

Table 2.5-2 lists the equipment associated with the UNH conversion system.

2.5.3.4 Normal and Accident Conditions in the Uranyl Nitrate Conversion System

As noted previously, the UNH conversion system will be a modification of an existing process. This existing facility is critically safe for processing 4% uranium. The modification will be the replacement of existing batch type process equipment with new precipitation

TABLE 2-5.2
UPMP UNH CONVERSION EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Centrifuge	Yes		Critically Safe Geometry
	Centrifuge	Yes		Critically Safe Volume
	Heat Exchanger	Yes		Geometrically Safe Cylinder and Slab
	Heat Exchanger	No		Geometrically Safe Cylinder and Slab
	Heat Exchanger	Yes		Critically Safe Slab and Volume
	Calciner (existing)	Yes		Geometrically Safe Cylinder
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Cylinder
	Pump (existing)	Yes		Geometrically Safe Cylinder
	Pump (existing)	Yes		Geometrically Safe Slab and Volume
	Pump (existing)	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	Yes		Geometrically Safe Slab and Volume
	Pump	No		Geometrically Safe Slab and Volume
	Pump (existing)	Yes		Geometrically Safe Slab and Volume

Reference: SNM-1097

TABLE 2-5.2
UPMP UNH CONVERSION EQUIPMENT LIST
(CONTINUED)

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Reactor	Yes		Geometrically Safe Cylinder
	Reactor	Yes		Geometrically Safe Cylinder
	Tanks (existing)	Yes		Critically Safe Slab
	Tanks (existing)	Yes		Geometrically Safe Slab
	Tank	Yes		Geometrically Safe Cylinder
	Tank	Yes		Geometrically Safe Cylinder
	Hopper (existing)	Yes		Geometrically Safe Slab
	Tank (existing)	Yes		Geometrically Safe Cylinder
	Tank (existing)	Yes		Geometrically Safe Cylinder
	Tanks (existing)	Yes		Geometrically Safe Slab
	Scrubber (existing)	Yes		Geometrically Safe Cylinder
	Break Tank	No		Geometrically Safe Cylinder
	Tank (existing)	Yes		Geometrically Safe Cylinder
	Break Tank	No		Geometrically Safe Cylinder
	Process Piping	Yes	1/2" to 2" Pipe	Geometrically Safe Cylinders and Slabs
	Floor Basin	No	3" Thick Slab	Critically Safe Slab
	Five Gallon Pails	Yes	11-1/4" ID x 13-1/2" High, 22 Liters	Geometrically Safe Cylinders

equipment. This new equipment, as well as some of the existing equipment, will be geometrically safe for 5% enriched uranium.

2.5.3.4.1 Failure of Concentration Control

As noted in Table 2.5-2, almost all of the equipment is geometrically safe and any failure of the UNH conversion concentrations control will not result in a critically unsafe condition.

2.5.3.4.2 Failure of Geometry Control

Failure of geometry control of the UNH conversion system will not result in a critically unsafe condition in new Uranyl Nitrate Conversion equipment because of the concentration control features described in Sections 2.5.3.1 and 2.5.3.2. Failure of geometry control in existing equipment is considered in the original analyses for this equipment and will not be discussed further in this document.

2.5.3.4.3 Backflow of Uranium into Unsafe Tanks

All the process vessels used in the UNH conversion system are geometrically safe. The flow of high concentration material either upstream or downstream of the process system will not result in an unsafe condition since all those tanks and vessels are geometrically safe.

The supply of and DI Water will be from geometrically safe break tanks which have air breaks from the main supply tanks.

2.6 PROCESS CONTROL SYSTEM

The UPMP process control system will be a commercially available system. It will be a distributed control system with both batch and continuous capabilities and will employ a Figure 2.6-1 is a sketch of the system configuration.

2.6.1 System Power

The process control system and laboratory equipment will be supplied with 120/208 VAC power through an Uninterruptible Power Supply (UPS) with a full load battery backup of at least 15 minutes. This UPS will be of the rectifier, battery charger, inverter and static switch type. The UPS provides power to the control system including field instruments, operators consoles, alarms, printers and loggers. It will not provide power to operate field equipment. Field equipment and final control elements will be designed to "fail safe" upon loss of power. The UPS will be supplied power from the plant emergency power generator during plant power outages.

2.6.2. Control System Features

The control system employs redundancy in three areas which are considered to require high reliability.

2.6.2.1 A will be employed even though the system will not be physically distributed. All control system controllers and input/output signals (I/O) will be located in one room with operator consoles in the adjacent room. The will provide assured system communications at all times as well as on-line maintenance of the communications system.

2.6.2.2 Dual operator consoles will allow dual control of each UPMP process and also provide for backup operation of all processes requiring high reliability by having those processes configured in both consoles. Key switch operation will be used to prevent simultaneous operation of those processes at each console.

FIGURE 2.6-1

UPMP CONTROL SYSTEM

Reference: SNM-1097

2.6.2.3 can be used in a † redundant configuration to provide high reliability for those processes configured on both operators consoles. When used in a redundant configuration, the will † provide both continuous and † and sequencing operations. † will provide primary control with the † in a standby state being continually † updated with current operating data from the † The will be ready to † assume control if the fails. Failures † will be detected by both internal and external cross-checking features.

2.6.3 System Operation

Signals to and from field devices will be interfaced to the control system through two types of highway connected devices.

2.6.3.1 Analog controllers which will be used in continuous control applications or which require complex control algorithms will be individual loop controllers. The mode of control (manual, auto, computer) and tuning parameters (setpoint, gain, rate, reset) can be adjusted from the operator's console. Alarm contacts will be provided to allow communication of status type information between controllers without using the data highway. Each controller will be a microprocessor that can be operated independent of highway integrity.

2.6.3.2 The uses dedicated † I/O and its own programs to operate and control process units. The has its and can † be viewed as a with † extensive analog control capabilities †

2.6.3.3 Control information other than start-stop and control parameter type information will not be transmitted over the highway. Control takes place in the or † The and † will use the highway to pass status and † process variables to the operators console for indication, trending, logging and operator interaction.

2.6.4 Operator Consoles

Two operator consoles, each with two color CRTs, will provide real-time interactive graphics to display all process parameters and provide the operator with the means to operate all processes and equipment, respond to alarm conditions, input requested data, demand CRT copies and logs, etc., through the use of numerical keys, dedicated keys and "soft keys" whose functions are keyed to the CRT display. Each console will have a 4-position key switch: Locked, which allows only monitoring of all the displays; Operate, which allows the operator to perform all normal operating functions; Tune, which allows the shift foreman or process engineer to change process or control loop tuning parameters if permission to do so was input during configuration; and Configure, which allows the control system engineer to modify or generate new graphic displays, control sequences, control logic, etc., through the use of a configuration keyboard on a separate engineering console.

A backup configuration keyboard will be supplied at one operator's console but will be covered and unavailable to the operator. Each console will have a capability for 100 graphic displays which include plant overview, groups, process graphics and special log formats. Each console also has the capability to do up to four real-time trends. Real-time and historical trending display for up to will also be available † on the console CRT through a trend unit on the data highway.

2.6.5 Hard Copy Printout

Each operator's console will support one printer and one logger. The logger will be capable of alpha-numeric printing only. The printer gives both alpha-numeric printing and black and white copies of CRT graphic displays on operator demand. Batch end reports, hourly, shift and daily logs or summaries, operation actions and alarms can be scheduled for printout on either the printer or logger as desired.

CHAPTER 3.0
SUPPORT SERVICES & EQUIPMENT

All processes involved in the Uranium Process Management Project require outside support and services. In most cases, the support systems provide chemicals required for operation which are not uranium bearing. In cases such as the solvent treatment system, uranium bearing materials are treated but the system requires only a short description for clarity. Since there is a commonality of purpose, the support systems have been grouped into one chapter and are detailed in the following sections.

3.1 SOLVENT TREATMENT

The solvent treatment system is designed to permit continuous treatment of the solvent inventory as it is circulated through the solvent extraction process. The basis of the process is the emulsification of the organic stream with an ammonium carbonate wash solution thereby chemically scrubbing out the residual uranium and the mono- and di-butyl phosphate degradation products. The incorporation of the continuous solvent treatment process allows batch acidification of the waste ammonium carbonate wash stream and adjustment of the solvent concentration during scheduled weekly shutdowns of the solvent extraction system.

The main solvent stream (CW) leaving the column, will contain approximately gm U/l and will provide the † principal load to the solvent treatment system with minor flows coming via the aqueous waste decanter and from the vent system decanters. The CW stream flows from the strip column, to the spent solvent surge tank. The solvent will be pumped from the spent solvent surge tank at twice the CW stream flow to the solvent wash tank where it will be combined with an equal volume of ammonium carbonate wash solution. The resultant two phase emulsion will be pumped from the bottom of the solvent wash tank through the solvent heater to the in-line mixer which takes suction from the upper region of the wash tank.

Reference: SNM-1097

The intimately mixed phases will be routed to a liquid/liquid centrifuge, where the organic and aqueous phases are separated. The solvent phase from the centrifuge will be split, with approximately one-half being routed to the solvent feed tank, and the remainder being recycled to the spent solvent surge tank. The aqueous stream from the centrifuge will be recycled to the chemical wash tank. Since the amount of impurities requiring removal by the solvent wash system are small, the aqueous wash solution can be used for a week of operation without depletion of the ammonium carbonate solution.

Treatment of the solvent with the ammonium carbonate wash solution will remove the hydrolysis products and their uranium complexes. The solubility limit for uranium in the form of ammonium uranyl carbonate is in the range of gm U/l. The reaction products from † solvent treatment strongly favor the aqueous phase and are effectively removed from the solvent. The aqueous wash solution is acidified on a batch basis during weekly shutdown of the solvent extraction system. The acidified aqueous phase will be centrifuged and disposed to the nitrate waste treatment system for recovery of residual uranium as a calcium uranate sludge.

Organics separated by centrifuging of the acidified wash solution will be collected in the neutralization tank, along with interfacial waste that is periodically purged from the solvent extraction columns. These organic bearing wastes are sampled for uranium and acid, neutralized with ammonium hydroxide, filtered and loaded into a drum for disposal via the incinerator.

3.1.1 Geometry Control of the Solvent Treatment System

As with the major process systems discussed previously, the solvent treatment system design makes extensive use of geometry control. The following summarizes the equipment in use in the facility:

(1) geometrically safe vessel †

(2) geometrically safe pumps †

(3) geometrically safe tanks †

(4) geometrically safe heat exchangers †

(5) geometrically safe centrifuge †

(6) geometrically safe venturi eductor †

(7) geometrically safe filter †

Table 3-1 summarizes the process equipment along with a brief description of the geometry and corresponding criticality safety designation.

3.2 FILTER CLEANING STATION

In both the nitrate waste treatment system and the rad waste treatment system, the filters may become plugged with solids thereby restricting the flow rate. When this occurs, it will be necessary to clean the filter media. This cleaning can be accomplished in two ways. The first and most timely will be cleaning in place and the second will be filter disassembly and transport to a separate filter cleaning area adjacent to the filter banks.

For in-situ filter cleaning, the media will be isolated from the process by closing the inlet and discharge valves. The filter housing will be drained. A special program in the UPMP process control system will be initiated and the filter will be flushed with dilute nitric acid.

If the in-situ cleaning is not effective, further cleaning of the filter will be necesary to maintain processing rates. The filter will be isolated, drained, and then disconnected from the piping system. The filter media will be transported to the cleaning station enclosure for further intensive cleaning.

TABLE 3-1
SOLVENT TREATMENT SYSTEM EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Centrifuge	Yes		Geometrically safe cylinder
	Heater	Yes		Geometrically safe cylinder
	Cooler	No		Geometrically safe cylinder
	Filter	Yes		Geometrically safe cylinder
	Eductor	Yes		Geometrically safe cylinder
	Pump	No		Geometrically safe volume
	Pump	Yes		Geometrically safe slab and volume
	Pump	Yes		Geometrically safe slab and volume
	Pump	Yes		Geometrically safe slab and volume
	Pump	Yes		Geometrically safe slab and volume
	Tank	No		Geometrically safe cylinder
	Tank	Yes		Geometrically safe cylinder
	Tank	Yes		Geometrically safe cylinder
	Tank	Yes		Geometrically safe cylinder
	Tank	Yes		Geometrically safe cylinder
	Tank	No		Geometrically safe with neutron absorber panels
	5 Gallon Pails	Yes	11-1/4" ID, 13-1/2" high, 22 liter volume	Geometrically safe volume
	Process Piping	Yes	1/2" to 3" range	Geometrically safe cylinders and slabs

Reference: SNM-1097

In the enclosure, manual cleaning of the media will be done with either a brush assembly or water jet wand. All liquid discharge in the enclosure will be routed to the nitrate waste sump.

3.2.1 Geometry Control of the Filter Cleaning Station

Geometry control has been implemented in this system. Table 3-2 lists the equipment summarized below:

(1) geometrically safe cylinders †

(2) geometrically safe pump †

(3) Geometrically safe process lines

3.3 NO_x ABSORPTION

Oxides of nitrogen will be generated during the dissolving/leacher operations. The rate and composition of NO_x generation will be dependent upon the rate of feed processing, the uranium oxidation state, the quantity of metal contaminants (Fe°) and the nitric acid strength used in the dissolution operation.

The NO_x generated in each dissolver in the scrap processing operation will be vented through two parallel, four inch diameter demisters. A DI water spray nozzle is provided for back wash of each individual demister pad. (Figure 3-1)

The two gas streams will be combined downstream of the reflux condensers where the condensibles are returned to the dissolver. The non-condensible stream will be combined with the non-condensibles coming from the leacher operation. This non-condensible stream from the leachers will go through a system similiar to that of the dissolvers.

The gasses generated in the pipe leachers † will be passed through a demister and to a 6-5/8" diameter leacher reflux condenser prior to mixing with the non-condensible gasses from the dissolving

TABLE 3-2

FILTER CLEANING STATION EQUIPMENT LIST

Equipment Label	Equipment Designation	Normally Contains Uranium	Geometry Description	Criticality Safety Description
	Pump	No		Geometrically safe slab and volume †
	Tank	No		Geometrically safe cylinder †
	Tank	No		Geometrically safe cylinder †
	Tank	No		Geometrically safe cylinder †
	Process Lines	No	1/2" to 2" Pipes	Geometrically safe cylinders

Reference: SNM-1097

FIGURE 3-1
DEMISTER PAD

operation. These combined non-condensible gas streams will be passed through two parallel † to the NO_x absorption column as shown in † Figure 3-2.

The NO_x absorption column is a inch in diameter † by foot tall tower whose active length contains † trays with bubble caps on each tray. The normal † absorber liquid is dilute nitric acid circulated through an external heat exchanger E-280. The tower design does have the capability of operating using once-through de-ionized water as the absorber liquid if necessary for improved efficiency. The NO_x absorber is equipped with in-line instrumentation for monitoring tower operating efficiency and effluent concentration.

The recovered acid will be returned to the SX process and DI make-up to the tower will be supplied from a separate source not connected to the main process break tank. This acid use/DI replenish operation will prevent the build-up of any residual uranium particulate that may enter via the NO_x off-gas stream from the dissolving operation.

3.3.1 Criticality Considerations

Since the effectiveness of any NO_x absorption system will be based upon contact and chemical kinetics, it is not practical to design the absorber as a geometrically safe tower. Instead, criticality safety will be assured by designing a dissolver and leacher off-gas system which prevents the carryover of uranium to the absorption column and which permits the use of a conventional NO_x absorber tower design. This will be done by placing the gaseous vent(s) for each dissolver or leacher at the top of the tank or vessel void space and extending the straight vertical run beyond the tank overflow. Any particulate in the gas flow from the vessels will be trapped in either of the two parallel demisters prior to going to the geometrically safe reflux condenser which will further assure disengagement of any uranium bearing liquids or particulate.

FIGURE 3-2
NO_x ABSORBER SYSTEM

Since the gas flow from each leacher will be much lower than that for the dissolver, only one demister will be required. The final liquid disengagement will be done in a geometrically safe reflux condenser in the same manner as the dissolver effluents. In this sense, the geometrically safe reflux condensers and demisters will prevent the transport of solubilized or particulate uranium to the NO_x system and will be the basic criticality control for the NO_x column. If this redundant system were to fail, the liquid in the column sump section will be recirculated through a density element which will alert the operators to a major change in tower liquid composition.

