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TIME STUDY OF FUEL ROD FABRICATION IN
THE KILOROD FACILITY

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OCTOBER 1965

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TIME STUDY OF FUEL ROD FABRICATION IN THE KILOROD FACILITY

J. E. Van Cleve, Jr., J. J. Varagona,¹ and A. L. Lotts

ABSTRACT

A time and motion study of fuel rod fabrication in the ORNL Kilorod Facility was performed to aid in the understanding of the process system and to serve as a guide in the extrapolation of data to larger and more sophisticated facilities. The Kilorod operation was divided into 28 operational subroutines composed of over 200 production work elements for which time values were determined. The maximum throughput of the system was determined to be 15.5 rods/day and the maximum crew effectiveness to be 87%.

INTRODUCTION

During the manufacture of 1100 fuel rods for the Brookhaven National Laboratory in the ORNL Kilorod Facility we had two major objectives: (1) the demonstration of the engineering feasibility of fabricating vibratorily compacted fuel rods filled with sol-gel process oxide, and (2) the collection, on a pilot-plant scale, of process data and operating experience to be later extrapolated to future remote re-fabrication facilities. As a portion of the second objective, we made a time and motion study of the fabrication operations and analyzed thoroughly the efficiency of the manpower and equipment. We felt that such a study would not only provide a base line for extrapolation to larger facilities but would also indicate areas where operations could be improved in the facility being examined.

The study involved the development of practical methods for determining the maximum effectiveness levels that could reasonably be expected from manpower and equipment. (Effectiveness is defined as the percent

¹Plant and Equipment Division

utilization of available work time.) The optimum schedule is that schedule that is possible when operating at the maximum levels of effectiveness. Equipment limitations, elemental time values, acknowledgments of overlaps within subroutines and between routines were all considered in calculating the effectiveness levels and schedules. In addition, the maximum production in the time available for doing work was determined. The operation of the facility was divided into time periods by two methods: (1) the production of enough rods to load one carrier (120 long or 200 short rods constituting a shipment) and (2) the processing of approximately 100 kg of oxide. The first break was of short duration, long enough to replace the loaded carrier with the empty carrier and perform necessary repairs. The second break was used for cleanup, preventive maintenance, review of the operating experience, and the determination of a material balance for the system. The study was performed in the rod fabrication portion (first and second levels) of the three-level Kilorod Facility (cell No. 4) in Building 3019 (Fig. 1). The process flow diagram is presented in Fig. 2, and a schematic drawing of the final product is illustrated in Fig. 3. Details pertaining to the engineering and construction of the Kilorod Facility, as well as preliminary operational data accumulated during start-up of the facility, are available in the literature.^{2,3}

²J. D. Sease, A. L. Lotts, and F. C. Davis, "New Remote Facility and Equipment at the Oak Ridge National Laboratory for Fabrication of Fuel Rods Bearing Uranium-233 and Thorium Oxide," pp. 33-43 in Proceedings of the 11th Conference on Hot Laboratories and Equipment, ANS Winter Meeting, New York, November 18-21, 1963, American Nuclear Society, New York, 1963.

³J. E. Van Cleve, Jr., and A. L. Lotts, "Experience in the Fabrication of Uranium-233 Bearing $\text{ThO}_2\text{-UO}_2$ Rods in a Lightly Shielded Facility at the Oak Ridge National Laboratory," to be published in the proceedings of the Symposium on Powder Filled Uranium Dioxide Fuel Elements, Worcester, Massachusetts, November 5-6, 1963.

Fig. 1. Kilorod Solids Preparation and Rod Fabrication Facility.

Fig. 2. Fuel Rod Fabrication Flow Sheet.

Fig. 3. Design Features of the BNL Fuel Rod.

DATA COLLECTION

In collecting data for the time and motion study, the Kilorod fabrication operation was observed for approximately three weeks during the production of rods ranging from near number 200 to 350. During this time operating subroutines were observed, and the time required to perform each operation was determined. Each subroutine was examined at least three separate times and evaluated each time. Extensive interviews with each technician were conducted to ascertain his personal appraisal of his particular portion of the overall system and also as an aid in determining work assignment overlaps.

