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1. EDT 607497

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2. To: (Receiving Organization) Distribution		3. From: (Originating Organization) PUREX Deactivation Eng.		4. Related EDT No.: N/A							
5. Proj./Prog./Dept./Div.: PUREX/UO3 Plant Deactivation		6. Cog. Engr.: M. B. Enghusen		7. Purchase Order No.: N/A							
8. Originator Remarks: This document was originally prepared to support the restart of the PUREX plant using the shear/leach process. The PUREX plant has been shutdown and this document is being issued as reference material for historical purposes.				9. Equip./Component No.: N/A							
				10. System/Bldg./Facility: N/A							
11. Receiver Remarks: N/A				12. Major Assm. Dwg. No.: N/A							
				13. Permit/Permit Application No.: N/A							
				14. Required Response Date: N/A							
15. DATA TRANSMITTED											
(A) Item No.	(B) Document/Drawing No.	(C) Sheet No.	(D) Rev. No.	(E) Title or Description of Data Transmitted	(F) Approval Designator	(G) Reason for Transmittal	(H) Originator Disposition	(I) Receiver Disposition			
	WHC-SD-CP-TI-171		0	Flowsheet For	N/A	1					
				Shear/Leach							
				Processing Of							
				N Reactor Fuel At							
				PUREX							
16. KEY											
Approval Designator (F)		Reason for Transmittal (G)			Disposition (H) & (I)						
E, S, Q, D or N/A (see WHC-CM-3-5, Sec.12.7)		1. Approval 2. Release 3. Information 4. Review 5. Post-Review 6. Dist. (Receipt Acknow. Required)			1. Approved 2. Approved w/comment 3. Disapproved w/comment 4. Reviewed no/comment 5. Reviewed w/comment 6. Receipt acknowledged						
(G)	(H)	17. SIGNATURE/DISTRIBUTION (See Approval Designator for required signatures)						(G)	(H)		
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Document Number: WHC-SD-CP-TI-171, REV 0

Document Title: Flowsheet For Shear/Leach Processing of N Reactor Fuel At PUREX

Release Date: 4/13/95

**This document was reviewed following the
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SUPPORTING DOCUMENT		1. Total Pages 82
2. Title Flowsheet For Shear/Leach Processing Of N Reactor Fuel At PUREX	3. Number WHC-SD-CP-TI-171	4. Rev No. 0
5. Key Words PUREX, Flowsheet, Shear, Leach, Shear/Leach	6. Author Name: M. B. Enghusen Signature Organization/Charge Code 17710/K42P1	
7. Abstract This document was originally prepared to support the restart of the PUREX plant using a new Shear/Leach head end process. However, the PUREX facility was shutdown and processing of the remaining N Reactor fuel is no longer considered an alternative for fuel disposition. This document is being issued for reference only to document the activities which were investigated to incorporate the shear/leach process in the PUREX plant.		
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FLWSHEET FOR SHEAR/LEACH PROCESSING OF N REACTOR FUEL AT PUREX

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Facility Operations Division
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January 1992

Westinghouse Hanford Operations
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FLWSHEET FOR SHEAR LEACH PROCESSING OF N REACTOR FUEL AT PUREX

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1.0 INTRODUCTION

This document presents the flowsheet for shear/leach processing of existing N Reactor irradiated fuel for recovery of uranium and plutonium. The shear/leach process represents one option for the disposition of the N reactor fuel.

This flowsheet presents the requirements, flow diagrams, material balances, and support technology for the shear/leach processing of the N reactor fuel in the PUREX plant. The shear/leach process replaces the chemical decladding process previously used at PUREX to provide a feed material for the existing solvent extraction process. This flowsheet does not contain information on the PUREX solvent extraction process for separation and concentration of Uranium and Plutonium product. The interfaces and impacts on the solvent extraction operation and the PUREX plant waste streams during processing are presented.

The shear/leach process provides several benefits over the chemical declad process previously used at the PUREX plant. The cladding hulls are mechanically segmented to expose the uranium and plutonium metal for dissolution. The spent hulls which remain after dissolution are stabilized and packaged for storage at the Waste Isolation Pilot Plant (WIPP). This process eliminates two liquid waste streams which were generated during the chemical decladding process. In addition, the liquid effluents from the solvent extraction process are also reduced due to the elimination of the fluoride, aluminum and zirconium in the dissolver product streams.

2.0 PROCESS SUMMARY

The flowsheet presented in this document is for the PUREX shear/leach processing of irradiated N Reactor Mark IV and Mark IA Zircaloy clad irradiated fuel elements. The shear/leach process replaces the Zirflex chemical decladding process and is installed in the PUREX plant head end operating cell(s). The product from the shear/leach process is routed to the existing PUREX solvent extraction process for separation and concentration of uranium and plutonium products. Figures 2.1 and 2.2 present the flow diagrams for the shear/leach and solvent extraction processes.

The N Reactor irradiated fuel contains a wide variety of Pu isotopic content (4 to 16 % ^{240}Pu) and fuel age (time since fuel was discharged from the reactor). The fuel elements are stored in canisters and shipped from the K basin storage areas in shielded rail cask cars to the existing PUREX tunnel. The fuel canisters are transferred from the rail cask car to an in-cell canister storage tank using the existing PUREX canyon crane. A remote operated in-cell crane system is used to transfer the canister from the canister storage tank to the canister receiving table. The table unloads the elements from the canister and transfers the elements to the fuel element separator. The separator transfers one element at a time into the fuel element shear. The shear mechanism divides the elements into 1.5 inch segments which drop into a basket in the dissolver.

The dissolver is operated continuously with nitric acid and water feed which dissolves the nuclear material leaving undissolved Zircaloy hulls. The dissolver product overflows to a product storage tank where it is cooled and transferred to one of several storage tanks for processing through the solvent extraction process, discussed later. The off gas from the dissolver is scrubbed, heated, filtered and routed through Iodine adsorbers before being exhausted through the existing PUREX head end off gas system located external to PUREX plant. The off gas system provides one additional filter and NO_x removal capabilities in the back up facility adsorption towers.

The Zircaloy hulls which remain in the dissolver baskets after dissolution of the nuclear material are rinsed, assayed and then stabilized for disposal at WIPP. The dissolver basket is removed from the dissolver using the in-cell crane and lowered into a hull rinse tank which removes residual nitrates. The basket is then nondestructive assayed (NDA) for significant undissolved/retained fissile material. Baskets with high level of undissolved fissile material are placed back into the dissolver for further processing. The hulls in the basket which do not contain significant fissile material are stabilized and packaged to meet storage criteria. The zirconium hull stabilization requirements for packaging are currently being identified. Two processes are given in this document for stabilization of the hulls. The first process involves mixing the hulls with a grout matrix and packaging in a waste container. The second process involves oxidation of the zirconium in an incinerator. The oxidized zirconium is then mixed with a grout matrix and packaged in a waste container.

The dissolver product in the head end storage tanks is processed through the existing PUREX solvent extraction (SX) processes which separates and converts the uranium and plutonium into nitrate products. The uranium nitrate is converted to uranium oxide at the UO_3 plant for storage/transfer off site. The plutonium is either converted to oxide at PUREX and transferred to the Plutonium Finishing Plant (PFP) or transferred to PFP as a nitrate. This flowsheet does not present the solvent extraction separation or oxide conversion flowsheets which already exist in various documents for Zirflex and/or Aluminum decladding processes previously used at PUREX. The composition and flows of product and waste streams from the shear/leach processing of N Reactor fuel at PUREX plant are presented in this flowsheet.

Figure 2.1

SHEAR/LEACH PROCESS FLOW DIAGRAM

(SL00207B)

Figure 2.2

PUREX SOLVENT EXTRACTION FLOW DIAGRAM

(SL00207C)

3.0 PROCESS DESCRIPTION

The shear/leach processing of N reactor fuel is conducted in the A (hull incineration option) and B PUREX plant head end operating cells. The product from the shear/leach dissolver is processed through the existing PUREX solvent extraction to separate the plutonium and uranium as nitrate product streams. The uranium nitrate is converted to uranium oxide at the UO_3 plant and stored or transferred offsite as needed. The Pu nitrate is either converted to oxide in the PUREX oxide line or loaded out as a nitrate. The Pu product is transferred to the Plutonium Finishing Plant for storage and disposition.

This flowsheet section presents the shear/leach process and discusses the impacts and interfaces with the PUREX plant solvent extraction operation. Two options are presented which represent different methods of handling the hull waste remaining after dissolution. Option A involves the grouting of the hulls remaining after dissolution of the fuel while option B incinerates the hulls prior to grouting. Selection of the option will depend upon the criteria for long term storage at the Waste Isolation Pilot Plant (WIPP).

This flowsheet does not present any information on existing PUREX plant equipment, solvent extraction process or plutonium conversion processes. A detailed description of the PUREX plant, solvent extraction process, and Pu oxide conversion is given in the PUREX Technical Manual, Safety Analysis Report and solvent extraction flowsheets (references 5,7,13 and 23). The UO_3 plant and process are described in detail in the UO_3 plant flowsheet and Safety Analysis Report (References 21 and 22).

3.1 FUEL DESCRIPTION

The inventory of N Reactor fuel to be processed by shear/leach process is listed in table 3-1 and illustrated in figure 3.1. N Reactor fuel elements consist of two concentric tubes with outer tube diameters of 2.40 to 2.42 inches. The tubes are 15 to 26 inches long and are made of uranium metal co-extruded into Zircaloy cladding which is then capped at both ends. The fuel elements were made with different initial uranium enrichments. The MK IV fuel elements have a ^{235}U enrichment of between 0.71 and 0.947% in both the inner and outer tubes and have an average weight of 50 pounds. The MK 1A "spike" fuel elements have 1.25% enriched uranium in the outer tube and 0.947% enriched uranium in the inner tube and have an average weight of 36 pounds.

Table 3.1 N Reactor Fuel Inventory.			
	0.71 to 0.95% ENRICHED MK IV	1.25% ENRICHED MK 1A SPIKE	TOTAL
Weapons grade*	291	39	330
Fuels grade*	1182	594	1776
Total	1473	633	2106

*Fuel with a ^{240}Pu content of less than 6% is classified as weapon grade and fuel with a ^{240}Pu content greater than 6% is classified as fuel grade. The fuel grade material includes approximately 45 MTU with nominal 9% ^{240}Pu content and approximately 15 MTU with a nominal 16% ^{240}Pu content.

The fuel grade fuel was discharged from N Reactor between 1970 and 1980 and is presently stored in the KE and KW Basins. The weapon grade fuel has been stored in the basins for 2-5 yr. Most of this fuel (197.6 MTU) came from the N Reactor final core discharge which was completed in April 1989. Because this fuel was not in the reactor for the normal irradiation period, it contains less than 6% ^{240}Pu (minimum 4%).

An inspection performed in 1981 identified a number of breached or broken fuel elements stored in the canisters. An estimated 6% of the fuel elements in the KE basin were either leaking or broken based on a visual inspection of open canisters. Degradation of the fuel occurs when the Zircalloy cladding is breached and the uranium metal reacts with the water to form uranium hydride and hydrated uranium oxide. The oxide layer initially forms a protective layer which later sloughs off to expose the metal.

The fuel stored in the KW basin is presently in sealed stainless steel canisters. The fuel in the KE basin is contained in open canisters which will be transferred to new sealed stainless steel canisters. The lid for each canister is removed prior to loading in rail cars for transfer to PUREX. The canister will contain 14 fuel elements and approximately 6.4 gal of water. The canister may also contain sludge generated during storage. The sludge is currently being characterized for content.

Processing of the fuel will occur when the weapon grade fuel is approximately 10 years old and the fuel grade fuel is 20 years old. The 16 % fuel grade material contains the highest fission product content, however, the fuel will be blended during processing to reduce impacts on processing. The 12 % fuel grade material with 80 % Mark IV and 20 % Mark IA represents the highest fission product content during processing. The key fission product content of the 6 and 12% fuel with 80 % Mark IV and 20 % Mark IA is listed in tables 3.2 and 3.3.

