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~~SECRET~~
~~(CLASSIFICATION)~~ GE-AEC BUSINESS RECORD

GENERAL ELECTRIC [redacted]

HANFORD ATOMIC PRODUCTS OPERATION – RICHLAND, WASHINGTON

DOCUMENT NO.

HW-78803 R [redacted]

SERIES AND COPY NO.

DATE

August 30, 1963

~~X RESTRICTED DATA~~

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TITLE

OBSERVATIONS ON NUCLEAR FUEL BUSINESS

AUTHOR

R. L. DICKEMAN

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| ~~Jed Baker~~ | ~~[illegible]~~ | ~~[illegible]~~ | | [illegible] |

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GE-AEC BUSINESS RECORD

54-3000-052 (7-59) A.E.C.-G.E.-RICHLAND, WASH.

(CLASSIFICATION)

N-REACTOR DEPARTMENT
GENERAL ELECTRIC
RICHLAND, WASHINGTON

DECLASSIFIED

PROGRESS IS OUR MOST IMPORTANT PRODUCT... ON VALUE

DEL

August 30, 1963

W. E. Johnson, General Manager
Hanford Atomic Products Operation

OBSERVATIONS ON NUCLEAR FUEL BUSINESS

Attached to this letter is a summary of some of the broad features of the nuclear fuel business as we see them. From this information and general knowledge of the business the following observations are drawn:

1. Sale of nuclear fuel can generate profit of substantial proportions for General Electric. The volume of such business can in time be comparable with the sale of new nuclear plants. For example, we believe that by 1973 sales of nuclear fuel for commercial power reactors may be of the order of 200 million dollars annually, when all components of fuel cost are included. This is a business in which General Electric should be a major factor.

2. Competition for replacement fuel loads in reactors sold by General Electric will be on the dual bases of cost and improved performance of the replacement load. General Electric, with its strong technical force and detailed knowledge of the initial reactor design, should be able to capture the replacement market for its own reactors <u>if it sells improved performance</u> rather than just trying to compete in price on a duplicate core in every case.

3. General Electric should take the objective of integrating its fuel business to any depth required. However, integrating too deeply too soon can lead to prolonged unprofitable operation. Proper timing of the various moves in the integration process is hence important.

4. The dominant factor in all major sectors of the nuclear fuel business is the policy and operations of the government. In all areas of the business (excepting only the step of enrichment itself) there are near-term opportunities to achieve economical production of commercial power reactor fuel by simultaneously carrying out manufacturing or other operations for the government. An outstanding example of this fact is the area of fabrication of fuel for naval reactors. Another, lying somewhat in the future, is fabrication of fuel for advanced Phase II or Phase III operation of N-reactor. Having made the decision to be a major factor in the nuclear fuel business, General Electric should compete vigorously for government fuel

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fabrication business.

5. The incentives to establish an integrated nuclear fuel business are of several types:

   a) Protection of supply lines against control by competitors. Integration down through the refining and milling - concentration steps may be required here. A single commercial refinery, owned by Allied Chemical Company, exists and has enough capacity to process all the fuel needed by the commercial power industry for many years. In the hands of a competitor this refinery could put General Electric at a distinct disadvantage. Similarly, mills which have advantageous contracts with low cost mines could, if controlled by competitors, put General Electric at a serious disadvantage.

   b) Protection of quality of materials at critical points. The conversion of $UF_6$ to $UO_2$ may be such a point. Fluorine content, particle size distribution, particle reactivity and $UO_2$ heat treatment history have all been found, in one case or another, to be crucial and essentially uncontrollable in the product of an uncontrolled vendor.

   c) Protection of proprietary position in technical processes, techniques, etc. Characteristically, General Electric takes the technical lead in product development and improvement. Protection of this lead is difficult if critical improvements must be turned over to suppliers for their use in supplying our materials.

6. Entry of General Electric into the chemical separations field seems inevitable. Only the question of timing is open. The incentives for this type of integration include:

   a) Valuable by-products, such as neptunium 237, and fission products, appear unavoidably during chemical separation.

   b) General Electric technical know-how in this area is unexcelled. General Electric should be able to do a better job than any other company.

   c) Control of the manner of re-cycling recovered fuel, and of the manner of its re-enrichment, can lead to significant economies in the fuel cycle itself as well as enhanced production of valuable trans-uranium by-products.

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7. Hanford is in many ways a natural site for a General Electric reprocessing plant. Waste disposal facilities already exist, ample isolation exists, a trained work force is available, good transportation by rail and water is available, and the site is near enough to the high power cost densely populated areas of the west coast.