3.4 AQUEOUS AND SOLVENT MAKE-UP (ASMU)

The aqueous and solvent make-up system will be the primary chemical support facility for this project. The facilty will consist of six (6) independent chemical preparation processes combined with a storage and supply tank area to support the main process needs of the project. Due to the volumes of chemicals required, the support processes and supply vessels will be of conventional, geometrically unsafe design. Descriptions of the steps which will be taken to assure critically safety of the support area have been outlined under the process descriptions of Chapter 2. In general, all criticality protection of these large support vessels will be accomplished by the use of either break tanks, air breaks, double block and bleed systems, or combinations of the above.

Table 3-3 details both the processes included in the facility and the major storage vessels.

3.5 SOLID WASTE HANDLING

Combustible and non-combustible waste generated in the main process areas will be transported to a two compartment waste box enclosure. The enclosure will accommodate two (2) (4' x 4' x 3 1/2') metal, wood, or cardboard boxes which will be placed in the enclosure through a rollup door. Each waste box will be monitored while in the enclosure to assure that the amount of

TABLE 3-3
AQUEOUS & SOLVENT MAKE-UP PROCESS
& CHEMICAL SUPPLY TANKS

Processes

Aluminum Nitrate Make-up
Weekly Solvent Adjustment
Bulk Solvent Make-up/Storage
Ammonium Bicarbonate Make-up
Ammonium Carbonate Make-up

Storage and Supply Tanks

% Lime Storage Tank		Gallons	†
% Lime Storage Tank		Gallons	†
DI Water Storage Tank	10,000	Gallons	
Rad Waste Tank		Gallons	†

uranium in the box is less than a safe batch. When the boxes are ready for removal, the box lids will be put on and the boxes transferred to the fuel manufacturing decontamination facility for further sorting prior to ultimate disposition to either the incinerator or burial.

3.6 PROCESS LABORATORY

The UPMP process laboratory will occupy 680 square feet of space adjacent to the control room/office complex. (Reference Figure 1-3). It will have thirty-four linear feet of open bench space, a sink and a fume hood with sink inside. Waste liquids will leave the lab through drain piping either to rad waste (for the liquids containing only trace uranium and chemicals - e.g., glassware wash water, safety shower water, etc.) or to nitrate waste (if the uranium or chemical content is unknown or high - e.g., unused portions of samples, out-of-date standards, etc.). Room air will be exhausted to the existing FMOX roof scrubber through ventilation provided for lab equipment and the fume hood. A normally closed rear exit door will be provided for emergency egress, and the room will be equipped with an overhead sprinkler system for fire control. Figure 3-3 shows the schematic layout of the UPMP process laboratory.

The laboratory will contain approximately fifteen pieces of newly purchased, standard analytical instruments and support equipment which supplement and serve as back-up to
These will provide selective, routine uranium concentration monitoring from process locations by performing analyses on samples
Both will be connected to inch, which to the various process sample points. Certain impurity measurements will also be made by the on additional inch after the uranium has been removed by
systems. Each of these inch can be manually sampled

FIGURE 3-3
UPMP PROCESS LABORATORY

in the lab for subsequent analysis on an or other instrument.

The process laboratory will be capable of performing all uranium and impurity analyses required for process control. Data from these analyses will be transmitted to the control room for use in process control activities. In addition, the lab will support the calibration checks of some of the on-line process measurement instrumentation.

CHAPTER 4.0
CRITICALITY SAFETY ANALYSES FOR EQUIPMENT & OPERATIONS

4.1 GE-WMD CRITICALITY SAFETY POLICY & METHODS

The Uranium Process Management Project facility, equipment and operations have been designed in accordance with criticality safety requirements using analytical methods and techniques documented in WMD's Special Nuclear Material License SNM-1097. The key elements are the following:

4.1.1 Double Contingency Policy

Process designs shall incorporate sufficient factors of safety to require at least two unlikely, independent and concurrent changes in process conditions before a criticality accident is possible.

4.1.2 Geometry Control

The preferred method for assuring nuclear criticality safety in production quantities of fissile materials is by the use of geometry control. Geometry control is defined to mean criticality safety under the following conditions:

4.1.2.1 Optimum moderation by water or by any other material more effective than water which can credibly cause optimum moderation in the system.

4.1.2.2 The optimum credible density of the fissile material taking into account the presence of the moderator as described in 4.1.2.1 above.

4.1.2.3 The presence of fissile material and moderator in all areas in which they are not physically excluded.

4.1.2.4 Full reflection by at least 12 inches of water at the closest boundary to the equipment unless other more effective reflectors are actually present and in such a configuration. (In this case, the more effective reflector must be assumed).

Reference: SNM-1097

4.1.2.5 The optimum degree of credible heterogeneity, in fissile material, moderator and neutron absorbers.

4.1.2.6 The maximum enrichment of fissile material permitted in the system.

4.1.2.7 Maximum and minimum equipment dimensions, as appropriate, which are pertinent to the geometrical configuration.

4.1.3 Fixed Neutron Absorbers

The use of fixed neutron absorbers is considered to be a form of geometry control to provide criticality safety under the following conditions:

4.1.3.1 The neutron absorber is a solid stable boron compound fixed in a matrix.

4.1.3.2 The neutron absorber and any hydrogeneous material used to thermalize neutrons are sealed in a stainless steel or other suitable container which may be an integral part of the process equipment.

4.1.3.3 The neutron absorber is installed as a permanent part of the equipment or system and is not easily moved or removed.

4.1.3.4 Prior to its use, the presence of the neutron absorber is verified.

4.1.3.5 The void volume of the neutron absorber system is negligibly small to prevent internal rearrangement.

4.1.3.6 The effectiveness of the neutron absorber system is analyzed and demonstrated by use of validated calculational methods.

4.1.3.7 The integrity of the neutron absorber is maintained against credible fire hazards and corrosive conditions.

4.1.3.8 The integrity of the neutron absorber is verified on a periodic schedule compatible with the corrosive nature of the environment.

4.1.3.9 Equipment from which neutron absorbers are removed, is tagged out and not used.

4.1.3.10 The neutron absorber is designed to withstand credible industrial accidents and natural events.

4.1.4 Administrative Controls

Where geometric control is not practical, criticality control may be based on control of U_{235} mass or control of moderation.

4.1.4.1 Where control is based on U_{235} mass limits, process operations are limited such that:

4.1.4.1.1 The mass of any single accumulation does not exceed 45 percent of the minimum critical mass (defined to be a safe batch) or,

4.1.4.1.2 The mass of any single accumulation does not exceed 75 percent of the minimum critical mass if double batching is not credible.

4.1.4.2 Where control is based on over moderation of fissile material accumulations, the accumulations are periodically assayed or sampled to assure the following:

4.1.4.2.1 The maximum fissile material concentration does not exceed one half of the minimum critical concentration for the given enrichment or

4.1.4.2.2 The H/U_{235} atomic ratio is not less than 5200

4.1.5 Definition of Critically Safe

The term "Critically Safe" means:

4.1.5.1 Under identified normal conditions, the effective neutron multiplication factor (Keff) is such that:

$$Keff + 3\sigma - Bias \leq 0.90$$

Where σ is the statistical uncertainty (if any) in the Keff value and bias is the applicable analytical bias based upon formal validation of the method used to determine Keff. (Bias = calculated Keff - actual Keff)

Reference: SNM-1097

4.1.5.2 Under specified accident conditions (such as those specified in Section 4.1.2 for geometry control) the effective neutron multiplication factor satisfies:

$$Keff + 3\sigma - Bias \leq 0.97$$

4.1.6 Analytical Methods Used In Criticality Safety Analyses

The analytical methods used in criticality safety analyses are:

4.1.6.1 The GEMER Monte Carlo Code

4.1.6.2 The GEKENO Monte Carlo Code with JRK Modified Hansen-Roach Cross Sections

4.1.6.3 The SAC Interaction Solid Angle Code

4.1.6.4 The reactivity formula with Kinf, M^2 and λ data taken from ARH-600 for homogeneous UO_2 and water mixtures.

4.1.6.5 The reactivity formula with Kinf, M^2 and λ data taken from DP-1014 and GEBLA calculations for heterogeneous lattices of UO_2 in water.

4.1.6.6 Standard geometric buckling formulas for cylinders, slabs and spheres.

4.1.6.7 Tabulated safe batch and safe geometry parameters

Table 4-1 summarizes the analytical biases which are applicable to the Monte Carlo Codes and reactivity formula.

4.1.7 UO_2 and Water Mixtures

In criticality safety analyses, the optimum credible form of fissile material and moderation is assumed to be full density UO_2 and water mixtures. The term full density means that the UO_2 and water combine such that the partial volumes they occupy add up to the total volume; that is, there is no void space or other "inert" material present. Full density homogeneous mixtures can be conveniently characterized by the weight fraction of water in the mixture as:

TABLE 4-1
BIASES FOR ANALYTICAL METHODS USED IN CRITICALITY

Method	Range of Application	Bias	Source
1. GEMER Monte Carlo Code	Lattices of Low Enriched UO_2 Rods in Water	-0.003	TRX Benchmarks
GEMER Monte Carlo Code	All other Low Enriched UO_2 and Water Systems	-0.010	GEMER Validation Study
2. GEKENO Monte Carlo Code with JRK Modified Hansen-Roach Cross Sections	Homogeneous Low Enriched UO_2 and Water Systems	0.00	Table 4-4
GEKENO Monte Carlo Code with JRK Modified Hansen-Roach Cross Sections and adjusted U^{238} Materials IDs	Heterogeneous Low Enriched	-0.01	Table 4-5
3. Reactivity Formula with ARH-600 Data	Homogeneous Low Enriched UO_2 and Water Systems	-0.017	Table 4-4
4. Reactivity Formula with DP-1014 and GEBLA Data	Heterogeneous Low Enriched UO_2 and Water Systems	0.00	Table 4-5

Reference: SNM-1097

$$\rho\text{-MIX} = \frac{1}{\frac{WF\ UO_2}{\rho(T)\text{-}UO_2} + \frac{WF\ H_2O}{\rho(T)\text{-}H_2O}}$$

Where WF H_2O is the weight fraction of water, WF UO_2 = 1-WF H_2O is the weight fraction of UO_2, $\rho(T)$-UO_2 = 10.96 gms/cm3 is the theoretical maximum density of UO_2, $\rho(T)$-H_2O = 1.00 gms/cm^3 and ρ-MIX is the density of the UO_2 and water mixture in grams/cm3 for these weight fractions. UO_2 and water densities are easily obtained from this formula since:

$$\rho\text{-}UO_2 = WF\ UO_2 \times \rho\text{-MIX}$$

and,

$$\rho\text{-}H_2O = WF\ H_2O \times \rho\text{-MIX}$$

(Table 4-4 shows typical results of the application of these relationships.)

For heterogeneous mixtures, characterization is usually made by use of the water to fuel volume ratio (W/F). In the case of square lattices of (infinite) unclad UO_2 rods in water, this value is :

$$W/F = \frac{(L^2 - \frac{\pi D^2}{4})}{\frac{\pi D^2}{4}}$$

Where D is the diameter of the rod and L is the center to center separation between rods. This W/F Ratio is related to the WF H_2O of a homogeneous Full Density UO_2 and Water mixture with the same total amounts of UO_2 and water by:

$$WF\ H_2O = \frac{1}{\frac{10.96}{W/F} + 1}$$

(This is also illustrated in Table 4-4.)

Reference: SNM-1097

4.1.8 The Reactivity Formula

The Reactivity Formula is often used to calculate effective neutron multiplication factors for cylinders slab or spheres. This relationship is:

$$Keff = \frac{Kinf}{1 + B^2M^2}$$

with

$$B^2 = \frac{\pi^2}{(\overline{R+\lambda})^2} \quad \text{for spheres,}$$

$$B^2 = \frac{Jo^2}{(\overline{R+\lambda})} + \frac{\pi^2}{(\overline{H+2\lambda})^2} \quad \text{for cylinders, and}$$

$$B^2 = \frac{\pi^2}{(\overline{X+2\lambda})^2} + \frac{\pi^2}{(\overline{Y+2\lambda})^2} + \frac{\pi^2}{(\overline{Z+2\lambda})^2} \quad \text{for slabs}$$

Kinf, M^2 and λ Parameters are listed in Tables 4-2 and 4-3, and are applicable to homogeneous UO_2 and water mixtures and heterogeneous lattices of UO_2 rods in water. The homogeneous data is taken from ARH-600 and the heterogeneous values are from DP-1014 and GEBLA calculations. This latter data in particular has been conservatively estimated and represents parameters applicable to the optimum rod diameter at the given W/F volume ratio.

4.1.9 Infinite Neutron Multiplication Factor (Kinf) Considerations

Ranges for optimum credible mixture densities and heterogeneity (where applicable) have been determined for criticality safety applications by an extensive study of infinite neutron multiplication factors (Kinf's) for UO_2 and water systems. This study has also been used to infer analytical biases (as discussed in Section 4.1.6) from a comparison with the corresponding values for the GEMER Monte Carlo Code.

4.1.9.1 Kinf Values For Homogeneous UO_2 and Water Mixtures

Table 4-4 shows a comparison of Kinf values determined from GEKENO (with Hansen-Roach Cross Sections), GEMER and ARH-600 for homogeneous UO_2 and water mixtures as a

Reference: SNM-1097

TABLE 4-2
REACTIVITY FORMULA*
Kinf, M^2 & λ PARAMETERS
FOR HOMOGENEOUS $U(5.0)O_2$ & WATER MIXTURES

WF H_2O	Kinf	M^2 (cm^2)	λ ** (cm)
0.05	1.23	37.0	8.35
0.10	1.345	31.5	7.45
0.20	1.432	28.5	6.65
0.25	1.442	28.0	6.45
0.30	1.440	28.0	6.30
0.40	1.410	28.2	6.05
0.50	1.346	28.7	5.92
0.60	1.245	29.3	5.86

* All Data is extrapolated from ARH-600
** 12 Inch Water Reflection

Reference: SNM-1097

TABLE 4-3
REACTIVITY FORMULA
Kinf, M^2 & λ PARAMETERS
FOR HETEROGENEOUS $U(5.0)O_2$ LATTICES IN WATER

W/F Volume Ratio	Kinf	M^2 (cm^2)	λ** (cm)	
1.0	1.452*	32.65*	7.5*	
2.0			6.85*	†
3.0			6.64*	†
4.0			6.52*	†
5.0			6.44*	†
6.0			6.39*	†
8.0	1.448*	29.00***	6.35***	
10.0	1.414*	29.00***	6.30***	
12.0	1.374*	29.75***	6.30*	
14.0	1.326*	29.75*	6.30*	

*Data Extrapolated From DP-1014, all other is from GEBLA Calculations.
**12 Inch Water Reflection
***Estimated

Values are from DP-1014 and GEBLA calculations. These latter data in particular have been conservatively estimated and represent parameters applicable to the optimum rod diameter at the given W/F volume ratio.