Figure 3.1

N REACTOR FUEL ROD ASSEMBLY

(SL00205A)

Table 3.2 Average Radionuclide Content (curies per MTU) of 12 % Pu 240 Fuel
(Worst case processing of 80 % Mk IV/20 % Mk 1A)

Nuclide	5.0 Year	10.0 Year	20.0 Year	30.0 Year
^3H	3.58E+01	2.70E+01	1.54E+01	8.81E+00
^{85}Kr	6.95E+02	5.03E+02	2.64E+02	1.38E+02
^{89}Sr	4.16E-06	5.40E-17	0.00E+00	0.00E+00
^{90}Sr	6.52E+03	5.79E+03	4.56E+03	3.59E+03
^{90}Y	6.52E+03	5.79E+03	4.56E+03	3.60E+03
^{95}Zr	1.23E-03	3.15E-12	2.06E-29	1.34E-46
^{95}Nb	2.73E-03	6.98E-12	4.56E-29	2.98E-46
$^{95\text{M}}\text{Nb}$	9.13E-06	2.33E-14	1.52E-31	9.96E-49
^{106}Ru	1.62E+03	5.20E+01	5.37E-02	5.54E-05
^{106}Rh	1.62E+03	5.20E+01	5.34E-02	5.54E-05
$^{119\text{M}}\text{Sn}$	1.81E-01	1.01E-03	3.36E-08	1.09E-12
^{123}Sn	4.27E-02	2.37E-06	7.28E-15	2.24E-23
^{129}I	2.71E-03	2.71E-03	2.71E-03	2.71E-03
^{134}Cs	6.14E+02	1.14E+02	3.96E+00	1.37E-01
^{137}Cs	8.19E+03	7.30E+03	5.79E+03	4.60E+03
$^{137\text{M}}\text{Ba}$	7.75E+03	6.57E+03	5.48E+03	4.35E+03
^{144}Ce	2.40E+03	2.79E+01	3.78E-03	5.12E-07
^{144}Pr	2.40E+03	2.79E+01	3.78E-03	5.12E-07
$^{144\text{M}}\text{Pr}$	2.88E+01	3.35E-01	4.54E-05	6.15E-09
^{147}Pm	7.51E+03	2.00E+03	1.43E+02	1.02E+01

Table 3.31 Average Radionuclide Content (Curies per MTU) of 6 % Pu 240 N
Reactor Fuel (Worst case processing of 80 % Mk IV/20 % Mk 1A).

Nuclide	5.0 Year	10.0 Year
^3H	1.38E+01	1.04E+01
^{85}Kr	3.00E+02	2.17E+02
^{89}Sr	3.62E-06	4.69E-17
^{90}Sr	2.82E+03	2.50E+03
^{90}Y	2.82E+03	2.50E+03
^{95}Zr	9.21E-04	2.35E-12
^{95}Nb	2.12E-03	5.23E-12
$^{95\text{M}}\text{Nb}$	6.83E-06	1.75E-14
^{106}Ru	5.21E+02	1.67E+01
^{106}Rh	5.21E+02	1.67E+01
$^{119\text{M}}\text{Sn}$	8.83E-02	5.04E-04
^{123}Sn	2.41E-02	1.34E-06
^{129}I	9.96E-04	9.96E-04
^{134}Cs	1.01E+02	1.88E+01
^{137}Cs	3.25E+03	2.90E+03
$^{137\text{M}}\text{Ba}$	3.08E+03	2.75E+03
^{144}Ce	1.20E+03	1.40E+01
^{144}Pr	1.20E+03	1.40E+01
$^{144\text{M}}\text{Pr}$	1.44E+01	1.68E-01
^{147}Pm	3.69E+03	9.84E+02

3.2 FUEL DELIVERY AND HANDLING

Fuel for shear leach processing at PUREX is transferred from the K basin storage in shielded cask contained inside railroad cars. Up to twelve canisters are loaded into each water cooled casks (reference drawing H-1-34671) with one to three casks per railroad car, depending on the type of car used. If approval to use existing casks and/or cask cars is not received, alternate transfer methods will be used.

The cask car(s) are transferred to the PUREX building railroad tunnel. Once inside the railroad tunnel, the car(s) are connected to the rail car puller. The rail car puller is used by the PUREX crane operator to position each rail car under the canyon horizontal door. Once the car is in position, the cask car lid is opened and the lids to the casks are removed. The canisters are lifted from the casks one at a time by the PUREX Remote Maintenance Crane through the horizontal door. The canister is then transferred to the shear process cell and lowered through the canister access portal in the cover block(s) into the canister storage tank, TK-B1. After transfer of the canisters to the canister storage tank the access portal is closed. Empty canisters stored in the canister storage tank are returned to the basins using the reverse process.

3.3 SHEAR/LEACH CELL EQUIPMENT

The equipment used for shear/leach processing of N reactor fuel is listed in table 3.3.1. Equipment numbers are listed for both Option A - Hull Grouting and Option B - Hull Incineration. The equipment locations within the operating cells is shown in figure 3.3.1 for Option A and figures 3.3.2 and 3.3.3 for option B (reference 20). Information on the in-cell equipment is given in the following sections.

A new in-cell crane (ICC) is installed in B cell and used to transfer fuel canister or dissolver basket between the individual cell stations. The ICC operates below the cell cover blocks and is remotely controlled from the head end control room. In-cell lighting and cameras are provided at key control locations to observation cell activities and for control of the crane and for observation of all cell activities.

Table 3.3.1 Shear/Leach Equipment Identification		
Equipment Number		Designation
Option A and B*		
TK-B1		FUEL CANISTER STORAGE TANK
E-B2		CANISTER RECEIVING TABLE
E-B3		FUEL ELEMENT PUSHER
E-B4		FUEL ELEMENT SEPARATOR
E-B5		FUEL ELEMENT SHEAR
TK-B6		DISSOLVER
TK-B7		PRODUCT STORAGE TANK
T-B8		DOWNDRAFT CONDENSER
E-B9		OFF GAS HEATER
F-B10 & F-B13		OFF GAS FILTERS
T-B11 & T-B12		IODINE ADSORBERS
TK-B14		HULL RINSE TANK
E-B15		NEUTRON MONITOR
E-B16		HULL DUMPER
Option A*	Option B*	
E-B17	E-A1	HULL HOPPER
None	E-B17	HULL DRYER
E-B18	E-A5	GROUT HOPPER
E-B19	E-A3	BLENDER
E-B20	E-A4	CONTAINER CAPPER/DECAPPER
None	E-A2	HULL INCINERATOR

* - Option A and B refer to the method of hull stabilization prior to packaging. Option A is the grouting of the hulls followed by packaging. Option B is the incineration of the hulls and packaging of the grouted oxide.

Figure 3.3.2

A-CELL EQUIPMENT DIAGRAM OPTION B

(SL00211A)

3.4 FUEL SEPARATION AND SHEARING

Fuel separation and shearing is accomplished by the dumping of the fuel in one canister onto a separator and feeding one fuel element at a time into the shear mechanism. Figure 3.4.1 shows the configuration of the fuel separation and shearing equipment. Fuel canisters stored in the fuel canister storage tank, TK-B1, are transferred to the canister receiving table, E-B2, using the ICC. On the receiving table, the canister is positioned horizontally with the canister lower connection point positioned into the tipping trunion, see figure 3.4.2. The receiving table tilts on an axis point located at the lower end of the canister. The canister is then lifted away from the elements which are held by gravity at a retaining panel. The table is then lowered back to horizontal position and the empty canister transferred back into the canister storage tank using the ICC. Solution from the canister is routed to the dissolver for processing.

The fuel element pusher, E-B3, slides the elements off the table and into the fuel element separator, E-B4. The fuel element separator collects one element and feeds the shear mechanism. Figure 3.4.3 demonstrates the operation of the fuel element pusher and separator. The fuel element shear segments one fuel element at a time into sections not to exceed 1.5 inches in length. The cut sections discharge to the dissolver charging chute and into a dissolver basket. If deemed necessary, an inert gas purge or water deluge is used during the shear process to eliminate potential uranium and zirconium fires. Periodic flushes of the equipment remove residual build up of fines or sludge.

3.5 DISSOLUTION

Dissolution of the fuel is conducted in an annular dissolver, TK-B4, which utilizes baskets to hold the segmented fuel. Fuel from the element shear is routed through the charging chute and into the first dissolver basket position, see figure 3.5.1. Up to three canisters (.7 to 1.0 MTU's per canister) are charged per basket with a total of seventeen basket positions available. When charging is completed, the baskets are rotated using the Basket Indexing System to the next position to allow charging of the next basket and for removal of hulls from the final basket position. Charging occurs at least every 13 to 18 hours to meet the 4 MTU per day processing rate.

The dissolver is supplied with continuous 10 molar recovered nitric acid and water feed streams, see figure 3.5.2. An air sparge located in the bottom of the dissolver is directed upward through the baskets to assist the dissolution of irradiated fuel, to provide solution mixing and ensure adequate heat removal. Dissolution of the fuel is continuous and controlled by adjusting the nitric acid feed, water feed, and dissolver temperature. Initial dissolution of newly sheared fuel will occur rapidly due to the uranium fines and large surface area and will be controlled by lowering the temperature in the dissolver or adjusting the acid and/or water feed streams.

Figure 3.4.1

Fuel Shearing Equipment

(SL00214A)

Cannister Receiving Table

(SL00215A)

Figure 3.4.2

FUEL ELEMENT SEPARATOR OPERATION
(SL00212A)

FIGURE 3.4.3

Continuous Dissolver

(SL00213A)

FIGURE 3.5.1

Figure 3.5.2

Continuous Dissolver Stream Diagram

(SL00201A)

The off gas from the fuel dissolution which contains nitrogen oxides, nitrous acid, gaseous fission products and excess air exits out the top of the dissolver and is routed into the off gas handling equipment, see section 3.6. The dissolver product stream, 3 molar nitric acid and 2 molar uranium nitrate, overflows from the dissolver stilling chamber to the product storage tank. The dissolver product is then transferred to additional storage tanks and handled as described in section 3.7

3.6 OFF GAS HANDLING

The off gas from the dissolver contains oxides of nitrogen (NO_x), gaseous fission products, nitrous acid, water vapor and air. The off gas is routed through a downdraft condenser, T-B8, to condense the water vapor and to absorb the nitrous acid. Some conversion (approximately 10%) of the NO_x to nitric acid will also occur in the tower. All solution from the tower is routed back to the dissolver. The off gas from the tower routed through a demister and then heated by the electric heater, E-B9, to 150 degrees centigrade for Iodine adsorption in the silver mordenite bed(s).

Gaseous fission products released during the dissolution of the N reactor fuel include ^{85}Kr , ^{133}Xe , ^{14}C , and ^{129}I . The Kr, Xe and C gases are discharged via the 291-A-1 stack without treatment to the environment. The ^{131}I (8 day half life) and other short lived iodine fission products are not present at the time of processing due to the age of the fuel (10 to 20 years) and short half lives of the isotopes. The ^{129}I is adsorbed in one of two silver mordenite beds placed in series downstream of the heater, T-B11 and T-B12. Each bed is capable of absorbing over 99 per cent of the Iodine released and are replaced prior to becoming saturated with iodine.

Particulate filtration will be accomplished in the processing cell by two high efficiency sintered stainless steel filters, F-B10 and F-B13, positioned on either side of the iodine adsorbers. The filters are 99.95 percent efficient at removing particulates and are connected to the existing PUREX dissolver off gas system at the cell wall. The existing system is located external to the PUREX plant and includes one fiberglass filter for particulate filtration and the back up facility where additional recovery/absorption of NO_x will occur. Discharge of the off gas is to the 291-A-1 stack via the off gas jets which are used to provide the vacuum for the dissolver.

3.7 FEED STORAGE

The dissolver product solution is stored in head end tanks until processed through PUREX solvent extraction. In the shear processing cell, a dissolver product storage tank, TK-B7, is installed which receives the overflow from the dissolver. The hold tank cools the product solution prior to transfer to D and E cell storage/processing tanks. In a D cell tank, the solution is digested at elevated temperatures to dissolve entrained uranium fines which did not drop out in the dissolver stilling chamber. The solution is then cooled and decanted to a second head end tank for feed storage. The solids which remain in the bottom of the tank after decanting is periodically washed with nitric acid and transferred to an existing dissolver or tank and the fines handled along with the dissolver fines, discussed later.

Tanks TK-D1, TK-D2, TK-D3, TK-D4, TK-D5, TK-E3, TK-E5, and TK-E6 may be used to store dissolver product. At 90 % capacity, a total of 42,750 gallons is available for storage. Samples and volume measurements taken while the dissolver product is stored in TK-D5 are used for accountability of the nuclear material transferred to the PUREX solvent extraction process.

The solids which are entrained out of the product digestion tank should be less than 10 microns in diameter (reference 20) and are not expected to cause problems in the PUREX solvent extraction equipment. A filter is designed for removal of the particulates but would not be installed unless dictated by actual operations. The filter would be installed in an unused E cell position and will use two of the E cell storage tanks as filter feed and receiver tanks. The filter will be designed to allow back flushing of the solids to a dissolver and/or for easy filter replacement and disposal by crane into 55 gallon drums.

3.8 PARTICULATE HANDLING

Particulates are generated during fuel storage, shear operation and dissolution of the fuel. The particulates from storage and shear processes are routed to the dissolver during fuel handling operations discussed previously. In the dissolver, the uranium, plutonium and fission products in the particulates has the opportunity to react and go into solution. The remaining particulates in the dissolver will contain mostly undissolved zirconium compounds which will either stay in the dissolver or transfer with the feed as small particles (<10 micron by design). Periodically, the dissolver will be shut down and the particles slurried into an existing PUREX vessel.

