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REPORT

FABRICATION COSTS FOR PLUTONIUM FUEL ELEMENTS
PART C:
VARIABLE COSTS OF FABRICATING UO_2 - $Pu_{0.2}$ FUEL RODS
FOR THE SAXTON REACTOR

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PART C: VARIABLE COSTS OF FABRICATING UO_2 - PuO_2 FUEL RODS
FOR THE SAXTON REACTOR

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September, 1965

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FABRICATION COSTS FOR PLUTONIUM FUEL ELEMENTSPART C: VARIABLE COSTS OF FABRICATING $\text{UO}_2\text{-PuO}_2$ FUEL RODS
FOR THE SAXTON REACTORINTRODUCTION

Third in a series on the costs of fabricating plutonium-bearing fuel elements on a laboratory scale, this report covers the variable (shop) cost of fabricating 150 fuel rods for the Saxton Reactor. The first two reports dealt with the fabrication costs of plutonium-enriched fuels for the Plutonium Recycle Critical Facility (PRCF) and the Experimental Boiling Water Reactor (EBWR).

The Saxton fuel rods will be used to make two fuel assemblies for irradiation testing under power reactor conditions. The purpose of the partial core loading of plutonium-enriched fuel elements in the Saxton Reactor, Saxton, Pennsylvania, is to develop information on plutonium utilization in prototypes of commercial reactor power plants, in this case a pressurized water reactor. Containing the highest plutonium enrichment of mixed oxide fuel (excluding test capsules) fabricated to date, the Saxton fuel rods will operate at an estimated surface heat flux of 550,000 Btu/hr-ft² and a central fuel temperature of 2000 °C.

Because the Saxton fuel design was quite similar to the EBWR fuel design, the fabrication proceeded smoothly under process conditions that can be considered well-developed, although only a small number of fuel rods were fabricated. However, some rather stringent specifications were placed on the fuel rods, which required a brief but intensive development and quality control effort in the areas of analyses of fuel purity, weld design and development, and control and specification of the

starting uranium oxide. Nevertheless, after the procedures were developed these specifications did not appreciably affect the fabrication yields and thus did not significantly increase direct fabrication costs.

Each of the first four reports in this series deals with a specific fuel design, and the costs therein are necessarily specific to the fuel design. The costs, therefore, may vary widely and may not be applied, with indescrition, to other plutonium fuel fabrication processes. A summary report, which will follow these initial reports, will condense the data and present the costs in more general terms which may be applicable to analyzing various fuel fabrication schemes. In addition to permitting later analyses, the purpose of the first four reports is to document experience in sufficient detail to identify important cost components, to assess the influence of yield and some processing variables on cost, and to improve internal planning, scheduling, and estimating. In the terms of scientific methodology, the first four reports represent data accumulation, which will be followed by classification and analyses having broader implications and useage.

SUMMARY

The variable (shop) cost (Table I) of fabricating plutonium-enriched fuel rods for the Saxton reactor was \$255/kg of fuel (as oxide), giving a unit cost of \$136 per fuel rod. With a rod length of 1 m, each fuel rod contains 530 g natural UO_2 -6.6 wt% PuO_2 fuel. The Zircaloy clad rods were 1 cm OD with a 0.6 mm wall. The costs were based on the fabrication of 150 rods by a well developed, pneumatic impaction-vibrational compaction process.

The shop labor requirements for each rod were 4.27 man-hours direct labor and 1.41 man-hours indirect labor. The direct

material cost was \$43 per fuel rod. The variable costs included direct materials, some processing costs for nuclear materials, shop labor, maintenance, direct overhead, and consumable supplies but did not include the cost of nuclear materials themselves, use charges, administrative overhead, research, development, or engineering costs.