In addition, we thoroughly analyzed the log book, both during the time and motion study and at the end of the production of 1100 fuel rods for BNL, to determine the equipment performance, frequency of breakdown, and on-stream time.

OPERATING TIME STUDY

Elemental time values, given in Appendix A, were determined for the 28 subroutines that constituted the Kilorod rod fabrication operation at the time of the study. Table 1 presents a tabulation of all subroutines and the times required to accomplish each of them. Also tabulated are the time values required to perform various units of work, such as time per rod for accomplishment of subroutine 7. It is to be noted that time values are given for 7, 10, and 15 rods/day schedules, in which the day was taken to be an 8-hr shift. The columns, in Table 1, headed "calendar" show the gross time required in the subroutine while the columns headed "work" give the time consumed in actual work, the difference being the nonworking time in each subroutine.

The data in Table 1 were used to obtain more efficient work schedules. The object, of course, was to properly sequence the work elements so that the nonwork time within each subroutine was minimized. The work assignments proposed and the various time values for each technician are presented in Tables 2-5 at 100% effectiveness. Data are presented for 7, 10, and 15 rods/day schedules. A normal delay

Table 1. Kilorod Subroutines

QRNL DWG. 64-6792

QRNL DWG. 64-6792

		Time in Minutes at 100% Effectiveness																
Subroutine Number	Subroutine	Subroutine Cycle				Daily Time (Maximum Routine Included)												
		Number of Rods	Time per Subroutine		Per Rod		7-Rod Schedule		10-Rod Schedule		15-Rod Schedule							
			Calendar	Work	Calendar	Work	Calendar	Work	Calendar	Work	Calendar	Work						
0	Energize equipment; pick up liquid nitrogen	DO ¹	12.	12.	1.71 ²	1.71 ²	12.	12.	12.	12.	12.	12.						
1	Load in shipping cask - one man	120	12.	12.	.1	.1												
2	- second man	120	9.	9.	.08	.08												
3	Jaw crusher	11	8.45	5.95	.77	.54	8.45	5.95	8.45	5.95	16.9	11.9						
4	Recycle	11	21.9	21.9	1.99	1.99	21.9	21.9	21.9	21.9	43.8	43.8						
5	³ Ball Mill - 16 fraction into fines	8	145.2	10.2	9.10 ⁴	.93			145.2	10.2	145.2	10.2						
6	Ball Mill - 6/+16 fraction into fines	10	432.1	12.1	.40	.37	13.2	12.1	13.2	12.1	13.2	12.1						
7	Blend; transfer bottle loading	1	11.2	8.2	11.2	8.2	78.4	57.4	112.0	82.0	168.	123.						
8	Sample (-168 -6/+16 fractions)	10	5.	5.	.5	.5	5.	5.	5.0	5.	10.	10.						
9	Seal samples	10	1.	1.	.1	.1	1.	1.	1.	1.	2.	2.						
10	Dispose of old bag (powder preparation cubicle)	10	2.1	2.1	.21	.21	2.1	2.1	2.1	2.1	4.2	4.2						
11	Seal old bag	10	1.	1.	.1	.1	1.	1.	1.	1.	2.	2.						
12	Compacting	1	16.7	7.5	16.7	7.5	116.9	52.5	167.	75.	250.5	112.5						
13	Transfer plugged rod for scanning	1	.9	.9	.9	.9	6.3	6.3	9.	9.	13.5	13.5						
14	Scanner check	1	9.8	4.6	9.8	4.6	68.3	32.2	98.	46.	147.	69.						
15	Welding	1	15.5	11.5	15.5	11.5	108.5	80.5	155.	115.	232.5	172.5						
16	Ultrasonic cleaning	5	39.45	13.95	7.89	2.79	78.9	27.9	78.9	27.9	118.4	41.9						
17	Dry, leak test, and weight	5	18.3	15.5	3.66	3.1	36.6	31.	36.6	31.	54.9	46.5						
18	Rod cleaning	10	10.7	10.7	1.07	1.07	10.7	10.7	10.7	10.7	21.4	21.4						
19	Smear - smear man	10	8.4	7.8	.84	.78	8.4	7.8	8.4	7.8	16.8	15.6						
20	- cubicle man	10	6.2	6.2	.62	.62	6.2	6.2	6.2	6.2	12.4	12.4						
21	Assemble hanger & load in carrier - hanger man	10	13.1	8.65	1.31	.87	13.1	8.65	13.1	8.65	26.2	17.3						
22	- carrier man	10	13.45	13.	1.35	1.3	13.45	13.	13.45	13.	26.9	26.						
23	Mark, weight, & record empty rod	5	15.	15.	3.	3.	30.	30.	30.	30.	45.	45.						
24	3-piece rod end assembly	20	6.	6.	.3	.3	6.	6.	6.	6.	6.	6.						
25	Remove and dispose of cleaning pads	50	10.	10.	.2	.2	10.	10.	10.	10.	10.	10.						
26	Load shipping cask - one man	120	12.	12.	.1	.1												
27	- second man	120	9.	9.	.08	.08												
Total Time (excluding routines 1, 2, 26, & 27) =			89.22 ²		53.18 ²		656.4		441.2		964.2		549.5		1398.8		840.8	