Particulates captured during the product feed decant and product filtration operations are accumulated with the dissolver particulates in one existing PUREX vessel. Two options are available for disposal of the particulates including (1) grouting of the fines and transfer in hull storage containers to WIPP and (2) neutralization of the fines and transfer to tank farm storage tanks. The method for disposal of the particulates will depend upon the WIPP acceptance for grouted fines as a stabilized matrix. The steps involved with handling the fines are not included with this flowsheet. Due to the small amount of solids present, disposal activities may be conducted yearly or after all the N Reactor fuel has been processed.

3.9 HULL DISPOSAL

The zirconium hulls which remain after the irradiated fuel material has been dissolved must be rinsed, assayed for nuclear material (E-B15), stabilized and packaged for disposal. The dissolver design includes a basket removal and insertion port (BR/IP). The port is valved to control air flow and includes water rinse jets for removal of dissolver solution and particulates back into the dissolver. The baskets are removed by opening the valve and lowering the basket handling grapple into the top of the basket. The grapple connects to the basket and slowly removes the basket while the water jets around the BR/IP flush the fuel in the basket. An additional flush nozzle located in the middle of the grapple is used to flush downward into the basket during removal for additional product and nitrate removal. When the basket is free of the dissolver the flushes are turned off and the BR/IP valve is closed.

The basket containing the hulls is transferred into the hull rinse tank, TK-B14, using the in-cell crane. The rinse tank contains water which is used to remove any residual nitrates which stabilizes the newly exposed zirconium surfaces (Reference 4). When the residual nitrate level in solution reaches 1 molar, the water is transferred to the dissolver and replaced with fresh solution.

The Zircaloy hulls are stabilized to eliminate pyrophoric hazard, packaged in approved containers and transferred to WIPP. The stabilization of the hulls and packaging are conducted to meet the WIPP requirements, reference 24. Stabilization of the zirconium will be conducted by one of two options. The preferred option involves disposal of the hulls as a grouted matrix which isolates the zirconium from the oxygen and eliminates pyrophoric hazard. The second option involves incineration of the hulls and disposal of the stable zirconium oxide or grouted zirconium oxide. Each option is discussed in later section.

3.9.1 Hull Grout Option

The hull basket is removed from the hull rinse tank and transferred to the neutron monitor for non destructive assay (NDA) of nuclear material, E-B15. Hulls which do not meet the requirements for disposal are reinserted into the dissolver via the BI/RP. Hulls which meet disposal limits are transferred to the hull dumper, E-B16. The dumper inverts the basket and empties the basket through a hopper into a blender, E-B19, containing grout mixture. The grout mixture is prepared in the grout hopper, E-B18, prior to hull addition and consists of dry grout matrix and water. The grout and hull material are blended to ensure even consistency.

Empty waste containers are transferred from a storage location into the cell using the PUREX remote crane. An in-cell conveyor system is used to transfer the container to a capper/decapper, E-B20, where the lid is removed. The container is then conveyed to a position under the blender. After the blender mixing is complete the contents are dumped out of the blender into waste containers. The container is transferred using the in cell conveyor to the capper/decapper which attaches the lid to the container. The container is then conveyed to a temporary in cell storage location where several containers may collect.

The PUREX remote crane is used to transport the containers from the cell to a waste container NDA. The assayed containers are transferred to cleaning area where surface contamination is removed. The clean containers are then transferred to the slug storage basin for temporary storage. The containers will eventually be transported to the WRAP facility and repackaged for WIPP disposal.

3.9.2 Hull Incineration Option

The incineration processing of the hulls will occur in A cell. The hulls are removed from the hull rinse tank and transferred to the NDA station to determine nuclear material content, E-B15. If the content is above limits for disposal, the basket will be returned to the dissolver for further processing. The basket from the NDA which meets disposal requirements is transferred to the dumper, E-B16. The elimination of water with the hulls is essential to eliminate the explosive reaction of the water during incineration. The dumper rotates the basket to the horizontal position to allow residual water to drop through a grating to a sump. The basket is then righted and transferred to a hull dryer, E-B17, which blows warm air through the hulls until they are dry. The basket is transferred back to the basket dumper which inverts the basket to empty the hulls into a transfer container.

The PUREX remote crane moves transfer container from the shear cell to the incineration cell. The container is placed on a tipping trunion which is used to empty the hulls into a feed hopper, E-H1, located above the incinerator, E-A2. The feed hopper controls the flow of hulls to the incinerator. In the incinerator, the zirconium hulls are converted to an oxide using elevated temperatures and excess oxygen supply. The oxide product is routed into a blender, E-A3, which is filled with grout prior to receiving incinerated hulls. The full blender is closed and mixed to ensure consistency.

Waste containers are transferred into the cell using the PUREX remote crane. An in cell conveying system routes the containers through a capper/decapper, E-A4, for removal of the lids. The container is positioned below the blender for loading. The blender outlet valve is opened and the waste transferred into the container. The container is conveyed to a capper/decapper station for lid installation. The PUREX remote crane is used to transport the containers from the cell to a waste container NDA. The assayed containers are then transferred to the slug storage basin for temporary storage. The containers will eventually be transported to the WRAP facility using approved transportation to be repackaged for WIPP disposal.

3.10 TIME CYCLES

The basis for this flowsheet is a fiscal year 250 day campaign at 4 MTU per day. The shear/leach process capability and interface assuming this basis are discussed below.

3.10.1 Shear\Leach Time Cycle

A time cycle diagram demonstrating the mechanical aspects of the shear/leach process is shown in figures 3.10.1 and 3.10.2. Both options for hull neutralization and disposal are shown. The diagrams demonstrate the capability to load one dissolver basket of fuel every shift with three canisters of fuel per basket. This feed rate is equivalent to 6.3 to 9 MTU per day. The operating basis for shear leach is to process 4 MTU per day which is equivalent to charging one basket every 13 to 18 hours. This allows for a operating efficiency of 44 per cent.

3.10.2 Interface With Solvent Extraction

The processing of shear/leach product through PUREX solvent extraction (SX) will require special coordination due to differing processing rates. The shear leach design nominal operating rate is 4 MTU per day. The PUREX SX processing rate can be varied from 5 to greater than 10 MTU per day. Waste streams from SX are only partially proportional to the processing rate. Lower processing rates tend to generate more waste per MTU processed, therefore, the operation of SX is conducted at a higher rates to reduce the overall liquid waste generation.

SHEAR LEACH SEQUENCE TIME LINE-OPTION A

Figure 3.10.1

SHEAR LEACH SEQUENCE TIME LINE-OPTION B

Figure 3.10.2

The processing of the shear/leach product through SX will occur as a batch process. The shear/leach process is operated continuously to fill the head end storage tanks, 42,750 gallons. When the product tanks are nearly full, the solvent extraction (SX) process will be initiated. When the SX process has stabilized, the feed from the head end tanks will be processed through SX, approximate feed rate 3.4 gallons per minute. When the head end storage tanks have been emptied, the SX process will either continue to operate on recycled UNH material or initiate a short term shutdown until the feed tanks are again full. The processing option used will depend on plant conditions at that time.

Figure 3.10.3 demonstrates the interrelationship between the shear/leach and SX process. For the figure, replacement of the silver reactor is assumed every 500 MTU (worst case required during fuel grade operation) and with SX shutdown after emptying head end feed tanks. The SX processing rate used for this figure was 8 MTU per day.

The SX flowsheets for processing of the shear/leach product are given in references 13 and 23. The SX section of the zirflex decladding flowsheet (reference 13) is applicable if the zirconium and aluminum contributions from the declad operations are omitted. The SX flowsheet for the aluminum clad fuel processing (reference 23) more closely relates to the shear/leach process. Once again, the aluminum contributions from head end need to be omitted. Either flowsheet can be used with appropriate modifications to achieve the desired operating rate. Some individual column adjustments may be necessary to adjust for the shear/leach product characteristics for nitric acid, uranium, and fission product concentrations. Some consideration will be given to eliminate or modify portions of the flowsheet to meet product specifications and reduce processing costs (i.e. elimination of the final purification cycles, reduced organic recovery scrub flows, etc.).

3.11 PROCESS SUPPORT

The cooling water, electrical and nitric acid support requirements for the shear leach process are discussed in the following sections. The support requirements for solvent extraction process can be found in the PUREX Technical Manual (Reference 5) and PUREX FLOWSHEET (reference 13).

3.11.1 Cooling Water/Steam

The cooling water and steam to the shear processing cell(s) is supplied from the PUREX steam and cooling water closed loop system(s) located outside of PUREX. Water is routed to the dissolver, condenser, product feed tank, and fuel canister storage tank from the cooling water header in the P&O gallery. Steam is routed to the dissolver product storage tanks from steam header in the P&O gallery. Flow measurement and controls are installed either in the P&O gallery piping or in the jumpers connecting the wall nozzles to the individual vessels.

SHEAR/LEACH AND SOLVENT EXTRACTION PRODUCTION INTERFACE

Figure 3.10.3
(SLO0206A)

The coil discharges from the shear leach vessels are routed back to the closed loop system using jumpers to tie into the return header wall nozzle connections. A discussion of the closed loop system is given below in the liquid effluents section.

3.11.2 Nitric Acid

The nitric acid supply to the continuous dissolver is transferred from the recovered acid storage tanks U1 and U2. Existing tank U1 and U2 pumps and transfer lines to the head end cells are used to route the nitric through new jumpers connecting the wall nozzles to the dissolver. Flowmeter(s) and control systems are installed in the sample gallery to control the flow rate.

3.11.3 Electrical Requirements

The heating requirements for shear/leach processing are supplied by the motor control centers in the PUREX P&O gallery. The electrical power is routed to wall nozzles and connected to the dissolver, hull incinerator, dissolver basket dryer and off gas heaters using electrical jumpers in the head end cells.

3.11.4 Demineralized Water

Demineralized water is supplied to the dissolver and feed storage tanks as needed to maintain the dissolver feed concentration. The demineralized water is supplied from a tank 223 in PUREX aqueous makeup area through a header in the P&O gallery to wall nozzle connections. Jumpers are used to connect the wall nozzles to the individual vessels. Flow control and indication are installed in the P&O gallery piping.

3.12 LIQUID WASTE

3.12.1 Shear/Leach Liquid Waste

Liquid waste streams generated during the shear leach process consist of water which is either routed to the dissolver for processing or sent to tank F18 for disposal to underground storage tanks (UGS). The water from the canister dumping operations, basket removal rinsing and replacement of hull rinse tank water is transferred into the dissolver for processing. The fuel canister storage tank water is routed to tank F18 for transfer to UGS as needed to maintain solution clarity for canister handling.

Any solution which inadvertently leaks from the process vessels is collected in the head end cell sumps and transferred to tank F18. The shear/leach cell leaks to Tk-F18 are included in the processing of the waste is discussed in the section below.

3.12.2 Solvent Extraction Liquid Wastes

The liquid wastes from solvent extraction consist of two basic types differentiated by the fission product content. The low fission product content material (<.1 BTU/Hr-gal.) is transferred from various waste tanks to an underground storage tank (UGS) in tank farms. This waste is generated from organic recovery, laboratory operations, vessel ventilation (jets), equipment leakage, acid recovery, and several other small streams. The low level waste (LLW) is collected in PUREX waste tank(s), sampled for activity and nuclear material content and adjusted with caustic and sodium nitrite to meet tank farm storage specifications. When tank farm specifications are met, the waste is transferred via double encased transfer lines to underground storage tanks. Table 3.12.1 gives the volume and concentration of the LLW for shear/leach processing of N reactor fuel (Reference 14). The LLW stored in tank farm storage tanks are processed through the waste evaporator to produce grout feed. From a 10 month operating campaign, a total of 51,380 gallons of grout will be produced and stored in grout vaults.

The high activity fission products in the shear/leach feed are separated from the uranium, plutonium and neptunium in the first SX processing column. The column waste stream is then concentrated and processed in the F cell acid recovery process to reduce waste volume and to remove as much nitric acid as possible (reference 5). The resulting concentrated high activity waste is adjusted to meet tank farm storage specifications and transferred to an UGS tank via double encased transfer lines. Table 3.12.2 gives the volume and constituents for high activity waste generated from shear/leach processing of N Reactor fuel. The chemical compositions and flow for the Zirflex Declad process previously used at PUREX is listed for comparison purposes. A significant volume reduction, 235 gallons per MTU versus 315 gallons per MTU, over the Zirflex process waste is possible due to the absence of the aluminum used to complex the corrosive fluoride from the Zirflex decladding operation.

The high level waste stored in tank farm consists of solid and liquid phases. The stored waste will be sluiced from the waste tanks to B plant where the solids and supernatant are separated. The solids are washed to remove soluble salts and the wash solution combined with the supernatant stream. The combined supernatant stream is treated to remove cesium and then transferred to a tank farm grout process feed storage tank. The cesium stream and the solids are combined to form feed for vitrification in the Hanford Waste Vitrification Plant (HWVP). For shear/leach processing of N reactor fuel a total of 75.2 gallons per MTU of grout and 36.4 kilograms per MTU of glass (HWVP product) will be produced.