DISCUSSION

A total of 150 Zircaloy clad UO_2 - PuO_2 fuel rods were fabricated to contain 85 kg of plutonium-bearing ceramic fuel material, including 5.5 kg of PuO_2 . Each rod was 1.0 m long and 1 cm diam, with 0.6 mm Zircaloy cladding. The fuel length was 0.9 m. A plenum was maintained above the fuel by a spring-loaded alumina pellet to hold the fuel in place. Each rod contained 530 g of natural UO_2 -6.6 wt% PuO_2 fuel. The mixed oxide fuel was made by the pneumatic impaction process, and the fuel rod was loaded by the vibrational compaction process.

The process costs were based on the complete fabrication of 150 fuel rods. Since the fuel design was similar to the EBWR fuel design,⁽¹⁾ the fabrication processes may be considered well developed. The variable costs in this report, therefore, represent both the current "state of the art" and the historic cost, with the exception of the inferred costs described below of the entire fabrication excluding development and the fabrication of ten special stainless steel clad fuel rods.

COST ACCUMULATION

Labor costs were obtained with the use of daily job tickets which indicated the time required for work such as housekeeping, record keeping, and accountability. Including wages and all

(1) See BNWL-131 B.

fringe benefits, the average hourly wage rate for direct labor was \$4.85. The indirect laboratory expense, which was 175% of direct labor cost, covered a broad range of miscellaneous costs (general supplies, maintenance, and building expense) incurred by the fabrication group. These rates were in effect in March and April, 1965.

Direct materials, supplies, and services were those costs actually incurred, except that the zirconium and hardware costs were inferred from EBWR cost experience. (The zirconium and hardware were provided at no expense to the fabricator.) The material costs included the zirconium, the stainless steel spring and alumina pellet, arc-fusion of UO_2 , and the purification and oxidation of plutonium. Consumable supplies included the cans, punches, and back-up plugs for the pneumatic-impaction process and some special plastic bags used in loading the cans and the fuel rods.

COST DATA

The cost and labor requirements for each process step are summarized on a single rod basis (Table II) and on a 100 kg basis (Table III). Accounting for over one-fourth of the processing and labor expenditures, the largest single cost was the vibrational compaction step. The vibrational compaction processing costs were divided as follows: supplies consumed, 12%; first end cap welding, 5%; tubing preparation, 4%; vibrational compaction, 41%; decontamination, 25%; and reject and rework expense, 13%.

For each process step, the cost data are presented in Tables IV through XV. The yield, recycle rates, and losses were included, and the unit variable cost of each process step was calculated. In calculating the unit variable cost, the recycle material was valued at the material value of the process step to which it re-enters. The samples, reject material, and material

unaccounted for (muf) have no value in terms of variable processing cost. (In calculations including nuclear material costs, however, which are not considered in this report, the samples and reject material will have a value.) The value and quantity of recycle fuel is deducted from the gross value and quantity of the fuel leaving the process to obtain the value and quantity of acceptable fuel leaving the process. This value was reduced to a unit value, and the unit cost of the process step was obtained by deducting the unit value of the fuel entering the process.

A flow diagram (Figure 1) and a brief description of operations and costs involved in each process step* is given below.

Tubing Preparation (Table IV)

The tubing was ultrasonically inspected, identified, cut-to-length, counterbored, washed, and weighed. The direct material cost was \$21 for tubing. Direct service is the cost of machining the tubing.

UO₂ Preparation (Table V)

Arc-fused natural UO₂ was crushed to -65 mesh and packaged. A small quantity of UO₂ was converted to U₃O₈ to adjust the O:U ratio for the pneumatic impaction step. Direct materials cost is for the arc-fusion of UO₂. Direct service charge is for analytical quality control of the UO₂.

PuO₂ Preparation (Table VI)

Plutonium is purified by vacuum remelting and oxidized (the direct material cost). The PuO₂ weight is verified, and

* For more details and pictures of the process steps, see HW-79291, Specifications for Vibrationally Compacted, Mixed Oxide (UO₂-PuO₂) Fuel Elements for the PRTR (Mark 1-L). General Electric Company, Richland, October 1, 1963.

the PuO_2 is weighed and repackaged in smaller batches for the blending and loading step (the processing cost).

