INEL-94/0030

Depleted Uranium Plasma Reduction System Study

Pete Rekemeyer[a]
Fred Feizollahi[a]
William J. Quapp
Blaine W. Brown

Published December 1994

Idaho National Engineering Laboratory
Lockheed Idaho Technologies Company
Idaho Falls, Idaho 83415

Prepared for the
U.S. Department of Energy
Assistant Secretary for Environmental Management
Under DOE Idaho Operations Office
Contract DE-AC07-94ID13223

MASTER

---

[a] Engineering, Construction, & Environmental Group, Morrison Knudsen Corporation.

DISTRIBUTION OF THIS DOCUMENT IS UNL

TJ

DISCLAIMER

DISCLAIMER

Depleted Uranium
Plasma Reduction System Study

INEL-94/0030

Prepared by:

Pete Rekemeyer and Fred Feizollahi
Morrison Knudsen Corporation

Date

Reviewed and Approved by:

Blaine W Brown

Blaine W. Brown, Sr. Engineering Specialist
Depleted Uranium Recycle Project

12-15-94
Date

Reviewed and Approved by:

WJ Quapp

William J. Quapp, Project Manager
Depleted Uranium Recycle Project

12-5-94
Date

ABSTRACT

A system life-cycle cost study was conducted of a preliminary design concept for a plasma reduction process for converting depleted uranium to uranium metal and anhydrous HF. The plasma-based process is expected to offer significant economic and environmental advantages over present technology. Depleted Uranium is currently stored in the form of solid UF_6, of which approximately 575,000 metric tons is stored at three locations in the U.S. The proposed system is preconceptual in nature, but includes all necessary processing equipment and facilities to perform the process. The study has identified total processing costs of approximately \$3.00/kg of UF_6 processed. Based on the results of this study, the development of a laboratory-scale system (1 kg/h throughput of UF6) is warranted. Further scaling of the process to pilot scale will be determined after laboratory testing is complete.

ACKNOWLEDGMENTS

The authors are grateful to Joe Foldyna, Joyce Fabre, and David Bean of the Morrison Knudsen Corporation in Boise for their help in designing the process and in preparing this report.

CONTENTS

FIGURES

TABLES

ACRONYMS

AC	alternating current
D&D	decontamination and decommissioning
DC	direct current
DOE	Department of Energy
DUPRS	depleted uranium plasma reduction system
ESP	electrostatic precipitator
HF	hydrogen fluoride
HVAC	heating, ventilation, and air conditioning
INEL	Idaho National Engineering Laboratory
MCC	motor control center
MK.	Morrison Knudsen Corporation
NEPA	National Environmental Policy Act
O&M	operation and maintenance
PLCC	project life-cycle cost
ROM	rough order of magnitude
SCF	standard cubic feet
SCFM	standard cubic feet per minute

Depleted Uranium Plasma Reduction System Study

1. INTRODUCTION

The U.S. Department of Energy's (DOE) Environmental Management Office of Technology Development (EM-50) commissioned this study to examine the feasibility of using the plasma reduction process for converting depleted uranium hexafluoride (UF_6) to uranium metal ingots. The preconceptual design of the facility for conversion of UF_6 to uranium metal was sized to convert an inventory of 4000,000 metric tons over 20 years. After the completion of this study, a better estimate of the DOE UF_6 inventory was developed and found to be nearer 575,000 metric tons. It is estimated that the additional inventory can be processed with a minimal increase in equipment, consumeables, and manpower. Thus, the unit costs determined in this study for processing the 400,000 metric ton inventory should be a bounding estimate if the entire inventory were to be processed in the same time period. This study is part of a larger effort to address possible uses for depleted uranium and examines options to reduce the cost of use.

DOE produced the depleted UF_6 in the uranium enrichment process, and has stored it in canisters for up to 50 years at three locations in the U.S. The depleted UF_6 contains 0.2% ^{235}U and uranium decay products, including radon.

1.1 Background

DOE is studying alternative management options for recycling the large quantity of UF_6 produced from the uranium enrichment process. The depleted uranium plasma reduction system (DUPRS) could potentially process the stored UF_6 and produce uranium metal and hydrogen fluoride (HF). HF is used commercially and uranium metal has potential commercial applications.

This plasma-based process appears to have an economic and environmental advantage over present technology used for UF_6 to uranium metal production. The process has successfully been demonstrated in bench-scale tests at the Idaho National Engineering Laboratory (INEL) during FY 1994. This report documents the results of a preconceptual design study that was performed to estimate the production costs of a facility that used the DUPRS to produce uranium metal. This report also contains a preconceptual design of the DUPRS based on the flow diagram in Figure 1 and a brief technical evaluation of the system.

1.2 Technical Approach

The DUPRS, illustrated in Figure 1, was divided into 15 unit operations, as follows.

1. Storage and receiving
2. Plasma reactor
3. Metal/gas cooling and separation

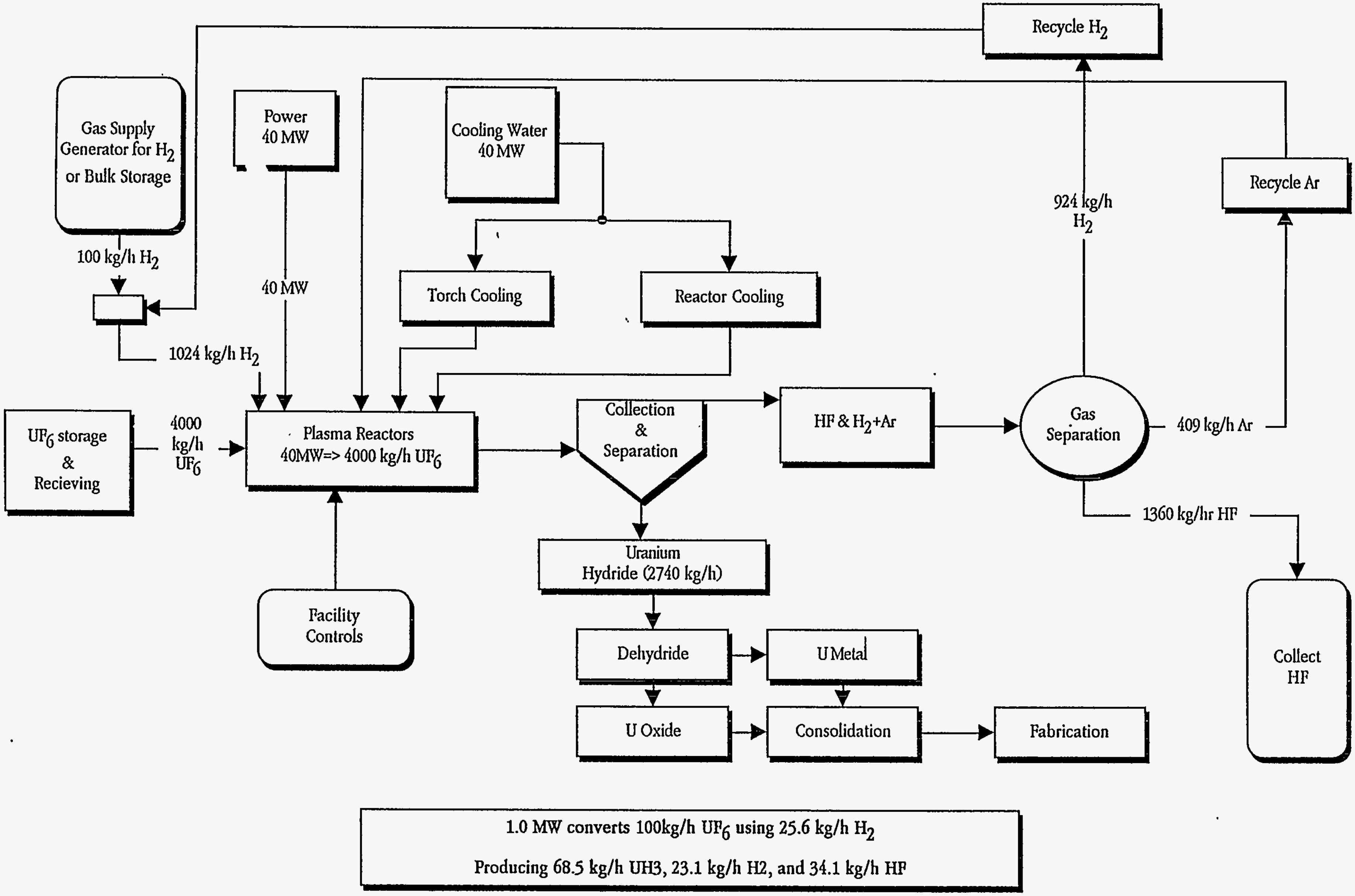


Figure 1. UF_6 plant flowsheet, plasma quench reduction of UF_6 by H_2.

4. Gas separation
5. Uranium metal melting
6. Uranium metal cutting and storage
7. Water cooling system
8. Supply hydrogen
9. Electrical distribution and motor control center (MCC)
10. Radiation monitoring
11. Utilities and mechanical
12. Administration and central control
13. Heating, ventilation, and air conditioning (HVAC)
14. Civil construction work
15. Maintenance.