**Table 3.12.1 Miscellaneous Waste Stream From Shear/Leach Processing
Of N Reactor Irradiated Fuel**

Volume: 124,000 Gallons per Month While Operating
 39,000 Gallons per Month While Shutdown

AVERAGE CONCENTRATIONS	
Na	0.3 M
CO ₂	0.04 M
MnO ₄	0.001 M
TOC	0.03 M
NO ₂	0.01 M
NO ₃	0.18 M
U	1.006 gm/l
Pu	0.0011 gm/l
OH	0.06 M

Table 3.12.2 High Fission Product Waste From Shear/Leach And
Zirflex Declad Processing Of N Reactor Irradiated Fuel

AVERAGE CONCENTRATIONS AND VOLUMES		
Process	Shear/Leach	Zirflex Declad
Volume	235 gal/MTU*	315 gal/MTU
Al	0.09 M **	0.42 M
Na	0.93 M	3.97 M
SO ₄	0.399 M	0.13 M
Fe(OH) ₃	0.107 M	0.15 M
Cr(OH) ₃	0.015M	0.009 M
Ni(OH) ₂	0.01 M	0.006 M
NO ₃ + NO ₂	3.807 M	2.02 M
U	1.17 gm/l	0.87 gm/l
Pu	0.004 gm/l	0.003 gm/l
OH	0.85 M	0.85 M

*Based on recycle operation of solvent extraction.

**Aluminum contributor will be eliminated after processing of stored fuel.

Fission Product Content Of Shear Leach Waste (Curies Per Liter)		
	6 % Pu 240 Fuel (80% Mark IV, 20% Mark 1A)	12 % Pu 240 Fuel (80% Mark IV, 20% Mark 1A)
⁹⁰ Sr	3.31	6.02
⁹⁰ Y	3.31	6.03
¹⁰⁶ Ru	0.022	0.0001
¹³⁴ Cs	0.025	0.005
¹³⁷ Cs	3.84	7.66
^{137m} Ba	3.638	7.24
¹⁴⁴ Pr	0.018	0.19
¹⁴⁷ Pm	1.30	0.19

3.13 LIQUID EFFLUENTS

The liquid effluents from the PUREX process consist of four streams; 1) process vessel steam condensate and cooling water from vessels with high potential for radionuclide contamination, 2) chemical sewer (CSL), 3) process condensate (PDD) and 4) the cooling water and steam condensate from vessels with low potential for contamination. At the present time a Best Available Technology document is being prepared which will identify the design for the low potential steam condensate and cooling water streams. The other 3 streams are discussed below.

The shear/leach process will use cooling water in the dissolver, dissolver tower, and product storage tanks. Some steam is required to heat the product storage tanks during digestion of the solids. The steam and cooling water used by shear leach will be connected to the high potential cooling water and steam condensate system discussed below.

3.13.1 High Potential Cooling Water And Steam Condensate Stream

The steam and water for PUREX vessel coils with a high risk of contaminant release are supplied from the PUREX closed loop system (reference 15) to headers located in the P&O gallery. The headers are routed to wall penetrations in the P&O which extend into the individual cells. Remote jumper connections are used to connect the wall penetration nozzles to the vessels. The coil discharges are routed, by jumpers, to wall penetration nozzles which are routed outside PUREX to the collection header.

The solution from the vessel discharge header is cooled with a quench water stream and monitored for contaminants, see figure 3.13.1. Contaminated solution caused by coil failure is routed into the 216-A-42 retention basin for sampling and laboratory analysis. Upon confirmation of radiological contamination, the water is transferred back to PUREX for disposal and/or recovery. Over time, the chemicals used for steam generation and corrosion products will build up in the recycled solution which will also require transfer of some of the coil discharge back to a PUREX tank for disposal and/or recovery.

The liquid (water or steam condensate) from the PUREX tank coils which is not contaminated is used to provide steam and cooling water for the PUREX plant, see figure 3.13.1. The noncontaminated condensate and water stream is separated into two streams to generate cooling water and steam supply. The cooling water stream is routed initially through a heat exchanger and further cooled in a refrigeration-cycle chiller. The cooled water is then routed back to the cooling water supply header. As needed, raw water is available to supplement the cooling water supply to the plant during emergency conditions.

The second noncontaminated condensate and water stream is deaerated, filtered, treated and passed through a steam generator to provide the steam supply to the building. Steam from the 200 East area powerhouse at 225 PSI is used in a steam generator to produce the required 100 PSIG steam from the recycle stream. The steam is then routed into the PUREX steam supply header(s). As needed, steam from the powerhouse is reduced down to 100 PSIG and added to the headers during emergency conditions. The steam condensate from the steam generator (supplied by the power house) is routed back into the closed loop system after deaerating and monitoring.

The average steam demand for the system while operating is approximately 2000 pounds per minute. The average cooling water supply is approximately 275 gallons per minute. During standby conditions the average steam demand is approximately 150 pounds per minute and the cooling water demand is approximately 50 gallons per minute. The average waste constituents in the condensed steam and cooling water stream is listed in table 3.13.1.

3.13.2 Process Condensate Stream (PDD)

The process condensate (PDD) effluent stream from PUREX consists of concentrator E-K4 condensed off gas and represents surplus water in the solvent extraction process which is not transferred out with the product or waste streams. Water is supplied to PUREX in the form of feed streams to several locations including:

1. Essential materials additions to columns and tanks.
2. Concentrator tower sprays.
3. Steam for T-L6 and E-L7 concentrators.
4. Tank and vessel ventilation and transfer steam jets.
5. Water add to tank F7.
6. Laboratory transfers of old samples to SX for recovery.
7. Tanks F15 and F16 steam jet ventilation during sugar denitration.
8. CWL and SCD recycle stream.
9. E-J8 condensate recycle makeup water.

Water from the solvent extraction process can exit PUREX in one of several streams including:

1. Uranyl nitrate product transferred to UO3 plant.
2. Plutonium nitrate product transferred to Plutonium Finishing Plant (PFP).
3. Tanks U3, U4, G8, R8 and F16 waste to UGS transfers.
4. PDD transfer to the waste effluent treatment system.

Figure 3.13.2 demonstrates the water balance for the PDD stream. The excess water in the PUREX process is boiled off in one of several concentrators (H4, J8, F6, K4). The condensate from the F6 and J8 concentrators are recycled to the process columns and tanks to reduce/replace water addition(s) to the SX process. The remaining excess water follows the general path from H4 to J8 to K4 to PDD. This routing allows for recovery and scrubbing in the concentrator off gas systems, (reference 5). The PDD stream from K4 is monitored for pH and contamination and is adjusted to meet transfer specifications for the Effluent Treatment Facility (ETF). Contaminated solution is transferred to the 216-A-42 retention basin for later recycling into PUREX solvent recycle process. The average concentration of chemicals and radionuclides in the PDD stream and the ETF discharge targets are given in table 3.13.2 (references 16 and 25 respectively).

If the solvent extraction process is not operating, there is no PDD flow and solution is collected in the solvent extraction concentrators and tanks. The solution is either processed through the columns during initial operation or sent to tank farms as low level waste.

3.13.3 Chemical Sewer Stream (CSL)

The chemical sewer stream from PUREX consists of water from several sources including floor drains from clean (noncontaminated) areas, ventilation steam condensate, overflows from water storage tanks, office area heater condensate, and water addition for line flush and cooling of steam condensate (see reference 17 for more complete discussion). The CSL is collected from these sources into one stream which is monitored for radionuclide contamination and pH. If the monitored stream is not within release limits the stream is diverted to the 216-A-42 retention basin and recycled to PUREX. The noncontaminated stream is routed to the Terminal Effluent Discharge System (TEDS) to further monitor discharge to the environment. The CSL stream flow during operation is approximately 1000 gallons per minute. The average composition of the CSL stream and the TEDS discharge targets are given in table 3.13.2 (reference 17).

Table 3.13.1 Composition Of Solution In Closed Loop System	
CONSTITUENT	CONCENTRATIONS**
Calcium PPB*	400
Chloride PPB	3600
Iron PPB	31
Magnesium PPB	250
Silicon PPB	3500
Sodium PPB	740
Sulfate PPB	1000
Tributylphosphate PPB	11
Alpha Activity (pCi/l)	5.4 (1200 Max.)
Beta Activity (pCi/l)	160 (1.2E+04 Max.)
Total Carbon (mg/kg)	30
²⁴¹ Am (pCi/l)	0.54
¹³⁷ Cs (pCi/l)	10 (300 Max.)
²³⁸ Pu (pCi/l)	0.43
^{239,240} Pu (pCi/l)	5.5 (550 Max.)
Radium Total (pCi/l)	2.0
⁹⁰ Sr (pCi/l)	1.8 (300 Max.)
²³⁴ U (pCi/l)	0.23
²³⁸ U (pCi/l)	0.16
pH (Dimensionless)	7.5

* PPB - Parts Per Billion

** Solution will be rerouted through the recycle system 750 times per month. Concentrations of radionuclides may reach 750 times listed values unless a maximum value is listed.

Figure 3.13.1

STEAM CONDENSATE AND COOLING WATER CLOSED LOOP SYSTEM

(SL00208A)

Figure 3.13.2 PUREX Process Condensate (PDD) Water Balance During Solvent Extraction Operation At 8 MTU/Day.*

() = Gallons per minute average flows

* - This balance assumes vessel ventilation jet(s) are replaced with blowers (15 GPM) and recycle of PDD from K4 to supplement J8 condensate recycle.

Table 3.13.2 Process Distillate Stream Average Composition And Target*		
CONSTITUENT	AVERAGE CONCENTRATION	ETF DISCHARGE TARGET
Total Organic Carbon	106,000	None
Acetone	57.5	50
1-Butanol	19	5000
2-Butanone	28.5	None
Butylated Hydroxytolune	100	None
Dibutylphosphate	17,400	None
Dodecane	9,140	None
Tetradecane	21,000	None
Tributylphosphate	74.5	None
Tridecane	32,800	None
Undecane	120	None
Ammonia	53.2	1300
Boron	16.4	None
Calcium	50.2	None
Cyanide	35.7	5.2
Fluoride	860**	2000
Mercury	0.966	2.0
Nitrate	55,600	10,000
Potassium	508	None
Silicon	219	None
Sodium	12,900	None
Total Alpha (pCi/L)	1.0E+05	15
Total Beta (pCi/L)	2.0E+05	50
⁹⁰ Sr (pCi/L)	5.0E+02	20
¹⁰⁶ Ru (pCi/L)	3.4E+04	30
¹⁰³ Ru (pCi/L)	1.9E+03	200 ppb

Table 3.13.2 Process Distillate Stream Average Composition And Target*		
CONSTITUENT	AVERAGE CONCENTRATION	ETF DISCHARGE TARGET
¹³⁴ Cs (pCi/L)	8.8E-03	None
¹³⁷ Cs (pCi/L)	4.5E+04	200
¹⁴⁷ Pm (pCi/L)	3.2E+03	None
Uranium (Gross) (pCi/L)	5.1E+01	40
³ H (pCi/L)	6.0E+07	None
²⁴¹ Am (pCi/L)	6.5E+03	None
¹²⁹ I (pCi/L)	5.6E+02	1
²³⁸ Pu (pCi/L)	1.2E+03	1.6
²⁴¹ Pu (pCi/L)	1.2E+05	None
²³⁹ Pu (pCi/L)	1.2E+04	1.2

* - ALL COMPOSITIONS ARE GIVEN IN PARTS PER BILLION UNLESS OTHERWISE STATED.

** - Fluoride discharge will reduce significantly during shear/leach due to the elimination of Ammonium Fluoride Ammonium Nitrate used in the Zirflex process.