Loading Cans (Table VII)*

Double-Canning (Table VIII)*

Pneumatic Impaction (Table IX)*

Opening (Table X)*

Crushing and Sieving (Table XI)

The fuel is crushed and sieved into the proper size fractions. Samples are taken for plutonium content and oxygen-to-metal ratios. The fuel is vacuum outgassed to remove volatile impurities and weighed into bottles in the proper amounts and size fractions for one fuel rod. Reject fuel consists of hood sweepings or other potentially impure fuel which is returned for chemical recovery. The high yield achieved on the relatively small quantity of fuel used in the Saxton project reflects the higher degrees of care taken in processing the fuel, of which only a small excess was provided. The additional care and smaller lot size required 15% greater labor expenditure than was required to crush and sieve the EBWR fuel. Direct service is the cost of analysis to determine oxygen-to-metal ratios, plutonium contents, and impurity levels.

Vibrational Compaction (Table XII)

Each bottle of fuel was loaded into the cladding by means of vibrational compaction. Previously, one end cap had been

* The pneumatic impaction process steps (Tables VII through X) are common to all ceramic fuel fabrication processes. These steps and costs are described in more detail in BNWL-131 A.

welded into the cladding. After loading, the end of the fuel rod was decontaminated.

Finishing (Table XIII)

The second end cap was welded into place. Both end zones were ultrasonically tested for defects. The fuel rods were etched, autoclaved, tested in a helium-leak detector, straightened, inspected, and packaged for shipping. The direct service charge is for ultrasonic inspection and straightening the fuel rods.

Rework (Table XIV)

The recycled material required a small amount of additional work before it re-entered the process.

Indirect (Table XV)

This category included record keeping, accountability, procurement of supplies, and other indirect work attributed directly to the fabrication job. Not being attributable directly to a particular job, indirect time devoted to general cleanup, meetings, accountability, etc. was also included. These latter indirect costs were prorated on a labor hours basis to each job in process during the period under study.

Material Requirements

The direct material requirements for each process step are shown in Table XVI. The plutonium losses (muf) were 1.2%, and the plutonium to be recovered from samples and reject fuel was 3.1%. The uranium losses (muf) were 1.6%, and the uranium to be recovered from samples and reject fuels was 4.4%. The zirconium losses were 8.6%. The combined recycle-reject rate for the mixed oxide fuel was 9.9% for the powder preparation processes, and the fuel recycle rate was 8.7% for the rod fabrication processes.

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TABLE I
VARIABLE COSTS OF FABRICATING SAXTON FUEL RODS

	<u>Cost Per Rod</u>	<u>Cost Per 100 kg.</u>
Direct Materials		
Zirconium	24.00	4480
Uranium	2.20	411
Plutonium	15.90	2970
Other	.63	118
Direct Labor	27.50	5150
Supplies	4.82	900
Direct Service	10.40	1940
Laboratory Expense	48.10	9010
Reject Expense	2.78	519
	<u>\$136.33</u>	<u>\$25,498</u>

TABLE IIVARIABLE COSTS PER ROD

<u>Process Step</u>	<u>Direct Materials</u>	<u>Processing</u>	
		<u>\$</u>	<u>Man-Hours</u>
Tubing Preparation	21.00	3.70	0.119
UO ₂ Preparation	2.20	1.86	0.130
PuO ₂ Preparation	15.90	5.35	0.150
Loading Pneumatic Impaction Cans		2.31	0.142
Double-Canning		.71	0.019
Pneumatic Impaction		1.59	0.106
Opening		1.07	0.056
Crush and Sieve		9.09	0.479
Vibrational Compaction	1.50	28.00	1.730
Finishing	2.13	19.91	1.191
Rework		1.97	0.148
Indirect		18.75	1.406
Sub Total	42.73	94.30	5.676
		42.73	
Total Cost		\$137.03	