Costs identified with the 15 unit operations were summarized, and total costs were developed using a bottoms-up estimating approach. The estimate uses costs from existing DOE projects, vendor quotes, and engineering experience to develop costs for equipment, structures, utilities, materials, maintenance, and labor for each unit operation. This information generates the following:

- Studies and bench-scale test costs
- Demonstration costs
- Production facility construction costs
- Operations budget-funded activities
- Operating and maintenance costs
- Decontamination and decommissioning
- Rough order of magnitude (ROM) life-cycle costs (20 years of operation).

1.3 Study Team

The overall project was initiated and directed by Carl Cooley of DOE, EM-50. A team of employees from the INEL and from the Engineering, Construction & Environmental Group of Morrison Knudsen Corporation (MK) performed the engineering and analysis for the plasma reduction process.

1.4 Key Assumptions

The design was prepared with the following assumptions:

1. The process flowsheet, material/energy balances, and plasma torch power requirements are based on the schematic flowsheet shown in Figure 1.
2. The proposed facility will process a total of 400,000 metric tons of UF_6 over a 20-year period, at a rate of 4 t per hour for 5,000 hours per year.
3. The facility will produce uranium metal as ingots and the by-product anhydrous HF.
4. The impurities in the system are bled off through the uranium metal and anhydrous HF streams. This does not affect product marketability.
5. The facility will be at or adjacent to the existing UF_6 storage areas to eliminate the need for offsite UF_6 transport.
6. The facility will include warehouse capacity to store 50% of the annual production of uranium ingots each year.
7. The ^{235}U content of the depleted UF_6 is 0.2%. The UF_6 cylinders have been in storage for 50 years.
8. Radon discharge of 1 Ci/h is assumed.

2. SYSTEM DESCRIPTION

The DUPRS will convert UF_6 to uranium metal ingots and produce anhydrous HF as a by-product. The system consists of all structures, buildings, and equipment needed to process the UF_6. All equipment identified in the system design is commercially available except for the plasma reactor. A process functional diagram of the DUPRS is shown in Figure 2. A conceptual facility layout and a perspective view of the facility are shown in Figures 3 and 4, respectively. Unit operations are described below.

2.1 Storage & Receiving

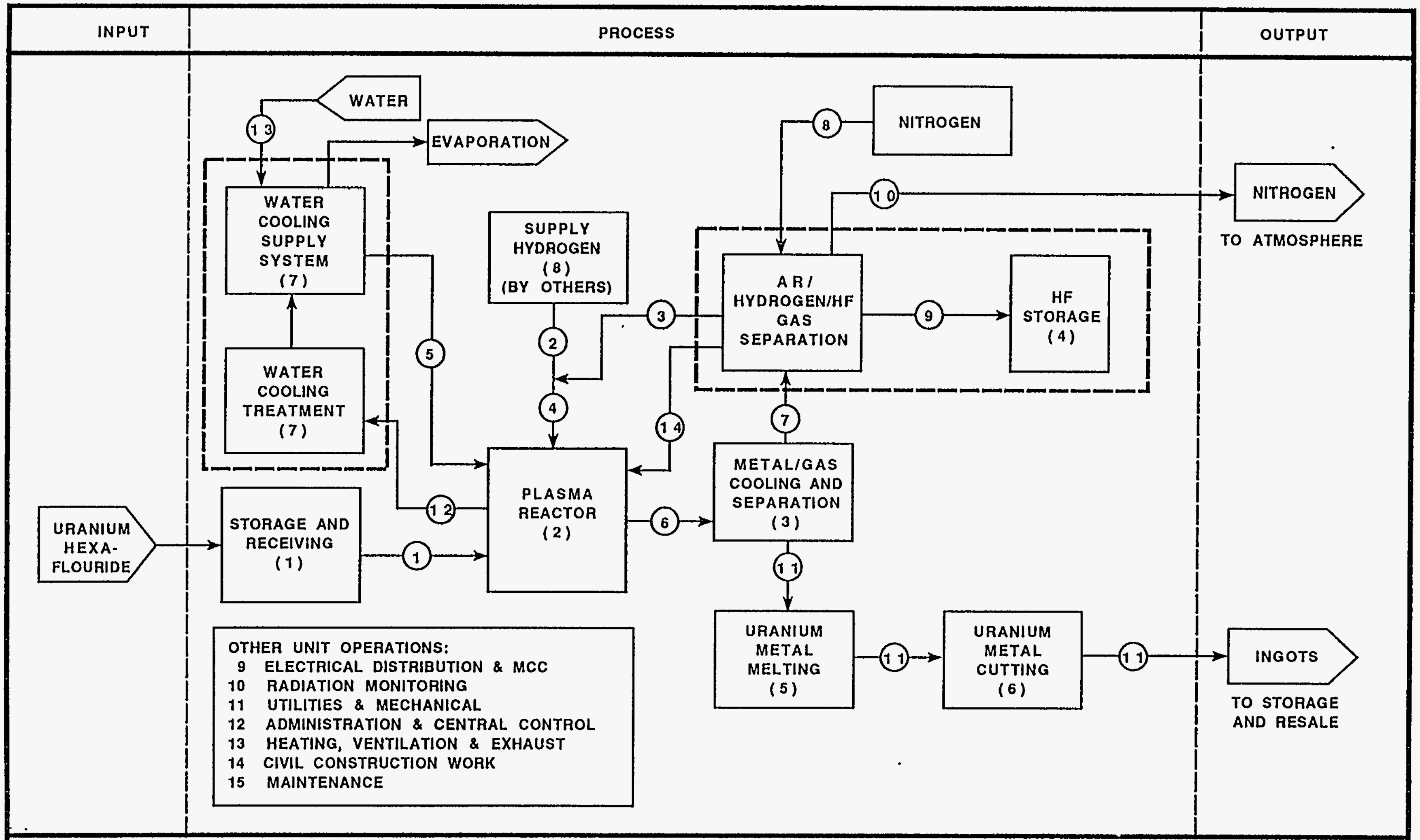
UF_6 is contained in sealed canisters at, or adjacent to, the existing production facility. Individual canisters will be moved from the inactive storage area to an enclosed staging area served by an overhead bridge crane. The canisters will be placed into indirectly heated overpacks with sealed enclosures. The cylinders will be heated to increase the temperature of the UF_6 to an estimated 140°F to convert solid UF_6 to UF_6 gas. The gas will be transferred by a vacuum pump and injected into the plasma torch reactor. The empty cylinders will be removed by the crane and taken to a storage area.

2.2 Plasma Reactor

The UF_6 will be injected into the four parallel plasma torch reactors, each processing 1 metric ton. The plasma torch reactors consist of a plasma torch and a reactor section. Argon gas is introduced to the plasma torch, which produces a high temperature (more than 10,000 K) plasma. A mixture of UF_6 and H_2 is introduced in the reactor section, downstream of the plasma torch. The reaction $UF_6 + 3\ H_2 \text{-->} U + 6\ HF$ proceeds in the reactor section. Because the net change in the number of moles is positive, the addition of inert gases in the reactor increases the yield by decreasing the partial pressure of products. The gas mixture exits the reactor zone and is quenched to prevent the recombination of uranium and fluorine. The plasma torch and reactor sections will be cooled with water, which is recirculated through a cooling tower.

2.3 Metal/Gas Cooling and Separation

The mixture of gases and submicron uranium metal powder will exit the reactor and diffuser section at an estimated temperature of 1,000°F and an estimated pressure of 10 psia. The product stream will be cooled to 250°F using indirect water/gas coolers combined with static solids separation in the bottom of the coolers. Final polishing of the gas stream for the removal of uranium metal will be accomplished by electrostatic precipitation. The metal/gas separation will remove more than 99.5% of the uranium metal. The design of the conventional precipitator will be modified by a conical bottom containing an air lock, live bottom bin, and screw feeders for positive uranium metal feed to the conveying system. The gas inlet to the precipitator will be through an inlet nozzle located on the side above the conical bottom. Gas discharge will be from the top.



NODE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
DESCRIPTION	U6 TO REACTORS	MAKE-UP H2	RECYCLE H2	H2 TO REACTORS	TOTAL COOLING WATER	DIFFUSER DISCHARGE	HF/H2 FROM ESPS	LIQUID N2 TO HF CONDENSER	HF TO BE SOLD	N2 TO ATMOSPHERE	U METAL TO FABRICATION FACILITY	TREATED WATER RETURN	COOLING SYSTEM MAKE-UP WATER	ARGON PLASMA GAS
FLOW RATE LB/HR	8,800	207	1,916	2,123	3.42×10^6	10,710	4,760	3,071	2,844	3,071	5,950	51,230	85,380	35,955

Figure 2. Process functional diagram of the DUPRS.