Reference: SNM-1097

TABLE 4-4
GEKENO, GEMER & ARH-600 KINF COMPARISON FOR HOMOGENENOUS $U(5.0)O_2$ + H_2O MIXTURES

Mixture WF H_2O	Equivalent W/F Volume Ratio	Uranium Density (gm/cc)	Mixture Density (gm/cc)	H/U Atomic Ratio	Hansen-Roach Cross Sections Kinf	GEKENO Kinf	†	σ	GEMER Kinf	†	σ	ARH-600 Kinf	
0.00	0.00	9.660	10.960	0.00	0.8775							<0.99 *	†
0.005	0.06	9.156	10.440	0.15	0.9763							<1.02 *	†
0.01	0.11	8.698	9.967	0.30	1.0217							<1.04 *	†
0.015	0.17	8.279	9.535	0.46	1.0566							<1.08 *	†
0.02	0.22	7.895	9.139	0.61	1.1079							<1.10 *	†
													†
0.03	0.34	7.215	8.439	0.92	1.1586							1.15	†
0.04	0.46	6.632	7.838	1.25	1.2220							1.19	†
0.05	0.58	6.127	7.316	1.58	1.2562							1.23	†
0.08361	1.00	4.830	5.980	2.73	1.3514							1.32	†
0.10	1.22	4.356	5.491	3.33	1.3779							1.345	†
													†
0.15	1.93	3.293	4.395	5.29	1.4346							1.402	†
0.15432	2.00	3.220	4.320	5.47	1.4420							1.405	†
0.20	2.74	2.583	3.663	7.49	1.4673							1.432	†
0.21490	3.00	2.415	3.490	8.20	1.4678							1.439	†
0.25	3.65	2.076	3.140	9.99	1.4704							1.442	†
													†
0.26738	4.00	1.932	2.992	10.94	1.4695							1.443	†
0.30	4.70	1.696	2.748	12.84	1.4648							1.440	†
0.31328	5.00	1.610	2.660	13.67	1.4562							1.440	†
0.35	5.90	1.400	2.443	16.13	1.4420							1.430	†
0.35377	6.00	1.380	2.423	16.40	1.4423							1.428	†
													†
0.38976	7.00	1.208	2.245	19.14	1.4275							1.415	†
0.40	7.31	1.163	2.199	19.98	1.4265							1.410	†
0.42194	8.00	1.073	2.107	21.87	1.4165							1.400	†
0.45	8.97	0.969	1.999	24.52	1.4030							1.385	†
0.45090	9.00	0.966	1.996	24.60	1.4026							1.385	†
													†
0.47710	10.00	0.878	1.905	27.34	1.3829							1.365	†
0.50	10.96	0.808	1.833	29.96	1.3673							1.346	†
0.5202	11.88	0.750	1.773	32.49	1.3545							1.330	†
0.55	13.40	0.671	1.692	36.62	1.3266							1.300	†
0.60	16.44	0.554	1.571	44.94	1.2713							1.245	†
													†
0.65	20.35	0.452	1.466	55.65	1.2096							1.175	†
0.67870	23.15	0.400	1.412	63.29	1.1547							1.130	†
0.70	25.57	0.364	1.375	69.91	1.1203							1.095	†
0.75	32.88	0.285	1.294	89.89	1.0219							<0.995*	†
0.77450	37.64	0.250	1.258	102.91	0.9670							<0.940*	†
													†
0.80	43.84	0.215	1.222	119.85	0.8974							-	†
0.85	62.11	0.153	1.158	169.79	0.7472							-	†
0.89720	95.65	0.100	1.103	261.51	0.5705							-	†
0.90	98.64	0.097	1.100	269.66	0.5584							-	†
0.95	208.24	0.046	1.048	569.29	0.3175							-	†

* Extrapolated

Reference: SNM-1097

function of the WF H_2O in the mixture. The values under the column "Hansen-Roach Cross Sections Kinf" are based solely upon the Hansen-Roach Cross Section sets (as determined by direct calculation of Kinf from the fission and absorption cross sections, transfer coefficients, and the fission spectrum). These are in excellent agreement with the corresponding GEKENO value. The GEKENO and GEMER values in this table were calculated using a simple cubical geometry (typically 200 to 400 cm on a side) and J=O boundary conditions on all six sides. Table 4-4 also lists equivalent W/F ratios, uranium densities and mixtures densities (specific gravity) for each of the mixtures based on the methods described in Section 4.1.7.

The Kinf values in Table 4-4 are plotted in Figure 4-1 and illustrate the following:

4.1.9.1.1 GEKENO with Hansen Roach cross sections is biased high relative to GEMER at and around optimum moderation. This relative bias is estimated to be in excess of 1.0% based upon a comparison of maximum values.

4.1.9.1.2 ARH-600 Kinf data is biased low relative to GEMER by approximately 0.7% at and arcund optimum moderation.

4.1.9.1.3 GEMER and GEKENO results indicate spectral differences such that GEKENO overpredicts the Kinf values relative to GEMER by 1.0% at optimum moderation but by even greater amounts at each end of the mixture WF water spectrum. For dry (< 0.01 WF H_2O) mixtures, this bias is 4 to 5% and for very dilute (> 0.75 WF H_2O) mixtures, it is 3 to 4%. These regions are of particular interest since they are points at which the UO_2 and water mixtures have Kinfs less than 1.0. (ARH-600 data is not available for these regions and can only be inferred by smooth curve extrapolation).

4.1.9.2 Kinf Values For Heterogeneous UO_2 Lattices In Water

As described in Section 4.1.7, heterogeneous square lattices of UO_2 rods in water are characterized by a Water to Fuel Volume Ratio (W/F) given by:

Reference: SNM-1097

FIGURE 4-1
K-INFINITE FOR $U(5)O_2$ & WATER MIXTURES

Reference: SNM-1097

$$W/F = \frac{(L^2 - \frac{\pi D^2}{4})}{\frac{\pi D^2}{4}}$$

For a given W/F Ratio, then, the Lattice spacing, L, is related to the rod diameter, D, by

$$L = \frac{D}{2}\sqrt{\pi(1 + W/F)}$$

This relationship has been used to determine lattice dimensions for use in GEMER Monte Carlo calculations of infinite neutron mutliplication factors for heterogeneous UO_2 and water mixtures. The geometry model used in the GEMER calculation consists of a cylindrical rod with the appropriate diameter D centered in a rectangular cuboid with "X" and "Y" dimensions of L. The "Z" dimension (with the Z axis also being the axis of cylindrical rod) was typically taken to be 400 cm. An infinite lattice was modelled by J=O boundary conditions on all six sides. Material densities were taken to be 10.96 grams/cm^3 for the UO_2 in the rod and 1.00 grams/cm^3 for the water moderator outside of the rod.

Table 4-5 lists the results of these GEMER calculations for a range of W/F Ratios from 1.0 to 10.0. The rod diameters were selected so as to include the optimum value for the associated W/F Ratio.

Also shown in Table 4-5 are Kinf values calculated with GEKENO using Hansen-Roach Cross Section Sets with U_{238} material IDs adjusted to correct for heterogeneity of the UO_2 in the lattice. The geometry model used in these calculations was a simple cube, 200 cm on a side and reflected via J=O boundary conditions on all six sides. The mixture specifications used were to "smear" the UO_2 and water into a homogeneous mixture with the same equivalent W/F Ratio (See Table 4-4) but with a U_{238} material ID reduced a number of units sufficient to result in a Kinf at least as great as the corresponding GEMER value. The number of units required to be subtracted was determined from the results in Table

Reference: SNM-1097

TABLE 4-5
GEMER & GEKENO KINF COMPARISONS FOR HETEROGENEOUS UO_2 ROD LATTICES IN WATER

Cell W/F Volume Ratio	Rod Diameter (Inches)	GEKENO Kinf	†	σ	GEMER Kinf	†	σ	Reactivity Formula* Kinf	
1.0	0.00							--	†
	0.70							--	†
	0.80							--	†
	0.90							--	†
	1.00							--	†
	1.10							1.452	†
	1.20							--	†
									†
2.0	0.00							--	†
	0.40							--	†
	0.50							1.525	†
	0.60							--	†
	0.70							--	†
									†
3.0	0.00							--	†
	0.20							--	†
	0.30							1.540	†
	0.40							--	†
	0.50							--	†
									†
4.0	0.00							--	†
	0.10							--	†
	0.20							1.530	†
	0.30							--	†
	0.40							--	†
									†
5.0	0.00							--	†
	0.10							--	†
	0.20							1.498	†
	0.30							--	†
									†
6.0	0.00							--	†
	0.10							1.460	†
	0.20							--	†
									†
8.0	0.00							--	†
	0.05							--	†
	0.10							1.448	†
									†
10.0	0.00							--	†
	0.05							1.414	†
	0.10							--	†

* From GEBLA and DP-1014

Reference: SNM-1097

TABLE 4-6
HANSEN-ROACH CROSS-SECTION KINF CALCULATIONS*
(HOMOGENEOUS - $U(5.0)O_2$ + H_2O - MIXTURES)

U-238 Mat. ID	K-INFINITES W/F=1.0	W/F=2.0	W/F=3.0	W/F=4.0	W/F=5.0	W/F=6.0	W/F=8.0	W/F=10.0
92840	.....	.....	.....	.....	.....	.....	.....	.....
92839	.....	.....	.....	.....	.....	.....	.....	
92838	.....	.....	.....	.....	.....	.....	.....	
92837	.....	.....	.....	.....	.....	.....	.....	
92836	.....	.....	.....	.....	.....	.....		
92835	.....	.....	.....	.....	.....	.....		
92834	.....	.....	.....	.....	.....			
92833	.....	.....	.....	.....	.....			
92832	.....	.....	.....	.....				
92831	.....	.....	.....	.....				
92830	.....	.....	.....	.....				
92829	.....	.....	.....					
92828	.....	.....	.....					
92827	.....	.....	.....					
92826	.....	.....						
92825	.....	.....						
92824	.....	.....						
92823	.....							
92822	.....							
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92814								
92813								
92812								
92811								
92810								
92809								
92808								
92807								
92806								
92805								
92804								
92803								
92802								
92801								

*GE developed based on exact infinite neutron multiplication factor calculations using 16 group Hansen-Roach cross section sets.

Reference: SNM-1097

4-6 which show Kinf values for the corresponding homogeneous Hansen-Roach Cross Section Sets but with the specified U_{238} Material ID. (The values in this table were computed directly from the fission and absorption cross section values, transfer coefficients and fission spectrum for the specified cross section set).

Because the Hansen Roach Cross Sections Sets for heterogeneous UO_2 and water mixtures were determined as specified above, the bias associated with GEKENO with these cross section sets is the same as that generally applicable to GEMER, that is, -0.01.

Also included in Table 4-5 are the Kinf values from Table 4-3 which are used in Reactivity Formula calculations for heterogeneous systems. Since the maximum Kinf in this data, 1.540, is greater than the corresponding GEMER value, by more than 0.003 (which is the magnitude of the assigned GEMER bias as discussed in Section 4.1.6) this bias assigned to the Reactivity Formula with these heterogeneous parameters is 0.00. This only applies to the optimum case, however, and applications for other conditions will require a bias evaluation based on Table 4-6. The range of values which may be applicable in such cases is 0.00 to -0.03. †

4.1.10 Equipment Interaction

Criticality safety of interacting equipment, assemblies and systems is determined in several ways. These include:

4.1.10.1 Use of GEMER or GEKENO Monte Carlo Codes for Keff or Kinf calculations for interacting systems.

4.1.10.2 Use of solid angle code (SAC) for equipment interaction evaluation.

4.1.10.3 Use of isolation by distance (12 feet or the orthographic projection, whichever is greater).

4.1.10.4 Use of neutron absorber panels to isolate vessels and equipment.

4.1.10.5 Disciplined layout of process piping.

4.2 UPMP SAFE GEOMETRIES & SAFE BATCH LIMITS

Equipment in UPMP used to process or store uranium compounds is considered to be geometrically safe if it retains the process material within the dimensional limitations of Tables 4-7 or 4-8 under normal and forseeable abnormal process or environmental conditions and provided that it is separated by at least 12 inches from concrete walls or other significant reflectors. These tables especially apply to equipment for which the assumption of reflection by 12 inches of water is conservative.

For cylinders and slabs which are not infinite in extent, the dimensional limitations of Tables 4-7 or 4-8 may be increased by means of standard buckling conversion methods or reactivity formula calculations incorporating the Kinf, M^2 and λ values in the applicable Table 4-2 or 4-3.

In addition to geometry control, criticality safety in selected UPMP equipment and operations is based upon uranium mass limits. Normally this mass limit is based upon a safe batch which is defined to be 45% of the minimum critical mass taking into consideration the geometry of the equipment and the enrichment and form of the fissile material. Table 4-9 lists safe batch limits for homogeneous mixtures of UO_2 and water in uncontrolled geometries as a function of U_{235} enrichment over the range of 1.1% to 15.0%. Safe batch limits for specified geometries are discussed in subsequent sections of this document (especially Sections 4.5 and 4.6).

4.3 CRITICALITY SAFETY OF UPMP CYLINDRICAL PROCESSING VESSELS

In Table 4-7, the safe geometry cylindrical diameter for homogeneous UO_2 and water mixtures is specified to be 9.5 inches. This value is applicable to cylindrical vessels of any height and constructed of any material provided that the material of construction does not reflect neutrons more effectively than a tight fitting 12 inch thick layer of water. Since materials of

TABLE 4-7
SAFE GEOMETRY VALUES
FOR HOMOGENEOUS UO_2-H_2O MIXTURES[1]

Nominal Weight Percent U-235	Infinite Cylinders Diameter Inches	Infinite Slabs Thickness, Inches	Spheres Volume, Liters
2.00	16.7	8.9	105
2.25	14.9	7.9	75.5
2.50	13.75	7.2	61
2.75	12.9	6.65	51
3.00	12.35	6.25	44
3.25	11.7	5.9	38.5
3.50	11.2	5.6	34
3.75	10.8	5.3	31
4.00	10.5	5.1	29
5.00	9.5	4.45	24
6.00	8.95	4.00	18.5
7.00	8.45	3.75	17.0

[1] For enrichment not specified in this table, smooth curve interpolation may be used.

TABLE 4-8
SAFE GEOMETRY VALUES
FOR HETEROGENEOUS MIXTURES OR COMPOUNDS[1]

Nominal Weight Percent U-235	Infinite Cylinders Diameter Inches	Infinite Slabs Thickness, Inches	Spheres Volume, Liters
2.00	11.1	5.6	35.7
2.25	10.5	5.1	30.7
2.50	10.1	4.8	27.3
2.75	9.7	4.6	24.7
3.00	9.4	4.4	22.6
3.25	9.2	4.3	20.9
3.50	9.0	4.2	19.2
3.75	8.9	4.1	18.2
4.00	8.8	4.0	16.9
5.00	8.3	3.6	13.0
6.00	7.9	3.5	11.0
7.00	7.4	--	7.6

[1] For enrichment not specified in this table, smooth curve interpolation of values may be used.

Reference: SNM-1097

TABLE 4-9
SAFE BATCH LIMITS FOR UO_2 & H_2O
(Kgs UO_2)

Nominal Weight Percent U_{235}	UO_2 Powder[1]	UO_2 Pellets[2]	Nominal Weight Percent U_{235}	UO_2 Powder[1]	UO_2 Pellets[2]
1.1	2629	510	3.4	34.6	31.0
1.2	1391	341	3.6	31.1	28.5
1.3	833	246	3.8	28.3	26.4
1.4	583	193	4.0	25.7	24.7
1.5	404	158	4.2	23.7	22.9
1.6	293.3	135	4.4	21.9	21.4
1.7	225.0	116	4.6	20.2	20.0
1.8	183.0	102	4.8	19.1	18.8
1.9	150.6	90.5	5.0	18.1	18.1
2.0	127.5	81.6	5.5	15.4	15.4
2.1	109.2	73.1	6.0	13.8	13.8
2.2	96.8	66.4	7.0	8.3	8.3
2.3	84.3	61.0	8.0	6.9	6.9
2.4	74.7	56.1	9.0	5.9	5.9
2.5	68.9	52.1	10	5.1	5.1
2.6	60.5	48.8	11	4.4	4.4
2.7	56.6	45.4	12	3.9	3.9
2.8	52.2	42.9	13	3.5	3.5
2.9	47.6	40.1	14	3.3	3.3
3.0	44.5	38.1	15	3.0	3.0
3.2	38.9	34.1			

[1] Homogeneous Mixtures
[2] Heterogeneous Mixtures

NOTE: For enrichments not specified above, smooth curve interpolation of safe batch values may be used.

Reference: SNM-1097

construction can in many cases actually reduce neutron reflection, a criticality safety evaluation has been performed for selected standard construction materials to evaluate their applicability to UPMP cylindrical processing vessels. The conditions or materials considered were:

- None (For comparison with the 9.5 inch in diameter in Table 4-7)
- Stainless Steel 304 Walls
- Carbon Steel Walls
- PVC Walls

This evaluation consisted of four sets of GEKENO calculations using JRK Modified Hansen Roach Cross Sections for infinite cylinders with standard gauge wall thicknesses. For processing and criticality safety considerations, only 10 inch cylinders were included and the geometries analyzed were restricted to Schedules 10, 20, 40, and 80. These correspond to the dimensions tabulated in Table 4-10. (Schedule 5 and 80S are shown for comparison only). The actual GEKENO geometry model used consisted of two concentric cylinders with dimensions appropriate for the inner diameter and wall thickness, respectively, enclosed in cuboid water reflector whose X and Y dimensions were at least 24 inches greater than 10.75 inches. The axial (i.e. "Z") dimensions of the concentric cylinders and cuboid were all 200 cm and J=O bounding conditions were applied at the top and bottom. Mixture and material specifications were taken to be the following:

- Fuel - Full density homogeneous UO_2 and water mixtures as defined in Section 4.1.7.
- Stainless Steel 304 - KENO/Hansen Roach Cross Section Set No. 200 with a (GEKENO Input) density of 1.00.
- Carbon Steel - KENO/Hansen Roach Cross Section Set No. 100 with a (GEKENO Input) density of 1.00.