8. The mining industry is highly fragmented, and many of the productive mines are controlled by mills. Control of a suitable number of mills by General Electric would suffice to protect sources of raw ores also.

9. The installed government capacity for enriching uranium far exceeds any plausible demand of the commercial nuclear fuel business for many years to come. Control of this capacity by a competitor would, however, be undesirable, and a government-run toll-enrichment business seems the most practical arrangement.

10. The fission products available from commercial power plants would have a recovery cost of the order of a few per cent of the fuel cycle itself. Assuming that their sale price, if a sufficiently large market could be found, would somewhat exceed cost of production, they represent a minor factor in the economics of the nuclear fuel cycle.

R L Dickeman

General Manager
N-Reactor Department

RL Dickeman:MCL:mk

cc: DL Condotta/EG Pierick
MC Leverett
LM Loeb
J Milne
RL Dickeman - 2

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Copy [redacted] 1 - FE Crever
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3 - PH Reinker
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5)
6)- Extras
7)

# OBSERVATIONS ON NUCLEAR FUEL BUSINESS

R. L. Dickeman

August 30, 1963

RESTRICTED DATA

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This document consists of 17 pages. Copy [redacted] of [redacted] copies. Series [redacted]

GROUP 1
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1. INTRODUCTION

This report summarizes information relative to the nuclear fuel cycle in order to give a general appreciation of the major aspects of the business. The data contained are in many cases approximations which are adequate for the present purpose but should not be used for making decisions in specific cases without further study.

The information is drawn from many sources, including some obtained from APED. Principal emphasis is on the areas of potential government-commercial interaction.

Figure 1 shows the general flow of materials in the nuclear fuel cycle.

2. MATERIALS FLOW AND COSTS IN NUCLEAR FUEL CYCLE

Figure 2 gives the quantitative relationships of materials flows. The basis is one pound of uranium as finished fuel charged into the reactor. The fuel is assumed to be $UO_2$ powder compacted by a high energy input process. The exposure of the fuel in the reactor is 15,000 MWD/T average, and each pound of uranium yields 54,000 KWH electric. (30% thermal efficiency assumed.) Fuel enrichment is 1.95% $U^{235}$ at start, and 0.71% $U^{235}$ at discharge. The $Np^{237}$ production shown assumes no recycling of $U^{236}$. Such recycling of $U^{236}$ would give greater production of $Np^{237}$.

Figure 3 is the corresponding cost flow chart. The chart is based on a hypothetical privately-owned complex of mines, mills, refineries, fuel fabricating plants, reactors, and separation plants with fuel being produced at the rate of 100 tons of U in fuel elements annually. The uranium is assumed to be government-owned, and a charge of 4 3/4% per annum is paid for its use. Enrichment is in government-owned diffusion plants. Other information appears in Table I, "Basic Data." Where private investment was implied, an interest rate of 12% per year was charged. Enrichment costs were assumed the same as in TID 7025 Vol. 4, "Guide to Nuclear Power Cost Evaluation," a standard reference for power plant estimators published by AEC.

The cost data are also summarized in Table II. Because of the approximations made the fuel cycle cost here computed is to be regarded as an approximation also. Figure 4 shows the distribution of costs among the major sources of cost in the fuel cycle.

3. ESTIMATED FUEL REQUIREMENTS

Tables III and IV show the estimated requirements for nuclear fuels over the next ten years. It is of special interest that naval fuel requirements strongly outweigh in dollar value commercial fuel requirements over most of the next decade.