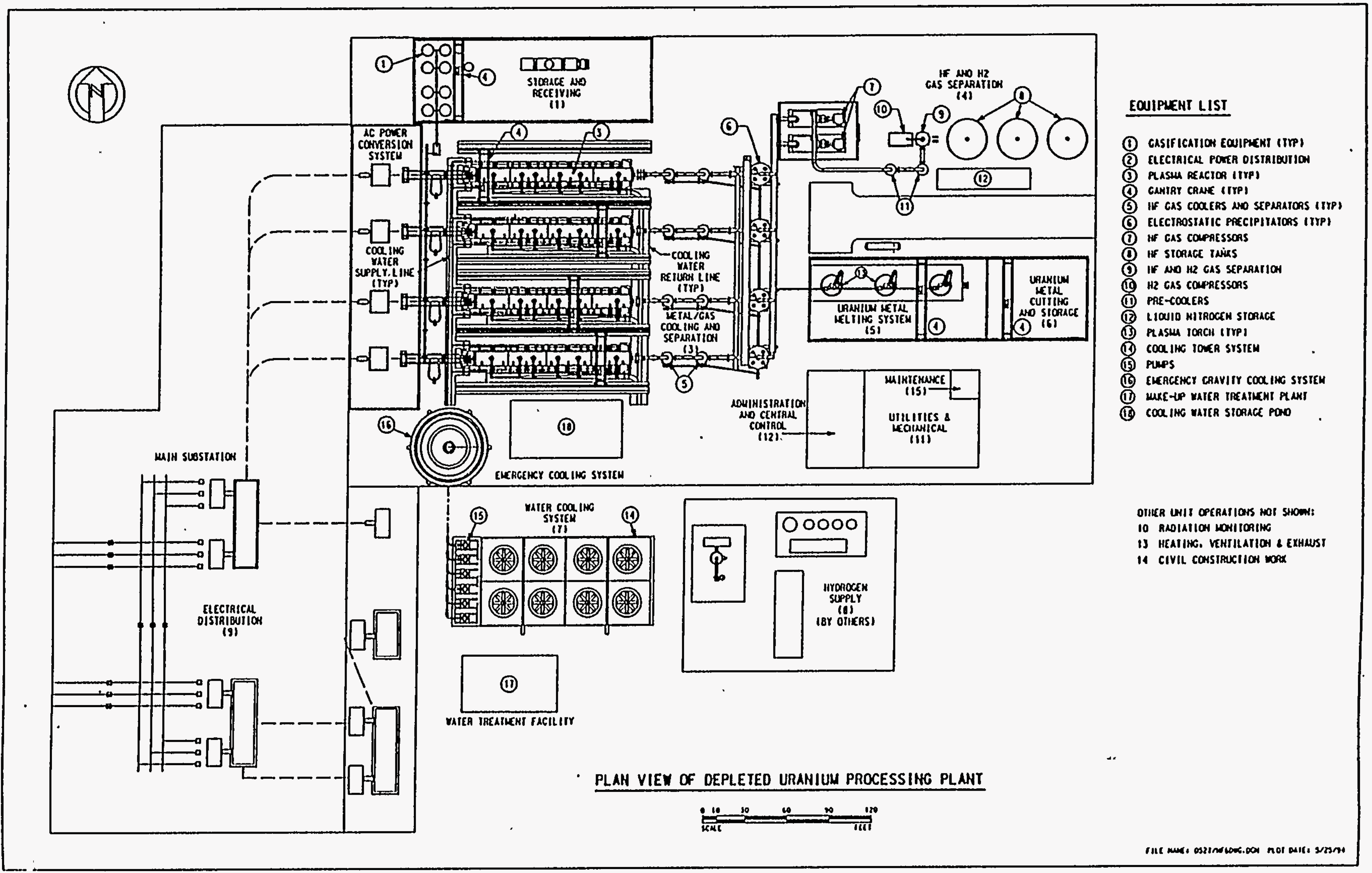


Figure 3. Conceptual layout of the DUPRS.

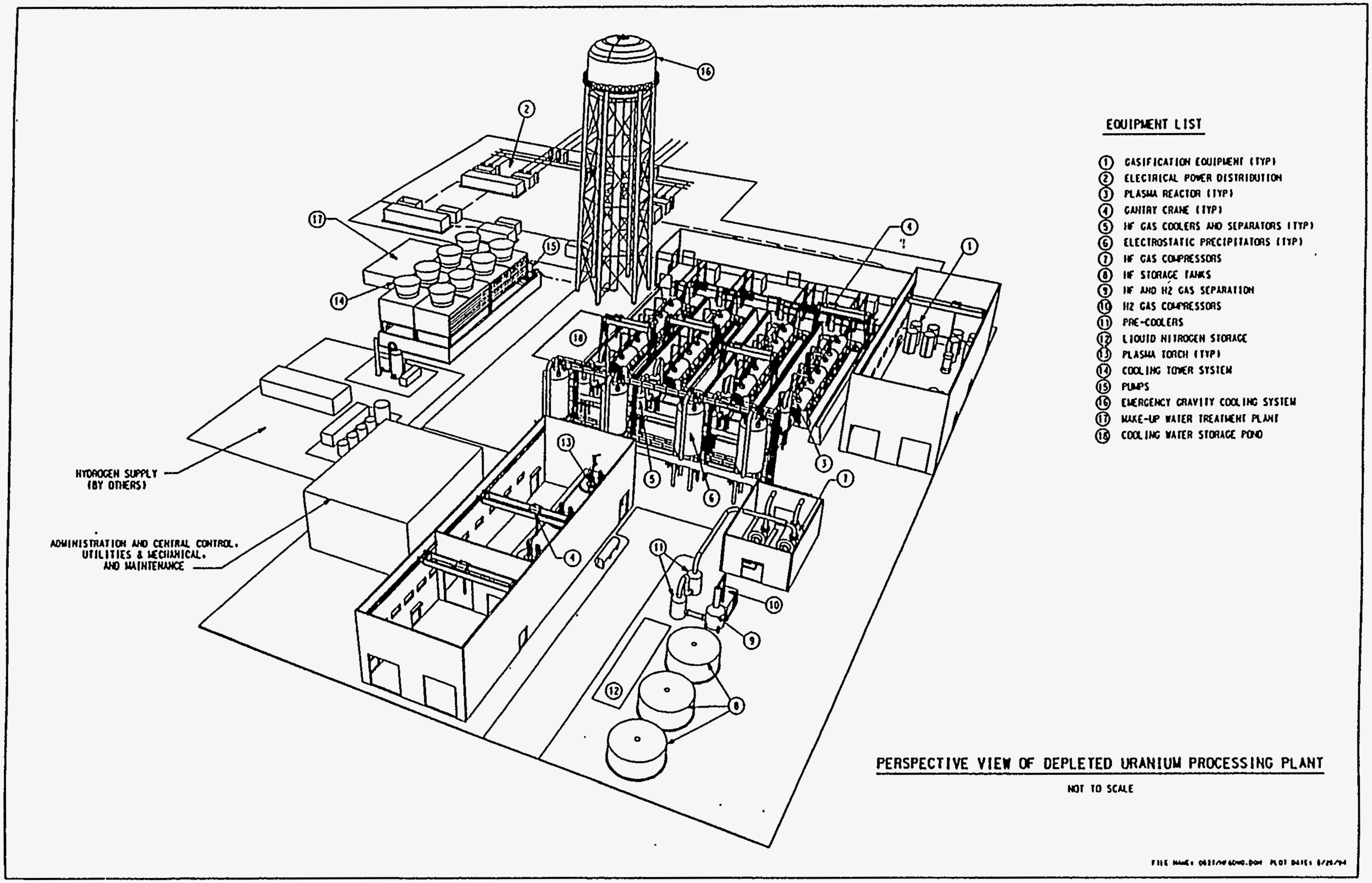


Figure 4. Perspective view of the DUPRS.

2.4 Gas Separation

After the solid uranium has been separated from the gas mixture, the by-product HF must be separated and removed from the system, and the remaining Ar/H_2 gas mixture must be separated and recycled to the plasma torch and reactor, respectively. Cryogenic condensation using liquid nitrogen will be used to separate the HF, which will be stored in tanks as a liquid. It is thought that the HF will eventually be offered for sale to industrial users. The Ar/H_2 gas mixture will be separated using membrane technology.

2.5 Uranium Metal Melting

The submicron-sized uranium metal powder separated from the gas stream will be melted in a plasma torch furnace under a helium gas atmosphere. Three melters will be required, all oriented in the upright position.

2.6 Uranium Metal Cutting and Storage

The melted uranium will be cast into a cooled mold. Three molds will be used to provide continuous processing rate. The ingots will be automatically cut to the required size and stored. The warehouse will be sized to store 50% of the annual production of ingots.

2.7 Water Cooling System

The plasma torch, reactor, and diffuser sections will be cooled by water circulating through a closed-loop cooling tower system. The system will be equipped with induced draft cooling tower fans and supported by a filtration and water treatment system. Approximately 1.5% of the circulation flow will be removed as blowdown, treated through a reverse osmosis unit, and returned to the cooling system. An additional 2.5% of the circulation flow will be makeup water required as a result of evaporation and reverse osmosis losses. An emergency gravity flow cooling system will back up the main system and will consist of an elevated 250,000 gal tank connected to the central system.

2.8 Hydrogen Gas Supply

The facility for the production of the gaseous hydrogen will be designed, installed, owned, operated, and maintained by an independent contractor. The cost of the facility will be covered by the price paid for the gas.