Reference: SNM-1097

TABLE 4-10
DIMENSIONS OF 10" DIAMETER,
SEAMLESS & WELDED PIPE*

Schedule	Outside Diameter (Inches)	Thickness (Inches)	Inside Diameter (Inches)
5	10.75	0.134	10.482
10	10.75	0.165	10.420
20	10.75	0.250	10.250
40	10.75	0.365	10.020
80	10.75	0.593	9.564
80S	10.75	0.500	9.750

*From ARH-600, Page II.A.2-6.

Reference: SNM-1097

- PVC - Materials and densities specified in Table II. F.1 of ARH-600 (Hydrogen = Hansen-Roach Cross Section Set No. 1102)

- Water Reflector - KENO/Hansen Roach Cross Section Set No. 502 with a (GEKENO Input) density of 1.00.

The results of the GEKENO calculations for the four cases are shown in Tables 4-11 through 4-14. These can be summarized as follows:

4.3.1 The maximum Keff ± σ calculated with GEKENO for a 9.5 inch bare infinite cylinder (which is a safe geometry as specified in Table 4-7) is only This † is an indication of the conservatism inherent in the use of GEKENO and Hansen Roach Cross Section Sets in this application.

4.3.2 For the three materials of construction considered in the analysis, the geometrically safe cylindrical diameter is significantly greater than the 9.5 inch Safe Geometry Value. These dimensions are:

- For Stainless Steel 304, Inch Schedule † inch ID) †

- For Carbon Steel, Inch Schedule inch † ID)

- For PVC, Inch Schedule inch ID) †

4.4 UPMP FIXED NEUTRON ABSORBER PANELS

Preliminary UPMP process design reviews have stressed the need for geometry control in criticality safety in addition to the use of historically-acceptable density or mass controls. Therefore, the UPMP design utilizes neutron absorber panels as a form of geometry control to be employed in addition to density and mass controls.

UPMP fixed neutron absorber panels are fixed in a † matrix of encased in † The absorber panels are affixed to and part of the chemical vessel structures. Inasmuch as their typical weights range from lbs, they are not † subject to movement or removal.

TABLE 4-11
GEKENO Keff VALUES FOR BARE INFINITE CYLINDERS
(Homogeneous $U(5.0)O_2$ + H_2O Mixtures)

Infinite Cylinders	WF H_2O	Keff ± σ
9.0" in Diameter	0.1	†
	0.2	†
	0.25	†
	0.3	†
	0.4	†
	0.5	†
9.5" in Diameter	0.1	†
	0.2	†
	0.25	†
	0.3	†
	0.4	†
	0.5	†
10.0" in Diameter	0.1	†
	0.2	†
	0.25	†
	0.3	†
	0.4	†
	0.5	†
10.5" in Diameter	0.1	†
	0.2	†
	0.25	†
	0.3	†
	0.4	†
	0.5	†

Reference: SNM-1097

TABLE 4-12
GEKENO Keff VALUES FOR
SS-304 INFINITE CYLINDERS
(Homogeneous $U(5.0)O_2$ + H_2O Mixtures)

Infinite Cylinders	WF H_2O	Keff	±	σ	
10.0" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†

Reference: SNM-1097

TABLE 4-13
GEKENO Keff VALUES FOR CARBON STEEL INFINITE CYLINDERS
(Homogeneous $U(5.0)O_2 + H_2O$ Mixtures)

Infinite Cylinders	WF H_2O	Keff	±	σ	
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†

TABLE 4-14
GEKENO Keff VALUES FOR
PVC INFINITE CYLINDERS
(Homogeneous $U(5.0)O_2 + H_2O$ Mixtures)

Infinite Cylinders	WF H_2O	Keff	±	σ	
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†
10" Schedule	0.1				†
	0.2				†
	0.25				†
	0.3				†
	0.4				†
	0.5				†

An extensive quality assurance plan is employed to certify the proper fabrication of the panels, to verify the presence of neutron absorbers in them, and to assure their proper installation.

was selected as the matrix material † because of ease of fabrication and desirable nuclear properties

Since the neutron absorber panels are encased in they have adequate fire resistance † against credible fire hazards in the facility.

Continued effectiveness of the neutron absorber panels is assured via the tank designs, †

4.5 CRITICALITY SAFETY OF UPMP PROCESSING VESSELS

Because of large throughput volumes and high flow rates, scrap and waste processing in WMD fuel manufacturing operations require large process and storage vessels. In the Uranium Process Management Project, this need has been satisfied while at the same time complying with the requirement for criticality safety by geometry control through the use of large diameter tanks with † neutron absorber panels. † Figure 4-2 shows a typical example. There are such † vessels in the UPMP facility; of these, the † dissolvers, are designed for heterogeneous † UO_2 and water mixtures. The remaining † vessels are designed for homogeneous UO_2 and water mixtures as based upon the following criticality safety analysis.

4.5.1 Vessel Descriptions

UPMP operations with processing vessels are † described in detail in Sections 2.1 through 2.4 and 3.1. In general, these vessels are inch thick † tanks with of inches and † heights of feet. The vessels are shielded † neutronically by † neutron absorber panels which are †

Reference: SNM-1097

FIGURE 4-2
UPMP VESSEL DESIGN

Reference: SNM-1097

inches thick and about inches longer than the tanks. The neutron absorber panels are spaced from inches away from the tank and are designed both to maximize the of the tank and minimize the neutron interaction with nearby equipment †

Tables 4-15 and 4-16 present a detailed description of the vessels and their associated neutron absorber panels for each of the vessels. †

4.5.2 Neutron Absorber Panels

The vessel neutron absorber panels have been designed to be stable fixed in a high density matrix. Table 4-17 lists the specifications for this material. Each panel is completely encased in gauge †

4.5.3 Analytical Methods

The effectiveness of the neutron absorber panels described in the previous section has been analyzed using the GEKENO Monte Carlo Code with JRK modified Hansen-Roach cross section sets. This analysis consisted of sets of calculations of the neutron multiplication factors for representative geometries as illustrated in Figure 4-3 with three different for the tanks and neutron absorber panels. The of the tanks were inches and were selected to conservatively span the range of geometries specified in Tables 4-15 and 4-16. Figures 4-4, 4-5 and 4-6 show the detailed dimensions of the vessels that were used in the geometry models. Reflection was modelled on the top and bottom of the tank by a tight-fitting 12 inch water reflector as shown in Figure 4-7. †

Materials of construction and fuel mixtures were also modelled conservatively. These were taken to be:

Fuel: Full density homogeneous UO_2 and water mixtures (as discussed in Section 4.1.7).

Steel: (GEKENO mixture No. 200 with a "mixture density" of 1.0).

TABLE 4-15
VESSEL DESCRIPTIONS

Vessel ID	Vessel Description	Vessel Geometry[1] Height (In)	Volume (Gallons)	Neutron Absorber Panel	
1.	Tank		500	IA	IIA
2.	Tank		500	IA	IIA
3.	Tank		500	IA	IIA
4.	Tank		600	IB	IIB
5.	Tank		600	IB	IIB
6.	Tank		600	IB	IIB
7.	Tank		600	IB	IIB
8.	Tank		600	IB	IIB
9.	Tank		500	IA	IIA
10.	Tank		500	IA	IIA
11.	Tank		600	IB	IIB
12.	Tank		600	IB	IIB
13.	Tank		600	IB	IIB
14.	Tank		500	IA	IIA
15.	Tank		500	IA	IIA
16.	Tank		600	IB	IIB
17.	Tank		600	IB	IIB
18.	Tank		750	IC	IIC
19.	Tank		750	IC	IIC
20.	Tank		600	IB	IIB
21.	Tank		600	IB	IIB
22.	Tank		750	IC	IIC
23.	Tank		750	IC	IIC
24.	Tank		500	IA	IIA
25.	Column		375	IE	IIE
26.	Column		375	IE	IIE
27.	Column		375	IE	IIE

[1] SS-304 L walls, 3/8 inch thick walls except as noted
[2] See Table 4-16
[3] 5/8 inch thick walls

TABLE 4-16
GEOMETRY DESCRIPTION OF NEUTRON ABSORBER PANEL

Designation	Type	(Inches)	(Inches)	Height (Inches)	Number of Panels
I.A					
B					
C					
D					
E					
II.A					
B					
C					
D					
E					

TABLE 4-17
NEUTRON ABSORBER PANEL COMPOSITION

A. Minimum Panel Density

B. Chemical Constituents — Composition Range (%)

C. Elemental Constituents

Element - Atomic Mass — Composition Range (%)

D. Densities Of Constituents — Density Range (grams/cm^3)

Reference: SNM-1097

FIGURE 4-3
STORAGE TANK GEOMETRY MODEL

FIGURE 4-4
VESSEL MODEL

FIGURE 4-5
VESSEL MODEL

FIGURE 4-6
VESSEL MODEL

Reference: SNM-1097

FIGURE 4-7
MODEL

Reference: SNM-1097

Mixture specification in Table 4-18. †

Water reflector: Full density water (GEKENO Mixture No. 502 with a "mixture density" of 1.0).

The calculations performed in this analysis were the following:

4.5.3.1 For each of the vessel models, the effective neutron multiplication factors for single water reflected vessels with "normal case" fuel densities of 100, 250, 400 and 750 gm U/l. †

4.5.3.2 For each of the vessel models, the effective neutron multiplication factors for single water reflected vessels with fuel mixtures ranging from 0.10 to 0.50 weight fraction of water. (This range includes optimum moderation and establishes that the vessels are geometrically safe). †

4.5.3.3 The effective neutron multiplication factor for a "damaged" worst case vessel which has lost its neutron absorber panels but which is still in conformance with its density control (assumed to be gm U/l). The worst case vessel determined by 2 above was found to be the inch model, however, differences between models were not significant. † † † † †

4.5.3.4 The effective neutron multiplication factors for the damaged inch geometry model with fixed masses of uranium (100 Kg, 250 Kg, 500 Kg and 1,000 Kg) and with varying weight fractions of water. The geometry model in this case assumed that the fuel mixture filled the tank from the bottom up to a height equivalent to the U mass content and the rest of the tank is filled with water. These results permit the determination of the minimum critical mass for the vessels under accident conditions in which the neutron absorber panels are lost. †

4.5.3.5 The infinite neutron multiplication factor for a planer array of undamaged inch geometry model vessels with its most reactive fuel mixture and with a 16 inch concrete reflector on the bottom. (The top reflector is †

TABLE 4-18
MIXTURE SPECIFICATIONS
FOR GEKENO

Reference: SNM-1097

the same 12 inch water reflector). The J=0 reflector boundary condition was placed at the † neutron absorber panel surface and † the region outside of the panel was assumed to contain various levels of interspersed water. These calculations thus establish that interaction between vessels (by virtue of the neutron † absorber panels) does not lead to a critically unsafe condition.

4.5.3.6 The effective neutron multiplication factor for a single undamaged inch geometry model with its most † reactive fuel mixture and with various levels of interspersed water in the air gaps between the tank and neutron absorber panels. These † calculations establish criticality safety of credible upsets that could lead to such conditions.

4.5.4 Results

The results of the calculations described in the previous section are listed in Tables 4-19 through 4-23. These are summarized as follows:

4.5.4.1 The maximum neutron multiplication factor for normal case operations with undamaged vessel (i.e., neutron absorber panels intact) and density control (of no more than gm U/l as discussed in Chapter 2) is † This value is in conformance with the 0.90 † limit specified in Section 4.1.5.1. The data in Table 4-19 also shows no significant dependence on the geometry model †

4.5.4.2 The maximum neutron multiplication factor for optimum moderation fuel mixtures in undamaged vessels is and occurs for a 0.25 WF H_2O fuel † mixture in the inch geometry model case. The † value is within the 0.97 limit specified in Section 4.1.5.2 and consequently the process vesssels † are geometrically safe for homogeneous UO_2 and water mixtures. This has been verified by a calculation performed with the GEMER Monte Carlo code using the 52 inch geometry model and the same materials and † densities as for the WF H_2O = 0.25 case. The GEMER result is a Keff of is compared to the † GEKENO value of in Table 4-20. †

Reference: SNM-1097

TABLE 4-19
VESSEL CALCULATION RESULTS
FOR NORMAL CONDITIONS

Geometry Model (Inches)	Fuel Mixture U Density (grams/liter)	GEKENO Keff ± σ
	100	
	250	
	400	
	750	
	100	
	250	
	400	
	750	
	100	
	250	
	400	
	750	

Reference: SNM-1097

TABLE 4-20
VESSEL CALCULATION RESULTS
FOR OPTIMALLY MODERATED FUEL MIXTURES

Geometry Model (Inches)	Fuel WF H_2O	GEKENO Keff ± σ
	0.10	
	0.20	
	0.25	
	0.30	
	0.40	
	0.50	
	0.10	
	0.20	
	0.25	
	0.30	
	0.40	
	0.50	
	0.10	
	0.20	
	0.25	
	0.30	
	0.40	
	0.50	

Reference: SNM-1097

TABLE 4-21
VESSEL CALCULATION RESULTS
FOR ACCIDENTS INVOLVING
LOSS OF NEUTRON ABSORBER PANELS

	Geometry Model inches	Fuel Mixture U Density, (grams/Liter)	Fuel WF H_2O	U Mass Kg	GEKENO Keff ± σ
A. DENSITY CONTROL RESULTS		250			†
B. MASS CONTROL RESULTS			0.25	100	†
				250	†
				500	†
				1000	†
			0.30	100	†
				250	†
				500	†
				1000	†
			0.40	100	†
				250	†
				500	†
				1000	†
			0.50	100	†
				250	†
				500	†
				1000	†
			0.60	100	†
				250	†
				500	†
				1000	†

Reference: SNM-1097

FIGURE 4-8
TANK CRITICAL MASS VARIATION
WITH H_2O WEIGHT FRACTION

Reference: SNM-1097

TABLE 4-22
VESSEL CALCULATION RESULTS
FOR INFINITE PLANAR ARRAYS

Geometry Model (Inches)	Fuel WF H_2O	Interstitial H_2O	GEKENO Kinf ± σ
	25	0.00	
		0.01	
		0.05	
		0.10	

TABLE 4-23
VESSEL CALCULATION RESULTS
FOR ACCIDENTS RESULTING IN
INTERSPERSED WATER IN AIR GAPS

Geometry Model (Inches)	Fuel WF H_2O	Panel Gap H_2O Density (gm/cm^3)	GEKENO Keff ± σ
	0.25	0.00	
		0.05	
		0.10	
		0.20	
		0.50	
		1.00	

Reference: SNM-1097

4.5.4.3 As in the results for the normal case, no significant dependence on geometry model is evidenced by the optimally moderated data. Accident condition cases considered in the remaining part of the analysis have utilized only the inch (or in some cases, inch) model. †

4.5.4.4 The effective neutron multiplication factors shown in Table 4-21 for the damaged inch vessel can be extrapolated to yield a conservative estimate of the minimum critical mass in the vessel under the assumption that the neutron absorber panels have failed. Using a criteria of Keff + 3σ = 0.95, these extrapolated values have been plotted in Figure 4-8 and indicate a minimum critical mass of kg of uranium. The 45% safe batch value is thus kg of uranium. †

4.5.4.5 The neutron multiplication factor for an infinite planar array of undamaged inch vessels with no interstitial water is 0.9578 ± 0.0029. This is an increase of about 2% over the Keff value for a fully reflected tank and signifies negligible interaction between tanks especially when compared to the Kinf of 1.4722 ± 0.0026 for a homogeneous UO_2 + 0.25 WF H_2O mixture. The results in Table 4.22 also indicate a slight spectral effect for gms/cm^3 of interstitial water. In this case, the Kinf + 3σ value is still less than 1.0. †

4.5.4.6 Table 4-23 shows that a single undamaged process vessel with an optimally moderated fuel mixture remains critically safe for interspersed water in the up to gm/cm^3. Since the gaps between the vessels and neutron absorber panels are water in excess of this level is incredible. In addition, the fixtures provided for holding the neutron absorber panels in place also prevent interspersed water in the gaps. †

In summary, the calculations described in the above sections have established that the processing vessels with neutron absorber panels comply with the requirements listed in Section 4.1.5 for both normal and specified accident conditions and hence are geometrically safe. The specified accident conditions considered were loss of neutron absorber panels and †

Reference: SNM-1097

presence of interspersed water in the air gap between the tank and neutron absorber panels. Loss of † geometry (other than the neutron absorber panels) has not been discussed in this section (it is addressed in the applicable parts of Chapters 2 and 3) because criticality safety in such cases is based upon density or mass controls.