Table 3.13.3 Average Composition In The Chemical Sewer Stream *		
CONSTITUENT	AVERAGE CONCENTRATION	DISCHARGE TARGET
Aluminum	227	50
Arsenic	<500	50
Barium	31.3	1000
Barium (EP Toxic)	<1000	None
Boron	16	None
Cadmium (EP Toxic)	<100	10.0
Calcium	1.84E+04	None
Chloride	155	250,000
Chromium (EP Toxic)	<500	50
Copper	29.3	1000
Fluoride	140	2000
Iron	216	300
Lead	5.5	3.2
Lead (EP Toxic)	<500	None
Magnesium	15.7	None
Mercury	0.11	2.0
Nitrate	516	None
Potassium	719	None
Selenium (EP Toxic)	<500	10
Silicon	2.57E+03	None
Silver (EP Toxic)	<500	50
Sodium	2.07E+03	None
Strontium	90.8	None
Sulfate	1.12E+04	250,000
Uranium	0.465	59

Table 3.13.3 Average Composition In The Chemical Sewer Stream *		
CONSTITUENT	AVERAGE CONCENTRATION	DISCHARGE TARGET
Zinc	14.7	5000
Ammonia	57.7	1300
Butylated hydroxytoluene	10	None
Chloroform	8.83	6.0
Alkalinity (Method B)	5.95E+03	None
Alpha Activity (pCi/L)	9.84E-01	15
Beta Activity (pCi/L)	2.22E+00	50
Conductivity (uS)	151	None
Ignitability (Degrees F)	210	None
pH (Dimensionless)	7.65	6.5-8.5
Reactivity Cyanide (mg/Kg)	<1.00E+02	100
Reactivity Sulfide (mg/kg)	<1.00E+02	None
TDS (mg/l)	5.63E+04	14,000
Temperature (degrees C)	25	None
Total Carbon (mg/Kg)	1.44E+04	None
TOX (ug [C1]/L)	7.05E+01	None
²⁴¹ Am (pCi/L)	1.03E-01	None
¹³⁷ Cs (pCi/L)	2.85E-01	200
¹⁴ C (pCi/L)	3.33E+00	2000
³ H (pCi/L)	2.29E+02	None
²³⁸ Pu (pCi/L)	7.62E-03	1.6
²³⁹ Pu (pCi/L) & ²⁴⁰ Pu (pCi/L)	3.09E-01	1.2
Radium Total (pCi/L)	9.74E-02	5
²³⁴ U (pCi/L)	1.71E-01	Total U = 40
²³⁸ U (pCi/L)	1.5E-01	Total U = 40

* - UNITS ARE GIVEN IN PARTS PER MILLION UNLESS OTHERWISE STATED

3.14 SOLID WASTE

The solid waste from the PUREX plant can be categorized into one of five classifications which includes: 1) Non-regulated waste, 2) Low-level waste, 3) Mixed waste, 4) Transuranic (TRU) and TRU mixed waste, and 5) hazardous waste.

The non-regulated waste consists of office waste from the non-radioactive areas of the plant. This waste is not regulated by the Washington Administrative Code (WAC) 173-303, Section 40 of the Code Of Federal regulations (CFR) or the atomic energy act and is transferred from accumulation areas to the land disposal site. Approximately 100,000 cubic feet of this waste is produced every year.

Low level waste (LLW) is waste that contains some radioactivity which is not classified as high level waste, spent nuclear fuel or byproduct material as defined by Department Of Energy (DOE) orders 5820.2A (DOE1988) and 5400.3 (DOE 1989). The low level waste contains transuranic radionuclides less than or equal to 100 nanocuries per gram of matrix. The LLW waste is packaged in approved LLW containers and transferred to the 200 west area Radioactive Solid Waste Treatment, Storage and Disposal Facility. Approximately 40,000 cubic feet of LLW is produced every year.

Mixed waste is waste which contains both radioactive waste (LLW) and dangerous waste as defined by 40 CFR (Part 261) and WAC 173-070 through 173-103. Mixed waste is packaged in accordance with 49 CFR and /or approved Safety Analysis Report for Packaging (SARP) and transferred to the Central Waste Complex for storage. A total of 190 cubic feet per year of waste is generated each year.

Transuranic (TRU) and TRU mixed waste is waste which contains alpha-emitting transuranic radionuclides (atomic number greater than 92) with half-lives greater than 20 years and in concentrations greater than 100 nanocuries per gram of waste matrix. The TRU mixed waste also contains dangerous waste as defined by 40 CFR and WAC (listed above). TRU and mixed TRU is packaged in accordance with 49 CFR and/or SARP's and transferred to the Transuranic Storage and Assay Facility (TRUSAF). The waste will be transferred to and repackaged at the WRAP facility for shipment to the Waste Isolation Pilot Plant (WIPP) for terminal storage. The shear leach process will generate approximately 5.8 cubic feet per MTU of TRU waste (5800 cubic feet per year for 250 day campaign). Three additional 55 gallon waste drums are generated each year from replacement of the iodine absorbers and off gas filters. The remainder of the PUREX plant will generate approximately 50 cubic feet per year of TRU mixed waste and 125 cubic feet per year of TRU waste.

Hazardous waste is waste which contains hazardous waste as defined by CFR and WAC (listed above) but does not contain any radioactive waste. Hazardous waste is packaged according to 49 CFR and transferred to an on-site Dangerous Waste Storage Facility. The waste is transferred to an approved off-site Treatment, Storage and Disposal Facility. Approximately 384 cubic feet per year of hazardous waste is transferred for disposal.

3.15 GASEOUS EFFLUENTS

The PUREX Plant has 18 gaseous effluent release points with potential radiological and non-radiological contamination, (reference 18). The shear/leach processing of N reactor fuel at PUREX eliminates the ammonia handling steps from the zircalox decladding process and will thereby eliminate the ammonia release to the environment. The NO_x and Iodine discharges from shear/leach are below the discharge limits and were discussed in previous sections. The remainder of the discharge volumes from the PUREX stacks and concentration of radionuclide and non-radiological contamination is given in reference 18.

4.0 PROCESS TECHNOLOGY

4.1 DISSOLUTION CHEMISTRY

4.1.1 Uranium Chemistry

Uranium metal is oxidized by nitric acid (acid concentration less than 8 M) to form uranyl nitrate by the following reaction (Reference 5):

The rate of dissolution of sheared N Reactor fuel has been studied by Swanson et al (Reference 4). Swanson's work showed that the dissolution rate at concentrations typically encountered in practical uranium dissolution conditions is governed by the following equation:

$$\frac{dU}{dt} = K \times (\text{SURFACE AREA}) \times ([\text{HNO}_3] + 2[\text{U}])^{2.6}$$

where:

$\frac{dU}{dt}$ = Dissolution rate of uranium, mg/h
 K = Reaction rate constant, $\text{mg/cm}^2 \cdot \text{h}^{-1} \cdot \text{M}^{-2.6}$
 Surface Area = Exposed surface area of uranium, cm^2
 $[\text{HNO}_3]$ = Concentration of nitric acid, mol/L
 $[\text{U}]$ = Concentration of uranyl nitrate, mol/L.

*K = 4.6 at 103 degrees centigrade

Dissolution rate is dependent upon the dissolution rate constant, surface area of exposed uranium available for reaction, and total nitrate concentration in solution. The dissolution rate constant is dependent upon temperature and typically increases with increasing temperature. Swanson's work demonstrated that the dissolution rate may be lower at the boiling point of the solution than just below the boiling point due to the beneficial effects of nitrous acid on the dissolution system and the deleterious effect of increased temperature on nitrous acid concentration. A rate equation for dissolution constant dependence on temperature was presented by Swanson however further studies indicated that any equation is only consistent within specific nitric and uranium concentration ranges. Since the study was conducted at approximately 8 M nitric and shear/leach product is between 2 to 4 M nitric the equations generated in the study are not applicable.

The surface area available for dissolution reaction is dependent upon the amount of fuel exposed during shearing and the amount of fuel degeneration which has occurred during storage. The surface area exposed during shearing is directly proportional to the cross section of the fuel and number of segments per element produced. This aspect of the surface area is directly controlled by the shear design and discussed in section 4.2. Increased exposure of the fuel in the reactor causes the fuel to become more brittle (i.e. lose tensile strength). This effect may result in fragmentation of the fuel during shear operation which will generate a variety of smaller and larger pieces. The smaller pieces have a larger surface area ratio providing increased dissolution rate for a specific shear segment size. As the smaller pieces dissolve, the remaining larger pieces will have a relatively constant surface area with a corresponding dissolution rate.

The N Reactor fuel has been stored for over 10 years, most approaching 20 years, and has suffered a varying degree of degeneration due to cladding failures, see section 3.1. The initial cladding cracking and deformation occur during discharge of the fuel from the reactor into the pool cell. The exposed uranium and zirconium metal surfaces convert to hydrides when exposed to the hydrogen generated by radiolysis of the water. The uranium hydride converts readily to uranium oxides in water releasing hydrogen, which can be used for further hydride formation. Both the zirconium hydride and the uranium oxide molecules are larger than their respective metal forms which causes expansion under the cladding. The expansion exposes more of the metal for conversion. The process for forming the oxides and hydrides is slow due to the limited hydrogen available but will continue as long as the fuel is stored in water. The uranium oxide and zirconium hydride formation significantly increase the surface area available for dissolution and has not yet been fully measured. The dissolution of the oxide will occur rapidly in the hot nitric acid. Since the fuel is sheared one element at a time, the effect on the overall reaction rate is not significant.

The concentration of nitrates both as nitric acid and UNH increase the dissolution rate. The relative nitrate concentration is constrained by the inlet nitric acid, nitric and UNH product outlet and reaction of the uranium as specified above. Variation of the nitrate concentration is limited by controlling the nitric and water supplied to the dissolver during operation. Upsets caused by solution fluctuations are minimized to provide constant reaction rates.

For a particular shear design, operating temperature, and total nitrate concentration for a continuous dissolver the dissolution rate will be relatively constant except for a minor increase in the rate when fines and small pieces of fuel are introduced to the dissolver. Water addition from the canisters and hull rinse will lower the reaction rate due to nitrate reduction and will be minimized whenever possible.

4.1.2 Plutonium Chemistry

Plutonium in the fuel dissolves in nitric acid to form plutonium nitrate per the following equation (reference 5):

The dissolution will occur stoichiometrically as long as the acid concentration is maintained. The dissolution rate is dependent on the exposed surface area and is therefore directly proportional to the uranium dissolution rate.

4.1.3 Iodine And Other Gaseous Fission Products

The ^{129}I , ^{85}Kr , ^{106}Ru and ^{133}Xe are volatile fission products which are released during the dissolution of the N Reactor fuel. The ^{131}I and other short lived gaseous fission products are no longer present in significant quantities due to the age of the fuel being processed and are not discussed any further. The ^{85}Kr and ^{133}Xe are inert and discharge through the dissolver off gas system into the PUREX main stack. The ^{106}Ru concentration at the earliest processing time is less than .2 % of the weapon grade fuel processed previously at PUREX using Zirflex decladding flowsheet. In addition to much lower concentrations, Ruthenium does not volatilize at significant levels in boiling nitric acid concentrations up to 8 molar if there is a continuous supply of nitrogen oxide or nitrogen dioxide (provided during metal dissolution), reference 1. For these reasons, Ruthenium discharge in the off gas will not be a problem.

Several alternatives were evaluated for removal of iodine from off gas (reference 6). The use of silver mordenite beds provides the required capture rates and minimizes waste volume. The high $\text{SiO}_2/\text{Al}_2\text{O}_3$ ratio of mordenites makes them more resistant than other silver zeolites to the acidic environment of the dissolver off gas. Laboratory work conducted by PNL under simulated plant conditions has demonstrated that a 20 cm deep bed of silver mordenite (18 wt% silver) reduces the iodine concentration in a gas stream from 10^{-7} moles I/L to $<10^{-11}$ moles I/L (References 3 and 8) which is equivalent to a retention factor of 10^4 .

The maximum concentration of Iodine in the fuel is $2.71\text{E-}03$ curies per MTU (Table 3.1). Sampling conducted during Zirflex Dissolution processing (reference 10) demonstrated that 65% of the Iodine would exit through the dissolver off gas system. Of the remaining 35 %, 15 % exits PUREX in various liquid waste streams and 20 % exits the vessel ventilation and dissolver off gas system (via recycled U8 to Back Up Facility). The administrative control value for Iodine releases (reference 12) is $7\text{E-}10$ micro curies/ml. At a stack flow rate of 70,000 scfm (minimum value) the Iodine release limit is 0.728 Ci/year (1.25 Ci/year at 150,000 scfm). The maximum Iodine release from shear leach at 1000 MTU per year is .54 ci/year which is below the limits.

4.1.4 Nitrogen Oxide Gases

The dissolution of uranium and plutonium metal liberates large quantities of water vapor and oxides of nitrogen (NO_x). The off gas stream is directed through a condenser which cools and condenses the water vapor. The water reacts with the NO₂ in the off gas to form nitric acid which is then routed with the water back into the dissolver. Conversion of the NO and NO₂ occurs per the following reactions:

Residence time within the condenser is relatively low and conversion of the NO to nitric acid is only about 10 percent based on process knowledge. The remainder of the NO_x off gas from the condenser is transferred through the PUREX back up facility (BUF) for additional recovery. Conversion of the NO_x is discussed further in reference 5. The release of NO_x out the PUREX main stack is monitored to ensure meeting emission regulations. At a nominal 4 MTU per day dissolution rate and using only 70 per cent efficiency for the back up facility, the NO_x exiting the BUF XB tower is only 0.9 volume per cent. The EPA limit for PUREX at XB outlet is 2 volume per cent (reference 19).

4.1.5 Nonvolatile Fission Products

The chemistry for nonvolatile fission product dissolution is not well defined. The fission products form soluble nitrates in nitric acid solutions (reference 5) and will be transferred to the PUREX SX process with the dissolver product solution. The majority will be separated by the HA column in SX and will exit PUREX in the high level waste stream discussed previously.

4.1.6 Particulate Generation

Studies on dissolution of unirradiated sheared fuel identified a solid particulate which is generated during dissolution (reference 9). The particulates were generated during a complete dissolution test and were initially as large as 6 to 8 mm in diameter. As the test continued the particulates "appeared to largely disappear as dissolution continued". The solids remaining after the near complete dissolution were collected. The quantity of solids generated was approximately 1×10^{-4} grams of solids per gram Uranium dissolved (100 grams per MTU). A sample of the initially observed solids was analyzed and found to contain equal parts of zirconium and uranium.