The hydrogen gas production facility will consist of a single train steam-methane reformer, a shift unit, and hydrogen purification unit. The steam-methane reformer generates carbon monoxide and hydrogen, the shift unit increases the hydrogen conversion by converting carbon monoxide and steam to carbon dioxide and hydrogen. The hydrogen purification unit will yield high-purity hydrogen by removing carbon oxides and methane in a pressure swing adsorption unit. The facility will be capable of producing 42,000 standard cubic feet (SCF) per hour of gaseous hydrogen. A by-product steam supply will also be available for export.

2.9 Electrical & Motor Control Center

Electrical power will be provided to the facility via two independent 138 kV transmission lines, each of which will be capable of supplying the required 100-MW load. The transmission lines will terminate at the facility's main substation. The 138 kV utility primary power voltage will be converted to 13.8 kV secondary voltage for distribution throughout the site by two 50 MV·A transformer banks. One transformer bank will supply the alternating current (AC) loads and the other the direct current (DC) loads. The main substation will consist of outdoor structures, insulators, busbars, power circuit breakers, isolator switches, resistors, and outdoor type switchgear and protective relays.

Underground feeders will carry the 13.8 kV secondary voltage to substations located near the loads being served. AC substations capable of converting the 13.8 kV secondary voltage to 4.16 kV and 480 V will be provided for the main processing area, the water cooling system area, the liquid hydrogen plant, and the maintenance/office complex. Substations capable of converting the 13.8 kV secondary voltage to 5 kV DC will be provided for the plasma torches and the smelters, and equipment capable of converting 480 V to 50 kV DC will be provided for the electrostatic precipitators (ESP).

The AC substations will consist of outdoor disconnect switches, distribution transformers, grounding resistors, and outdoor type switchgear. The DC substations will consist of outdoor disconnect switches, transformer/rectifier sets, power factor and harmonic filter cabinets, and rectifier cooling systems.

2.10 Radiation Monitoring

Redundant environmental monitoring will be required to analyze work areas and the environment for radon, HF, hydrogen, argon, and suspended particulates.

2.11 Utilities and Mechanical

Utilities and mechanical systems include service water, closed-circuit cooling tower water, compressed air, service instrument air, and auxiliary systems.

2.12 Administration and Central Control

Facilities will be provided for onsite administrative personnel. See Table 1 for a breakdown of required personnel. Space will also be provided to house the central control room.

2.13 HVAC

All enclosed areas will have ventilation systems designed to standards for radon control. HVAC costs have been included in the building costs.

Table 1. Estimated facility administrative staff (day shift only unless otherwise noted).

Job	FTE workers
Security (4 shifts)	4
Plant manager	1
Shift superintendent (3 shifts)	3
Maintenance superintendent	1
Procurement/accounting manager	1
Environmental, safety, and health manager and staff (3 shifts)	6
Personnel manager	1
Support	3
Environmental engineer	2
Secretary/clerk	3
Total	25

2.14 Civil Construction Work

The DUPRS plant will be surrounded by an 8-ft high chain-link fence. In addition, yard piping, sanitary sewers, and stormwater sewers will be provided. The plant will have a network of paved roadways for maintenance vehicles to access key pieces of equipment.

2.15 Maintenance

An enclosed building will be provided for maintenance personnel. It will be sized to accommodate the equipment requiring routine maintenance.

3. MASS FLOW RATES

This section contains a summary of the mass flow rates of the major input and output of the DUPRS. Detailed information on mass flow rates is presented in the process functional diagram in Figure 2.

3.1 Flow Rates

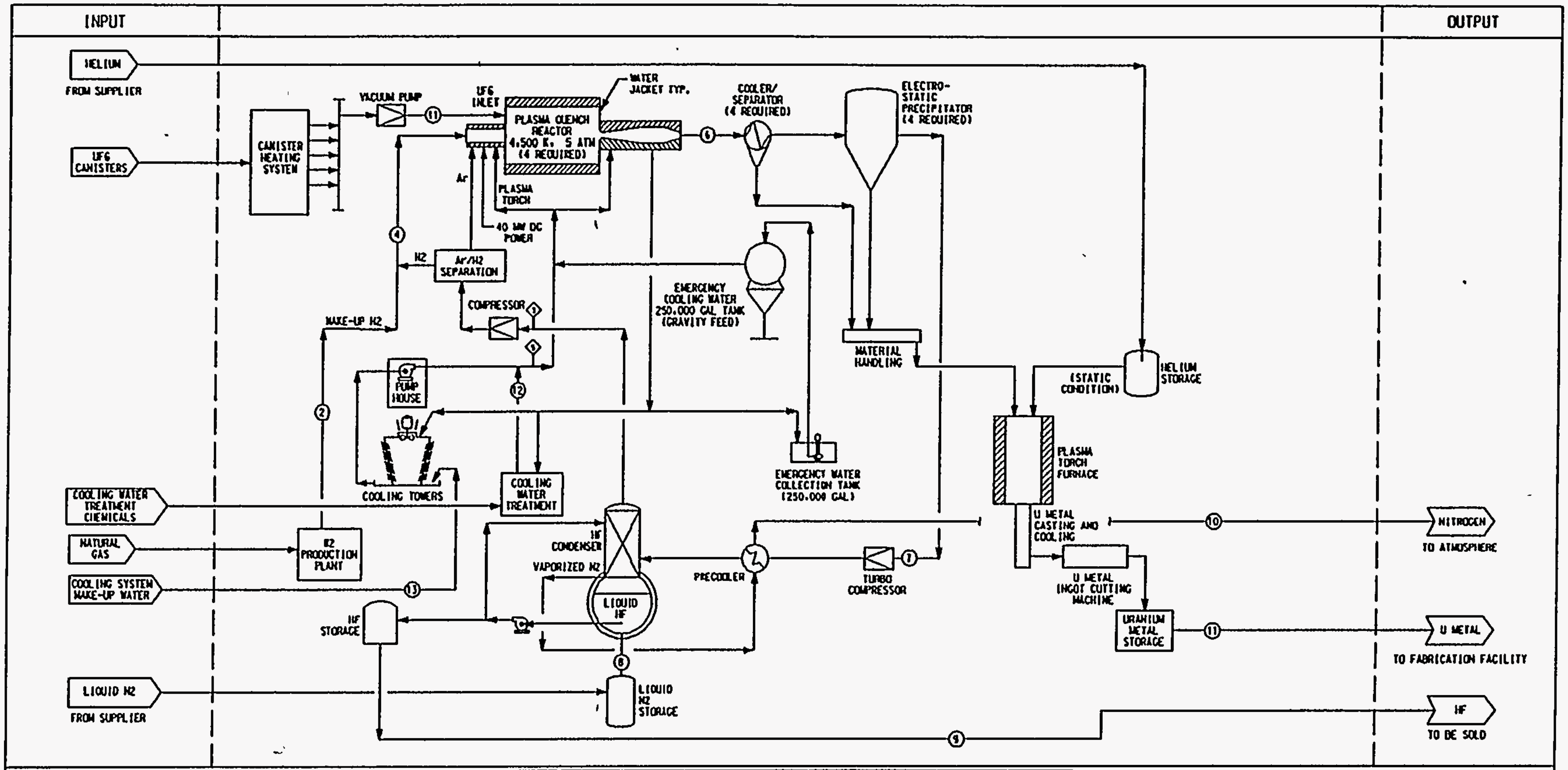
For the purpose of this study, the feed rates are calculated based on the assumption that the facility will operate for 20 years and process 4 metric tons of UF_6 per hour (see Table 2). A total of 400,000 metric tons will be processed (see Figure 5).

Table 2. Amounts to be processed in the various DUPRS areas.

DUPRS areas	lb/h
UF_6 to reactors	8,800
Makeup H_2	207 (619 SCFM)
Recycle H_2	1,916 (5,732 SCFM)
Recycle Ar	35,955 (5,385 SCFM, 36:1 Ar/UF_6 molar ratio)
H_2 to reactors	2,123 (6,351 SCFM)
Total cooling water	3.415×10^6
Diffuser discharge	10,710
HF/H_2/Ar from ESPs	4,760 (11,875 SCFM)
Liquid N_2 to HF condenser	3,071 (656 SCFM)
HF (to be sold)	2,844
N_2 (to atmosphere)	3,071 (656 SCFM)
Uranium metal	5,950
Treated water return	51,230
Cooling system makeup water	85,380

3.2 Reusable Product

The hydrogen production facility will generate a by-product steam supply that will be available for export. The uranium metal and the HF will be sold for reuse.



STREAM NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	Ar
STREAM	UF6 TO REACTORS	MAKE-UP H2/Ar	RECYCLE H2	H2 TO REACTORS	TOTAL COOLING WATER (SEE NOTE 1)	DIFFUSER DISCHARGE	HF/H2 FROM ESP'S	LIQUID N2 TO HF CONDENSER	HF TO BE SOLD	N2 TO ATMOSPHERE	U METAL TO FABRICATION FACILITY	TREATED WATER RETURN	COOLING SYSTEM MAKE-UP WATER	
TEMPERATURE, °F	140	AMB.	-30	AMB.	68	1,000	230	-290	40	70	AMB.	68	68	68
PRESSURE, ATM	5	10	2	10	10	0.5	0.03871	2	1	1	1	10	3	1
TOTAL FLOW, LBS/HR	8,800	207	37,871	2,123	3,415,000	46,665	40,715	3,071	2,844	3,071	5,950	51,230	65,380	35,955
TOTAL FLOW, SCFM		619	13,117	6,351			11,875	656		656				5,385
COMPONENTS, LBS/HR:														
UF6	8,800													
U METAL						5,950					5,950			
H2		207	1,916	2,123		1,916	1,916							
HF						2,844	2,844		2,844					
N2								3,071		3,071				
WATER					3,415,000							51,230	65,380	

NOTES:

1. TOTAL COOLING WATER FOR PLASMA QUENCH SYSTEMS, COOLER/SEPARATORS, TURBO COMPRESSORS, U METAL MELTING, PLASMA TORCHES AND DC CONVERSION SYSTEM COOLING.