4.6 CRITICALITY SAFETY OF UPMP DISSOLVER & LEACHING VESSELS

UPMP scrap processing operations employ different † types of dissolving vessels depending on the nature of the material being processed. Oxidized high grade scrap (UO_2 hard scrap, powder or high grade sludge) is processed in kg batches in dissolvers. Low grade scrap (predominantly incinerator † ash and oxidized low grade sludges) is processed in inch Schedule cylindrical leachers. † Low grade scrap leaching operations are limited to † individual batches of one three or five gallon pail at a time with a uranium content of less than one safe batch (18.1 kg UO_2). Because dissolver and leacher operations can potentially involve oxidized hard scrap, † these vessels have been designed to be geometrically safe for heterogeneous lattices of UO_2 in water. These heterogeneous lattices have been very conservatively assumed to be square lattices of (infinite) rods in water with optimum rod diameters and water to fuel (W/F) volume ratios. The applicable criticality safety analyses are contained in the following two sections.

4.6.1 Dissolvers

The UPMP dissolvers are large † vessels with neutron absorber † panels similiar to the design shown in Figure 4-2. The design and form of the neutron absorber panels are the same as those in the processing vessels (as † specified in Table 4-17) and comply with the same quality and operational considerations as discussed in Section 4.4. The key differences between the † processing vessels and dissolvers are the † dissolver geometry, analytical methods and material contents.

4.6.1.1 Dissolver Geometry

Table 4-24 describes the important geometrical features of the dissolvers. The significant difference † from the geometry for processing vessels is † that the latter have an † inches as compared to inches for the † dissolvers.

4.6.1.2 Analytical Methods

4.6.1.2.1 Geometry Model

Figures 4-9, 4-10, and 4-11 show the geometry model used in this criticality safety analysis of the † dissolvers. As in the case of the criticality safety analysis of processing vessels, key geometric † dimensions have been conservatively adjusted to reflect fabrication tolerances and, where applicable, corrosion allowances.

4.6.1.2.2 Fuel Mixtures

dissolvers will be used in operations with † oxidized sludge, powder, and pellets predominantly in the form of U_3O_8 powder. Since the potential exists for heterogeneity due to particle size effects, the † dissolvers have been analyzed for the case of optimum lattices of UO_2 rods in water. (This is overly conservative and is subject to future revision based on particle size studies in oxidized scrap.) Since modelling of rod lattices in vessels is not † practicable with the current version of the GEMER Monte Carlo Code, this analysis has been performed with GEKENO using the heterogeneous cross section sets discussed in Section 4.1.9.2. All other material specifications are the same as those described in Section 4.5.3 for (homogeneous) processing vessels. †

Although the GEMER Monte Carlo Code is not directly applicable to the dissolver criticality safety † analysis, it has been used to validate GEKENO with the heterogeneous Hansen-Roach cross section sets. This has been done by performing comparison calculations with GEKENO and GEMER for infinite planar slabs of UO_2 rod lattices in water with metal thicknesses, air gaps and neutron absorber panels †

TABLE 4-24
DISSOLVER DESCRIPTION †

Vessel Number:		†
Vessel Height:	Inches	†
	Inches	†
	Inches	†
Vessel Wall Thickess:	Inches	†
Vessel Volume:	Gallons	
Neutron Absorber Panel Types		† †

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*See Table 4-16

Reference: SNM-1097

FIGURE 4-9
STORAGE TANK GEOMETRY MODEL

Reference: SNM-1097

FIGURE 4-10
VESSEL MODEL
FOR DISSOLVER

FIGURE 4-11
GEOMETRY MODEL
FOR DISSOLVER

sides) representative of the dissolver geometry. The GEMER calculations were performed for a lattice of 0.35 inch in diameter UO_2 rods in water with W/F volume ratio of 3.0 and the GEKENO calculations were performed using the heterogeneous UO_2 and water cross section set for the same W/F volume ratio. The volume ratio was selected for these comparisons because it is closest to optimum. Table 4-25 contains the results of this comparison study and indicates no significant bias of GEKENO relative to GEMER.

4.6.1.2.3 Description of Dissolver Calculations

The calculations performed in this analysis were the following:

4.6.1.2.3.1 The effective neutron multiplication factor for a single water reflected dissolver, with fuel-water mixtures ranging from water to fuel volume ratios of 1.0 to 6.0. This range spans optimum moderation conditions and establishes that the dissolvers are geometrically safe for heterogeneous UO_2 in water.

4.6.1.2.3.2 The effective neutron multiplication factor for a single dissolver which has lost its neutron absorber panels and which contains uranium masses of 100 kg, 250 kg, 500 kg, and 1,000 kg. The results of these calculations permit the determination of the minimum critical mass for the dissolvers under accident conditions which compromise the integrity of the neutron absorber panels.

4.6.1.2.3.3 The infinite neutron multiplication factor for a planar array of undamaged dissolvers with the most reactive (heterogeneous) fuel mixture and with a 16 inch concrete reflector on the bottom. (The top reflector is the same 12 inch water reflector as for the two previous cases). The J=0 reflector boundary condition was placed at the neutron absorber panel surface and the region outside of the panel was assumed to have various levels of interspersed water. This set of calculations was performed to establish that interaction between dissolvers and other processing vessels does not lead to a critically unsafe condition.

TABLE 4-25
VALIDATION OF GEKENO HETEROGENEOUS CROSS SECTION SETS †

W/F Volume Ratio	Slab Thickness (Inches)	GEKENO Keff ± σ	GEMER * Keff ± σ	
3.0	4.3			†
	5.0			†
	5.6			†

*0.35 Inch in Diameter $U(5.0)O_2$ Rods

Reference: SNM-1097

4.6.1.2.3.4 The effective neutron multiplication factor for a single undamaged dissolver with its most reactive (heterogeneous) fuel mixture and with various levels of interspersed water in the air gaps between the tank and neutron absorber panels. †

4.6.1.3 Results

The results of the calculations described in the previous section are listed in Tables 4-26 through 4-29. These are summarized as follows:

4.6.1.3.1 dissolvers with neutron absorber panels are geometrically safe for heterogeneous UO_2 mixtures, with a maximum GEKENO result (in Table 4-26) of †

4.6.1.3.2 Figure 4-12 shows a plot of the results in Table 4-27 extrapolated for uranium masses corresponding to a Keff + 3 σ = 0.95 value. From this figure, the minimum critical (heterogeneous) mass in the † dissolvers under accident conditions in which the neutron absorber panels are compromised is in excess of kg of uranium. †

4.6.1.3.3 As shown in Table 4-28, the maximum GEKENO neutron multiplication factor for an infinite planar array of dissolvers with the most reactive † (heterogeneous) fuel mixture is † Infinite planar arrays are thus critically safe. In addition, this result, along with those in .1 and .2 above are less than the corresponding values for processing vessels and hence the † dissolvers can be replaced by processing † vessels in UPMP facility interaction analyses.

4.6.1.3.4 The results in Table 4-29 show that the Keff for dissolvers with full density water in the air † gaps between the tank and neutron absorber † panels is only increased by † and the dissolvers are still † critically safe under this condition.

In summary, dissolvers are geometrically safe † vessels (for UO_2 rod lattices in water) and are less

Reference: SNM-1097

TABLE 4-26
DISSOLVER CALCULATION RESULTS
FOR OPTIMALLY MODERATED FUEL MIXTURES

W/F Volume Ratio	GEKENO Keff ± σ	
1.0		†
2.0		†
3.0		†
4.0		†
5.0		†
6.0		†

TABLE 4-27
DISSOLVER CALCULATION RESULTS
FOR LOSS OF NEUTRON ABSORBER PANEL CONDITIONS
WITH MASS CONTROL

W/F Volume Ratio	U Mass Kg	GEKENO Keff ± σ	
3.0	100		†
	250		†
	500		†
	1000		†
4.0	100		†
	250		†
	500		†
	1000		†
5.0	100		†
	250		†
	500		†
	1000		†
6.0	100		†
	250		†
	500		†
	1000		†

Reference: SNM-1097

TABLE 4-28
DISSOLVER CALCULATION RESULTS
FOR INFINITE PLANAR ARRAYS

W/F Volume Ratio	Interstitial H_2O	GEKENO Keff ± σ	
3.0	0.00		†
	0.01		†
	0.05		†
	0.10		†

TABLE 4-29
DISSOLVER CALCULATION RESULTS
FOR ACCIDENTS RESULTING IN
INTERSPERSED WATER IN AIR GAPS

W/F Volume Ratio	Panel Gap H^2O Density (gm/cm^3)	GEKENO Keff ± σ	
3.0	0.00		†
	0.05		†
	0.10		†
	0.20		†
	0.50		†
	1.00		†

Reference: SNM-1097

FIGURE 4-12
DISSOLVER TANK
CRITICAL URANIUM MASS VARIATION WITH W/F

Reference: SNM-1097

reactive than processing vessels under similiar conditions. †

4.6.2 Leachers

A comparison of Tables 4-4, 4-5, and 4-12 indicates that inch Schedule Stainless Steel 304 infinite † cylinders are geometrically safe for heterogeneous UO_2 rod lattices in water. This is demonstrated in the following sections and is the basis for the design of the leachers in the UPMP scrap processing † operations.

4.6.2.1 Geometry Description

Table 4-30 shows geometry specifications for optimum UO_2 rod lattices in water and inch Schedule † cylinders.

4.6.2.2 Analytical Methods

This criticality safety analysis has been performed with the GEMER and GEKENO Monte Carlo Codes and the reactivity formula with the heterogeneous mixture parameters in Table 4-3. The GEMER calculations were performed for cases with W/F volume ratios of 1.0 to 6.0 with explicit modelling of rod lattices in the leacher. Figure 4-13 shows a plot of the GEMER Geometry Model for the W/F volume ratio = 3.0 case. GEKENO calculations were performed for W/F volume ratios of 1.0 to 10.0 using the heterogeneous Hansen-Roach Cross Sections discussed Section 4.1.9.2. The Reactivity Formula calculations were performed for geometrically unrestricted safe batches (18.1 kg UO_2). Full water reflection was assumed in all cases.

4.6.2.3 Results

Table 4-31 shows the results of these calculations. The maximum neutron multiplication factor calculated with GEMER is and occurs for a W/F volume † ratio of 3.0. Since the radius of the inch † Schedule cylinder is cm, the safe batch † results with the reactivity formula and the Keff values from GEKENO imply that under safe batch controls, the Keff of the 10 inch Schedule stainless steel 304 †

Reference: SNM-1097

TABLE 4-30
GEOMETRY SPECIFICATIONS
FOR SCHEDULE INFINITE CYLINDERS †

A. Rod Lattice Parameters:

W/F Volume Ratio	Optimum Rod Diameter* (Inches)	Lattice Spacing (Inches)
1.0	1.10	1.378646
2.0	0.50	0.767495
3.0	0.30	0.531736
4.0	0.20	0.396333
5.0	0.20	0.434161
6.0	0.20	0.468947

B. Inch Schedule Cylinder Parameters: †

OD	Inches	†
Wall Thickness	Inches	†
ID	Inches (Radius = cm)	†

* Reference Table 4-5

Reference: SNM-1097

FIGURE 4-13
GEMER GEOMETRY MODEL
FOR LEACHERS

Reference: SNM-1097

TABLE 4-31
SCHEDULE LEACHER †
CALCULATIONAL RESULTS

A. Infinite Cylinder Results:

W/F Volume Ratio	GEMER Keff ± σ	GEKENO Keff ± σ	
1.0			†
2.0			†
3.0			†
4.0			†
5.0			†
6.0			†
8.0			†
10.0			†

B. Safe Batch Results:

W/F Volume Ratio	Safe Batch* Radius (cm)	Reactivity Formula Keff	
1.0		0.675	†
2.0			†
3.0			†
4.0			†
5.0			†
6.0			†
8.0		0.898	†
10.0		0.906	†
12.0		0.898	†
14.0		0.888	†

*18.1 Kg $U(5.0)O_2$

Reference: SNM-1097

cylinder is less than 0.90. It is therefore concluded that the inch Schedule stainless steel 304 † cylinder is geometrically safe for UO_2 rod lattices in water.

4.7 CRITICALITY SAFETY OF UPMP SOLVENT EXTRACTION COLUMNS

Scrap processing operations in the Uranium Process Management Project employ solvent extraction † (SX) columns to recover purified uranium in the form of uranyl nitrate hexahydrate (UNH) from digest feed material with potential metallic impurities or neutron poisons (such as boron, gadolinium or cadmium). These SX columns have been designed to be geometrically safe for homogeneous mixtures of UO_2 and water based upon the following analysis.

4.7.1 Solvent Extraction Column Geometry

Figure 4-14 shows an illustration of the most reactive SX column design. The vessel consists of a foot † high inch Schedule cylindrical pipe connected † on each end by a large disengaging section. † These sections have an † transition section from the inch cylindrical pipe to a final cylindrical tank inches high, inches in diameter and inches † thick. The disengaging sections are not † neutronically isolated by use of neutron absorber panels and rely only on their geometrical dimensions and stainless steel walls for geometric safety. The upper disengaging section has vent holes (not † shown in Figure 4-14) at the bottom of the transition piece which permit complete † drainage in the event of leakage.

4.7.2 Analytical Methods

The generic SX Model depicted in Figure 4-14 has been analyzed using the GEKENO Monte Carlo Code and homogeneous UO_2 and water Hansen-Roach Cross Sections. Figure 4-15 shows the geometry model and materials used in this analysis. The transition piece in † this configuration was modelled with the GEKENO generalized geometry option and the remaining parts were modelled with regular geometry.

FIGURE 4-14
GENERIC SOLVENT EXTRACTION MODEL

Reference: SNM-1097

FIGURE 4-15
SOLVENT EXTRACTION UNIT GEOMETRY MODEL

4.7.3 Results

For this analysis, GEKENO calculations were performed for the water reflected SX column as shown in Figure 4-15 for homogeneous UO_2 and water mixtures spanning the range of optimum moderation. The results are listed in Table 4-32. The maximum neutron multiplication factor is and occurs for a WF H_2O of 0.20. † Since the operation of the SX columns yields uranium densities of only gm U/l in the solvent (which † is equivalent to a UO_2 water mixture with a WF H_2O much greater than 0.50) the Keff result for † 0.50 WF of H_2O is an upper limit for the normal case. The SX columns are thus geometrically safe for homogeneous UO_2 and water mixtures.

4.8 CRITICALITY SAFETY OF UPMP THREE AND FIVE GALLON PAILS

Three and give gallon pails are used in the Uranium Process Management facility to handle heterogeneous UO_2 pellet scrap and homogeneous UO_2 powder and sludges. These containers are both restricted to a gross weight of 35 Kg with contents which are normally dry (< 0.05 WF of H_2O for powder or pellets) or wet (>0.50 WF of water for sludges). As shown in the following analyses, both types of pails are geometrically safe.

4.8.1 Container Geometries

Table 4-33 contains a description of the geometry of three and five gallon pails. Both are a maximum 11-1/4 inches in diameter with heights of 8-13/16 inches for the three gallon pail and 13-1/2 inches for the five gallon pail. The actual volumes are 13.7 and 21.0 liters respectively although the volumes resulting from the maximum diameters and heights are 14.4 and 22.0 liters.

4.8.2 Analytical Methods

A comparison with Tables 4-7 and 4-8 shows that the five gallon pail is geometrically safe by virtue of its volume (21.0 liters versus a safe geometry value of 24 liters for homogeneous UO_2 and water mixtures) whereas

Reference: SNM-1097

TABLE 4-32
SOLVENT EXTRACTION CALCULATION RESULTS

WF H_2O	GEKENO Keff	±	σ	
0.10				†
0.20				†
0.25				†
0.30				†
0.40				†
0.50				†

TABLE 4-33
THREE & FIVE GALLON PAIL GEOMETRIES

Pail Designation	Height (Inches)	Diameter Top	Diameter Bottom	Volume (Liters)
Three Gallon	8-13/16	11-1/4	10-23/32	13.7
Five Gallon	13-1/2	11-1/4	10-23/32	21.0

Reference: SNM-1097

the three gallon is slightly larger than a safe volume (13.7 liters versus 13.0 for the safe volume for heterogeneous UO_2 and water). In addition to this, explicit calculations have been performed with the GEKENO and GEMER Monte Carlo Codes to demonstrate that the pails are geometrically safe for homogeneous (for the five gallon pail) and heterogeneous (for the three gallon pail) UO_2 and water mixtures. The geometry specifications used in these calculations are listed in Table 4-34. The pails were assumed to be completely surrounded by a least 12 inches of water and the contents were modelled as homogeneous or heterogeneous UO_2 and water mixtures as described in Section 4.1.7 and 4.1.9. The three gallon pail GEKENO calculations were performed with the Hansen-Roach Cross Section sets adjusted for heterogeneous effects.