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Figure 1

URANIUM FUEL CYCLE

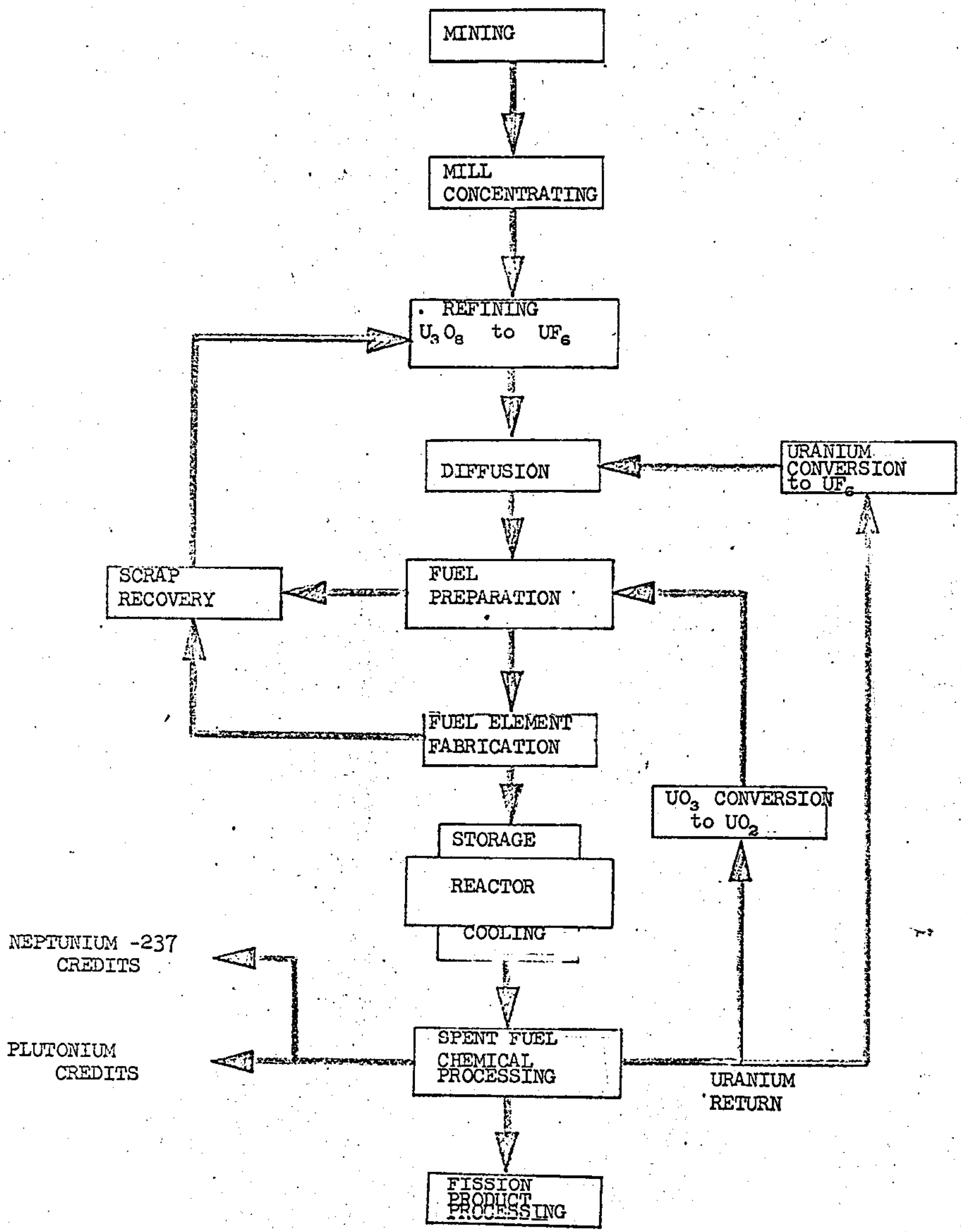




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FIGURE 2

MATERIAL FLOW BASED ON
1 lb. of U THROUGH THE REACTOR

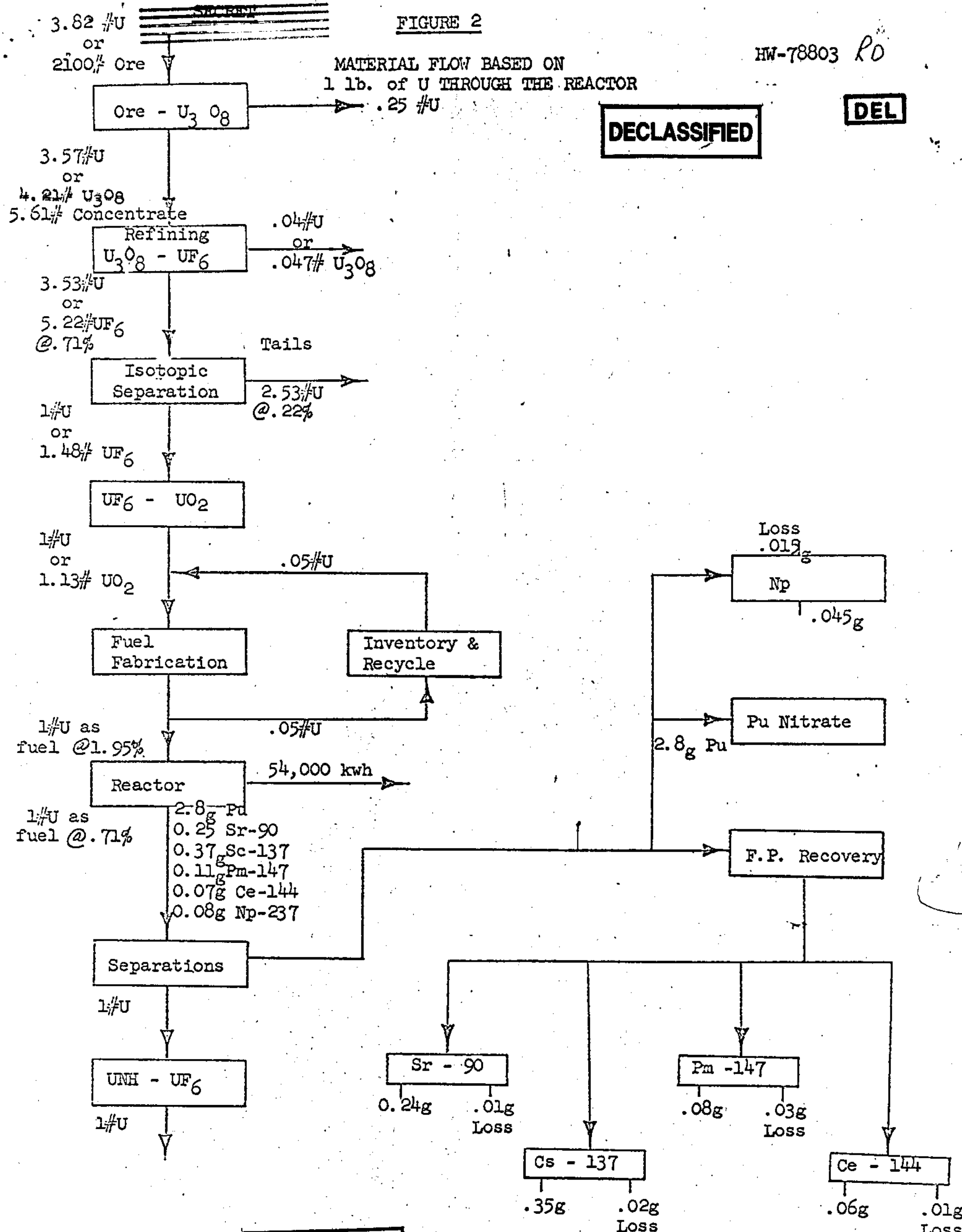


FIGURE 3





COST FLOW
BASED ON 1 LB OF U THROUGH THE REACTOR

Charges Thru
UNH-$UF_6$
Conversion

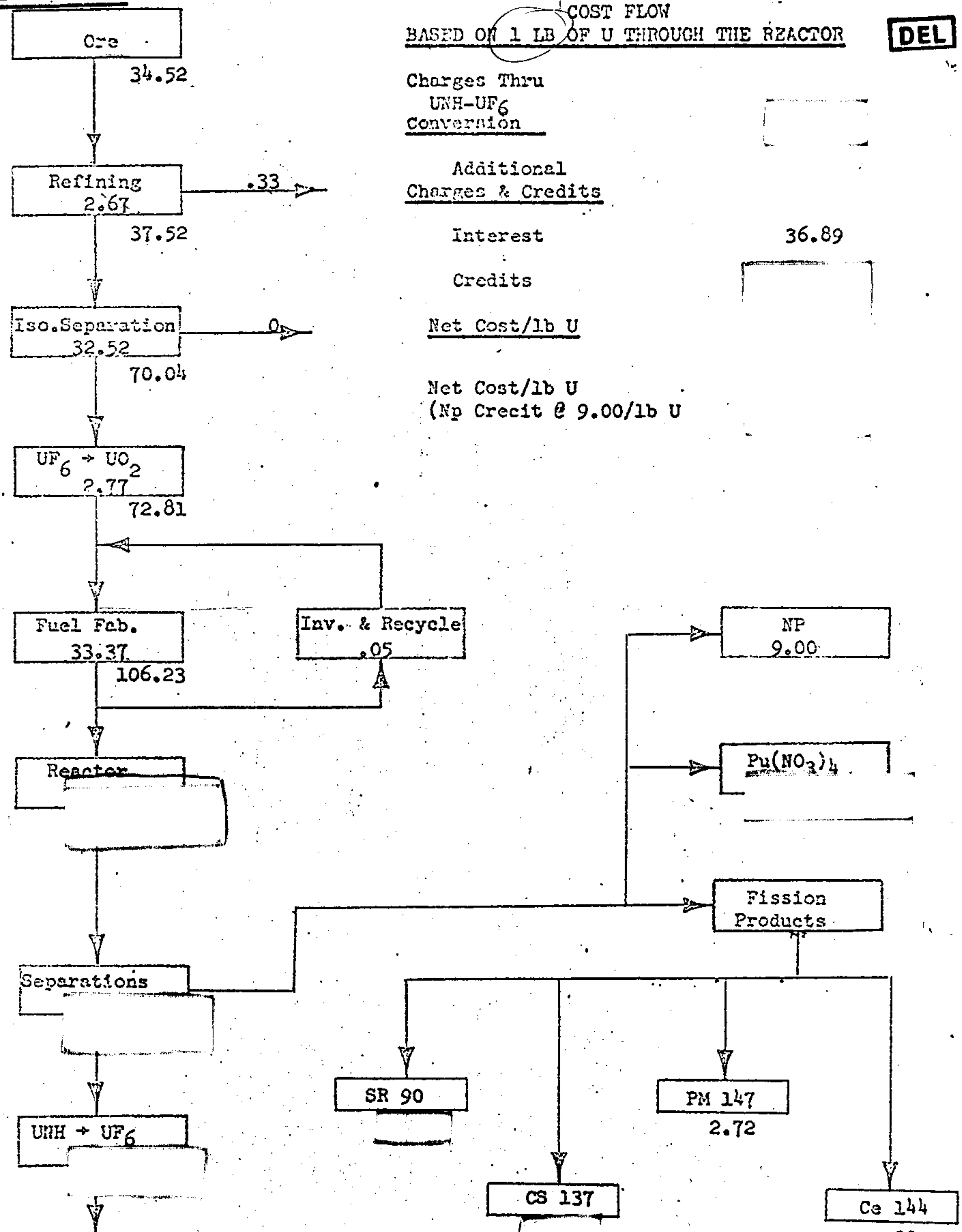
Additional
Charges & Credits

Interest 36.89

Credits

Net Cost/lb U

Net Cost/lb U
(Np Credit @ 9.00/lb U



# TABLE I

## BASIC DATA

Production rate: 100 tons/year

Fuel element design:

19 rod cluster, 10 foot effective length, rods .45" O.D.,

.025" Zirc cladding, 90% theoretical density

$UO_2$ - .533 lb/ft of rod, 5.33 lb/rod, 101.3 lb/element

Cladding - .0944 lb/ft., .944 lb/rod, .177 lb/lb. $UO_2$

Fittings - .75 lb. each, 1.5 lb/fuel element, .0148 lb/lb $UO_2$

Spacers, etc. - 1 lb/element, .01 lb/lb $UO_2$

Material Costs:

Cladding: $34/lb for tubing, 70% yield after acceptance

$$\text{Cost } (\$/\text{lb } UO_2) = \frac{\$34}{.70} \times .177 = \$8.60/\text{lb } UO_2$$

Fittings: Fabricated from Zirc sheet at $12/lb., 90% material yield

$$\text{Cost } (\$/\text{lb } UO_2) = \frac{\$12}{.90} \times .0148 = \$.197/\text{lb } UO_2$$

Spacers, etc: Fabricated from stock at $15/lb, 80% material yield

$$\text{Cost } (\$/\text{lb } UO_2) = \frac{\$15}{8} \times .01 = \$.19/\text{lb } UO_2$$

Other material costs at 4% of total Zirc. costs - $.36/lb $UO_2$

Total Material Cost = $8.60 + .20 + .19 + .36 = $9.35/lb $UO_2$

Direct Labor: 38 men at $6500/year = $247,000/year

Throughput: 200,000 lb/year

$$\text{Direct Labor } (\$/\text{lb } UO_2) = \frac{\$247,000}{200,000} = \$1.24/\text{lb } UO_2$$

| | |
|---|---|
| IME at 100% | $1.24/lb $UO_2$ |
| Depreciation & Mat'l, Overhead | 1.76 |
| Mfg. Overhead | $3.00 |

Other Overhead Costs:

| | |
|---|---|
| Engineering | \$1,000,000/year |