PFD FOR URANIUM DEPLETED PROCESSING PLANT

FILENAME: 0521/PFD-UDPP.DGN PLOT DATE: 10/10/94

Figure 5. Mass flow balance for the DUPRS.

3.3 System Waste

The air treatment facilities for the DUPRS will generate secondary waste. The nature and quantity of these secondary wastes have not been determined. NO_2 will be discharged to the atmosphere or treated and released as nitrogen. Cooling water will be a closed system and will not be discharged, except that portion which will be discharged from the reverse osmosis unit. The uranium metal and the HF will be sold for reuse.

Other secondary waste will consist of housekeeping trash, disposable garments, equipment maintenance waste, spent baghouse, ventilation and high-efficiency particulate air filter elements, accumulations in equipment drains and floor drains, machinery oil, and decontamination waste.

3.4 Key Assumptions for Mass Flow Calculations

The key assumptions for the mass flow calculations are:

- The uranium contains 0.2% ^{235}U
- The DUPRS will be located near the stored UF_6.

4. LIFE-CYCLE COST ESTIMATE

This section contains a summary of the project life-cycle cost (PLCC) estimate for the DUPRS. The PLCC estimate includes treatment costs for processing UF_6. The cost of transporting UF_6 to the processing facility has not been included. The facility has been sized to treat 400,000 t of UF_6 over a 20-year operating life. The total operating time during the facility life cycle is 100,000 hours.

4.1 Estimating Methods, Basis, and Assumptions

The following assumptions were used to derive the life-cycle cost estimate:

1. Generation of hydrogen will be accomplished by a lessee. The lessee will absorb all capital and operating costs and will be included in the cost of the hydrogen supplied.

2. Building costs include materials to construct pre-engineered buildings, concrete slabs, excavation, backfill, and site work. Where only concrete slabs are to be constructed, their costs, including excavation, backfill, and site work, are included as a building cost in the appropriate unit operation. The building costs also include HVAC, crane support structures (where appropriate), and electrical installation.

3. Pre-engineered buildings will house the following unit operations:

    - Administration and central control
    - Storage and receiving
    - Plasma reactor
    - Uranium-metal melting
    - Uranium metal cutting and storage
    - Maintenance.

    The unit operations that will be built on open-air concrete pads are:

    - Metal/gas cooling and separation
    - HF and H_2 gas separation
    - Water cooling system.

4. Raw material usages and costs will be as shown in Table 3.

Table 3. Raw material usages and costs.

Item	Annual quantity	Cost
UF_6	44,000,000 lb	None
Hydrogen	196,500,000 SCF	\$3.70/1,000 SCF
Nitrogen	360,000,000 SCF	\$2.80/1,000 SCF
Ar/H_2 separation	1,710,000,000 SCF	\$1.00/1,000 SCF Ar separated
Electrical energy	250,000 MW·h	\$0.03/kW·h
Helium	Negligible	—

5. The HVAC system will be maintained by maintenance personnel. Maintenance personnel costs are absorbed in the maintenance unit operation.

6. Administrative personnel are allotted $7,000 for computers, desks, etc.

7. The allowance for piping/mechanical includes structural supports for platforms, piping, and walkways and minor pump and piping systems.

8. The allowance for electrical/controls includes all additional instrumentation required to ensure safe operation of the unit operations and their interaction with other unit operations.

9. The allowance for calibration/testing/startup includes calibrating gauges and instruments to ensure compatibility with the process requirements. The allowance also includes startup costs associated with vendor-supplied equipment and the integration of the equipment into the treatment system.

10. The electrical utility cost is spread proportionally across the unit operations.

11. Makeup water used in the water cooling system unit operation is assumed to cost $17/1,000 SCF.

12. Cutting of the uranium ingots will be performed within an argon atmosphere.

Figure 6 shows the steps used in the cost estimating approach.

Cost information in this report was obtained during the second quarter of FY 1994. The information is based on the currently available knowledge about waste processing requirements, technology availability, and cost data. The information may require updating when additional knowledge is gained in these areas. All facilities except the hydrogen production plant are assumed to be government owned and contractor operated.

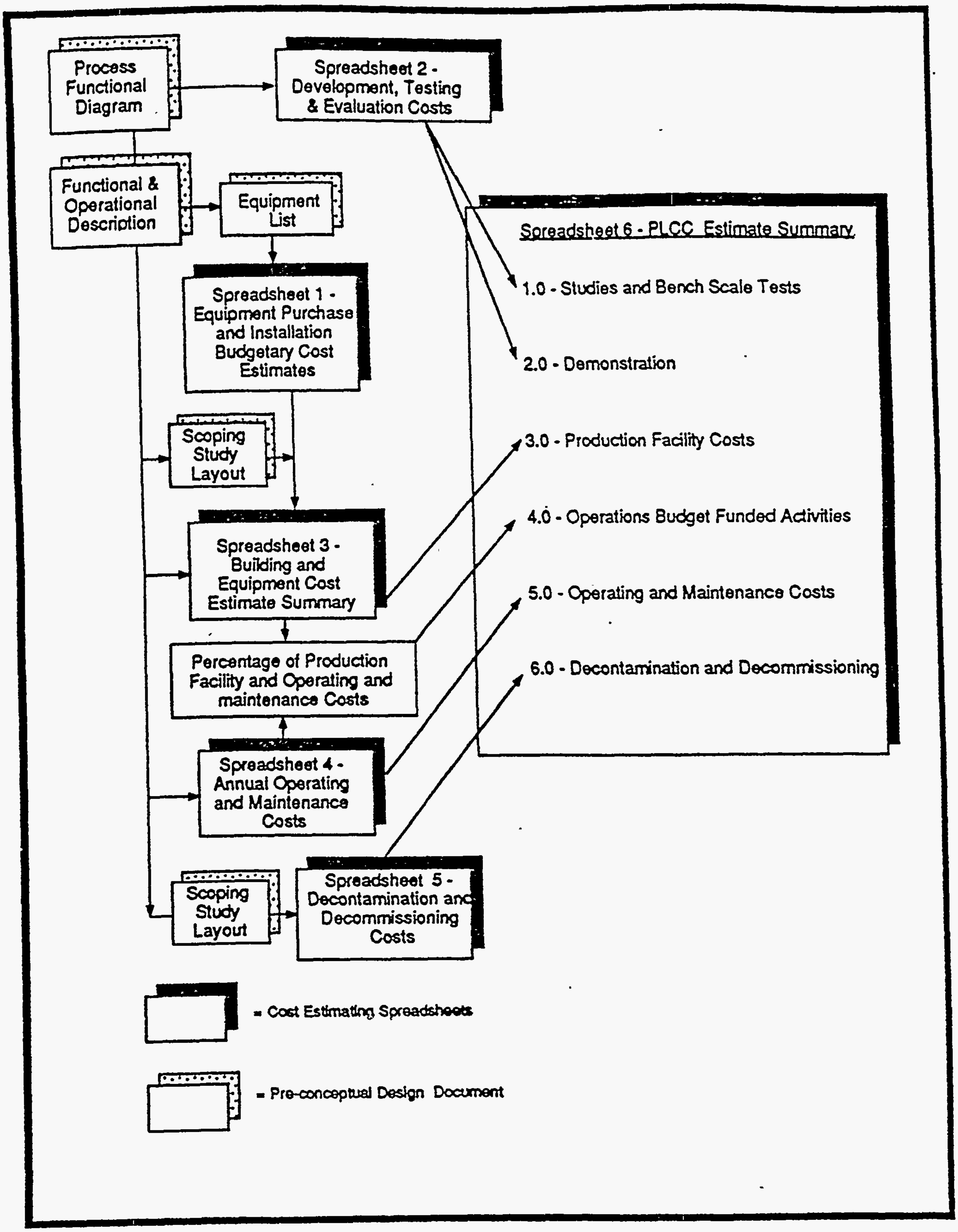


Figure 6. Diagram of cost estimating approach.

4.2 Treatment Facility PLCC Estimate Summaries

The PLCC estimate is divided into six components (see Figure 6). Each was estimated separately. A summary of the PLCC estimate is presented in Table 4. Detailed cost breakdown spreadsheets are presented in Appendix A. Discussions of the cost components are presented below.

4.2.1 Studies and Bench-Scale Tests and Demonstration Tests

Bench-scale studies were undertaken at the INEL to demonstrate the feasibility of the process. These experiments successfully demonstrated that a plasma torch could be used to reduce UF_6 to U and HF. Small quantities of metallic uranium were produced, and the rapid quench of the product stream was also demonstrated. No back-reaction of the products to UF_x compounds was detected.