4.8.3 Results

Tables 4-35 and 4-36 show the results of the GEKENO calculations for the three and five gallon pails. As summarized in Table 4-37, these containers satisfy the necessary requirements specified in Sections 4.1.2 and 4.1.5 and are consequently geometrically safe.

4.9 CRITICALITY SAFETY OF UPMP FURNACE BOATS

Furnace boats used in the Uranium Process Management Project oxidation furnace operations are inch by † inch by inch rectangular pans which can † contain heterogeneous or homogeneous mixtures of UO_2 and water. Since the boat thickness of inches is † greater than the safe geometry infinite slab thickness of 3.6 inches for heterogeneous mixtures, the rectangular pans have been analyzed with the reactivity formula and the heterogenous Kinf, M^2 and λ Parameters in Table 4-3. Table 4-38 shows these results. Since the maximum Keff is 0.883, the furnace boats are geometrically safe.

4.10 CRITICALITY SAFETY OF UPMP ROLL CRUSHER

Oxidized scrap exiting the UPMP oxidation furnace is dumped from a furnace boat into a slab hopper, through a roll crusher and into a three or five gallon pail. Figure 4-16 shows a sketch of this configuration. The geometry of the roll crusher is such that it has an

TABLE 4-34
THREE & FIVE GALLON PAIL
GEOMETRY MODELS

Pail Description	Radius (cm) Inner	Radius (cm) Outer*	Height (cm) Inner	Height (cm) Outer*
Three Gallon	14.370	14.42	23.00	23.10
Five Gallon	14.367	14.420	33.814	33.920

* Carbon Steel Pails

TABLE 4-35
FIVE GALLON PAIL CALCULATION RESULTS
(Homogeneous $U(5.0)O_2$ and Water Mixtures)

WF H_2O	GEKENO Keff	±	σ	GEMER Keff	±	σ	
0.05							†
0.086							†
0.10							†
0.1158							†
0.15							†
0.1573							†
0.20							†
0.2183							†
0.25							†
0.2711							†
0.30							†
0.3172							†
0.3486							†
0.35							†
0.40							†
0.45							†
0.50							†

Reference: SNM-1097

TABLE 4-36
THREE GALLON PAIL CALCULATION RESULTS
(Heterogeneous $U(5.0)O_2 + H_2O$ mixtures)

W/F Volume Ratio	GEKENO Keff ± σ	
1.0		†
2.0		†
3.0		†
4.0		†
5.0		†
6.0		†

TABLE 4-37
SUMMARY OF CALCULATION RESULTS FOR
THREE & FIVE GALLON CONTAINER

Pail Designation	Normal Case Keff ± σ	Optimum Moderation Accident Case Keff ± σ	
Three Gallon			†
Five Gallon			†

Reference: SNM-1097

TABLE 4-38
OXIDATION FURNACE BOAT NEUTRON MULTIPLICATION FACTORS FOR
HETEROGENEOUS $U(5.0)O_2$ LATTICES
IN WATER CALCULATED WITH THE REACTIVITY FORMULA

W/F Volume Ratio	Keff*	
1.0	0.843	
2.0		†
3.0		†
4.0		†
5.0		
6.0		†

* 12 Inch Water Reflected

Reference: SNM-1097

FIGURE 4-16
OXIDATION FURNACE BOAT DUMP STATION

Reference: SNM-1097

active volume of less than 4-7/8 inches by 9 inches by 19 inches (13.7 liters). This is a geometrically safe for heterogeneous UO_2 and water as shown by the reactivity formula results in Table 4-39. (Kinf, M^2 and λ parameters used in this analysis are those in Table 4-3).

4.11 CRITICALITY SAFETY OF PROCESS SUMPS AND FLOOR BASINS

Liquid spills and vessel overflows in the UPMP fluoride waste, nitrate waste, rad waste, dissolver, solvent extraction and UNH concentration areas are contained in area floor basins and collected in process sumps for pumping back into waste stream process vessels. These basins and sumps normally do not contain significant volumes of liquids with uranium densities in excess of the minimum critical value (> gm U/l), but they † have been designed to be critically safe for more extreme conditions. These conditions and the applicable criticality safety analysis are presented in the following sections.

4.11.1 Geometries

The floor basin is a slab type area with a maximum depth of inches relative to the surrounding walkway. It is capable of holding 50% to 100% of the contents of a typical vessel and is molded into the concrete † floor rather than created by curbs above the floor level. The process sump is a inch Schedule † inch OD and inch thick) inch † deep stainless steel pipe imbedded in the concrete floor and covered by a inch deep, inch diameter † cylindrical grating.

4.11.2 Analytical Methods

The process sump floor basin configuration has been analyzed with the GEKENO Monte Carlo Code for homogeneous mixtures of UO_2 and water. The credible accident conditions assumed in this analysis are:

Optimum moderation of the UO_2 and water mixture and nominal (inch thick) water reflection on the top. † Full reflection by water is not assumed for the condition because such a condition is not credible for

TABLE 4-39
ROLL CRUSHER CALCULATION RESULTS
FOR HETEROGENEOUS $U(5.0)O_2$ & WATER MIXTURES
ANALYZED WITH THE REACTIVITY FORMULA

W/F Volume Ratio	Keff	
1.0	0.837	
2.0		†
3.0		†
4.0		†
5.0		†
6.0		†
8.0	0.824	
10.0	0.802	

Reference: SNM-1097

the large floor basin areas and uranium masses and densities involved.

A fuel mixture with a 0.50 weight fraction of water and with full (12 inch thick) water reflection on top.

Figure 4-17 shows the GEKENO Geometry Model. The following specific cases were analyzed:

(1) Isolated floor basin with optimally moderated fuel and nominal water reflection on top.

(2) Isolated floor basin with a fuel mixture having a 0.50 (and greater) weight fraction of water and with full water reflection on top.

(3) Isolated process sump with optimally moderated fuel and full water reflection on top.

(4) The full process sump-floor basin configuration with optimally moderated fuel and nominal water reflection on top.

(5) The full process sump-floor basin configuration with a fuel mixture with 0.50 (and greater) weight fraction of water and full water reflection on top.

4.11.3 Results

The results of these GEKENO calculations are listed in Table 4-40. These are summarized as follows:

(1) The maximum Keff for the nominally reflected isolated floor basin with optimally moderated UO_2 and water is It is thus † critically safe for this condition.

(2) The maximum Keff for the fully reflected isolated floor basin with UO_2 and water mixtures with weight fractions of 0.50 or more is The † isolated floor basin is critically safe for this condition.

(3) The maximum Keff for the fully reflected process sump with optimally moderated UO_2 and water is

Reference: SNM-1097

FIGURE 4-17
GEKENO GEOMETRY MODEL
FOR PROCESS SUMP-FLOOR BASIN ANALYSIS

Reference: SNM-1097

TABLE 4-40
UPMP PROCESS SUMP & FLOOR BASIN
CALCULATION RESULTS
(Homogeneous $U(5.0)O_2$ & Water Results)

	WF H_2O	GEKENO Keff ± σ	
Case A. Isolated Floor Basin with Nominal Water Reflection on Top	0.10		†
	0.20		†
	0.25		†
	0.30		†
	0.40		†
	0.50		†
Case B. Isolated Floor Basin with Full Water Reflection on Top	0.50		†
	0.60		†
	0.70		†
Case C. Isolated Process Sump with Full Water Reflection on Top	0.10		
	0.20		†
	0.25		†
	0.30		†
	0.40		†
	0.50		†
Case D. Process Sump-Floor Basin Configuration with Nominal Water Reflection on Top	0.10		†
	0.20		†
	0.25		†
	0.30		†
	0.40		†
	0.50		†
Case E. Process Sump-Floor Basin Configuration with Full Water Reflection on Top	0.50		†
	0.60		†
	0.70		†

Reference: SNM-1097

the process sump by itself is † geometrically safe.

(4) The maximum Keff for the optimally moderated configuration with nominal water reflection on top is † and occurs for a UO_2-H_2O mixture with a weight fraction of water of 0.25. The process sump-floor basin is thus critically safe for this condition.

(5) The maximum Keff for the fully reflected process sump-floor basin configuration with 0.50 or more water is † and is critically safe for this condition.

4.12 CRITICALITY SAFETY OF UPMP EQUIPMENT INTERACTION

Criticality safety for interaction between individual pieces of equipment in the UPMP facility will be demonstrated for optimum or maximum credible interspersed moderation between units. The methods used and areas of application are as follows:

4.12.1 Monte Carlo Code Applications

GEKENO and GEMER Monte Carlo Codes will be used in the analysis of close-packed interacting systems with regular units or close spacings. Typical analyses will be:

(1) filter area †
(2) Furnace queue conveyors (with three or five gallon pails)
(3) vessel piping (general) †
(4) Discharge furnace conveyors (with three gallon Pails)
(5) Dissolver queue conveyors (with three gallon pails)
(6) piping †
(7) Rad waste tank piping †
(8) Leacher area
(9) Oxidation furnace boat dump station

4.12.2 Solid Angle Code Applications

In selected cases, criticality safety of interacting units in the UPMP facility are demonstrated using the Solid Angle Code (SAC). Typical examples are:

(1) Solvent extraction cell
(2) Oxidation furnace
(3) Dissolver area

For application in the Solid Angle Code, neutron multiplication factors for the unreflected units are computed assuming normal case geometries but optimally moderated fuel (i.e., UO_2 and water) mixtures. These unreflected Keffs are calculated with GEKENO or GEMER Monte Carlo Codes or with the reactivity formula using the Kinf, M^2 and λ parameters listed in Table 4-41. Table 4-42 summarizes unreflected Keff values for typical units. Units in solid angle calculations are in addition required to be separated by at least 12 inches edge-to-edge. Closer spacings require analysis by other methods such as Monte Carlo.

4.12.3 Isolation By Distance

Equipment and operations in the UPMP facility are considered to be nuclearly isolated if they are separated from all other accumulations of fissile material by distances which are equivalent to the isolation provided by an eight inch thick slab of water or 12 feet edge-to-edge separation.

4.12.4 Isolation of Process & Dissolver Vessels

As noted in Sections 4.5 and 4.6, the use of neutron absorber panels in process and dissolver † vessel designs is such that infinite planar arrays of the vessels have neutron multiplication factors less than 1.0 under optimum moderation and full (top and bottom) reflection. While not nuclearly isolated, such vessels in the UPMP facility are considered to have negligible interaction (due predominantly to the neutron absorber panels) and are not usually † considered in interaction analyses. Monte Carlo analyses referenced in 4.12.1(3) and 4.12.1(6) also demonstrate generically that vessels and their † associated piping are critically safe.

TABLE 4-41
REACTIVITY FORMULA PARAMETERS
FOR UNREFLECTED UNITS*
FOR USE IN THE SAC SOLID ANGLE CODE

Material Type	Kinf	M^2 (cm^2)	λ (cm)
Homogeneous	1.442	28.0	2.1
Heterogeneous	1.540	29.7	3.2

* $U(5.0)O_2$ and H_2O Mixtures

TABLE 4-42
UNREFLECTED KEFFS FOR SOLID ANGLE CALCULATIONS

Equipment	UO_2 & Water Mixture Form	Keff	Source	
Three Gallon Pails	Heterogeneous	0.715	GEKENO	
Five Gallon Pails	Homogeneous	0.767	GEKENO	
Inch Schedule Cylindrical Tanks	Homogeneous		GEKENO	† †
Leachers	Heterogeneous		GEMER	†
Solvent Extraction Columns	Homogeneous		GEKENO Calculation	†
Furnace Boats	Heterogeneous	0.618	Reactivity Formula	
Roll Crusher	Heterogeneous	0.678	Reactivity Formula	

Reference: SNM-1097

4.12.5 Criticality Safety of UPMP for Process Piping Interaction

In the UPMP facility, process piping has been designed to be critically safe by implementation of the following generic guidelines.

4.12.5.1 Interaction of process piping in excess of 2 inches in diameter and which normally contains levels of uranium in excess of 1,000 ppm must be specifically analyzed using Monte Carlo reactivity formula or Solid Angle Code methods. Subject to the additional guidelines below, piping involving diameters of 2 inches or less, or uranium densities of less than 1,000 ppm do not require a specific interaction analysis.

4.12.5.2 Minimum spacing of process piping from other piping and equipment containing uranium is shown in Table 4-43.

4.12.5.3 Pipe runs, where possible, are to be routed in planar slabs with slab thicknesses of no more than 4 inches. At least a 3 foot surface-to-surface spacing is required when two or more of such pipe runs are stacked on top of each other.

4.12.5.4 Piping to equipment is to be designed so that individual lines and connections are separated as far as practicable from other lines and connectors.

4.12.5.5 Overflow lines, vents, etc., which do not normally contain uranium bearing materials are not considered in area interaction analyses. These are to be spaced as far away as practicable from uranium bearing equipment and process piping.

TABLE 4-43
SPACING GUIDELINES
FOR UPMP PROCESS PIPING

Equipment		Normal Required Minimum Spacing, (Inches)
From	To	
>2" Pipe	Other Piping, Equipment or Vessel	12"
>3" Piping	Other Piping, Equipment or Vessel	18"
>4" Piping	Other Piping, Equipment or Vessel	24"
Angled Takeoffs Process Piping	Other Piping, Equipment or Vessel	15"

Reference: SNM-1097

CHAPTER 5.0
RADIOLOGICAL SAFETY CONSIDERATIONS

5.1 BUILDING VENTILATION SYSTEMS

The UPMP heating, ventilating, and air conditioning systems are provided to maintain the temperature, humidity, air cleanliness, ventilation rate, and contamination control environments required within the facility. Temperature and humidity are controlled as required for the processes performed in the areas served, and for the efficient performance of operating personnel. The release of radiological and non-radiological particulates, aerosols, fumes, and vapors is controlled to as low a level as practical by filtration through low, medium, and high efficiency filters and by scrubbing the air with deionized water.

The UPMP controlled areas are maintained at a negative pressure with respect to atmosphere and adjacent areas (with the exception of the GECO vaporization room which shares a common wall with no openings between it and UPMP). Because the vaporization area is considered as having the higher potential for contamination, it is maintained at a higher negative pressure. Automatic room static-pressure sensors continuously modulate control dampers to maintain the required pressure differentials between adjacent areas and the environment.

5.1.1 Recirculation Systems

Separate recirculation systems are used to segregate the main process and solvent extraction areas. All recirculated air passes through high efficiency particulate air (HEPA) filters and is scrubbed prior to being returned to the work areas. Clean recirculated supply air enters those sections of the room with the least potential for contamination. Returns are located so that the air flow is directed away from areas normally occupied by personnel.

5.1.2 Equipment Enclosures

Special enclosures are provided to supplement the primary containment offered by the process equipment. Enclosures are provided for each piece of process equipment where a potential for airborne contamination exists. Each enclosure has been designed to minimize the potential for direct contact of radioactive material by the operator and to maintain exposures ALARA.

An automatic air bypass damper is provided on each exhaust duct to maintain a constant negative pressure within the enclosure. By properly adjusting this damper, the required air flow through routine access openings (such as those required for material transfers or cleanouts) is provided. Under normal, and most anticipated abnormal process conditions, respiratory protective equipment will not be required.

5.1.3 Absolute Filter Systems

Exhausted air from enclosures is filtered by a HEPA filter provided for each dry containment system. Exhausted air is further filtered by a secondary bank of HEPAs prior to discharge to the environment.

The primary and secondary absolute filter systems consist of ~40% efficient, fiberglass prefilters followed by the HEPA filters. The HEPA filters are 99.97% efficient for 0.3 micron and greater dust particle sizes.

The filter housings are designed such that the fiberglass prefilter is totally sealed and cannot be bypassed, thereby assuring that all entrained particulate material must pass through the prefilter before reaching the HEPA filters. The HEPA filters are enclosed on all four sides with spacer material to assure that no buildup of material can occur in the perimeter of the housing.