| Marketing | 250,000/year |
| Finance and Rel. | 30,000/year |
| Taxes and Insurance | 190,000/year |
| Total | \$1,470,000 per year or \$7.35/lb $UO_2$ |

TABLE II

SUMMARY OF FUEL CYCLE CHARGES AND CREDITS

| | | |
|---|---|---|
| Conversion Costs: | | |
| $U_3O_8$ Concentrate - 4.21 at 8.20/lb (1) | 34.52 | |
| Conversion to $UF_6$ - 3.53 at .75/lb (2) | 2.67 | |
| Enrichment | 32.52 | |
| Process Loss | .33 | |
| Sub Total: | 70.04 | |
| Conversion $UF_6$ to $UO_2$ | 2.77 (3) | |
| Total Conversion: | | 72.81 |
| Recycle: .05 lb/uranium $1/# | | .05 |
| Fuel Fabrication: | | 33.37 |
| Direct labor | 2.83 | |
| Mfg. Overhead | 5.37 | |
| Material | 10.57 | |
| Tooling | .80 | |
| Complaints | 2.50 | |
| Engineering | 11.30 | |
| Shipment - irradiated fuel | | |
| Separations | | |
| UNH to $UF_6$ | | |
| Total: | | |
| Interest Charge: | | 36.89 |
| 5 years at 4-3/4% on 70.04 | 16.63 | |
| 4-1/2 years at 12% on 36.19 | 19.54 | |
| | .72 | |
| Total Gross Cost: | | |