Demonstration and scaling will proceed through three phases: (a) laboratory development, (b) pilot-scale testing, and (c) production-scale testing. Laboratory development will consist of large bench-scale testing, pilot-scale increases throughput to the 100–200 kg/h rate and includes the complete plant. Production-scale addresses issues associated with the scaling of specific pieces of hardware, such as plasma devices or particle collection systems. Total research and development costs are estimated at about 5% of total life-cycle costs.

4.2.1.1 Laboratory Development. Sufficient experimental data were acquired during successful bench-scale demonstration, and the theoretical understanding of the thermal plasma reduction of UF_6 has progressed to the point that a large bench-scale demonstration reactor can be designed. However, the performance of each component must be evaluated. The major attributes of this reactor are an increase in volume-to-surface ratio by a minimum of a factor of 10 and the development of a high-efficiency (>60%) multiple source plasma with co-axial UF_6 injection. Throughput of UF_6 is expected to be on the order of 1 kg/h. Detailed process diagnostics and a detailed material balance will be performed. Component designs will be experimentally evaluated and performance characteristics verified coincident with the development of the pilot-scale reactor design.

4.2.1.2 Pilot Scale. The pilot-scale demonstration increases throughput of UF_6 to the 100-200 kg/h range. At this scale, the performance of all major components can be addressed, and realistic data on plasma device operating lifetimes, system efficiencies, etc., can be evaluated and problem areas can be identified. Pilot scale is an important step for a process that is significantly different from other conventional chemical processes.

4.2.1.3 Production-Scale Testing. It is anticipated that the performance of some components, which are identified during pilot-scale testing, will need to be further evaluated and modified. An example may be the scaling of plasma devices and reactors to the multimegawatt level. Additional design, testing, and evaluation will be performed in parallel with the development of the plant design and construction.

Table 4. ROM life-cycle cost estimate summary for the DUPRS.

Cost component	Cost items	Cost ($ × 1000)
1.0 Studies and bench-scale test and demonstration costs	(5% of 6.0)	$55,948
Subtotal 1.0		
2.0 Production facility construction costs		
2.1 Design cost	(18% of 2.4)	$26,079
2.2 Inspection cost	(7% of 2.4)	$10,142
2.3 Project management	(10% of 2.4)	$14,488
2.4 Construction cost		
2.4.1 Building structure costs		$3,464
2.4.2 Equipment costs		$108,849
2.4.3 Indirect	(29% of 2.4.1 and 2.4.2)	$32,571
Subtotal 2.4		$144,884
2.5 Construction management	(17.1% of 2.4)	$24,775
2.6 Management reserve	(10% of 2.4)	$14,488
2.7 Contingency	(25% of 2.1 through 2.5)	$55,092
Subtotal 2.0		$289,948
3.0 Operations budget-funded activities		
3.1 Conceptual design	(1.5% of 2.0)	$4,349
3.2 Safety assurance	(1% of 2.0)	$2,899
3.3 National Environmental Policy Act (NEPA) permitting	($6 million for environmental impact statement, $1 million for environmental assessment)	$7,000
3.4 Preparation for operations	(100% of 4.0)	$37,664
3.5 Project management	(10% of 3.1 through 3.4)	$5,191
Subtotal 3.0		$57,103
Total Initial Cost	(1.0, 2.0, and 3.0)	$402,999
4.0 Operation and maintenance (O&M) costs		
4.1 Annual operating costs		$9,660
4.2 Annual utility costs		$9,123
4.3 Annual material costs		$2,026
4.4 Annual maintenance costs		$9,322
4.5 Contingency	(25% of 4.1 through 4.4)	$7,533
4.6 Subtotal 4.0		$37,664
4.7 Total 20-year O&M cost	(20 times Subtotal 4.0)	$753,280
5.0 Decontamination and decommissioning		$18,622
6.0 ROM life-cycle costs	(20 years operation)	$1,174,901

4.2.2 Facility Capital Costs

The third cost component, production facility construction costs (also referred to as facility capital cost or "line-item" cost), consists of five key subcomponents:

4.2.2.1 Design. The design subcomponent includes Title 1, or preliminary design, and Title 2, or detailed design. Design is estimated at 25% of facility construction cost for an alpha facility.

4.2.2.2 Inspection. The inspection subcomponent includes Title 3, or engineering support, during construction. Inspection is estimated at 7% of the facility construction cost.

4.2.2.3 Project Management. The project management subcomponents include project management costs incurred by both DOE and the site management and operations contractor. Project management is estimated at 10% of facility construction cost.

4.2.2.4 Construction Cost. Facility construction cost estimates are developed from a preconceptual design package. The preconceptual design packages include a process functional diagram with mass flow rates, a facility layout, and a summary of functional and operational requirements. Construction is divided into the following three parts:

4.2.2.4.1 Building and Structures—Building and structure costs are estimated by multiplying building unit costs by the space required by each unit operation. Assumed unit rates are applied to several categories of buildings: \$180/ft^2 for the administration and central control building, \$225/ft^2 for all other enclosed buildings, and \$45/ft^2 for cast-in-place concrete slabs. Building unit rates include all material and labor needed for constructing the building shell, including utilities, lighting, HVAC, and site development costs. Site development costs include all excavation and backfill activities and assume that all utilities (power, sanitary and storm sewers, site communication and alarms) and access roads are available within 100 ft from the outer walls of the treatment facility. Special steel supports, foundations, and ventilation ducts and hoods required by the process components are not included in the standard building unit rates. These rates include costs for imposing stringent DOE health and safety standards on facility construction.

4.2.2.4.2 Equipment—Cost estimates for major equipment were obtained by soliciting budgetary costs from suppliers or by making engineering judgments. Cost for equipment installation is estimated to be an additional 20% of the equipment capital cost. Allowances for electrical, instrumentation, and mechanical bulks are estimated as a percentage of the total equipment purchase and installation costs. Details are documented in Appendix A.

4.2.2.4.3 Indirect Costs—Indirect costs include subcontractor overhead and fee. This is estimated at 29% of the total of building, structure, and equipment costs.

4.2.2.5 Construction Management. The construction management subcomponent is estimated at 17% of construction costs, which is the sum of the equipment, building, and indirect costs. Construction management includes material and services procurement and control activities, which are usually handled by the site construction management contractor.

Allowance for project scope change or management reserve is estimated at 10% of construction costs.

Because the costs are a planning-level estimate, a 25% contingency is included. The contingency is applied to the total of all components in the production facility construction cost.

4.2.3 Preconstruction and Preoperational Activities

The fourth cost component (operations budget-funded activities) includes conceptual design, safety assurance, National Environmental Policy Act (NEPA) compliance efforts and permitting, preparation for operation, and project management costs. Conceptual design is estimated to be 1.5% of the total production facility construction cost; the cost for safety assurance (safety analysis reports) is estimated at 1% of the total production facility construction cost. The costs for an environmental impact statement for NEPA compliance and for the Resource Conservation and Recovery Act, Toxic Substances Control Act, Clean Air Act, and state, local, and other permits are estimated at $6 million. The cost for an environmental assessment is estimated at $1 million. All other subcomponents of the cost of the operations budget-funded activities, including preoperation readiness reviews, facility startup, operator hiring, and training costs, are assumed to be equal to 1 year of total facility operating costs.

4.2.4 Operating Cost

The fifth cost component (operation and maintenance [O&M]) consists of five subcomponents: operating labor, utilities, consumable materials, maintenance parts and equipment, and maintenance labor costs. The first three subcomponents are estimated by analyzing the requirements of the facility (see Tables 1 and 5 for personnel requirements for administration and operations, respectively). The remaining two subcomponents are estimated as a percentage of the original equipment installed at the facility. Accordingly, the costs for annual maintenance spare parts and replacement equipment are estimated to be 7% of the original equipment purchase cost. Maintenance labor is estimated to cost 250% of the cost of spare parts and replacement on an annual basis.

4.2.5 Decontamination and Decommissioning

The sixth cost component, decontamination and decommissioning (D&D), is estimated by multiplying a D&D unit rate of $450 per square foot of area cleaned by the square footage of the total facility (Schlueter 1992).

Table 5. Estimated facility operation staff.

Unit operation	Total FTE workers
Storage and receiving	10
Plasma reactor	8
Metal/gas cooling and separation	4
HF and H_2 gas separation	2
Uranium metal melting	4
Uranium metal cutting	4
Water cooling system	4
Supply hydrogen	0
Electrical dist. and MCC	4
Radiation monitoring	2
Utilities and mechanical	2
Total	44

5. SYSTEM EVALUATION

The goal of evaluating the system is to qualitatively assess technology risks, including system maturity and development work needed to make the system ready for detailed design. Key issues related to system compliance are identified and discussed.

Below is a listing of issues and uncertainties observed during the preconceptual design.

- Plasma quench technology has only been demonstrated at a small bench scale. Considerably more research and development is required to verify process kinetics and scalability.

- Bench-scale and pilot-plant testing would be required before any final design could be started. Although all of the equipment identified in this feasibility study except for the plasma reactors is used in industry, it has not been used for this purpose nor in this combination.

- The process will contain gaseous hydrogen at high temperature. A leak has the potential to cause an explosion. This risk is comparable to many chemical process industries and must be managed carefully in design.