TABLE IIIVARIABLE COSTS PER 100 kg

<u>Process Step</u>	<u>Direct Materials</u>	<u>Processing</u>	
		<u>\$</u>	<u>Man-Hours</u>
Tubing Preparation	3920	649	22.3
UO ₂ Preparation	411	348	24.2
PuO ₂ Preparation	2970	1000	28.0
Loading Pneumatic Impaction Cans		431	26.6
Double-Canning		132	3.6
Pneumatic Impaction		298	19.9
Opening		200	10.5
Crush and Sieve		1699	89.5
Vibrational Compaction	280	5242	324.0
Finishing	398	3722	223.0
Rework		369	27.7
Indirect		3505	263.0
Sub Total	\$7979	\$17595	1062.3
		7979	
Total Cost		\$25574	

TABLE IVTUBING PREPARATION, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$21.00 Per Tube	3920
Consumable Supplies	0	
Direct Labor	0.110 Man-Hours Per Tube	100
Laboratory Expense	175%	175
Direct Services	\$2.00 Per Tube Machining	374
Total Shop Cost		<u>\$4569</u>

OUTPUTS

	<u>Percent</u>	<u>Output Per 108.6 kg In</u>
Yield	100	108.6
Recycle		
Samples		
Reject		
muf		

VALUE ANALYSIS

Value of Direct Material Entering Process	\$3920
Process Variable Cost per 100 kg Fuel	<u>\$ 649</u>
Total Value 100 kg Fuel Leaving Process	
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	
Total Value of 0 kg Fuel Leaving Process	
Value of Recycle: 0 kg at \$0 per kg	
Total Value of 0 kg Acceptable Fuel	
Unit Value of 100 kg Fuel Entering Next Process	\$4569
Value of Direct Material Entering This Process	<u>\$3920</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u><u>\$ 649</u></u>

TABLE VUO₂ PREPARATION, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$2.00 Per Pound UO ₂	411
Consumable Supplies	0	
Direct Labor	0.245 Man-Hours Per kg Out	113
Laboratory Expense	175%	196
Direct Services	Analysis \$.25 Per kg (Est.)	24
Total Shop Cost		\$744

OUTPUTS

	<u>Percent</u>	<u>Output Per 106.0 kg In</u>
Yield	98	103.9
Recycle		
Samples	1/2	0.5
Reject	.1	1.1
muf	1/2	0.5

VALUE ANALYSIS

Value of Direct Material Entering Process	\$411
Process Variable Cost per 100 kg Fuel	\$333
Total Value 100 kg Fuel Leaving Process	\$744
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod 106.0 kg	
Total Value of 106.0 kg Fuel Leaving Process	\$789
Value of Recycle: 0 kg at \$0 per kg	\$ 0
Total Value of 103.9 kg Acceptable Fuel	\$789
Unit Value of 100 kg Fuel Entering Next Process	\$759
Value of Direct Material Entering This Process	\$411
Process Variable Cost per 100 kg Acceptable Fuel	\$348

TABLE VIPuO₂ PREPARATION, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$0.45 Per Gram PuO ₂	\$2970
Consumable Supplies	0	
Direct Labor	4.06 Man-Hours Per kg.	130
Laboratory Expense	175%	228
Direct Services	\$40 Per kg (Est.)	625
Total Shop Cost		\$3953

OUTPUTS

	<u>Percent</u>	<u>Output Per 104.2 kg In</u>
Yield	99.7	103.9
Recycle	0	0
Samples	0.2	0.2
Reject	0	0
muf	0.1	0.1

VALUE ANALYSIS

Value of Direct Material Entering Process	\$2970
Process Variable Cost per 100 kg Fuel	\$ 983
Total Value 100 kg Fuel Leaving Process	\$3953
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	104.2
Total Value of 104.2 kg Fuel Leaving Process	\$4120
Value of Recycle: 0 kg at \$0 per kg	\$ 0
Total Value of 103.9 kg Acceptable Fuel	\$4120
Unit Value of 100 kg Fuel Entering Next Process	\$3970
Value of 100 kg Fuel Entering This Process	\$2970
Process Variable Cost per 100 kg Acceptable Fuel	\$1000

