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FABRICATION COSTS FOR PLUTONIUM FUEL ELEMENTS
PART A:
VARIABLE COSTS OF FABRICATING $\text{UO}_2\text{-PuO}_2$ FUEL RODS
FOR THE PLUTONIUM RECYCLE CRITICAL FACILITY

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Ceramics Research and Development Section
Reactor and Materials Technology Department

September, 1965

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INTRODUCTION

This report discusses the variable costs of fabricating 500 fuel rods for the Plutonium Recycle Critical Facility (PRCF). Part of a series on the costs of fabricating several types of plutonium-enriched fuels, this report includes direct material and direct labor, yields and losses, and overhead expenses charged to the fabrication group. Research, development, and engineering expenses are not included because they vary with the level of experience, uniqueness of the fuel design, and the level of process developments. Several nuclear materials' costs were omitted because, for the purposes of this initial report, they are not incurred by the fabrication group and thus do not constitute a variable expense.

In an effort to update and expand upon previous cost programs, this series will cover fuel element fabrication costs on a laboratory scale ranging from hundreds to thousands of individual pieces. Previous cost experience^(1, 2) was gained in 1963 during the fabrication of plutonium-enriched fuel elements by swage compaction for the Plutonium Recycle Test Reactor (PRTR). Although this previous work has been outdated by substantial changes in fabrication processes, it established that plutonium fuels could be fabricated for a slight cost premium (7.2%) over enriched uranium fuels of equivalent power generation.

The report series will present the variable costs of fabricating several types of plutonium-enriched fuels, such as test elements for physics research, fuel rods for the Saxton Reactor and the Experimental Boiling Water Reactor, and fuel rods for the PRTR. Following this basic work, analyses will be performed relative to (1) the effects of various parameters

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1. C. H. Bloomster. An Analysis of the Fabrication Cost of Plutonium-Enriched Fuel Elements, HW-SA-3543. General Electric Co., Richland, Washington, May, 1964.
 2. C. H. Bloomster and R. D. Widrig. Costs of Fabricating $\text{UO}_2\text{-PuO}_2$ Swage Compacted Fuel Elements, HW-SA-3132. General Electric Co., Richland, Washington.

on the costs of fabricating plutonium fuels, (2) the incremental costs of fabricating plutonium fuels compared to enriched uranium fuels, (3) the effects of equipment variables, process variables, and plant size, and (4) the major fixed and variable overhead costs.

Each of the reports in this series deals with a specific fuel design, and the costs therein are necessarily specific to the fuel design. The costs, therefore, vary widely and may not be applied, with indiscretion, 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 actual 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 usage.

SUMMARY

Based on the fabrication of 500 rods by a well developed, pneumatic-impaction, vibrational-impaction process, the variable cost (Table I) of fabricating plutonium-enriched fuel rods for PRCF was determined to be \$88/kg of fuel (as oxide). This represents a unit cost of \$99 per fuel rod. Each rod contains 1.1 kg of UO_2 -2 wt% PuO_2 fuel, is 3 ft long and 1/2 in. ID with Zircaloy cladding.

For each rod the shop labor requirements were 3.79 man-hours direct labor and 1.37 man-hours indirect labor. The variable costs included direct materials, some processing costs for nuclear materials, shop labor, direct overhead, analytical services, and consumable supplies, but did not include the cost of nuclear materials themselves, use charges, administrative overhead, research, development, or engineering costs.

FABRICATION PROCESS

Critical experiments in the PRCF required the fabrication of 1500 UO_2 - PuO_2 fuel rods. This study was based on the fabrication of 517 fuel rods during March and April, 1965. The fuel was clad in 0.035 in. Zircaloy-2. Three feet long and 0.505 in. ID, each rod contained 1128 g of UO_2 -2 wt% PuO_2 fuel giving a total of 584 kg of mixed oxide fuel for the 517 rods. Since the rods were for critical experiments only, tight specifications were not required for cladding defects or fuel impurities.