Credits:

| | |
|---|---|
| $UF_6$ at (.71) | 10.63 |
| Pu $(NO_3)_4$ | |
| Total Credits | |
| Net Costs/(lb U) | |
| (Exposure - 15,000 MWD/T or 7.5 MWD/lb at 30% efficiency - 54,000 Kwhr/lb U) | |
| Net fuel cost - mills/Kwhr: | (1.84)(4) |
| Neptunium Credits included: | (5) (1.61)(4) |

Notes:

(1) Average AEC price for domestic CY-1962

(2) Determined by difference

(3) Verbal quote from Spencer Chemical

(4) Based, on Standard cost of $UF_6$ for Government Operating Plants and 6% interest charges.

(5) Neptunium credit of $9, at $200/gm Np.

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Figure 4

BREAKDOWN OF FUEL COST

AEC OWNED FUEL

TOTAL FUEL COST:

1. $U_3O_8$ Concentrates
2. Enrichment
3. Conversion to $UF_6$ & Losses
4. Conversion of $UF_6$ to $UO_2$ & Losses
5. Fuel Fabrication
6. Separations to $UF_6$
7. Interest Charges

Totals

TABLE III

TONS OF URANIUM AS

FUEL ELEMENTS PER YEAR

| Weapons Program | 1963 | 1968 | 1973 |
|---|---|---|---|
| Savannah River | | | |
| Hanford | 6,800 | 7,700 | 7,700 |
| Total | | | |
| Commercial (US) Fuels | 134 | 340 | 850 |
| Navy Fuels | | | |
| Total | | | |
| % Weapon (Reactors) | | | |
| % Hanford Reactors | 69 | 70 | 67 |
| % Commercial Reactors | 1.3 | 3.1 | 7.4 |
| % Navy Fuels | | | |

Fuel Fabrication Business

| | Dollars in Millions | | |
|---|---|---|---|
| | 1963 | 1968 | 1973 |
| Commercial | 9 | 23 | 57 |
| Navy (Rough estimate) | | | |
| Total | | | |

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TABLE IV

KG'S $U^{235}$ PER YEAR - INPUT

| Weapon Reactors Program | 1963 | 1968 | 1973 |
|---|---|---|---|
| Savannah River | | | |
| Hanford | 46,100 | 53,800 | 53,800 |
| Total Weapons Reactors | | | |
| Commercial (US) Fuels (2% $U^{235}$) | 2,400 | 6,200 | 15,400 |
| Navy Fuels | | | |
| Total | | | |
| % Weapon (Reactors) | | | |
| % Hanford Reactors | 67 | 67 | 60 |
| % Commercial Reactors | 3.5 | 7.6 | 17 |
| % Navy Reactors | | | |



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4. ADDITIONAL INFORMATION

MINING

The industry has many domestic mines with a wide range of capacities. The total domestic capacity probably substantially exceeds commercial and government requirements at present although there is considerable foreign ore being purchased by AEC. The current rate of buying of $U_3O_8$ by AEC is about 27,000 tons per year of which 15.8 thousand is domestic. The rate of buying by AEC is scheduled to decrease to 18,000 tons per year by 1966 at which time the AEC's purchase contracts with domestic producers expire. The buying program beyond 1966 has not been established. The existing investment in domestic mines is approximately $56 million. In 1962 it was estimated there were 55 million tons of $U_3O_8$ reserves available.

MILLING

There are 23 domestic milling and concentrate firms. The biggest operator is Kermac which accounts for about 15 per cent of the industry. There are 8 others each accounting for 6 to 10 per cent of the industry, and the remaining fourteen have 24 per cent of the market divided among them. In 1961 the value of $U_3O_8$ concentrate shipped to AEC by domestic producers was $285 million. The industry invested capital is about $350 million in mining and milling facilities combined.

REFINING

There are two Government refineries, one of which is presently idle. The operating capacity of Government refineries is thought to be about 13,000 tons per year of $U_3O_8$. The Government investment in feed materials facilities is $277 million.