TABLE VIILOADING PNEUMATIC IMPACTION CANS, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material		
Consumable Supplies		
Direct Labor	See BNWL-131 A and BNWL-131 B	
Laboratory Expenses		
Direct Services		
Total Shop Cost		\$424

OUTPUTS

	<u>Percent</u>	<u>Output Per 109.9 kg In</u>
Yield	99.87	109.8
Recycle	0.1	0.1
Samples	0	
Reject	0.025	
muf	0.004	

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$4729
Process Variable Cost per 100 kg Fuel	\$ <u>424</u>
Total Value 100 kg Fuel Leaving Process	\$5153
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	109.9 kg
Total Value of 109.9 kg Fuel Leaving Process	\$5660
Value of Recycle: 0.1 kg at \$47 per kg	\$ <u>5</u>
Total Value of 109.8 kg Acceptable Fuel	\$5655
Unit Value of 100 kg Fuel Entering Next Process	\$5160
Value of 100 kg Fuel Entering This Process	\$ <u>4729</u>
Process Variable Cost per 100 kg Acceptable Fuel	\$ <u><u>431</u></u>

TABLE VIIIDOUBLE CANNING, SAXTON

<u>INPUTS</u>		<u>Cost Per</u> <u>100 kg In</u>
<u>Variable Costs</u>	<u>Primary Units</u>	
Direct Material		
Consumable Supplies	See BNWL-131 A and BNWL-131 B	
Direct Labor		
Laboratory Expense		
Direct Services		
Total Shop Cost		\$132

<u>OUTPUTS</u>	<u>Percent</u>	<u>Output</u> <u>Per kg In</u>
Yield	100	109.8
Recycle		
Samples		
Reject		
muf		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$5160
Process Variable Cost per 100 kg Fuel	\$ 132
Total Value 100 kg Fuel Leaving Process	\$5292
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	
Total Value of 0 kg Fuel Leaving Process	
Value of Recycle: 0 kg at \$0 per kg	
Total Value of 0 kg Acceptable Fuel	
Unit Value of 100 kg Fuel Entering Next Process	\$5292
Value of 100 kg Fuel Entering This Process	\$5160
Process Variable Cost per 100 kg Acceptable Fuel	\$ 132

TABLE IXPNEUMATIC IMPACTION, SAXTON

<u>INPUTS</u>		<u>Cost Per</u> <u>100 kg In</u>
<u>Variable Costs</u>	<u>Primary Units</u>	
Direct Material		
Consumable Supplies	See BNWL-131 A and BNWL-131 B	
Direct Labor		
Laboratory Expense		
Direct Services		
Total Shop Cost		\$269

<u>OUTPUTS</u>	<u>Percent</u>	<u>Output Per</u> <u>109.8 kg In</u>	<u>Destination</u>
Yield	97.39	106.8	
Recycle	2.61	3.0	Load Pneumatic Impaction Cans
Samples	0	0	
Reject	0	0	
muf	0	0	

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$5292
Process Variable Cost per 100 kg Fuel	\$ <u>269</u>
Total Value 100 kg Fuel Leaving Process	\$5561
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	109.8 kg
Total Value of 109.8 kg Fuel Leaving Process	\$6110
Value of Recycle: 3.0 kg at \$47 per kg	\$ <u>141</u>
Total Value of 106.8 kg Acceptable Fuel	\$5969
Unit Value of 100 kg Fuel Entering Next Process	\$5590
Value of 100 kg Fuel Entering This Process	\$ <u>5292</u>
Process Variable Cost per 100 kg Acceptable Fuel	\$ <u>298</u>

TABLE XOPEN PNEUMATIC IMPACTION CANS, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material		
Consumable Supplies	See BNWL-131 A and BNWL-131 B	
Direct Labor		
Laboratory Expense		
Direct Services		
Total Shop Cost		\$181

OUTPUTS

	<u>Percent</u>	<u>Output Per 106.8 kg In</u>
Yield	99.52	106.2
Recycle	0	0
Samples	0.25	0.3
Reject	0.23	0.3
muf	0	0