The fuel material was a physical blend of the oxides of uranium and plutonium, densified by the pneumatic impaction process. After impaction the mixed oxide was crushed and sieved into the desired size fractions and then loaded into the cladding to 87% TD by the vibrational compaction process. After the compaction step, a cap was welded into the tubing; and the rods were etched, inspected, and shipped. Both the vibrational compaction and the pneumatic impaction processes were well developed and had been used extensively in the laboratory.

COST ACCUMULATION

Labor costs were obtained from daily job tickets which indicated the time worked on each process step, the output, and the time required for indirect work such as cleaning, record keeping, and accountability. The average hourly wage rate for direct labor was \$4.85, including wages and all fringe benefits. The indirect laboratory expense, which was 175% of direct labor cost, covered a broad range of miscellaneous costs, e.g., general supplies and maintenance, 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. The material costs included the zirconium, the arc-fusion of UO_2 , and the purification and oxidation of plutonium metal. Consumable supplies consisted of cans, punches, and punch protectors 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). The largest single cost is the vibrational compaction step which accounts for one-fourth of the total cost.

For each process step, the cost data, yield, recycle rates, and losses are presented. In calculating the unit variable cost, the recycle material was valued at the material value of the process step to which it reenters. 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 for the present, the samples and reject material will have a value.) The value of the recycled fuel is deducted from the gross value of the fuel leaving the process, which then represents the value of the acceptable fuel leaving the process. This value is reduced to a unit value, and the unit cost of the process step is obtained by deducting the unit value of the fuel entering the process.

MATERIAL REQUIREMENTS

Table IV presents the gross material requirements and yields for each process step. The plutonium losses (muf) were 0.5% and the plutonium recovered from samples and reject fuel was 1.3%. The uranium losses (muf) were 1.0% and the uranium recovered from samples and reject fuels was 2.6%. The zirconium losses were 4%. The combined recycle-reject rate was 14.8% in the powder preparation steps and 4.0% in the rod fabrication steps.

PROCESS FABRICATION

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

* muf is an accountability term used for differences between book values and physical inventory values. It includes weighing and analytical errors, material lost to waste, and material later recovered from glove box filters.

** 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)," October 1, 1963, prepared by the Staff of Ceramics Research and Development Operation.

Tubing Preparation (Table V)

The tubing was cut to length, counterbored, washed, and inspected. The direct materials cost was \$6 for tubing and \$2.25 for end caps. Since the fuel rods were for critical experiments only, low quality (low cost) tubing was used for the fabrication.

UO₂ Preparation (Table VI)

Arc-fused 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 was for the arc-fusion of UO₂.

PuO₂ Preparation (Table VII)

Several methods of preparing PuO₂ were used during the fabrication of the fuel rods, only one is considered here. Plutonium was purified by vacuum remelting and oxidized to PuO₂; the direct material cost was the servicing cost for these steps. The PuO₂ weight was verified, and the PuO₂ was weighed and packaged in smaller batches (the processing cost) for the blending and loading step.

Loading Pneumatic Impaction Cans (Table VIII)

Blended in 24-kg batches, each batch of UO₂ and PuO₂ was divided into 6-kg lots which were loaded into cans attached to the blending glove box with a plastic bag. After loading, the can was removed from the glove box by sealing-off the plastic bag. The consumable supply cost was for the can and plastic bag.

Double-Canning (Table IX)

In a fume hood, the plastic bag was removed from the can which was inserted in an outer can. A lid, containing an outgas tube, was welded to the outer can to form a double-can assembly. The consumable supply cost was for the outer can assembly.

Pneumatic Impaction (Table X)

The double-can assembly was attached to a vacuum line and heated to 1150 °C. After reaching temperature, the can assembly was impacted;

after cooling, a grit-blaster was used to remove baked-on lubricants from the exterior of the can. The consumable supply cost included punches, punch protectors, and plugs.

Breakout (Table XI)

The can assembly was split open in a press in a glove box, and the fuel was removed and sampled for density. The direct service cost consisted of the analysis to determine fuel density.

Crushing and Sieving (Table XII)

The fuel was crushed and sieved into the proper size fractions. Samples were taken for plutonium content and oxygen-to-metal ratios. The fuel was weighed into bottles in the proper amounts and size fractions for one fuel rod. Direct service cost includes analysis to determine oxygen-to-metal ratios and plutonium contents.