¹DO = one day output.²Based on 7 rod day.³Ball milling done overnight and unattended.⁴Ball milling attended maximum of twice a day (plus one -6/+16 fraction ball milling) to produce fines to meet maximum schedule.

Table 2. Optimized Work Assignments and Time Values for Technician A

Subroutine No.	Time Values at 100% Operator Effectiveness					
	7-Rod Schedule		10-Rod Schedule		15-Rod Schedule	
	Calendar	Work	Calendar	Work	Calendar	Work
	minutes					
3	8.45	5.95	8.45	5.95	16.9	11.9
4	21.9	21.9	21.9	21.9	43.8	43.8
5			145.2 ^a	10.2	145.2 ^a	10.2
6	13.2	12.1	13.2 ^b	12.1	13.2 ^b	12.1
7	78.4	57.4	112.	82.	168.	123.
8	5.	5.	5.	5.	10.	10.
10	2.1	2.1	2.1	2.1	4.2	4.2
19	8.4	7.8	8.4	7.8	16.8	15.6
22	13.45	13.	13.45	13.	26.9	26.
Gross calendar time	<u>150.9</u>		<u>329.7</u>		<u>445.</u>	
Less overlapping routines			135. ^a		135. ^a	
Net calendar time	<u>150.9</u>		<u>194.7</u>		<u>310.</u>	
Work time		<u>125.25</u>		<u>160.05</u>		<u>256.8</u>
Plus 15% delay allowance, on work time		18.79		24.01		38.5
Work time, including delay allowance		<u>144.04</u>		<u>184.06</u>		<u>295.3</u>
Plus non work, within technician's routine		25.65		34.65		53.2
Routine time, including delay and nonwork		<u>169.69</u>		<u>218.71</u>		<u>348.5</u>

^a2 hr and 15 min unattended ball milling.^b7 hr overnight (beyond 8-hr work day) unattended ball milling.

Table 3. Optimized Work Assignments and Time Values for Technician B

Subroutine No.	Time Values at 100% Operator Effectiveness					
	7-Rod Schedule		10-Rod Schedule		15-Rod Schedule	
	Calendar	Work	Calendar	Work	Calendar	Work
minutes						
9	1.	1.	1.	1.	2.	2. ^a
11	1.	1.	1.	1.	2.	2. ^a
12	116.9	52.5	167.	75.	250.5	112.5
18	10.7	10.7	10.7	10.7	21.4	21.4
20	6.2	6.2	6.2	6.2	12.4	12.4 ^a
23	30.	30.	30.	30.	45.	45.
25	10.	10.	10.	10.	10.	10.
Gross calendar time	<u>175.8</u>		<u>225.9</u>		<u>343.3</u>	
Less overlapping routines	.26.5 ^a		26.5 ^a		43. ^a	
Net calendar time	<u>149.3</u>		<u>199.4</u>		<u>300.3</u>	
Work time		<u>111.4</u>		<u>133.9</u>		<u>205.3</u>
Plus 20% delay allowance, on work time		22.3		26.8		41.1
Work time, including delay allowance		<u>133.7</u>		<u>160.7</u>		<u>246.4</u>
Plus nonwork, within technician's routine		37.9		65.5		95.
Routine time, including delay and nonwork		<u>171.6</u>		<u>226.2</u>		<u>341.4</u>

^aSubroutines 9 and 11, 4 1/2 min of 20, and 20 min of 23 done with Subroutine 12 during 7 and 10 rods/day schedule ($1 + 1 + 4.5 + 20 = 26.5$); subroutines 9 and 11, 6 min of 20, and 30 min of 23 done with Subroutine 12 during 15 rods/day schedule ($2 + 2 + 9 + 30 = 43$).