All filter housings are equipped with a magnahelic gauge to measure the pressure differential (Δ P) across the filters. On the secondary filter banks, a pneumatically controlled damper is used to automatically adjust the airflow through the filters. As the HEPA filters load

with particulate material, the damper automatically opens to compensate for the increased Δ P. When a differential pressure is observed to have reached four inches of water, the effectiveness of the system is investigated. A filter is replaced following evidence of the inability of the exhaust system to perform its function properly or maintain minimum inward airflow. The filters are never operated at Δ P values which exceed the manufacturer's ratings.

5.1.4 Ductwork

Ductwork for the exhaust and recirculation air main trunklines have continuous welded longitudinal seams and companion angles with gaskets at all joints. Horizontal ducting between process enclosures and primary filters has been kept to a minimum, and where utilized, the duct has been equipped with cleanout openings for inspection and removal of uranium accumulation in the unlikely event it occurred.

The building ventilation major equipment and specifications are listed in Table 5-1.

5.2 EQUIPMENT OPERATION

5.2.1 Facility Exhaust System

This main exhaust system draws air from four different areas, treats the air to meet emission requirements and monitors the air as it is exhausted. The four air collection areas are:

- o Dry hoods (hoods which contain a powder)
- o Wet hoods (hoods which contain a slurry or liquid)
- o Rooms which require a high make-up ratio (solvent extraction and dissolution rooms)
- o Main process area

5.2.1.1 Dry Exhaust System

Each of the dry hoods is provided with an exhaust air duct connection and a bypass air spoiler damper. Exhaust air flow is through a primary HEPA filter on the exhaust piping from each individual hood thus minimizing balancing problems which occur when primary HEPA filters are shared between hoods. The primary HEPA filters are connected in parallel and ducted to the downstream side

TABLE 5-1
BUILDING VENTILATION SYSTEMS
MAJOR EQUIPMENT LIST

BLOWERS

Process Area Recirculation Blower (B-950)	45,500 cfm
Process Area Exhaust Blower (B-965,966)	16,000 cfm ea
Solvent Extraction Recirculation Blower (B-940)	20,000 cfm
Process Lab Blower (B-970)	3,200 cfm
Control Room Supply Blowers (B-975, 976)	5,750 cfm ea
Equipment Room Supply Fans (B-985,986,987,988)	10,000 cfm ea
UPMP Corridor Supply Fan (B-2016X)	12,000 cfm

FILTERS

Process Area Recirculation Filters (F-950)	32 Unit
Process/Scrubber Exhaust Filters (F-965, 966)	16 Unit
Solvent Extraction & Dissolver Filters (F-940)	20 Unit
Process Lab Filters (F-970)	2 Unit
Control Room Filters (F-975)	6 Unit

SCRUBBERS

Process Area Recirculation Scrubber (S-950)	200 gpm
Process Area Exhaust Scrubber (S-965)	120 gpm
Solvent Extraction and Dissolver Scrubber (S-940)	140 gpm

HEATING/COOLING COILS

Process Area Exhaust Scrubber Coils (HV-968)
Process Area Recirculation Coils (HV-951,952)
Solvent Extraction and Dissolver Room Coils
(HV-941, 942)
Process Lab Coils (HV-971, 972)

Reference: SNM-1097

of the scrubber reheat coil. From here the air travels through one of the redundant secondary HEPA filters and its corresponding exhaust fan.

Pressure in each hood relative to the room is sensed by a pressure differential transmitter and a pneumatic signal is transmitted to the pressure differential controller. The spoiler damper is modulated as required to maintain the hood at a negative pressure of 0.2 to 0.75 inches of water with respect to the room. If pressure in the hood increases and becomes greater than -0.2 inches of water, the spoiler damper will close to insure that there is a minimum of 80 LFPM at all points with an average of at least 100 LFPM air velocity into any routine hood opening including open doors, slides, etc. A pressure differential indicator is provided at each hood.

5.2.1.2 Wet Exhaust System

The wet exhaust system handles the furnace scrubber, dissolver, leacher, process filter enclosure, filter hood, and the tanks. An NO_x absorber and blower are provided in the facility for that equipment emitting gases with a high NO_x content. A manual damper is provided for small hoods. The wet hoods are connected in parallel and ducted to the exhaust scrubber. The exhaust scrubber sprays 120 gpm of recirculated, acidified, de-ionized water into the airstream via a 4 foot thick packing section primarily to remove non-radiological particulates and fumes. The air leaving the scrubber passes through a heating coil to decrease the relative humidity of the air prior to passing through the secondary filter, thus keeping the secondary filter dry.

5.2.1.3 High Make-up Ratio Rooms

The solvent extraction and dissolution rooms are provided with a air turnover rate of at least eight room air changes per hour. The dissolver hoods are located in the dissolution room on the mezzanine and thus the air flow to the hoods can provide room exhaust. The exhaust air from these rooms is adjusted by automatic room pressure control dampers.

The air is ducted to the scrubber in a similar manner to that being used for the wet hoods.

5.2.1.4 Main Process Area

The main process area is provided with an air turnover rate of at least eight room air changes per hour. Discrete confinement zones are provided using localized supply and return openings to minimize the consequences of an airborne release. Main overhead supply ducts provide clean, recirculated air above the center walkways. High and low return openings are provided at various locations behind the process tanks along the perimeter walls to minimize airborne releases and direct the air flow away from the operators. In addition, under normal operating conditions, process enclosure access openings will be closed so that the facility exhaust system will be exhausting a significant portion of room air via the bypass dampers on each enclosure.

5.2.2 Solvent Extraction & Dissolution Room Make-up & Recirculation System

This system maintains the required air temperature and provides make-up and air purification for the solvent extraction and dissolution rooms. Air make-up is provided from the main process area and is equal to the air being exhausted from the room. Individual pressure control devices and air operated dampers are provided to maintain the proper negative pressure by regulating the exhaust air rate from each room.

The recirculated air is passed through a HEPA filter, cooled, scrubbed and heated, if necessary, and then sent through each room. The system is provided with control devices and dampers to maintain a constant flow through the system. A pressure differential indicator and alarm switch are provided on the secondary HEPA filter.

5.2.3 Process Area Recirculation System

The process area recirculation system consists of a 32 unit HEPA filter, cooling coil section scrubber system, reheat coil, recirculation fan, supply air ductwork and automatic controls.

The operation of the recirculation air fan is started from the control room. The recirculation fan flow rate is sized to provide a minimum of eight air changes per hour. This flow, along with the make-up air, is capable of cooling the process area. The recirculated air passes through a filter plenum and into the HEPA filter unit. The air is passed through a cooling coil scrubber and reheat section where the air is simultaneously washed with de-ionized water, cooled and dehumidified to obtain the specified room dew point temperature.

The recirculated air is next reheated and returned to the process area. The system is provided with control devices and dampers to maintain a constant flow rate through the main recirculation duct. A pressure differential indicator and alarm switch are provided for the secondary HEPA filter system.

Cooling, heating and humidity control are provided by the sprayed coil dehumidifier and the reheat coil. A temperature transmitter located in the process area transmits a pneumatic signal to a receiver controller which in turn modulates a three way chilled water valve and a two way steam control valve to maintain desired room temperature. Recirculated deionized water is continuously sprayed over the downstream side of the chilled water coil to scrub the air stream. The water level in the recirculation sump is maintained by a controlled volume of DI water. This volume of make-up water is determined by the evaporation rate and an 11 liter/minute purge to the wet exhaust scrubber. This will ensure scrubber efficiency and prevent contaminants from collecting in the sump.

An ionization type smoke detector is located in the return air duct upstream of the HEPA filter plenum. On detection of smoke, a remote alarm is energized in the control room and the system is shut down.

5.2.4 Process Area Make-up Air System

A separate outside air system is provided to supply make-up air to the process area. The system provides 100% outside air and incorporates a roughing filter at the roof intake, cooling coils, steam heating coils,

ductwork and controls. The system utilizes existing condensing units. A room pressure sensor is utilized to modulate the control damper to maintain the main process area at the proper negative pressure.

5.2.5 ASMU Operating Area (Non-controlled)

The aqueous and solvent make-up (ASMU) operating area HVAC system will provide fresh air ventilation for the summer and heating for the winter. The area will be kept slightly positive or at atmospheric pressure since it is a noncontaminated area located adjacent to a contaminated area.

5.2.6 ASMU Chemical Mix Area (Non-Controlled)

Heating and ventilation is provided in the bulk storage area. Continuous air make-up is provided to prevent fume accumulation. The unit is supplied with a heater to eliminate pipe freezing concerns.

5.2.7 Control Room and Office (Non-Controlled)

The control room/office area/computer room system consists of a return and make-up air plenum, filter section, charcoal filter, fan and cooling coil section, heating coil section, ductwork and automatic controls.

The supply fan is energized manually and operates continuously. A redundant fan is supplied to ensure that a reliable system is provided. A manual make-up air damper is set to allow 240 cfm of make-up air to mix with 5,600 cfm of HEPA-filtered return air. The 240 cfm make-up provides the positive pressure required for these non-contaminated areas. The air is drawn through a steam heating coil, a chilled water coil and sent to the different areas. A carbon filter is provided to remove unwanted fumes from the atmosphere.

5.2.8 HEPA Filter Banks

Flow through the recirculation and main exhaust HEPA filter banks will be controlled by a damper controller in order to maintain the required negative static pressure at each fan suction. In the event that the filter bank plugs to the point where the required

negative pressure cannot be maintained, a controller for the recirculating air units will modulate the fresh air dampers towards the closed position. When a HEPA filter bank differential pressure reaches 4" of water, a visual/audible and printed alarm will be indexed in the UPMP control room and the effectiveness of the system will be investigated.

5.3 PERSONNEL EXPOSURE CONTROLS

The UPMP facility will be operated according to the radiological control plan which exists for the current fuel manufacturing building. This includes exposure controls, personnel monitoring techniques, bioassay programs, area posting and radiation surveys.

5.3.1 Measurement of Air Concentrations

Work area air concentrations in the UPMP facility will be continuously sampled with the addition of 47 stationary air samplers (SAS). Each sampling unit has a flow meter with flow rate control and a filter holder containing a round glass fiber filter which, per existing radiation protection procedures, is changed every shift, or sooner if conditions warrant.

These filter samples are analyzed each shift for alpha activity within approximately four hours following removal from the filter holder. This analysis is performed by placing the filters into individual planchets and loading them into low background alpha counting systems. The total counting time for all filters is approximately two hours.

Individual airborne exposures will be assigned to personnel working in the facility based upon sample results and the amount of time spent in each work area.

The SAS samplers are augmented by four additional continuous air monitors which continuously monitor air concentrations and provide early warning of containment failure or releases for each area. If a problem does exist, employees in the area will either be evacuated or required to wear respiratory protection until the problem is resolved. Additional air concentrations are determined using high volume, portable units as necesary

to determine the temporal nature of air concentrations in accordance with WMD procedures.

5.3.2 Contamination Controls

Process areas of the UPMP facility are designated as controlled areas similar to the controlled process areas of the existing fuel manufacturing building. UPMP controlled areas include the main process tank area, oxidative furnace area, dissolver/leacher areas, solvent extraction cell and the maintenance shop.

Radiation workers will access the controlled areas through existing change rooms, where they will don standard controlled area protective clothing (i.e. coveralls, head covering, shoe covers, rubber gloves). Persons exiting the controlled area will monitor for contamination following removal of protective clothing in the change rooms.

The UPMP processes have been designed to offer complete containment to the work areas, thus minimizing the potential for surface and airborne contamination. Liquid effluent streams are piped directly into closed process vessels which are vented into the main scrubber exhaust system. Solid waste streams are transferred into and out of the process areas in closed three and five gallon pails and are not opened outside of approved hoods. Specially designed enclosures are provided for pail loading and unloading.

The existing fuel manufacturing building contamination control plan and action guides will be used for the UPMP facility. If contamination in excess of the guideline limits occurs, the necessary decontamination action is taken per existing procedures, based upon knowledge of the particular circumstances and the behavior of the material involved.

5.3.3 Criticality Detection & Evacuation Alarm System

The UPMP facility is adequately covered using the existing criticality warning system and with the addition of one detector in the main process area. The alarm signal will be of sufficient volume in all areas to be evacuated with the addition of 21 horns to the

existing system. The evacuation alarm sound will be consistent with that of the existing fuel manufacturing building. Individuals evacuating the UPMP facility will do so according to evacuation procedures outlined in the existing site emergency plan.

5.3.4 Operating Instructions to Workers

The operation of the UPMP facility will be conducted according to Process Requirements and Operating Documents (PRODs) prepared by process engineers with inputs from nuclear safety engineering personnel. These documents provide on-the-floor instructions to operations personnel and contain criticality and radiological safety provisions. Each equipment operator is provided adequate training to follow these operating documents.

CHAPTER 6.0
ENVIRONMENTAL CONSIDERATIONS

6.1 OVERVIEW

The UPMP facility will have a positive environmental impact with respect to the facility's currently approved operations and with respect to the entire fuel manufacturing cycle. In this regard, the UPMP license amendment should receive favorable treatment under the provisions of 10 CFR 51.5(d)(4). The activities are included in the current facility license and the project represents only a rearrangement of the current process coupled with modifications and inclusion of new equipment and processes for which safety has not been demonstrated under the current license. In support of these claims, the following environmental benefits/improvements are demonstrated:

(1) The quantity of uranium in radioactive liquid (fluoride, nitrate, rad waste) exiting the normal confines of the manufacturing operations and entering the open waste treatment systems will be reduced by approximately % †. This eliminates any major potential for its contribution to a radiological impact on the environment.

(2) The quantity of calcium fluoride sludge produced and precipitated in the final process lagoons from rad waste will decrease by approximately % †. This eliminates a significant quantity of radioactive materials generated during fuel production and their attendant environmental impact potential including considerations for site decommissioning.

(3) The uranium concentration of the remaining calcium fluoride sludge will be signicantly reduced resulting in a non-hazardous waste which can be considered for disposal under Options 1 and 2 of SECY 81-576 or chemical uses in other non-nuclear operations. This eliminates the need for disposing of current generation material at a low level radioactive waste burial site.

Reference: SNM-1097

(4) These process modifications make the WMD fuel manufacturing operations more self-supporting at a single location thereby eliminating over-the-road shipment of scrap for reprocessing and return shipment of UNH solutions. This eliminates the potential of a release to the environment during an accident on the highway.

(5) The new process chemistry will eliminate the use of hydrogen peroxide in the current UPS. This eliminates a potentially hazardous industrial chemical operation.

(6) The UPMP process design emphasizes resource conservation. Solutions and chemicals associated with the process are treated so as to permit recycling within the operations. This results in a reduction in the quantity of waste chemicals and the need for their disposal.

(7) UPMP provides the first step in developing the capability to recover uranium from past plant effluent residues. This is an essential part of the GE Closure & Decommissioning Plan for the Wilmington Manufacturing Department facility.

(8) Notwithstanding the fact that UPMP will add a single atmospheric discharge point, the overall discharge to the atmosphere from the fuel manufacturing cycle is expected to be reduced. At the WMD site, the atmospheric discharge will be insignificantly increased, however, the atmospheric discharges from reprocessing WMD scrap will be eliminated at the current reprocessing facility. The net result should be a favorable impact on the fuel manufacturing cycle environment.

(9) UPMP will result in a slight increase in the nitrate-based chemical processing at WMD. Offsetting this is the fact that nitrate-based chemical processing will be eliminated at another facility. This slight increase at WMD poses no increased environmental risk because of the biological disposal option in use in this area.

Reference: SNM-1097

The following segments of UPMP will contribute to the overall improvement in WMD environmental quality:

Fluoride waste treatment
Rad waste treatment
Nitrate waste treatment
Scrap processing
UNH conversion

The effect of each of these segments on releases to the environment is discussed in detail in the following section.