Vibrational Compaction (Table XIII)

Each bottle of fuel was loaded into the cladding with the use of high energy vibrational compaction. Previously one end cap had been welded into the cladding. After loading, the open end of the fuel rod was decontaminated and the other end cap was welded in place.

Finishing (Table XIV)

The fuel rods were etched, tested in a helium-leak detector, inspected, and packaged for shipping.

Rework (Table XV)

The recycled material required a small amount of additional work before it reentered the process.

Indirect Work (Table XVI)

Indirect work included record keeping, accountability, procurement of supplies, and other indirect work attributed directly to the fabrication job. Not being attributable to a particular job, other indirect time which was devoted to general cleanup, meetings, breaks, 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.

ACKNOWLEDGEMENT

The author is indebted to the members of Plutonium Fuels Engineering for their assistance and cooperation in preparing this report.

FIGURE 1

Flow Diagram: Fabrication of UO_2 - PuO_2 Fuel Rods for the PRCF

TABLE I
VARIABLE COSTS OF FABRICATING PRCF FUEL RODS

	<u>Cost Per Rod, \$</u>	<u>Cost Per 100 kg, \$</u>
Direct Materials		
Zirconium	8.25	730
Uranium	4.93	436
Plutonium	10.18	900
Direct Labor	25.00	2210
Supplies	5.46	484
Direct Services	1.46	129
Laboratory Expense	<u>43.70</u>	<u>3870</u>
Total Variable Cost	\$98.98	\$8759

TABLE II
VARIABLE PROCESSING COSTS PER ROD

<u>Process Step</u>	<u>Direct Materials, \$</u>	<u>Processing</u>	
		<u>Cost, \$</u>	<u>Labor, man-hours</u>
Tubing Preparation	8.25	1.50	0.116
UO ₂ Preparation	4.93	3.85	0.282
PuO ₂ Preparation	10.18	1.23	0.047
Loading		4.82	0.308
Double-Canning		1.50	0.043
Pneumatic Impaction		3.36	0.237
Open		2.16	0.123
Crush and Sieve		9.85	0.539
Vibrational Compaction		27.15	1.77
Finish		4.02	0.271
Rework		0.67	0.050
Indirect		<u>15.20</u>	<u>1.37</u>
Subtotal	\$23.36	\$75.30	5.16
		<u>23.36</u>	
Total Cost		\$98.66	

TABLE III
VARIABLE PROCESSING COSTS PER 100 kg

	Direct Materials, \$	Processing	
		Cost, \$	Labor, man-hours
Zirconium Preparation	730	132	10.3
UO ₂ Preparation	436	339	24.9
PuO ₂ Preparation	900	109	4.2
Load		426	27.2
Decontamination		132	3.8
Pneumatic Impaction		297	21.0
Opening		191	10.9
Crush and Sieve		870	47.7
Vibrational Compaction		2398	157.0
Finishing		357	24.0
Rework		59	4.4
Indirect		<u>1344</u>	<u>121.0</u>
Subtotal	\$2066	\$6654	456.4
		<u>2066</u>	
Total Cost		\$8720	

TABLE IV

RELATIVE MATERIAL REQUIREMENTS PER PROCESS STEP, kg

Step	Fuel		Zirconium		Uranium		Plutonium	
	In	Out	In	Out	In	Out	In	Out
Tubing Preparation			1.040	1.040				
UO ₂ Preparation					1.036	1.015		
PuO ₂ Preparation							1.018	1.015
Loading	114.8	114.7			1.015	1.015	1.015	1.015
Double-Canning	114.7	114.7			1.015	1.015	1.015	1.015
Pneumatic Impaction	114.7	111.7			1.015	1.015	1.015	1.015
Open	111.7	111.2			1.015	1.010	1.015	1.010
Crush	111.2	100.0			1.010	1.000	1.010	1.000
Load	104.0	100.9	104.0	100.9				
Finish	100.9	100.0	100.9	100.0				
Rework	100.0	100.0	100.0	100.0				
Indirect	100.0	100.0	100.0	100.0				