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$5590
Process Variable Cost per 100 kg Fuel	\$ <u>181</u>
Total Value 100 kg Fuel Leaving Process	\$5771
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	106.8 kg
Total Value of 106.8 kg Fuel Leaving Process	\$6160
Value of Recycle: 0 kg at \$0 per kg	\$ <u>0</u>
Total Value of 106.2 kg Acceptable Fuel	\$6160
Unit Value of 100 kg Fuel Entering Next Process	\$5790
Value of 100 kg Fuel Entering This Process	\$ <u>5590</u>
Process Variable Cost per 100 kg Acceptable Fuel	\$ <u>200</u>

TABLE XI

CRUSH AND SIEVE, SAXTON

<u>INPUTS</u>		<u>Cost Per</u>
<u>Variable Costs</u>	<u>Primary Units</u>	<u>100 kg In</u>
Direct Material	0	
Consumable Supplies	0	
Direct Labor	0.841 Man-Hours per kg	408
Laboratory Expense	175%	715
Direct Services	\$180 per 72 kg	250
Total Shop Costs		<u>\$1373</u>
<u>OUTPUTS</u>	<u>Output Per</u>	<u>Destination</u>
	<u>106.2 kg In</u>	
Yield	100.0	
Recycle	3.0 (-)	Load Pneumatic
Samples	1.0 (-)	Impaction Cans
Reject	1.2 (-)	
muf	1.2 (-)	
<u>VALUE ANALYSIS</u>		
Value of 100 kg Fuel Entering Process		\$5790
Process Variable Cost per 100 kg Fuel		<u>\$1373</u>
Total Value 100 kg Fuel Leaving Process		\$7163
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod 106.		
Total Value of 106.2 kg Fuel Leaving Process		\$7630
Value of Recycle: 3.0 kg at \$47 per kg		<u>\$ 141</u>
Total Value of 100.0 kg Acceptable Fuel		\$7489
Unit Value of 100 kg Fuel Entering Next Process		\$7489
Value of 100 kg Fuel Entering This Process		<u>\$5790</u>
Process Variable Cost per 100 kg Acceptable Fuel		<u>\$1699</u>

TABLE XIIVIBRATIONAL COMPACTION THROUGH DECONTAMINATION, SAXTON

<u>INPUTS</u>		Cost Per
<u>Variable Costs</u>	<u>Primary Units</u>	<u>100 kg In</u>
Direct Material	\$1.50 Per Rod	280
Consumable Supplies	\$3.25 Per Rod	608
Direct Labor	1.592 Man-Hours Per Rod	1442
Laboratory Expense	175%	2523
Direct Services		
Total Shop Cost		<u>\$4853</u>

<u>OUTPUTS</u>	<u>Percent</u>	<u>Output Per</u> <u>108.7 kg In</u>	<u>Destination</u>
Yield	93.75	101.9	Vibrational Compaction
Recycle	6.25	6.8	
Samples	0		
Reject	0		
muf	0		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process (Fuel, \$7489; Zr, \$4569)	\$12058
Process Variable Cost per 100 kg Fuel	<u>\$ 4853</u>
Total Value 100 kg Fuel Leaving Process	\$16911
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	108.7 kg
Total Value of 108.7 kg Fuel Leaving Process	\$18400
Value of Recycle: 6.8 kg at \$75 per kg	\$ 510
Total Value of 101.9 kg Acceptable Fuel	<u>\$17890</u>
Unit Value of 100 kg Fuel Entering Next Process	\$17580
Value of 100 kg Fuel Entering This Process	<u>\$12058</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$ 5522</u>

TABLE XIIIFINISHING - STARTING WITH SECOND END CAP, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$2.13 Per Rod	\$ 398
Consumable Supplies	0	
Direct Labor	1.170 Man-Hours Per Rod	\$1060
Laboratory Expense	175%	\$1855
Direct Services	Test and Straighten Fuel Rods	\$ 529
Total Shop Cost		\$3842