Pyrophoricity of the dry solids has not been conclusively established. Solids collected during initial studies were rinsed, dried and tested for pyrophoricity by sparking with a Tesla coil. One good flash was produced during testing which was later determined to be caused by residual uranium. The test concluded that the particulates "should not pose a high pyrophoric hazard." If complete dissolution of the uranium can be assured, the remaining zirconium solids are not highly pyrophoric. The particulates can be stabilized for storage either by submersion in water or by mixing with a stable nonoxidizing material with a greater than 1 to 1 ratio (reference 11).

4.2 SHEAR DESIGN

Dissolution of the sheared fuel with controlled parameters is consistent and follows the rate equation discussed in previous section(s). If the fuel element is sheared to expose smooth annular surfaces of uranium, the surface area of a sheared section would remain constant over the entire dissolution reaction. For constant surface area, constant temperature and constant total nitrate concentration a constant dissolution rate can be determined. This constant dissolution rate can be converted to a fuel section maximum dissolution time to remove all the uranium based on the distance from an exposed uranium surface to the farthest point in the interior of the fuel section from the exposed surface. Table 4-2 shows the dissolution time for various dissolution path lengths for annular sections of sheared fuel. The piece size in the table refers to the farthest distance from a shear surface to unexposed uranium in a sheared section of the fuel element. For the table the nitrate concentration is based on 2 M uranyl nitrate and 3 M nitric acid solution and the reaction rate expressed in section 4.1.1. Solution temperature is assumed to be 105 °C which is three degrees below the estimated boiling point of this solution. Surface area is assumed to be the annular region of a sheared element (see section 3). The time for dissolution is inversely related to the piece size to be dissolved.

Table 4.2 Dissolution Time vs. Fuel Piece Size.

Piece Size (inches)	Dissolution Time (hours)
4.0	242
3.5	212
3.0	182
2.5	151
2.0	121
1.5	91

4.3 HULL HANDLING AND DISPOSAL

4.3.1 Cladding Hulls Packaging

Packaging of the hull waste is conducted to meet the criterion for WIPP storage (Reference 24). The pyrophoric nature of zirconium fines or small pieces requires stabilization prior to packaging. The two options for meeting this requirement include mixing the hulls with grout or incinerating the hulls to a stable oxide. Figure 4.3.1 demonstrates the options for hull stabilization and packaging. Grouting of the hulls isolates the zirconium from oxygen and disperses the zirconium in a matrix which effectively eliminates potential oxidation reactions. Incineration of the hulls converts the zirconium to a stable oxide form at additional equipment and operating expense.

4.3.2 Hull Oxidation

The oxidation of zirconium follows the reaction equation:

The temperatures required for oxidation range between 800 and 1500 degrees C. Laboratory tests conducted at temperatures of 1100 to 1200 degrees C demonstrated over 95 % oxidation (Reference 20). The oxidized hull pieces did not disintegrate during the test which indicates a need for mechanical breakdown of the hulls during the oxidation process or increased temperature during oxidation. The reaction rate is dependent upon the size of the material, temperature and air inlet rate.

Incinerating zircaloy materials when water is present can be explosive (Reference 1). A drying station is required to eliminate the water prior to the oxidation process.

Figure 4.3.1

Hulls Treatment Options

(SL00204A)

5.0 PROCESS CONTROL

5.1 PROCESS CONTROL LOCATION

All activities for shear leach processing in the head end cells are controlled remotely from the PUREX head end control room. All mechanical handling steps use the new closed circuit TV system and lighting to support activities.

5.2 INSTRUMENTATION

Monitoring and control equipment will be designed to be remotely operated. Transmitters mounted on racks in the P & O Gallery will receive signals from sensing elements, convert them to a standard 4-20 ma signal and send them to recorders, indicators, alarms and controllers in the Head End Control Room.

Purged dip tubes are used to measure liquid level, density and pressure. The air purge rate will be 1 SCFH maximum.

Thermocouples or resistance temperature instruments are used to sense temperatures in the in-cell equipment. The sensing element is installed in a thermowell for protection from corrosive atmospheres.

Magnetic flow meters or rotameters are used for in-cell liquid flow measurements. Gas flows are measured by orifice plates or anemometer type flow instruments.

Steam jets are used for most solution transfers between canyon vessels.

5.3 PROCESS SAMPLING

Air and solution sampling are utilized to provide necessary process control data. The sampling equipment is located in the sample gallery. The sampled stream is routed to a process sampler using cell jumper and wall nozzle connections as described in the PUREX Technical Manual.

The dissolver off gas is continuously sampled to monitor the ^{129}I and NO_x concentrations. The NO_x monitors send signals to recorders and alarms in the Head End Control Room. Routine process control liquid samples will be taken of the hulls rinse solution to determine when it needs to be changed out. Accountability samples will be taken in TK-D5 and in recovered acid tanks TK-U1 and TK-U2.

5.4 EQUIPMENT REQUIREMENTS

The minimum instrumentation and control requirements for each vessel or piece of equipment are listed below:

Canister Storage Tank

1. Liquid level.
2. Solution temperature.

Dissolver

1. Solution temperature and control.
2. Solution level.
3. Solution specific gravity.
4. Air sparge rate and control.
5. Pressure/Vacuum.
6. Cell air bleed flow rate and control.
7. Nitric acid flow and control.
8. Demineralized water flow and control.

Product Storage Tank

1. Liquid level.
2. Solution temperature and control.
3. Cooling water flow and control.

Head End Feed Storage Tanks

1. Liquid level.
2. Solution specific gravity.
3. Solution temperature and control.

Dissolver Condenser

1. Outlet off gas temperature.
2. Cooling water flow and control.
3. NOx content.

Off Gas Heaters

1. Off gas temperature and control.

Canyon Filters

1. Differential pressure.
2. DOP test ports.
3. Off gas flow and control.
4. Flush ports.

Hull Rinse Tank

1. Liquid level and sampler.

Hull Dryer

1. Drying air temperature.
2. Humidity/moisture content in outlet air.

Calciner

1. Temperature(s) and control(s).
2. Operating controls.
3. Screw rotation.

6.0 OFF STANDARD CONDITIONS

The parameters essential to control are outlined in section 5.0 "PROCESS CONTROL". The control limits and off-standard conditions will be identified in a preliminary hazard assessment.

7.0 EQUIPMENT DESCRIPTION

This section describes the new equipment required for the shear/leach processing of N Reactor fuel at PUREX. The PUREX building and existing equipment are described in the PUREX technical manual(reference 5).

7.1 IN-CELL CRANE (ICC)

The ICC is a remote operated crane that is used to transfer canisters, dissolver baskets and waste packaging within the processing cell. Controls for the crane are located in the head end control room.

7.2 IN-CELL VIDEO CAMERAS, LIGHT and AUDIO MONITORING EQUIPMENT

In-cell video cameras, lighting and audio monitoring equipment are strategically positioned around the cell. The monitors provide video and audio monitoring of crucial in-cell operations which require remote equipment manipulation. Adequate lighting is provided for all video monitoring operations. The cameras, light fixtures, and audio monitoring equipment is designed to be remotely installed.

7.3 FUEL CANISTER STORAGE TANK (TK-B1)

The fuel canister storage tank is an open rectangular water tank divided into sections by a stainless steel insert. The tank will provide storage for full and empty fuel canisters. A heat exchange system will be provided to maintain temperature in the tank.

7.4 CANISTER RECEIVING TABLE (E-B2)

The fuel canister receiving table is a mechanism that removes the fuel elements from the canisters. The canisters are positioned onto the table using the ICC. On the table, the full fuel canister is lifted (tilted) in a vertical position to transfer the fuel to a retention plate. The table then returns to a horizontal position. The empty canister is transported back to the storage tank. This design is similar to the canister dumper mechanism (H-1-34875) which was successfully operated in the K East spent fuel segregation project.

There is a fluid catch pan beneath the receiving table. The water is spilled from the canisters and drains off the receiving table onto the fluid catch pan, and is routed to the dissolver.

7.5 FUEL ELEMENT PUSHER (E-B3)

The fuel element pusher transfers the fuel elements from the receiving table to the fuel element separator. It also retains all of the fuel elements in a specific area prior to and during transfer to the element separator. The pusher is composed of wiper plates, located on both sides of the fuel elements on the receiving table. The blades are operated remotely to transfer elements to the separator.

7.6 FUEL ELEMENT SEPARATOR (E-B4)

The fuel element separator is a mechanism that selects a single fuel element from a number of elements fed by the element pusher. The selected element is transferred by the separator to the shear charging chute in the orientation required for shearing.

7.7 FUEL ELEMENT SHEAR (E-B5)

The fuel element shear is a slow speed, low impact cutting device that segments the fuel elements in preparation for the dissolution process. The fuel element shear is composed of eight separate cutting blades which are physically part of the same section. Each blade shall cut a 1.5 in. section from a fuel element. The shear blades shall function in unison so that a fuel element will be segmented all at once. The physical cutting section of the shear, the cutting blades, cutting base and connecting pivot, shall be designed for multiple rapid remote replacement over the life of the shear. The remaining parts of the shear shall be designed to withstand five times the anticipated duration of operation.

The hydraulic cylinders, pump, reservoir, and controls shall be an integral unit assembled on a stainless steel frame work. The shear blade assembly shall be independently remotely replaceable. The package shall be remotely installed. Electrical jumpers for control and power will be required. Spare shear blade assemblies will be stocked in spares.

The pyrophoric nature of the metals being sheared may require an inert gas shielding system. The shielding gas system will be available for use but the gas supply jumper will not be installed unless deemed necessary by development testing. If the use of the shielding gas is required, the gas supply jumper will be installed and the inert gas utilized to blanket the shearing operation eliminating the oxidation of the pyrophoric metals.

The shear is surrounded by a metal enclosure that acts to contain the shielding gas, if used, and any fines generated during the shearing operation.

Spray nozzles are provided inside the enclosure so that any uranium or zircaloy fines adhering to the inside can be washed into the dissolver. The metal enclosure is designed to be remotely installed on the shear.

7.8 DISSOLVER (TK-B6)

7.8.1 Dissolver

The dissolver is an annular vessel with an internal carousel which has positions for seventeen dissolver baskets. The carousel supports the dissolver baskets while they are rotated full circle by a central shaft connected to an external drive. The drive mechanism utilizes a Geneva plate and indexing arm to control rotation of the dissolver carousel and insure positioning at the charging and basket removal ports, see figure 3.5.1. The external diameter of the dissolver is based on the dissolver cell width of 14 ft (effective width is less due to nozzles protruding from the walls), the spacing between baskets in the dissolver (12 inch minimum), and the dissolver basket diameter (12 in ID). The dissolver has an outside diameter of approximately 13 ft. The annulus has an internal diameter of 8 ft.

The dissolver has an approximate height of 13 ft. Approximately 18 in. of headspace is provided between the normal operating liquid level and the top of the dissolver. The inner annulus of the dissolver extends upward approximately 10 ft from the dissolver floor. The top plate of the inner annulus is just below the dissolver carousel.

The dissolver basket charging chute is provided for the transfer of the segmented fuel elements to the basket in the dissolver. The chute is cylindrical and extends from the shear enclosure to below the fluid level in the dissolver. The cylinder protruding into the dissolver is orificed to provide air flow from the shear into the dissolver. The charging chute is equipped with a motor operated gate valve to limit air flow during charging.

The BI/RP (basket insertion/removal port) is provided for insertion and removal of dissolver baskets to and from the dissolver. The port has a gate valve which is normally closed. The gate valve is opened to remove or insert a basket into the dissolver. A skirt extends downward at the port to approximately 6 inches below the liquid level. This skirt acts as an airlock eliminating large in leakage of air to the dissolver when the gate valve is opened to remove or insert a basket. The skirt has a fixed orifice to control the air sucked through the BI/RP. Outside of the dissolver, the port has a wash down funnel to catch the rinse water used during removal of the basket.

Recycled acid, process water, and condensate returning from the dissolver condenser are added to the dissolver solution through separate flanges at the top of the dissolver. More than one addition point may be used to add each of the chemicals to the dissolver.

The dissolver off gas is evacuated from the dissolver via a line which extends above the dissolver and is connected to the dissolver condenser.

Sidewall penetrations into the dissolver are used for various services and instrumentation needs. Penetrations into the sidewalls are necessary because certain services can not be performed from penetrations into the top of the dissolver. The orientation of the dissolver carousel doesn't allow for access to the bottom of the dissolver from above. Penetrations for services include a line for the cooling coil inlet, a line for the cooling coil outlet, a line for the air sparge ring inlet, and an electrical connection for the electrical strip heaters in the inside of the dissolver annulus. Penetrations for instrumentation include two lines for temperature probes, a line for weight factor and specific gravity indication, and a spare line.