TABLE V
TUBING PREPARATION, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$8.25 per Tube	\$730
Consumable Supplies	0	
Direct Labor	0.112 Man-Hour per Tube	48
Laboratory Expense	175%	84
Direct Services	0	
Total Shop Cost		<u>\$862</u>

OUTPUTS

	<u>Percent</u>	<u>Output Per 104 kg In</u>	<u>Destination</u>
Yield	100	104	Vibrational Compaction
Recycle			
Samples			
Reject			
muf			

VALUE ANALYSIS

Value of 100 kg Fuel Equivalent Entering Process	0
Process Variable Cost per 100 kg Fuel	<u>\$862</u>
Total Value 100 kg Fuel Leaving Process	\$862
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	104 kg
Total Value of 104 kg Fuel Leaving Process	\$896
Value of Recycle: 0 kg at \$0 per kg	<u>0</u>
Total Value of 104 kg Acceptable Fuel	\$896
Unit Value of 100 kg Fuel Entering Next Process	\$862
Value of 100 kg Fuel Entering This Process	<u>0</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$862</u>

TABLE VI
UO₂ PREPARATION, PRCF

<u>INPUTS</u>		Costs Per
<u>Variable Costs</u>	<u>Primary Units</u>	<u>100 kg In</u>
Direct Material	\$2.02 per lb of UO ₂	\$436
Consumable Supplies	0	
Direct Labor	0.245 Man-Hour per kg Out	118
Laboratory Expense	175%	206
Direct Services		
Total Shop Cost		\$760

OUTPUTS

	<u>Percent</u>	<u>Output Per</u> <u>103.6 kg In</u>	<u>Destination</u>
Yield	98.0	101.6	Load Pneumatic Impaction Cans
Recycle			
Samples	0.5	0.5	Recovery
Reject	1	1.0	Recovery
muf	0.5	0.5	Lost

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	0
Process Variable Cost per 100 kg Fuel	<u>\$760</u>
Total Value 100 kg Fuel Leaving Process	\$760
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	103.6 kg
Total Value of 103.6 kg Fuel Leaving Process	\$787
Value of Recycle: 0 kg at \$0 per kg	<u>0</u>
Total Value of 101.6 kg Acceptable Fuel	\$787
Unit Value of 100 kg Fuel Entering Next Process	\$775
Value of 100 kg Fuel Entering This Process	<u>0</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$775</u>

TABLE VII
PuO₂ PREPARATION, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	\$0.45 per g PuO ₂	\$900
Consumable Supplies	0	
Direct Labor	4.06 Man-Hours per kg PuO ₂	38
Laboratory Expense	175%	69
Direct Services		
Total Shop Cost		\$1,007

OUTPUTS

	<u>Percent</u>	<u>Output Per 101.8 kg In</u>	<u>Destination</u>
Yield	99.7	101.5	Load Pneumatic Impaction Cans
Recycle	0	0	
Samples	0.2	0.2	Recovery
Reject	0	0	
muf	0.1	0.1	Lost

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	0
Process Variable Cost per 100 kg Fuel	<u>\$1,007</u>
Total Value 100 kg Fuel Leaving Process	\$1,007
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	101.8 kg
Total Value of 101.8 kg Fuel Leaving Process	<u>\$1,023</u>
Value of Recycle: 0 kg at \$0 per kg	<u>0</u>
Total Value of 101.5 kg Acceptable Fuel	\$1,023
Unit Value of 100 kg Fuel Entering Next Process	\$1,009
Value of 100 kg Fuel Entering This Process	<u>0</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u><u>\$1,009</u></u>

TABLE VIIILOADING CANS FOR PNEUMATIC IMPACTION, PRCFINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	\$6.10 per 6 kg	\$102
Direct Labor	1.452 Man-Hours per	117
Laboratory Expense	175%	205
Direct Services		
Total Shop Cost		\$424

OUTPUTS

	<u>Percent</u>	<u>Output Per 114.8 kg In</u>	<u>Destination</u>
Yield	99.87	114.7	Decontamination and Welding
Recycle	0.1	0.1	Load Pneumatic Impaction Cans
Samples	0	0	
Reject	0.025	Insignificant	
muf	0.004	Insignificant	