Table 4. Optimized Work Assignments and Time Values for Technician C

Subroutine No.	Time Values at 100% Operator Effectiveness					
	7-Rod Schedule		10-Rod Schedule		15-Rod Schedule	
	Calendar	Work	Calendar	Work	Calendar	Work
	minutes					
0	12.	12.	12.	12.	12.	12.
13	6.3	6.3	9.	9.	13.5	13.5
15	108.5	80.5	155.	115.	232.5	172.5
16	78.9	27.9	78.9	27.9	118.4	41.9 ^a
17	36.6	31.	36.6	31.	54.9	46.5
24	6.	6.	6.	6.	6.	6.
Gross calendar time	<u>248.3</u>		<u>297.5</u>		<u>437.3</u>	
Less overlapping routines	78.9 ^a		78.9 ^a		118.4 ^a	
Net calendar time	<u>169.4</u>		<u>218.6</u>		<u>318.9</u>	
Work time		<u>163.7</u>		<u>200.9</u>		<u>292.4</u>
Plus 20% delay allowance, on work time		32.7		40.2		58.5
Work time, including delay allowance		<u>196.4</u>		<u>241.1</u>		<u>350.9</u>
Plus nonwork, within technician's routine		5.7		17.7		26.5
Routine time, including delay and nonwork		<u>202.1</u>		<u>258.8</u>		<u>377.4</u>

^aSubroutine 16 done with subroutines 15 and 17.

Table 5. Optimized Work Assignments and Time Values for Technician S

Subroutine No.	Time Values at 100% Operator Effectiveness					
	7-Rod Schedule		10-Rod Schedule		15-Rod Schedule	
	Calendar	Work	Calendar	Work	Calendar	Work
	minutes					
14	68.3	32.2	98.	46.	147.	69.
21	13.1	8.65	13.1	8.65	26.2	17.3
Net calendar time	<u>81.4</u>		<u>111.1</u>		<u>173.2</u>	
Work time		<u>40.85</u>		<u>54.65</u>		<u>86.3</u>
Plus 15% delay allowance, on work time		6.12		8.20		12.9
Work time, including delay allowance		<u>46.98</u>		<u>62.85</u>		<u>99.2</u>
Plus nonwork, within technician's routine		40.55		56.45		86.9
Routine time, including delay and nonwork		<u>87.53</u>		<u>119.3</u>		<u>186.1</u>

allowance, granted for the technician to change from one task to another, is included in each work assignment. An additional delay allowance of 15 to 20% is allowed because of interference of operations.

As mentioned, the data are presented at 100% effectiveness which does not make any allowance for nonproductive work other than that required by each subroutine. Work of this nature is required for such measures as contamination control, repair and maintenance, making a material balance, and time spent in recycling nonspecification grade rods. Each of these items contribute to lowering the effectiveness level.

The data for the individual technicians were used to determine the ultimate in work balance under the operating conditions. The results, called the "crew time average", are shown in Table 6. The calculations used in determining these data are presented in Appendix B.

The effectiveness levels at 7, 10, and 15 rods/day production rates are presented in Fig. 4. The crew average based on 3.5 technicians is designated by M; the letters A, B, C, and S identify the four men assigned to the operation. Since the man represented by the letter S also had supervisory functions, S was counted as 0.5. The total operation without benefit of overlapping routines and delay allowances, based on a 3.5-man crew, is designated by O. We allowed a total of 108 min each day for fatigue and personal time. Personal time of 60 min is allowed because the work area is remote and radiation controlled. A breakdown of this special personal time allowance is presented in detail in Appendix C.