6.2 EFFLUENT QUALITY

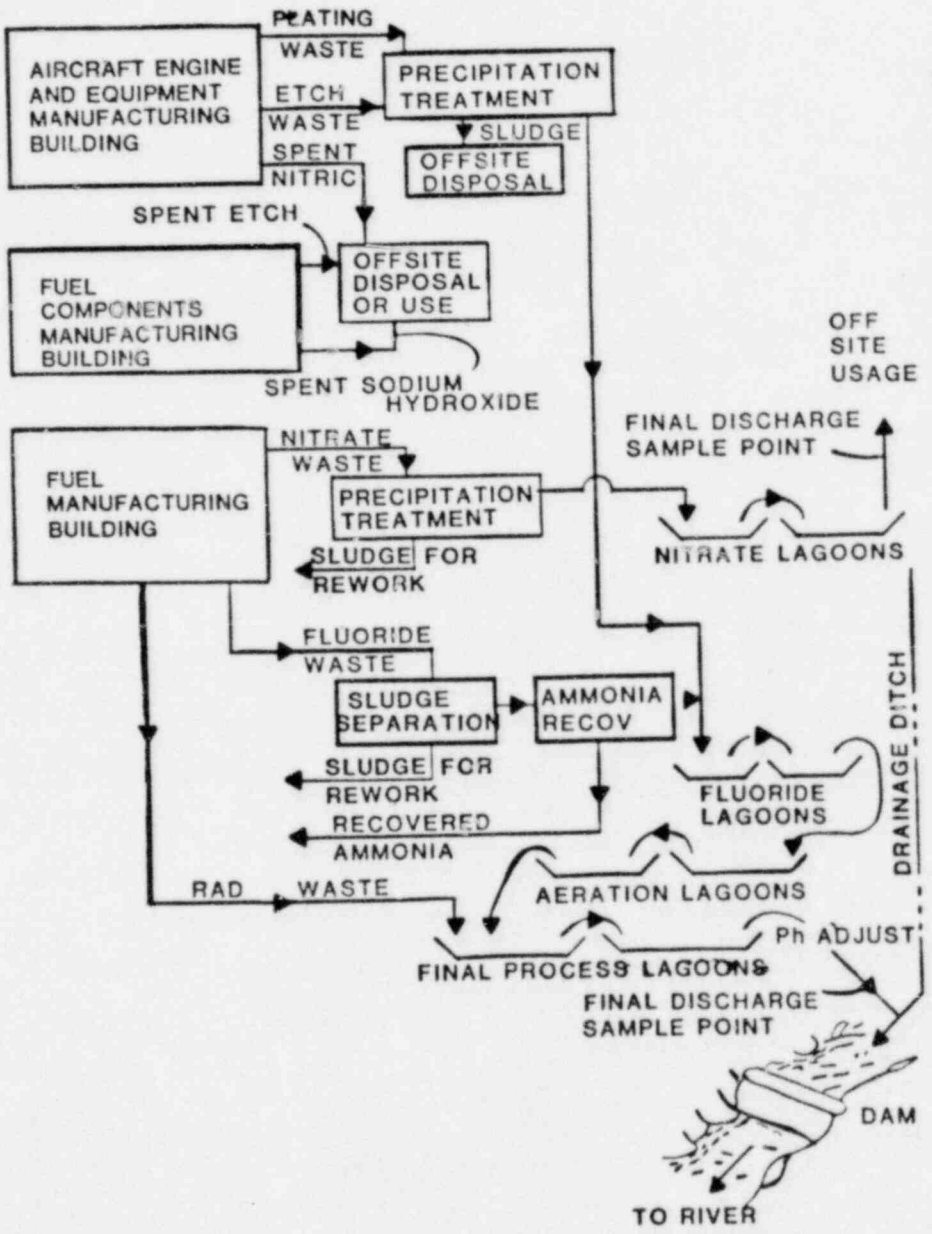
6.2.1 Treated Process Liquid Effluents

The existing process liquids are segregated by chemical characteristics prior to the treatment processes thus providing the opportunity to achieve optimum removal efficiencies. A flow diagram portraying this segregration and the overall process effluent flow path is provided in Figure 6-1. Figure 6-2 indicates how the Uranium Process Management Project segments fit into the existing treatment concepts.

6.2.1.1 Fluoride Waste Treatment

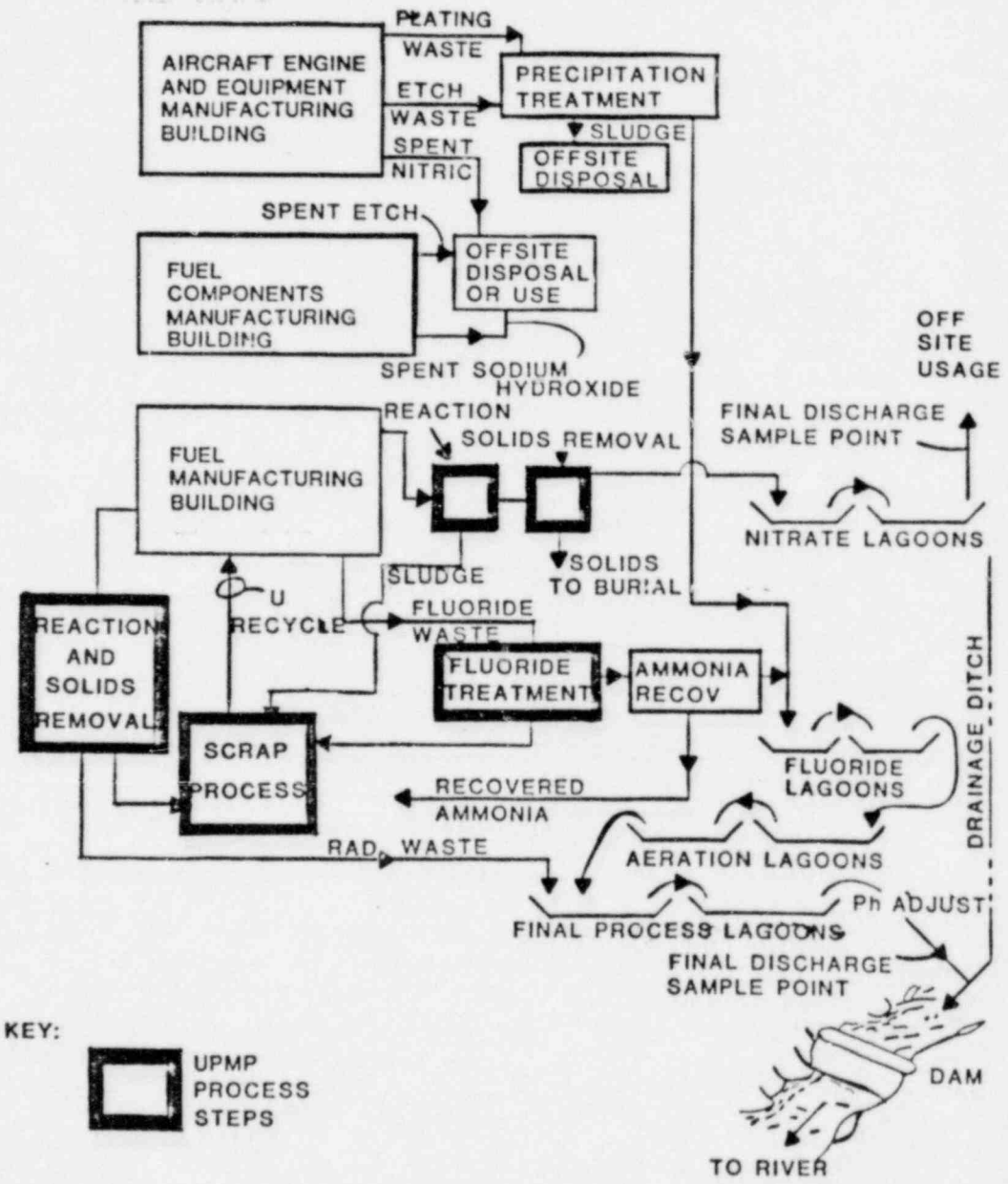
The UPMP units (which have already been tested) are designed to reduce the uranium chemical concentration to part per million prior to the existing waste treatment steps. This represents a significant reduction in uranium concentration from the present range of parts per million at this point in the waste treatment process. As a result, the residual concentration of uranium in the lagoon systems will be reduced by a factor of and the calcium fluoride solids will be less than parts per million on an as-produced basis orless than pCi/gm at 4% enrichment. This low activity concentration will allow consideration of disposal Options 1 or 2 as detailed in SECY 81-576. This will also allow consideration of other beneficial uses of the material or, in any case, disposal at a burial facility other than one licensed to receive low level radioactive waste. It should be pointed out that the calcium fluoride solids are not

FIGURE 6-1
PROCESS EFFLUENT FLOW PATH



Reference: SNM-1097

FIGURE 6-2
WILMINGTON SITE PROCESS EFFLUENTS & TREATMENT



Reference: SNM-1097

expected to be a hazardous waste under the criteria of the Resource Conservation and Recovery Act regulations. The liquid remaining after treatment has a uranium concentration of less than one part per million, equivalent to present day values.

The residual fluoride concentration in the treated liquid will not change from present day values.

6.2.1.2 Rad Waste Treatment

The installation of the chemical treatment capability for uranium precipitation and multi-stage solids removal will result in a lower residual uranium concentration in the treated rad waste liquid entering the final process lagoons. The concentration is projected to be less than parts per million, substantially less than the present range of parts per million. The sludge produced in the treatment will be recycled to scrap processing thereby reducing the quantity of sludge reaching the final lagoon system and the quantity of uranium precipitated in the final process lagoons. This chemical treatment will also reduce the amount of fluorides discharged to the final process lagoons.

6.2.1.3 Nitrate Waste Treatment

The installation of the additional reaction vessels and solids removal equipment is expected to reduce the concentration of uranium discharged to the nitrate lagoons to parts million, less than 5% of present day values. In addition, no sludge will be expected to be discharged to the nitrate lagoons due to the increased effectiveness of the chemical treatment and solids removal processes.

The overall volume generation rate of nitrate waste is not expected to change significantly. Any changes in composition are also expected to be minor. In any event, these minor changes will be well within the assimilative capacity of the receiving treatment facility.

6.2.1.4 Scrap Processing

The scrap processing operation will not have an impact on the treated process effluent discharged from the site. The scrap processing portion of UPMP can be separated into three separate major chemical operations: oxidation, dissolution and extraction. The gaseous effluents from the oxidation operation are treated by wet scrubbers and condensers with subsequent release through the single UPMP exhaust stack. The gaseous effluents from the dissolution process contains oxides of nitrogen at the vessels. These are passed through demister pads, condensers and finally through a NO_x absorber which reduces the nitrogen oxide levels prior to release through the exhaust stack. The discard liquid streams from both these operations are routed to the nitrate waste system for further treatment. The insoluble fraction from the leaching operation will be packed for offsite disposal. These solid wastes are discussed in Section 6.4.2.

- The product, purified uranyl nitrate, is transferred to the product storage tanks from which it is processed through a dedicated conversion operation which produces ceramic grade UO_2 powder.

- The solvent stream is pumped from the strip column to the solvent treatment system wash where an ammonium carbonate solution is used to strip the solvent of the organic decomposition products. The clean organic stream is recycled to the extraction columns while the waste products (~ liters/week) are sent to the on site incinerator for disposal. †

- The extraction column aqueous waste (AW) liquor contains all of the metal impurities which were extracted from the feed stream plus an insignificant amount of solvent/organic carryover. The AW stream is processed through the secondary nitrate waste treatment operation in which it is lime treated and the resultant precipitate, which includes the heavy metal ions as well as the trace residual organics, is filtered and packed for subsequent off site disposal.

Reference: SNM-1097

6.3 AIRBORNE EMISSIONS

All process emissions from the Uranium Process Management Project will be discharged through one new exhaust stack. The three effluent constituents of potential concern (uranium activity, fluoride and nitrogen oxide concentrations) will be continuously sampled or monitored as is described in the current facility license information.

The uranium activity and fluoride concentration will be determined based on a continuous sampling system similar to those already serving the existing chemical processing area exhausts. The nitrogen oxide concentration will be continuously monitored at the discharge of the NOx absorber by an on line nitrous oxide (NO) analysis. The monitoring unit is catalyst based and measures the total NOx content of the gas stream by converting the NO_2 to NO. The NO_2 contribution can be determined by a difference technique by periodically bypassing the catalyst.

It is estimated that the uranium activity in the exhaust stream will be about 0.05×10^{-12} µCi/cc. This activity is about one third the 1983 average concentration of 0.14×10^{-12} µCi/cc for all stacks on the site and would be expected to cause less than a two percent increase in total activity released from the site. This value is conservative since it includes no consideration for the reduction in the current exhausts resulting from the discontinued operation of UPS.

This processing activity replaces the same type of processing activity at another reprocessing facility with newer, modern technology. The net effect is that emissions from the fuel manufacturing cycle will be reduced slightly.

The fluoride releases are anticipated to be less than 100 grams per week. This quantity would equate to a fluoride concentration of 2.5×10^{-3} µgms/M^3 at the site boundry using conservative meterological assumptions. This concentration is well below the generalized threshold of 1 µgm/M^3 for effects on sensitive species found in the National Academy of Sciences Biological Effects of Atmospheric Pollutants - Fluorides.

The nitrogen oxide releases are anticipated to be 0.7 pounds per hour. This will result in an increase in the mean annual average ambient air NO_2 concentrations as a result of the Uranium Process Management Project of less than 0.003 ppm. This value, 6% of the federal air quality standards, is obtained by averaging the projected maximum annual NO_2 concentrations in each of the sixteen sectors surrounding the site. While representing a slight increase for WMD operations, it actually results in a decrease in discharge as a function of nuclear fuel produced.

The methodology for determining this concentration is based on the US Nuclear Regulatory Commission Regulatory Guide 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooler Reactors."

The meteorological data used for the calculations was obtained from the New Hanover County Airport for the period 1978-1982 and is representative of the GE-WMD site. The data tabulation was performed by the National Oceanic and Atmospheric Administration, National Climatic Center, Asheville, N.C. These are the same data as used in site evaluations of the current license.

6.4 SOLID WASTE

6.4.1 Sludges from Fluoride, Rad Waste & Nitrate Wastes

The significant benefit realized from the Uranium Process Management Project has been detailed in Sections 6.2.1.1 (Fluorides), 6.2.1.2 (Rad Waste), and 6.2.1.3 (Nitrates).

In summary:

- The accumulation in the final process lagoons of sludges from the radwaste stream will be eliminated.
- It is anticipated that the ongoing accumulation of uranium bearing sludges in the nitrate lagoons will be reduced to less than % of the present quantities. †

Reference: SNM-1097

- The disposal of calcium fluoride sludge disposal at other than a NRC licensed burial facility, as well as alternate uses of the material, can now be considered.

6.4.2 Other Solid Wastes & Sludges

The processing of uranium bearing materials in the form of sludges, powder, ceramics and ash at the UPMP facility results in the generation of moist filter cake and solid waste products.

Prior to the implementation of the UPMP facility, all ash and selected discrepant material, much in the form of sludges, were transported via intrastate trucklines to the uranium processing facility in Tennessee. The residues from processing this discrepant material were disposed of from that facility. With the implementation of the UPMP facility, the potential for these discards is shifted to WMD but does not represent any increased discard for the fuel manufacturing cycle. This discarded material is composed of three different types:

(1) The insoluble fraction from the leaching operation. The major contributor is the incinerator ash resulting from the burning of HEPA filters and other combustible wastes generated on the site. The resultant material should not exceed 50 metric tons per year of moist, liquid-free filter cake containing less than 0.1% uranium.

(2) The sludge precipitated from the treatment of the solvent extraction aqueous waste stream in the secondary nitrate waste treatment operation. This treatment process output should not exceed 80 metric tons per year of moist, liquid-free sludge containing less than 0.05% uranium.

(3) The contaminated, non-combustible scrap and debris generated during the day to day, normal operation of the facility, similar in characteristics to the type of material generated in the present fuel fabrication operations.

Reference: SNM-1097

Because of the improved technology being implemented in the project and the efficiency of operations, these quantities will be less than the quantities produced under the current arrangement.

6.5 REDUCED TRANSPORTATION RISK

The provision for on site capability to recover uranium from process scrap and sludges will eliminate the present transportation associated risks from the shipment of uranium bearing sludges and the return shipments of uranyl nitrate.

6.6 CLOSURE & DECOMMISSIONING

The Closure & Decommissioning Plan for the WMD facility is predicated upon complete removal of all sludges and other contaminated materials from the site prior to the closure and decommissioning. The Uranium Process Management Project provides a key element for accomplishing this plan.

The disposal of sludges resulting from the treatment of the fluoride waste stream and the treatment of liquids in the final process lagoons will be facilitated with this project because it will no longer be necessary to send these materials to a low level radioactive waste facility for burial. The Uranium Process Management Project also provides one already operational, key element of technology required in the event that the facility is decommissioned.