An air sparge ring is located at the bottom of the solution annulus with a nozzle located directly under each basket location. The sparge air induces flow of the solution within the dissolver. The induced flow in turn improves dissolution and removal of heat from the reacting surfaces.

Heating is provided to the dissolver by three independent electrically powered strip heating circuits. Each circuit consists of nine strip heaters, approximately 72 inch long and 1.5 inch wide. The strip heaters are attached to the inside of the internal annulus of the dissolver and the heat is conducted through the wall to the solution. The strip heaters are hooked up in parallel so the failure of a single element will not effect the operation of any of the other elements. Each independent circuit is capable of providing 27 kW. The heating elements provide heat for initial startup of the dissolver and to provide additional heat to maintain the reaction temperature as necessary.

A cooling coil is located inside the dissolver annulus supported by the inside wall of the annulus. The cooling coil maintains the reaction temperature as necessary and provides a degree of emergency cooling if required.

The dissolver solution recirculates in the dissolver and is circulated through a stilling chamber connected to the dissolver. The stilling chamber has connections to the dissolver at the elevation of the normal liquid level and another line a few feet above the bottom of the dissolver. A screened drain line is connected between the stilling chamber and dissolver at the bottom of the dissolver so the chamber can drain completely if the dissolver is jetted out. An overflow line from the stilling chamber is connected to a hold tank in the cell.

7.8.2 Dissolver Basket

Each dissolver basket is a 12 inch diameter by 10 feet 6 inch long vertical pipe with a perforated bottom plate and perforations in the pipe wall. The perforations allow circulation of the nitric acid/uranyl nitrate solution, in and through the element segments, inside the basket.

A groove inside the collar at the top of the basket provides a means of supporting the basket during transport. A basket grapple will utilize the groove to lock onto the basket for lifting and transport.

The collar at the top of the basket also serves as a means of supporting the basket when it is in the hulls rinse tank, the drying station, the basket dumping device, the basket storage rack, or in the dissolver carousel.

The dissolver basket is designed to withstand the corrosion caused by the dissolver solutions for a period of time equal to twice the time required to process the remaining N Fuel. If a basket is damaged or worn out it will be disposed of by being placed in a canyon burial box.

7.8.3 Dissolver Basket Grapple

The basket grapple is used to transport dissolver baskets between the dissolver, the hulls rinse tank, the hulls drying station, the basket dumping station, and the basket storage rack. The grapple is stored on a rack in the cell until needed. The in-cell crane will be used in conjunction with the grapple in transporting baskets.

A water spray nozzle is located on the bottom of the grapple. The spray nozzle is used for rinsing of the hulls in the baskets upon removal from the dissolver.

7.9 PRODUCT STORAGE TANK (TK-B7)

The dissolver product storage tank receives solution from the dissolver stilling chamber for transfer to storage tanks prior to feed to SX. Nozzles are provided on the top of the tank for cooling coil inlet and outlet, solution transfer into and out of the tank, electrical connection to an immersion heater, an agitator for solution mixing, and instrumentation including temperature, weight factor, and specific gravity. Nozzles are also provided for the addition of demineralized water, nitric acid, and miscellaneous chemical additions.

Heating for the product storage tank is provided by an electrically powered immersion heater. The heating element provides heat to maintain the product solution at the desired temperature. The storage tank also has a cooling coil which is used to lower the temperature of the solution in order to facilitate the transfer of solution to the head end feed digestion tank (existing tank TK-D2). Cooling water is provided by the PUREX closed loop cooling system.

7.10 HEAD END SOLUTION STORAGE TANKS

All of the tanks that will be used for dissolver product solution storage are existing standard 5000 gal tanks except TK-D3/D4. TK-D3/D4 is an existing "bathtub" tank with a dividing wall in the middle. Each half of the tank has a capacity of 7,700 gal.

7.11 DOWNDRAFT CONDENSER (T-B8)

The off-gas from the dissolver is routed to the dissolver downdraft condenser. The condenser consists of a double pass heat exchanger. Process vapors enter shell side and travel downward through the shell with condensate forming on the tubes. Condensate is collected at the bottom of the condenser and returned to the dissolver. Cooling water is provided to the condenser from the PUREX closed loop cooling system.

7.12 ELECTRIC HEATER AND IODINE ADSORBERS (E-B9, T-B11 & T-B12)

The iodine removal equipment consists of silver mordenite adsorbers installed in series with sample taps installed before and after the first bed and after the second bed. A continuous sample of the dissolver off gas is routed to off gas sampling equipment installed in the Sample Gallery. The adsorbers are designed so that the silver mordenite beds can be removed by the PUREX or ICC and packaged in 55-gal drums for disposal.

An electric heater and demister is installed upstream of the filters and absorbers. The heater is capable of heating the off gas from the dissolver to 150 degrees C prior to entering the filters and silver mordenite beds.

7.13 OFF GAS FILTERS (F-B10 & F-B13)

Filtration equipment consists of metal filters in the dissolver cell and the existing fiberglass filter located external to PUREX (F-1A, -1B or 1C. Both in-cell filter vessels will be designed so that they can be remotely changed using a canyon crane. The existing fiberglass filters located external to PUREX will be used to provide additional filtration (Reference 5).

7.14 HULL RINSE TANK (TK-B14)

The hull rinse tank is an open top tank capable of completely submerging a dissolver basket in a water bath. The solution in the rinse tank is circulated around the hulls (basket) to remove excess nitrates. The top of the tank is designed to collect any solution which drips from the basket during removal. Water replacement lines and solution level instrumentation lines are provided.

7.15 NEUTRON MONITOR (E-B15)

An in-cell neutron monitor is used to determine if any uranium is left on the hulls before the hulls are processed. The monitor is shielded and located at a distance to minimize the effects from surrounding radiation sources. The monitor is similar to the neutron monitor(s) used in the PUREX facility.

7.16 HULL HANDLING

The method for handling hulls is dependent upon the requirement for stabilization of the hulls and fines. Two options are provided which represent either grouting the hulls without stabilization (option A) or by incineration of the hulls (option B). The descriptions provided below include equipment for both options. The letter after the title identifies the option involved.

7.16.1 Hull Dumper (A & B) (E-B16)

The basket dumper holds and supports one dissolver basket of spent hulls and is capable of inverting the basket for hull removal. The rotation of the dumper is controllable to allow for horizontal positioning which allows for additional solution drainage.

7.16.2 Hull Dryer (B) (E-B17)

The dissolver basket filled with hulls is positioned vertically in a drying station. The station consists of an enclosed area (tank) that allows the basket to drain through grating to the cell sump. A dryer positioned at the top of the tank blows heated air through the basket from the top down. The air exiting the dryer is monitored for moisture to assure the removal of the water from the hulls.

7.16.3 Hull Hopper (A & B) (E-B17 or E-A1)

The hull hopper is a stainless steel bin large enough to contain two baskets of hulls (350 lbs.). The hull hopper has one outlet port with a remote operated valve to control the hulls transfer into the blender (option A) or the incinerator (option B).

7.16.4 Blender (A & B) (E-B19 OR E-A3)

The blender is a dual cone blender with a single valve on one end used for filling and dumping the blender. Grout mix and water are transferred to the blender from the P&O gallery supply lines. Either hulls or calciner oxide is then routed into the blender with the grout. When a batch has been collected the blender is rotated and then positioned for unloading into the waste containers.

7.16.5 Waste Container Handling Equipment (A & B) (E-B20 OR E-A4)

The waste container conveying equipment is used to remotely transfer the waste containers within the cell. The conveying equipment is operated remotely using in cell monitors and positioners. A waste container lid removal and installer (capper/decapper) is located at one position within the cell for preparing the drums for loading and transfer out of the cell.

7.16.6 Waste Container Assay Unit (A & B)

The waste container assay unit provides the following capabilities: (1) Resolution acceptable for Waste Isolation Pilot Plant certification of transuranic (TRU) waste; and (2) detection of the TRU/non-TRU threshold (100 nCi/g) and the maximum plutonium-239 limits (200 g/drum). Shielding is provided to reduce the gamma ray exposure to the scanning unit. A steel box houses the unit to shield the contents from the background radiation, provide a noncontaminated location, and allow the unit to be moved into and out of the canyon more easily.

7.16.7 Hull Incinerator (B) (E-A2)

The hulls from the hopper (option B) are routed to a rotary drum incinerator capable of producing temperatures up to 1500 degrees C. The rotation of the drum and temperature are controlled remotely. The movement of the material is controlled so that only the smaller particles travel to the discharge end of the furnace. The always-present fill of a finer-grained, already oxidized, powdery material, which remains in the furnace and moderates the conversion of the newly filled-in metal pieces, protects the newly introduced shells from too strong a reaction. The rotation of the drum can be varied to allow for the proper amount of time for the hulls to oxidize.

The incinerator incorporates a hulls bin and feed chute, cool down area, and discharge chute. The incinerator off gas is filtered by sintered metal blow back filters with a HEPA filter. The filter is connected to the dissolver off gas system.

The incinerator is capable of handling a processing rate of 150 pounds of hulls per 6 h, 7 d a week.

7.16.8 Oxide Transfer Equipment (B)

The hull incinerator oxide is dumped, from the incinerator, into an oxide weight hopper of polished stainless steel. The hopper is located over the blender and has a remotely controlled outlet valve for blender feed control.

8.0 SAFETY

The key safety items identifiable at this time are described in the following subsections.

8.1 URANIUM AND ZIRCONIUM FIRES

The potential for fires to occur during transportation of the fuel from the storage basins to the PUREX tunnel are discussed in the existing SAR's for processing N Reactor irradiated fuel using the Zirflex dissolution process (reference 7). The fire potential of the fuel prior to dumping the canisters will be controlled by storage of the fuel in water.

Several studies have been conducted on the potential hazards associated with fuel shearing. Sparking has been observed during testing however fuel fires were not initiated (reference 9). Previous shear testing for the Process Facility Modification project demonstrated unirradiated N reactor fuel could be safely sheared in an air or argon purge as well as a water deluge (reference 2). An inert sparge may be incorporated in the design to eliminate potential fire hazards. The purge system is designed into the shear design and will be used as necessary to eliminate fire hazards.

Dissolution of sheared fuel was conducted at the Nuclear Fuel Services in West Valley, New York, facility where several fires occurred during dissolution operation. Several studies were conducted which suggested that the preferential dissolution of the beryllium in the fuel end caps resulted in sensitized zirconium metal which was the ignition source for the fires. Later studies proved this theory to be incorrect (Reference 4). The fires were later attributed to processing of the fuel without adequate solution coverage. In the dissolver, runaway reactions were caused by "dissolution and vapor phase oxidation reactions of U metal". In the vapor space the fuel did not have solution to carry away the heat generated. Fires in the dissolver will not occur if the fuel is covered and temperature controlled.

8.2 URANIUM AND ZIRCONIUM HYDRIDE

Uranium and zirconium will react with hydrogen to produce uranium and zirconium hydrides. The source for the hydrogen is radiolysis of the water in the fuel storage areas and is discussed further in section 8.5 below. The hydrides are very reactive and pose a serious hazard when exposed which could lead to fires or rapid oxidation. Uranium hydride reacts quickly with water to form uranium oxides. Examination of stored fuel revealed no Uranium hydride and zirconium hydrides at low concentrations (100 to 400 ppm) with high dispersion (reference 1). Hydrides should therefore not be a problem during processing.

8.3 CRITICALITY

Criticality control in the dissolver will be by use of critically favorable geometry. Storage of the dissolver product will comply with the existing criticality limits for PUREX head end vessels. The storage of high plutonium content dissolver product, from 12 % Pu 240 processing, in tanks D3 and D4 represents the only criticality concern for shear/leach processing. The criticality limits for 12 % Pu 240 content fuel is listed below:

Tank D3/D4	Limit :	12 % Pu 240 25,500 grams Pu (Equivalent to a maximum of 435 gm./l U)
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In order to ensure meeting these limits for dissolution of 12 % fuel, the dissolver product will be measured and diluted as necessary prior to transfer into tanks D3 or D4. Similar controls were necessary while processing N reactor fuel using the Zirflex dissolution process.

8.4 VESSEL OVERHEATING

The dissolver product hold tank and all dissolver product storage tanks (TK-D1, TK-D2, TK-D3, TK-D4, TK-D5, TK-E3, TK-E5, TK-E6) are connected to the cooling water supply and have sufficient cooling capacity to remove heat generated during storage or processing of the fuel.

8.5 HYDROGEN BY RADIOLYSIS

The generation of hydrogen by radiolysis will not impact the shear leach process. The canister storage tank will be open to the cell atmosphere which will provide adequate dilution of generated gasses. The dissolver will be operated under vacuum with over 50 SCFH of air flow easily capable of handling any hydrogen generated. The remainder of the product storage tanks are connected to the process ventilation system which will provide the protection evaluated by the existing PUREX SAR.