OUTPUTS

	<u>Percent</u>	<u>Output Per 101.9 kg In</u>	<u>Destination</u>
Yield	98.2	100.0	
Recycle	1.8	1.9	Vibrational Compaction
Samples			
Reject			
muf			

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$17580
Process Variable Cost per 100 kg Fuel	\$ 3842
Total Value 100 kg Fuel Leaving Process	\$21422
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	101.9 kg
Total Value of 101.9 kg Fuel Leaving Process	\$21840
Value of Recycle: 1.9 kg at \$75 per kg	\$ 142
Total Value of 100.0 kg Acceptable Fuel	\$21700
Unit Value of 100 kg Fuel Entering Next Process	\$21700
Value of 100 kg Fuel Entering This Process	\$17580
Process Variable Cost per 100 kg Acceptable Fuel	\$ 4120

TABLE XIVREWORK, SAXTONINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	0	
Direct Labor	0.148 Man-Hours Per Rod	134
Laboratory Expense	175%	235
Direct Services	0	
Total Shop Cost		<u>\$369</u>

OUTPUTS

	<u>Percent</u>	<u>Output Per 100 kg In</u>
Yield	100	100
Recycle		
Samples		
Reject		
muf		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$21700
Process Variable Cost per 100 kg Fuel	<u>\$ 369</u>
Total Value 100 kg Fuel Leaving Process	\$22069
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	
Total Value of 0 kg Fuel Leaving Process	
Value of Recycle: 0 kg at \$0 per kg	
Total Value of 0 kg Acceptable Fuel	
Unit Value of 100 kg Fuel Entering Next Process	\$22069
Value of 100 kg Fuel Entering This Process	
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$ 369</u>

TABLE XVINDIRECT LABOR, SAXTON

<u>INPUTS</u>		Cost Per
<u>Variable Costs</u>	<u>Primary Units</u>	<u>100 kg In</u>
Direct Material		
Consumable Supplies		
Direct Labor	1.406 Man-Hours Per Rod	1275
Laboratory Expense	175%	2230
Direct Services		
Total Shop Cost		\$3505
<u>OUTPUTS</u>		Output Per
	<u>Percent</u>	<u>100 kg In</u>
Yield	100	100
Recycle		
Samples		
Reject		
muf		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$22069
Process Variable Cost per 100 kg Fuel	\$ <u>3505</u>
Total Value 100 kg Fuel Leaving Process	\$25574
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	
Total Value of 0 kg Fuel Leaving Process	
Value of Recycle: 0 kg at \$0 per kg	
Total Value of 0 kg Acceptable Fuel	
Unit Value of 100 kg Fuel Entering Next Process	\$25574
Value of 100 kg Fuel Entering This Process	
Process Variable Cost per 100 kg Acceptable Fuel	\$ <u><u>3505</u></u>

TABLE XVI

MATERIAL REQUIREMENTS PER PROCESS STEP

<u>Process Step</u>	<u>Fuel</u>		<u>Zirconium</u>		<u>Uranium</u>		<u>Plutonium</u>	
	<u>In</u>	<u>Out</u>	<u>In</u>	<u>Out</u>	<u>In</u>	<u>Out</u>	<u>In</u>	<u>Out</u>
Tubing Preparation			1.086	1.086				
UO ₂ Preparation					1.060	1.039		
PuO ₂ Preparation							1.042	1.039
Load Pneumatic Impaction Cans	1.099	1.098			1.039	1.038	1.039	1.038
Double Can	1.098	1.098			1.038	1.038	1.038	1.038
Pneumatic Impaction	1.098	1.068			1.038	1.038	1.038	1.038
Open	1.068	1.062			1.038	1.032	1.038	1.032
Crush and Sieve	1.062	1.000			1.032	1.000	1.032	1.000
Vibrational Compaction	1.087	1.019	1.086	1.019				
Finish	1.019	1.000	1.019	1.000				
Rework	1.000	1.000	1.000	1.000				
Indirect	1.000	1.000	1.000	1.000				

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