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$1,784
Process Variable Cost per 100 kg Fuel	424
Total Value 100 kg Fuel Leaving Process	\$2,208
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	114.8 kg
Total Value of 114.8 kg Fuel Leaving Process	\$2,535
Value of Recycle: 0.1 kg at \$17.84 per kg	2
Total Value of 114.7 kg Acceptable Fuel	\$2,533
Unit Value of 100 kg Fuel Entering Next Process	\$2,210
Value of 100 kg Fuel Entering This Process	1,784
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$426</u>

TABLE IX
DOUBLE-CANNING, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	\$5.25 per 6 kg	\$88
Direct Labor	0.199 Man-Hours per 6 kg	16
Laboratory Expense	175%	28
Direct Services		—
Total Shop Cost		\$132

OUTPUTS

	<u>Percent</u>	<u>Output Per 114.7 kg In</u>	<u>Destination</u>
Yield	100	114.7	Pneumatic Impaction
Recycle			
Samples			
Reject			
muf			

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$2,210
Process Variable Cost per 100 kg Fuel	<u>132</u>
Total Value 100 kg Fuel Leaving Process	\$2,342
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	114.7 kg
Total Value of 114.7 kg Fuel Leaving Process	\$2,690
Value of Recycle: 0 kg at \$0 per kg	<u>0</u>
Total Value of 0 kg Acceptable Fuel	\$2,690
Unit Value of 100 kg Fuel Entering Next Process	\$2,342
Value of 100 kg Fuel Entering This Process	<u>2,210</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$132</u>

TABLE X
PNEUMATIC IMPACTION, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	\$1.64 per 6 kg	\$ 27
Direct Labor	1.090 Man-Hours per 6 kg	88
Laboratory Expense	175%	154
Direct Services		
Total Shop Cost		\$269

OUTPUTS

	<u>Percent</u>	<u>Output Per 114.7 kg In</u>	<u>Destination</u>
Yield	97.39	111.7	Opening
Recycle	2.61	3.0	Load Pneumatic Impaction Cans
Samples			
Reject			
muf			

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$2,342
Process Variable Cost per 100 kg Fuel	<u>269</u>
Total Value 100 kg Fuel Leaving Process	\$2,611
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	114.7 kg
Total Value of 114.7 kg Fuel Leaving Process	\$2,995
Value of Recycle: 3.0 kg at \$17.84 per kg	<u>54</u>
Total Value of 111.7 kg Acceptable Fuel	\$2,941
Unit Value of 100 kg Fuel Entering Next Process	\$2,639
Value of 100 kg Fuel Entering This Process	<u>2,342</u>
Process Variable Cost per 100 kg Acceptable Fuel	\$297

TABLE XI
BREAKOUT, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	0	
Direct Labor	0.588 Man-Hours per 6 kg	\$ 48
Laboratory Expense	175%	83
Direct Services	Density Samples	50
Total Shop Cost		\$181

OUTPUTS

	<u>Percent</u>	<u>Output Per 111.7 kg In</u>	<u>Destination</u>
Yield	99.52	111.2	Crushing
Recycle	0		
Samples	0.25	~0.3	Recovery
Reject	0.23	~0.2	Recovery
muf	0		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$2,639
Process Variable Cost per 100 kg Fuel	181
Total Value 100 kg Fuel Leaving Process	\$2,820
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	111.7 kg
Total Value of 111.7 kg Fuel Leaving Process	\$3,150
Value of Recycle: 0 kg at \$0 per kg	0
Total Value of 111.2 kg Acceptable Fuel	\$3,150
Unit Value of 100 kg Fuel Entering Next Process	\$2,830
Value of 100 kg Fuel Entering This Process	2,639
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$191</u>

TABLE XII
CRUSHING AND SIEVING, PRGF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	0	
Direct Labor	0.429 Man-Hours per kg	\$208
Laboratory Expense	175%	364
Direct Services	Chemical Analyses	81
Total Shop Cost		\$653

OUTPUTS

	<u>Percent</u>	<u>Output Per 111.2 kg In</u>	<u>Destination</u>
Yield	89.96	100.0	Vibrational Compaction
Recycle	9.09	10.1	Load Pneumatic Compaction Cans
Samples	0.03	0.0+	Recovery
Reject	0.54	0.6	Recovery
muf	0.38	0.4+	Lost