There is one privately owned refinery (Allied Chemical Company) having a capacity of 6,000 tons per year. Investment in this facility is not known.

ISOTOPIC SEPARATION

There are three Government owned plants in which gaseous diffusion processes are used for separation of uranium isotopes. These are located at Paducah, Kentucky, Oak Ridge, Tennessee and Portsmouth, Ohio.

CHEMICAL SEPARATIONS

Government plants for chemical separations operations exist at Idaho Falls, Savannah River and Hanford. Those at Idaho Falls are designed primarily for processing highly enriched fuels, while those at Savannah River and Hanford are designed for processing relatively slightly enriched or natural uranium fuels. The Purex plant at Hanford, which is typical of efficient large scale operations, has a capacity of 7,000 to 8,000 tons of uranium per year and an investment of $80 million. The cost of processing uranium through Purex is about $1500 per ton at 5,000 ton per year throughput rate.

A private processing plant is being built by Nuclear Fuels Services in New York state. The cost of the plant proper is said to be about $28 million and the cost of the plant plus waste disposal facilities is about $32 million. The plant will have a nominal capacity of one ton per day, but its proponents claim that this can be raised to 3 to 4 tons per day. An operating schedule of about 200 days per year is planned. The cost of processing a ton of uranium through this plant is estimated by our Chemical Processing Department to be about $23,000.

FISSION PRODUCTS AND TRANS-URANIUM ISOTOPES

Fission products and trans-uranium isotopes are produced by power reactors on so large a scale that utilization as tracers, in research, in irradiation, etc. would use only a fraction of the production. The only application of size possibly sufficient to use up a significant fraction of the production is that of heat sources, for space devices or other unattended operation. The cost of recovering the fission products amounts to a few per cent of the net fuel cycle cost. If a market for the products could be found and they could be sold somewhat above cost they would make a desirable but not major impact on the economics of the fuel cycle. While a number of trans-uranium isotopes are of interest as heat sources (Pu-238, Cm-242, Cm-244) Pu-238, whose predecessor is Np-237, is the one of most interest. It has a somewhat larger impact on the fuel cycle economics than the fission products.

Extensive studies are underway and proposals have been made at HAPO to separate and package these materials in quantity.

URANIUM PROCESSING PLANTS (MILL CONCENTRATES)

Contracts for these to extend through December 31, 1966 (except for two plants with contract expiration dates of February 28, 1965, and December 31, 1963, respectively, having a combined output of 1,557 tons by their expiration date).

TITLE: URANIUM PROCESSING PLANTS WITH MORE THAN A 2000 TON DELIVERY SCHEDULE

| Company | $U_3O_8$ T/Deliverable 4/1/62 - 12/31/66 | % of Market |
|---|---|---|
| Anaconda Co. | 5,354 | 7.1 |
| Atlas Corp. | 7,625 | 10.1 |
| Homestake-Sapin Partners | 7,495 | 9.9 |
| Kermac Nuclear Fuels Corp. | 11,350 | 15.1 |
| Phillips Petroleum Co. | 6,673 | 8.8 |
| Texas-Zinc Minerals Corp. | 4,204 | 5.8 |
| Union Carbide Nuclear Co. (2 plants) | 5,625 | 7.5 |
| Utah Construction & Mining Co. | 4,562 | 6.0 |
| Western Nuclear, Inc. | 4,525 | 6.0 |
| Remaining 14 Plants | 17,997 (1,286 avg/plant) | 23.7 (1.7% avg/plant) |
| All - Total | 75,410 ton delivered | |

FUEL ELEMENT FABRICATORS (CONTINENTAL U.S. ONLY)

1. Aluminum
2. Beryllium
3. Ceramic
4. Cermet
5. Glass Fiber
6. Graphite
7. Highly Enriched U
8. Niobium
9. Plastic Dispersion
10. Stainless Steel
11. Tantalum
12. Titanium
13. Tungsten
14. Zirconium

| | | | |
|---|---|---|---|
| Aerojet-General Nucleonics | 2-3-4-5-6 | San Ramon | Cal |
| Atomergic Chemetals Co. | 8-11-12-13-14 | Garden City | NY |
| Atomics Internat'l Div. NAA, Inc. | 1-4-6-10-14 | Canoga Park | Cal |
| Babcock & Wilcox Co. | 1-3-4-7-14 | New York | NY |