- Fire prevention and protection must be a critical element of the design, because uranium dust is pyrophoric and there exists a potential for hydrogen gas releases. Therefore, process controls, safety interlocks and detection systems will be necessary components of the process.

- Control and treatment of radon will be necessary for worker, public, and environmental protection.

- HF is extremely toxic and dangerous to handle. Although there are industrial procedures for handling HF, the combination of high-temperature, positive and negative pressures, and ignitable materials make safety designs a crucial part of any process design.

- The UF_6 canisters would be returned to their original storage area. No provisions have been made for their decontaminating, decommissioning, or recycling.

6. CONCLUSION

DOE is currently storing approximately 576,000 metric ton of depleted UF_6. Treatment methods must be developed to convert this UF_6 to a stable form. One method being considered is to use a plasma-based process to reduce the UF_6 to uranium metal. This process has the potential advantage of recycling all of the feed (as uranium metal and anhydrous HF) instead of merely treating and disposing of the waste.

This investigation has demonstrated the feasibility of using the plasma-based process. Successful results of bench-scale experiments suggest that the process is sufficiently well understood to proceed to laboratory and pilotscale.

A conceptual design of a production-scale facility was developed to provide estimates for the life-cycle costs. The use of certain assumptions was necessary to estimate the life-cycle costs. However, all of the equipment to be used has already been proven industrially, albeit not in this application. The total cost of processing 400,000 t of UF_6 is estimated to be approximately $1.2 billion, or approximately $3.00 per kg of UF_6 processed. This compares favorably with other proposed treatment methods.

REFERENCES

1. Schlueter, R., et. al, Low Level and Transuranic Waste Transportation, Disposal and Facility Decommissioning Cost Sensitivity Analysis, EGG-WTD-10092, May 1992.

Appendix A

Cost Tables

Appendix A

Cost Tables

Table A–1: Equipment Purchase & Installation Budgetary Cost Estimates – Depleted Uranium (Cost Module DUPRS)

				DEPLETED URANIUM					
				MATLS. & EQUIP.			INST. COSTS		
	DESCRIPTION	FAC. CAT.	HP	QTY	Unit Cost $1000's	Amount $1000's	Unit Cost $1000's	Amount $1000's	Total U.O.
1	**Storage and Receiving**	I							
	– Gasification Equipment	E		8	60	480	12	96	576
	– Material Handling Equipment	E		1	95	95	19	19	114
	– Vapor Collection & Distribution System	E		1	277	277	55	55	332
	– Instrumentation	E		1	163	163	33	33	196
	– Allowance for piping/mechanical	E		1	42.6	43	85	85	128
	– Allowance for electrical/controls	E		1	42.6	43	85	85	128
	– Allowance for calibration/testing/start–up	E		1	10.5	11	77.4	77	88
	Total Storage and Receiving					1112		450	1562
2	**Plasma Reactor**	II							
	– Plasma Torch	E		4	1200	4800	240	960	5760
	– Reactor w/ converging/diverging nozzles & diffus	E		4	3753	15012	751	3004	18016
	– Instrumentation/Controls (Cooling Water)	E		4	140	560	28	112	672
	– Structural Supports	E		4	180	720	36	144	864
	– Safety separation wall	E		5	60	300	12	60	360
	– Gantry Crane	E		4	20	80	4	16	96
	– Instrumentation (Reactor)	E		1	814	814	163	163	977
	– Allowance for piping/mechanical	E		1	2147.2	2147	3007.2	3007	5154
	– Allowance for electrical/controls	E		1	1503	1503	2148	2148	3651
	– Allowance for calibration/testing/start–up	E		1	518.7	519	4807	4807	5326
	Total Plasma Reactor					26455		14421	40876
3	**Metal/Gas Cooling & Separation**	II							
	– Material Handling Equipment	E		1	160	160	32	32	192
	– Hydrogen Flouride Gas Coolers/Separators	E		8	92	736	18	144	880
	– Electrostatic Precipitators	E		4	162	648	32	128	776
	– Gas Compressors including motors	E		2	140	280	28	56	336
	– Instrumentation	E		1	407	407	81	81	488
	– Allowance for piping/mechanical	E		1	182.4	182	252	252	434
	– Allowance for electrical/controls	E		1	127.7	128	180	180	308
	– Allowance for calibration/testing/start–up	E		1	50.8	51	436.5	437	488
	Total Metal/Gas Cooling & Separation					2592		1310	3902
4	**HF and Hydrogen Gas Separation**	II							
	– Gas Compressors including motors	E		2	140	280	28	56	336
	– HF & Hydrogen Gas Separation	E		2	210	420	42	84	504
	– Pre–Cooler	E		4	55	220	11	44	264
	– Liquid Nitrogen Storage	E		4	60	240	12	48	288
	– Pumps	E		4	3	12	1	4	16
	– Hydrogen Fluoride Storage Tank	E		3	48	144	10	30	174
	– Additional piping/mechanical allow. not incl. bel	E		1	35	35	7	7	42
	– Instrumentation	E		1	305	305	61	61	366
	– Allowance for piping/mechanical	E		1	135.1	135	191.1	191	326
	– Allowance for electrical/controls	E		1	94.6	95	136.5	137	232
	– Allowance for calibration/testing/start–up	E		1	37.7	38	331	331	369
	Total HF and Hydrogen Gas Separation					1924		993	2917
5	**Uranium Metal Melting**	II							
	– Plasma torch metal melt. sys. (incl. inst/controls)	E		3	5000	15000	1000	3000	18000
	– Crane	E		1	25	25	5	5	30
	– Allowance for piping/mechanical	E		1	1502.5	1503	2103.5	2104	3607
	– Allowance for electrical/controls	E		1	1051.8	1052	1502.5	1503	2555
	– Allowance for calibration/testing/start–up	E		1	351.6	352	3306	3306	3658

Table A–1: Equipment Purchase & Installation Budgetary Cost Estimates – Depleted Uranium (Cost Module DUPRS)

	DESCRIPTION	FAC. CAT.	DEPLETED URANIUM						
			HP	MATLS. & EQUIP.			INST. COSTS		
				QTY	Unit Cost $1000's	Amount $1000's	Unit Cost $1000's	Amount $1000's	Total U.O.
	Total Uranium Metal Melting					17932		9918	27850
6	**Uranium Metal Cutting & Storage**	II							
	– Mech. & Friction Saws (in Argon Atmosphere)	E		4	45	180	9	36	216
	– Crane	E		1	30	30	6	6	36
	– Ingot Forms (Water Cooled)	E		4	60	240	12	48	288
	Instrumentation	E		1	41	41	8	8	49
	– Allowance for piping/mechanical	E		1	45	45	63	63	108
	– Allowance for electrical/controls	E		1	31.5	32	45	45	77
	– Allowance for calibration/testing/start–up	E		1	11.4	11	103	103	114
	Total Uranium Metal Cutting & Storage					579		309	888
7	**Water Cooling System**	II							
	– Cooling Tower System	E		8	165	1320	33	264	1584
	– Pumps	E		5	7	35	1	5	40
	– Filters	E		5	12	60	2	10	70
	– Emergency Gravity Cooling System	E		1	750	750	150	150	900
	– Make–up water treatment plant	E		1	2600	2600	520	520	3120
	– Instrumentation	E		1	305	305	61	61	366
	– Allowance for piping/mechanical	E		1	476.5	477	664.3	664	1141
	– Allowance for electrical/controls	E		1	333.6	334	474.5	475	809
	– Allowance for calibration/testing/start–up	E		1	117.6	118	1074.5	1075	1193
	Total Water Cooling System					5999		3224	9223
8	**Supply Hydrogen**								
	– Hydrogen supplied by lessee								
	Total Supply Hydrogen								
9	**Electrical Distribution & MCC**	III							
	– Main Subitation – AC Source	E		1	250	250	50	50	300
	– Main Substation – DC Source	E		1	159	159	318	318	477
	– Cooling Water Pumps & Towers	E		1	444	444	888	888	1332
	– Liquid Hydrogen Plant	E		1	123	123	246	246	369
	– Filters, Turbo Compressors and Gas Area	E		1	129	129	258	258	387
	– Casting & Maintenance Buildings Electrical	E		1	75	75	15	15	90
	– Rectifier Building Electrical	E		1	48	48	96	96	144
	– Liquid Hydrogen Plant Electrical	E		1	45	45	9	9	54
	– Filters, Turbo Compressors and Gas Area	E		1	45	45	9	9	54
	– Cooling Water Pumps and Towers	E		1	49	49	98	98	147
	– Grounding Resistors (15 kV & 5 kV)	E		8	8.5	68	17	136	204
	– 25 MVA Transformers (138Kv – 13.8 kV)	E		4	425	1700	85	340	2040
	– 20 MVA Transformers (13.8Kv – 4.16 kV)	E		2	300	600	60	120	720
	– 5 MVA Transformer (13.8 Kv – 4.16 kV)	E		1	34	34	68	68	102
	– 2.5 MVA Transformer (13.8 kV – 4.16 V)	E		1	23	23	46	46	69
	– 2.5 MVA Transformer (13.8 kV – 480 V)	E		1	21	21	42	42	63
	– 1 MVA Transformers (4.16 kV – 480 kV)	E		1	56	56	112	112	168
	– 250 VA, 480 V AC – 50 kV DC Bridges	E		1	100	100	20	20	120
	– 5 – 10 MW, 13.8 kV Ac – 800 V DC Bridges	E		1	3000	3000	600	600	3600
	– 138 kV, 3–Pole, Power Circuit Breaker Isolators	E		1	72	72	144	144	216
	– 138 kV, Power Circuit Breakers	E		1	198	198	396	396	594
	– 138 kV, 3–Pole, Transformer Circuit Switchers	E		1	160	160	32	32	192
	– Allowance for piping/mechanical	E		1	74	74	1212.9	1213	1287
	– Allowance for electrical/controls	E		1	370	370	2425.8	2426	2796
	– Allowance for calibration/testing/start–up	E		1	156.9	157	3841	3841	3998