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$2,830
Process Variable Cost per 100 kg Fuel	653
Total Value 100 kg Fuel Leaving Process	\$3,483
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	111.2 kg
Total Value of 111.2 kg Fuel Leaving Process	\$3,880
Value of Recycle: 10.1 kg at \$17.84 per kg	180
Total Value of 100 kg Acceptable Fuel	\$3,700
Unit Value of 100 kg Fuel Entering Next Process	\$3,700
Value of 100 kg Fuel Entering This Process	2,830
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$870</u>

TABLE XIIIVIBRATIONAL COMPACTION AND WELDING, PRCFINPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	\$3.01 per Rod	\$ 267
Direct Labor	1,708 Man-Hours per Rod	735
Laboratory Expense	175%	1,288
Direct Services		
Total Shop Cost		\$2,290

OUTPUTS

	<u>Percent</u>	<u>Output Per 104.0 kg In</u>	<u>Destination</u>
Yield	97.0	100.9	Finishing
Recycle	3.0	3.1	Vibrational Compaction
Samples	0		
Reject	Tubing		
muf	0		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process (Fuel, \$3700; Zr, \$862)	\$4,562
Process Variable Cost per 100 kg Fuel	2,290
Total Value 100 kg Fuel Leaving Process	\$6,852
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	104.0 kg
Total Value of 104.0 kg Fuel Leaving Process	\$7,130
Value of Recycle: 3.1 kg at \$37.00 per kg	115
Total Value of 100.9 kg Acceptable Fuel	\$7,015
Unit Value of 100 kg Fuel Entering Next Process	\$6,960
Value of 100 kg Fuel Entering This Process	4,562
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$2,398</u>

TABLE XIV
FINISHING, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Material	0	
Consumable Supplies	0	
Direct Labor	0.269 Man-Hours per Rod	\$116
Laboratory Expense	175%	202
Direct Services		
Total Shop Cost		<u>\$318</u>

OUTPUTS

	<u>Percent</u>	<u>Output Per 100.4 kg In</u>	<u>Destination</u>
Yield	99.15	100.0	Finished
Recycle	0.85	0.9	Vibrational Compaction
Samples	0		
Reject	Tubing		
muf	0		

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$6,960
Process Variable Cost per 100 kg Fuel	<u>318</u>
Total Value 100 kg Fuel Leaving Process	\$7,278
Quantity of Fuel Processed per 100 kg Fuel in Finished Rod	100.9 kg
Total Value of 100.9 kg Fuel Leaving Process	\$7,350
Value of Recycle: 0.9 kg at \$37 per kg	<u>33</u>
Total Value of 100 kg Acceptable Fuel	\$7,317
Unit Value of 100 kg Fuel Entering Next Process	\$7,317
Value of 100 kg Fuel Entering This Process	<u>6,960</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$357</u>

TABLE XV
REWORK, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Labor	0.05 Man-Hours per Rod	\$21
Laboratory Expense	175%	38

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$7,317
Process Variable Cost per 100 kg Fuel	59
Total Value 100 kg Fuel Leaving Process	\$7,376
Unit Value of 100 kg Fuel Entering Next Process	\$7,376
Value of 100 kg Fuel Entering This Process	<u>7,317</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$59</u>

TABLE XVI
INDIRECT LABOR, PRCF

INPUTS

<u>Variable Costs</u>	<u>Primary Units</u>	<u>Cost Per 100 kg In</u>
Direct Labor	1.37 Man-Hours per Rod	\$489
Laboratory Expense	175%	855

VALUE ANALYSIS

Value of 100 kg Fuel Entering Process	\$7,376
Process Variable Cost per 100 kg Fuel	1,344
Total Value 100 kg Fuel Leaving Process	\$8,720
Unit Value of 100 kg Fuel Entering Next Process	\$8,720
Value of 100 kg Fuel Entering This Process	<u>7,376</u>
Process Variable Cost per 100 kg Acceptable Fuel	<u>\$1,344</u>

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