8.6 SHEAR PURGE

Previous shear testing for the Process Facility Modification (PFM) project demonstrated that unirradiated N Reactor fuel could be safely sheared in an air atmosphere as well as in an argon atmosphere or in a water deluge, (Reference 9). No sparks were observed when shearing in an argon atmosphere. Shearing in air produced brighter sparks than shearing in a water deluge, but no fires occurred in either case. Equal amounts of fines smaller than 1600 microns (maximum size considered a fire hazard) were generated and collected when shearing in the argon atmosphere and the water deluge. The fines collected were less than 0.5% of the fuel sheared. Fines were also generated in the air atmosphere (as indicated by the sparking) but none were collected. It is believed that all the fines oxidized in the air atmosphere. Both the above report and Swanson, et al, (Reference 4) recommend that reactive fines be allowed to oxidize as they are formed so that metal fines accumulation can be minimized.

Due to its age and deterioration, the irradiated fuel in the storage basins may generate more fines during shearing than the unirradiated fuel used in the PFM shear tests. The shear concept for this project is different than the PFM shear design which also may affect the amount of fines generated. Therefore, the need for an argon cover gas will not be decided until a prototype shear has been built and tested and more information is known about the condition of the fuel in the storage basins. The dissolver off gas system will be sized to handle the argon cover gas should it be required.

9.0 ESSENTIAL MATERIALS

The essential materials required for shear/leach processing of irradiated N Reactor fuel are listed in table 9.1. The solvent extraction essential material requirements are given in table 9.2.

Table 9.1 Essential Materials Shear/Leach Process		
Material	Purpose	Quantity
10.4 M HNO ₃	Fuel dissolution	400 Gal/MTU
Water	Fuel dissolution	As Needed
	Basket Removal	80 Gal./Basket
Grout	Hull Stabilization	35 Cubic feet/MTU
Water	Cooling coils	100 GPM*
Steam	Storage tanks	15 Lbs./Hr.*

*Steam and water are supplied from closed loop system.

Table 9.2 Solvent Extraction Essential Materials		
Material	Purpose	Quantity
Ferrous Sulfamate	1BX Stream Makeup	15.8 g/MTU
Sulfamic Acid	1BX Stream Makeup	9.7 Kg/MTU
Nitric Acid	AMU Makeup area, Column feeds	180 Kg/MTU
Hydroxylamine Nitrate	2BX and 2DIS	3.8 Kg/MTU
Sodium Nitrate	Waste Tanks	11.2 Kg/MTU
Organic (25%TBP)	Solvent for SX	41.2 Kg/MTU
Sodium Carbonate	Organic Recovery	8.7 Kg/MTU
Potassium Permanganate	Organic Recovery	1.3 Kg/MTU
Sugar	Waste Treatment	48.8 Kg/MTU
Sodium Hydroxide	Waste Treatment	156.7 Kg/MTU
Aluminum Nitrate Nonahydrate*	Fluoride Control	30.0 Kg/MTU
Oxalic Acid	Process Flushes	4.1 Kg/MTU
Tartaric Acid	Process Flushes	0.9 Kg/MTU
Sulfuric Acid	Water Treatment	1.9 Kg/MTU
Steam	Vessel Heating, Jet Transfers, etc.	115K Kg/MTU**
Water	Tank and Vessel Cooling	170 Gal/MIN**

* ANN will be eliminated shortly after startup.

** Steam and water will be supplied from closed loop system(s).

10.0 REFERENCES

1. Orme, R. M., 1985, *Flowsheet For N Reactor Fuel Processing at the Process Facility (PFM) Project*, SD-PFM-ER-007, Westinghouse Hanford Company Richland, Washington.
2. Orme, R. M., D. E. Scully, E. D. Waters, 1987, *Pilot Dissolver Test Report - Process Facility Modifications (PFM) Project*, SD-PFM-DTR-007, Westinghouse Hanford Company Richland, Washington.
3. Scheele, R. D., L. L. Burger, B. T. Halko, 1988, *Comparison of Silver Sorbents for Application to Radioiodine Control at the PUREX Process Facility Modification*, PNL-6607, Pacific Northwest Laboratory, Richland, Washington.
4. Swanson, J. L., et al, 1985, *Laboratory Studies of Shear/Leach Processing of Zircaloy Clad Metallic Uranium Reactor Fuel*, PNL-5708, Pacific Northwest Laboratory, Richland, Washington.
5. WHC, Nov. 1989, *PUREX Technical Manual*, WHC-SP-0479, Westinghouse Hanford Company, Richland, Washington.
6. Burger, L. L., Scheele, R. D., July 1985, *The Status Of Radioiodine Control For Nuclear Fuel Reprocessing Plants*, PNL-4689, Pacific Northwest Laboratory, Richland, Washington.
7. Roemer, J. J., 1987, *PUREX Plant Final Safety Analysis Report*, SD-HS-SAR-001, Westinghouse Hanford Company Richland, Washington.
8. Thomas, T. R., et al, 1977, "Airborne Elemental Iodine Loading Capacities of Metal Zeolites and a Method of Recycling Silver Zeolite, ICP.", 1119, Idaho National Engineering Laboratory, Idaho, July.
9. Lambard, D. L., *N Reactor Fuel Rotary Shear Test Report, Phase III*, SD-PFM-OTR-009, March, 1987.
10. Schofield, J.S., "Iodine Monitoring And Removal Requirements During Process Of Fast Flux Test Facility Fuel In PUREX", Letter number 14300-88-110, November, 1988, Westinghouse Hanford Company, Richland, Washington.
11. *Management of Waste Cladding Hulls. Part I. Pyrophoricity and Compaction*, ANL-8139.
12. *Westinghouse Environmental Compliance Manual*, WHC-CM-7-5, October 1988, Westinghouse Hanford Company, Richland.

13. Allen, G. K., et al, "PUREX Flowsheet - Reprocessing N Reactor Fuels", PFD-P-020-000001, Rev. A-7, July, 1985, Rockwell Hanford Operations, Richland.
14. Hedegren, D. C., "PUREX WASTE VOLUME PROJECTIONS -- FISCAL YEARS 1991-2015", Letter number 1740-91-028, May, 1991, Westinghouse Hanford Company, Richland.
15. Moore, J. D., "Functional Design Criteria-PUREX Steam Condensate Recycle System", WHC-SD-C103-FDC-002 REV 0, Westinghouse Hanford Company, Richland.
16. "PUREX Plant Process Condensate Stream Specific Report", WHC-EP-0342 , Addendum 12 , August 1990, Westinghouse Hanford Company, Richland.
17. "PUREX Plant Chemical Sewer Stream-Specific Report", WHC-EP-0342 , Addendum 2 , August 1990, Westinghouse Hanford Company, Richland.
18. Bergman, D. W., McBride, D. J., "PUREX/UO₃ Gaseous Effluent Projections For Remaining Fuel Reprocessing", WHC-SD-CP-TI-159, March, 1990, Westinghouse Hanford Company, Richland.
19. "Prevention Of Significant Deterioration Permit Number PSD-X80-14" U.S. Environmental Protection Agency, Region X, EPA, 1980.
20. Dale, R. N., "Shear/Leach Of N Reactor Fuel At PUREX", WHC-SD-PCR-001, 1991, Westinghouse Hanford Company, Richland.
21. Bourger, F. H., "UO₃ Plant Safety Analysis Report", SD-CP-SAR-002, September, 1991, Westinghouse Hanford Company, Richland.
22. Young, M. A., "UO₃ Plant Process Flowsheet", WHC-SD-CP-PC-001 Rev. 0, March, 1991, Westinghouse Hanford Company, Richland.
23. Matheison, W. E., Nicholson, G. A., "PUREX Chemical Flowsheet - Processing Aluminum Clad Fuel ", ARH-214-DEL, February 15, 1968, Atlantic Richfield, Richland.
24. "TRU Waste Acceptance Criteria For The Waste Isolation Pilot Plant", WIPP/DOE-069 Rev. 1, January 1989, Westinghouse Hanford Company, Richland.
25. McDonald, S. N., "Project C018H Waste Water Engineering Alternatives", WHC-SD-C018H-ER-001 Rev. 0, EABSCO Environmental & Hare Crowser Inc., August 1991, Richland.
26. Crane, A. F., "Functional Design Criteria For 200 Area Treated Effluent Disposal System Project W049H", WHC-SD-W049H-FDC-001 Rev. 1, 1991, Westinghouse Hanford Company, Richland.

11.0 FLOW DIAGRAM(S)

The flowsheet for the continuous dissolver is shown in figure 11.1 and the concentration of the streams is given in table 11.1. The bases used to generate the flowsheet is given below.

SHEAR/LEACH FLOWSHEET BASES

1. This flowsheet is based on processing 4 MTUs/day of fuels grade material in a continuous process.
2. The following overall equation was used for fuel dissolution:

Based on knowledge of PUREX dissolver operation during zirflex decladding process (metal dissolution steps), 10% of the NO released into the dissolver off-gas is oxidized to NO₂ and recycled back to the dissolver as nitric acid (i.e. 10 % recovery of NO back to the dissolver).

3. An air bleed of 80 SCFM is required to oxidize the NO in the off-gas to NO₂ based on the following equations:

4. The NO_x generated during fuel dissolution will contribute 20 scfm to the dissolver off-gas.
5. A dissolver sparge rate of 20 SCFM is required assuming the dissolver will contain 17 baskets. This was "scaled" up from the 7.3 SCFM sparge rate used in the 12 basket pilot plant dissolver. A combined sparge and air bleed rate of 100 SCFM is assumed to ensure excess oxygen.
6. All water concentrations are based on saturated conditions at the temperatures given.
7. The following equation was used to calculate the density of uranyl nitrate solution:

$$SpG = 1 + 0.033 ([HNO_3]) + 0.23 ([U]) - (9.8E-4)(T-25^\circ C)$$

8. Uranium losses to the cladding hulls were assumed to be 0.5% of the fuel charge.

9. The dissolver will have a stilling chamber on the product outlet that will be designed so that solids greater than 10 microns in diameter will settle and remain in the dissolver. Solids with a diameter of 10 microns or less will be entrained out of the dissolver with the dissolver product.
10. The 0.64 kg/day of cladding fines which are entrained out of the dissolver with the dissolver product is based on data from laboratory and pilot plant development work. In laboratory studies of leach processing of N Reactor fuel (Reference 4), Swanson reported 0.1 g undissolved solids/kg of uranium dissolved. In the pilot plant work, reference 2, the undissolved solids entrained in the dissolver product ranged from 0.06 to 0.46 g/kg U dissolved. In addition to this, there were some solids which settled to the bottom of the pilot plant dissolver and remained there. The amount of solids was not determined. When a size distribution was done on part of the filtered solids from the pilot plant, 65 wt% were larger than 10 microns.

The upper range of 0.46 g/kg U was used for calculations in this flowsheet. This converts to a daily rate of 1.84 kg of undissolved solids for 4 MTUs of fuel. It was assumed that 35 wt% of these solids or 0.64 kg/day will be entrained in the dissolver product.

11. The amount of solids remaining in the dissolver was estimated by taking 65% of 1.84 kg/day or 1.2 kg/day and increasing it by 50 % to be conservative. All testing conducted utilized a rotary shear which generates more fines than the hydraulic shear presented in this flowsheet.

Figure 11.1

LEGEND

GASES -----
 LIQUIDS -----
 SOLIDS -----

Continuous Dissolver Flowsheet

(SL00201B)

Table 11.1 Shear/Leach Flowsheet Stream Composition

SOLID AND LIQUID STREAMS

Stream Number	1	3	4	5	6	7	8
STREAM DESCRIPTION	Fuel Charge	Nitric Acid	Canister Water	Dissolver Product	Cladding Fines	Cladding Hulls	Hull Rinse
TEMPERATURE, C				105			
Specific Gravity		1.33	1.00	1.65			
FLOW, CFM							
FLOW, GPM		1.57		1.53			
BATCH Gal./day			80				50
U metal Kg/day	4000					20	
Cladding Kg/day	281				1.85	279	
HNO ₃ , M		10.4		3.0			
U (diss) M				2.0			
U, Moles	16807			16723			
HNO ₃ , Moles		88785		24919			

GASEOUS STREAMS

Stream Number	2	9	10	11	12	13
STREAM DESCRIPTION	Air Bleed And Sparge	Dissolver Off-gas	Concenser Off-Gas	Heater Off-Gas	Iodine Adsorber Off-Gas	Back Up Facility Off-Gas
TEMP, C	20	80	30	150	150	20
FLOW, CFM	100	120	120	167	167	110
I-129, 10E-6 Ci/ml		0.89	0.89	1E-04	1E-08	1E-08
N ₂ , Vol %	79	65.2	65.22	65.22	65.22	71.3
O ₂ , Vol %	21	16.12	16.12	16.12	16.12	17.2
NO & NO ₂ , Vol %		14.63	14.63	14.63	14.63	4.8
H ₂ O, Vol %		4.2	4.2	4.2	4.2	6.4
N ₂ , Moles	134237	134237	134237	134237	134237	134237
O ₂ , Moles	33175	33175	33175	33175	33175	33175
NO & NO ₂ , Moles	0	30100	30100	30100	30100	9030