FUEL ELEMENT FABRICATORS (Cont'd)

| | | | |
|---|---|---|---|
| Belock Instrument Corp. | 2 | College Point | NY |
| Bendix Filter Div. | 5-10 | Madison Heights | Mich |
| Beryllium Corp. | 2 | Reading | Pa |
| Bram Metallurgical-Chemical Co. | 2-8-11-12-13-14 | Philadelphia | Pa |
| Bridgeport Brass Co. Reactive Metals | 12-13-14 | Niles | Ohio |
| Brush Beryllium Co. | 2-3 | Cleveland | Ohio |
| Combustion Engineering, Inc. | 1-3-10-14 | Windsor | Conn. |
| Coors Porcelain Co. | 2 | Golden | Colo. |
| Crucible Steel Co. of America | 10-12 | Pittsburgh | Pa |
| Electron Beam Techniques, Inc. | 1-3-10-11-12-13-14 | Plainville | Conn. |
| Gen. Atomic Div. Gen. Dynamics | 1-2-3-4-6-7-10-14 | San Diego | Cal |
| Gen. Elec. Co. Ind. Sales Oper. | 1-3-7-8-10-11-12 13-14 | Schenectady | NY |
| Graphite Specialties Div. | 6 | Sanborn | NY |
| High Temperature Materials, Inc. | 6-13 | Boston | Mass |
| Martin Co. Nuc. Div. | 1-2-3-4-6-7-10-14 | Baltimore | Md |
| Metals & Controls Div. | 1-3-4-6-7-8-10-14 | Attleboro | Mass |
| 3M Co. Nuclear Prods. | 3-6-7 | St. Paul | Minn |
| National Carbon Co. | 6 | New York | NY |
| National Lead Co. | 1-3-4-7-10-14 | New York | NY |
| National Research Corp. Metals Div. | 8-11 | Newton | Mass |
| Nuclear Materials & Equip. Corp. (NUMEC) | 1-2-3-4-5-6-7-8 9-10-11-12-13-14 | Apollo | Pa |
| Nuclear Metals, Inc. | 1-2-4-7-8-10-11-12-13-14 | W. Concord | Mass |
| Ringsdorff Carbon Corp. | 6 | E. McKeesport | Pa |
| Semi-Elements, Inc. | 8 | Saxonburg | Pa |

FUEL ELEMENT FABRICATORS (Cont'd)

| | | | |
|---|---|---|---|
| Speer Carbon Co. | 3-6-7 | St. Mary's | Pa |
| Sylcor-Div Sylvania | 1-3-4-7-8-10-11 12-13-14 | Hicksville | NY |
| United Mineral & Chemical Corp. | 2-3-6-8-12-14 | New York | NY |
| United Nuclear Corp. | 1-6-7-10-14 | Washington | DC |
| Westinghouse Atomic Power Div. | 1-3-4-7-14 | Pittsburgh | Pa |
| Westinghouse Atomic Power Div. | 1-3-4-7-10-14 | Pittsburgh | Pa |

URANIUM METAL, ALLOY AND COMPOUND PRODUCERS

1. Carbide
2. Depleted
3. Dioxide ($UO_2$)*
4. Dispersions
5. Enriched
6. Natural

| | | | |
|---|---|---|---|
| Atomergic Chemetals Co.* | 2-3 | Garden City | NY |
| Atomics Internat'l Div. NAA, Inc. | 1-2 | Canoga Park, | Cal |
| City Chemical Corp. | 2-6 | New York | NY |
| Delta Chemical Works | | New York | NY |
| Gen. Atomic Div. Gen. Dynamics | 1-3-4 | San Diego | Cal |
| Grace & Co.* | 1-2-3-4-5-6 | Washington | DC |
| Kerr-McGee Oil Inds. Inc.* | 1-2-3-5-6 | Oklahoma City | Okla |
| Kulite Tungsten Co. | 2 | Ridgefield | NJ |
| Mackay, Inc.* | 1-2-3-6 | New York | NY |
| 3M Co. Nuclear Prods. | 1 | St. Paul | Minn |
| Monsanto Research Corp. | 2-5 | Dayton | Ohio |
| National Carbon Co. | 1-4 | New York | NY |
| Neutronics Lab | 5 | Tinley Park | Ill |
| Norton Co.* | 3 | Worcester, | Mass |
| Nuclear Materials & Equip. Corp.* (NUMEC) | 1-2-3-4-5-6 | Apollo | Pa |
| Reactor Experiments, Inc. | 2-6 | Belmont | Cal |
| Semi-Elements, Inc. | 1 | Saxonburg | Pa |
| Shattuck Chem. Co.* | 2-3-6 | Denver | Colo |
| United Nuclear Corp.* | 1-2-3-4-5-6 | Washington | DC |
| Var-Lac-Oid Chemical Co. | 1-2-3-6 | New York | NY |
| Vitro Corp. of America | 1 | New York | NY |