Table A-1: Equipment Purchase & Installation Budgetary Cost Estimates – Depleted Uranium (Cost Module DUPRS)

			DEPLETED URANIUM						
				MATLS. & EQUIP.			INST. COSTS		
	DESCRIPTION	FAC. CAT.	HP	QTY	Unit Cost $1000's	Amount $1000's	Unit Cost $1000's	Amount $1000's	Total U.O.
	Total Electrical Distribution & MCC					8000		11523	19523
10	**Radiation Monitoring**	III							
	– Area Monitors	E		5	5	25	1	5	30
	– Air Monitors	E		35	6	210	1	35	245
	– Allowance for piping/mechanical	E		1	2.4	2	12	12	14
	– Allowance for electrical/controls	E		1	11.8	12	24	24	36
	– Allowance for calibration/testing/start–up	E		1	4.5	5	35.5	36	41
	Total Radiation Monitoring					254		112	366
11	**Utilities and Mechanical**	II							
	– Instrument Air			1	70	70			70
	– Service Air System	E		1	50	50			50
	– Sump Pump	E		1	15	15			15
	– Allowance for piping/mechanical	E		1	0.7	1			1
	– Allowance for electrical/controls	E		1	3.3	3			3
	– Allowance for calibration/testing/start–up	E		1	2.8	3			3
	Total Utilities and Mechanical					142			142
12	**Administration and Central Control**								
	– Included in Building Costs								
	Total Administration and Central Control								
13	**HVAC**								
	– Included in Building Costs								
	Total HVAC								
14	**Civil Construction Work**								
	– Roads, Stormwater	E		1	1600	1600			1600
	– Sanitary Sewer, Yard								
	– Piping, Fencing'								
	Total Civil Construction Work					1600			1600
15	**Maintenance**								
	– Included in Building Costs								
	Total Maintenance								

Table A–2: Building and Equipment Material & Installation Cost Estimate Summary – Depleted Uranium (Cost Module DUPRS)

		DEPLETED URANIUM								
		Building Area					Material & Equipment Costs			Total
	UNIT OPERATION	Cost Category 1 sq.ft	Cost Category 2 sq.ft	Cost Category 3 sq.ft	Cost Category 4 sq.ft	Total Area Cost $1000	Purchase Cost $1000	Installation Cost $1000	Total Cost $1000	Cost per Unit Oprtn. $1000
1	Storage and Receiving			7,000		915	1112	450	1562	2477
2	Plasma Reactor			2,800		575	26455	14421	40876	41451
3	Metal/Gas Cooling & Separation	2,130				96	2592	1310	3902	3998
4	HF and Hydrogen Gas Separation	5,110				230	1924	993	2917	3147
5	Uranium Metal Melting			2,400		100	17932	9918	27850	27950
6	Uranium Metal Cutting & Storage			1,200		50	579	309	888	938
7	Water Cooling System	14,440				650	5999	3224	9223	9873
8	Supply Hydrogen									
9	Electrical Distribution & MCC						8000	11523	19523	19523
10	Radiation Monitoring						254	112	366	366
11	Utilities and Mechanical					90	142		142	232
12	Administration and Central Control		3,900			470				470
13	HVAC									
14	Civil Construction Work						1600		1600	1600
15	Maintenance			2,400		288				288
	Total Cost					3,464			108,849	112,313
			Post Totals To Table 4, Item			2.4.1			2.4.2	

01:47 PM

Table A–3: Annual Operating & Maintenance Costs – Depleted Uranium (Cost Module DUPRS)

		DEPLETED URANIUM					
	UNIT OPERATION	Operating FTE	Utilities $1000	Materials $1000	Maintenance Labor (1) $1000	Maintenance Materials (2) $1000	Totals $1000
1	Storage and Receiving	10	44		110	44	154
2	Plasma Reactor	8	6344	727	2,645	1,058	3,703
3	Metal/Gas Cooling & Separation	4	67		260	104	364
4	HF and Hydrogen Gas Separation	2	67	1,008	193	77	270
5	Uranium Metal Melting	4	269		1,793	717	2,510
6	Uranium Metal Cutting & Storage	4	44		58	23	81
7	Water Cooling System	4	44		600	240	840
8	Argon Gas		1710				
9	Supply Hydrogen		359	116			
10	Electrical Distribution & MCC	4	44		800	320	1,120
11	Radiation Monitoring	2	44		25	10	35
12	Utilities and Mechanical	2	44		15	6	21
13	Administration and Central Control	25	44	175			
14	HVAC						
15	Civil Construction Work				160	64	224
16	Maintenance						
	Unit cost ($/unit)	$140,000					
	Total Cost	9,660	9123	2,026			9,322
	Post Totals To Table 4, Item	4.1	4.2	4.3			4.4

Notes: 01:48 PM

1. Annual Maintenance Labor is 250 % of maintainence material cost.
2. Maintenance Material is assumed to be 7 % of equipment capital cost.
3. Recycle of Ar based on membrane technology. Cost data supplied by Prax Air For 1 X 10^6 SCFH gas mixture comprised of 1/3 H_2 and 2/3 Ar, the capital cost would be $10–12 million. Operating power requirements would be 6000 kW. For a 10 year lifetime, 15 % interest, and $0.06/kWh, this yields approximately $1.00/1,000 SCF Ar produced.

Table A–4: Decontamination & Decommissioning Costs – Depleted Uranium (Cost Module DUPRS)

	UNIT OPERATION	DEPLETED URANIUM				
		Building Area				Total Area Cost
		Cost Category 1	Cost Category 2	Cost Category 3	Cost Category 4	
		sq.ft	sq.ft	sq.ft	sq.ft	$1000
1	Storage and Receiving			7,000		3,150
2	Plasma Reactor			2,800		1,260
3	Metal/Gas Cooling & Separation	2,130				959
4	HF and Hydrogen Gas Separation	5,110				2,300
5	Uranium Metal Melting			2,400		1,080
6	Uranium Metal Cutting & Storage			1,200		540
7	Water Cooling System	14,440				6,498
8	Supply Hydrogen					
9	Electrical Distribution & MCC					
10	Radiation Monitoring					
11	Utilities and Mechanical					
12	Administration and Central Control		3,900			1,755
13	HVAC					
14	Civil Construction Work					
15	Maintenance			2,400		1,080
	Total Cost	▨	▨	▨	▨	18,622
	01:47 PM	Post Totals To Table 4, Item				5.0

Table A–5: Factor Sheet for –
Depleted Uranium (Cost Module DUPRS)

FACTOR FOR COSTS

	LLW
A	3
B	2
C	2.5
D	1.2
E	1
	1

BUILDING UNIT RATE COSTS / ENGG AND O & M LABOR COSTS / DECOMMISSIONING UNIT RATE COSTS

COST CATEGORY 1	$45	Bldg. Cost for Concrete Slab
COST CATEGORY 2	$180	Bldg. Cost for Administration
COST CATEGORY 3	$225	Bldg. Cost for all other Process Bldgs.
COST CATEGORY 4		Not Used
DECONRATE	$450	Area Cost for Decontamination
TRMRATE	$150,000	Unit Cost for Research Manpower
MTDRATE	$150,000	Unit Cost for Mock–up Test Demo
FTERATE	$140,000	Unit Cost for Operating FTE

COST FACTORS USED IN SUMMARY TABLE

Item	%	
1.4	10	
1.5	25	
2.2	30	
2.3	7	
2.4	10	
2.5.3	29	
2.6	17.1	
2.7	10	
2.8	25	
3.1A	25	
3.1L	18	
3.2	7	
3.3	10	
3.4.3	29	
3.5	17.1	
3.6	10	
3.7	25	
4.1	1.5	
4.2	1	
4.4	100	
4.5	10	
5.5	25	
5.7	20	years
6.5	25	
6.7	20	years

ALLOWANCES FOR EQUIPMENT TABLE

Category	Mix	Mechanical		Mech./Piping		Elect./Const.		Calib. Testing	
		Mat'l. & Equip.	Inst. Costs	Mat'l. & Equip.	Inst. Costs	Mat'l. & Equip.	Inst. Costs	Mat'l. & Equip.	Inst. Costs
I	MH Handling cranes, shredders	5	50	5	50	5	50	2	30
II	Pumps, Tanks, process equipment	10	70	10	70	7	50	2	50
III	Elect. Cont., CCTV, Instruments Monitoring	1	30	1	30	5	60	2	50