The distribution of each technician's time for a production rate of 7 rods/day is presented in Fig. 5. The total time required by each technician's assignment is presented over the letter designated and the subroutine numbers are at the base of each column. The crew time average (column M) shows that slightly more than 180 min/day is required to produce seven rods.

Table 6. Average Crew Time

	Crew Time Values at 100% Operator Effectiveness					
	7-Rod Schedule		10-Rod Schedule		15-Rod Schedule	
	Calendar	Work	Calendar	Work	Calendar	Work
	minutes					
Net calendar time (Average of A, B, C, and S)	<u>178.4</u>		<u>253.5</u>		<u>378.5</u>	
Work time (Average of A, B, C, and S)		<u>126.1</u>		<u>157.</u>		<u>240.2</u>
Plus 18% delay allowance, on work time		22.7		28.3		43.2
Work time, including delay allowance		<u>148.8</u>		<u>185.3</u>		<u>283.4</u>
Plus ^a nonwork, within technician's routine		<u>31.4</u>		<u>49.8</u>		<u>74.7</u>
Routine time, including delay and non-work		180.2		235.1		358.1

^a Nonwork in minutes per day:

$$\begin{aligned}
 \frac{\text{Crew minutes nonwork}}{\text{Day}} &= \frac{\text{Minutes}^b}{\text{Day}} \times \frac{\text{Crew}^c}{3.5} \\
 7 \text{ rods/day } c &= \frac{25.65 + 37.9 + 5.7 + 40.55}{1} \times \frac{1}{3.5} = 31.4 \text{ min} \\
 10 \text{ rods/day} &= \frac{34.65 + 65.5 + 17.7 + 56.45}{1} \times \frac{1}{3.5} = 49.8 \text{ min} \\
 15 \text{ rods/day} &= \frac{53.2 + 95. + 26.5 + 86.9}{1} \times \frac{1}{3.5} = 74.7 \text{ min}
 \end{aligned}$$

^b From technician routines (nonwork), Tables 2-5.

^c Crew size is 3.5, counting S (working supervisor) as 1/2 technician.

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Fig. 4. Effectiveness vs Daily Output.

Fig. 5. Distribution of Technician's Time for a Production Rate of 7 rods/day.

The effectiveness readings for both process and the 3.5 man crew in terms of the lost production time experienced and overall times for completing a cask (120 rods) are presented in Fig. 6. The calculations used in arriving at these data are presented as a part of Appendix B. The abscissa, "total days," for the figure depends upon whether the process effectiveness or the crew effectiveness is to be determined.

1. For the process effectiveness: the "cask total days" is the time from the first rod in the cask to the first rod in the succeeding cask; and the "campaign days" is the time spent in carrying out house-keeping functions and maintenance after the processing of approximately 100 kg of oxide.

2. For the crew effectiveness: the "cask total days" is the same as for the process effectiveness; and the "lost work time days" is obtained from the examination of the operating logbooks. The multiplication factor takes into account the number of rods that were recycled to produce the 120 specification grade rods for the shipment.

PROCESS AND CREW EFFECTIVENESS

All lost production time experienced during the entire operation is summarized in 25 categories and presented in Table 7. The process and crew effectiveness are given for each cask, which constitutes a shipment. Special attention should be given to the crew and process effectiveness determined in the final two shipments (Nos. 841 through 900 and Nos. 901 through 1100). Since the number of rods in the eighth shipment was only 60, recalculation of the maximum effectiveness was required. The results of this calculation compared with the operating experience showed that the crew and process effectiveness for this shipment would have to be calculated on a 15 rods/day basis. Using the 15 rods/day figures, the maximum effectiveness was found to be 97.2% contrasted to 48.9% based on a 7 rods/day figure. The crew and process effectiveness were determined at 81 and 76%, respectively.

PROCESS EFFECTIVENESS

USE TOTAL DAYS AS CASK TOTAL DAYS LESS CAMPAIGN DAYS

CREW EFFECTIVENESS

USE TOTAL DAYS AS

(CASK TOTAL DAYS-LOST WORK TIME DAYS) $\times \left[\frac{120}{120 + \text{NUMBER OF REWORKS}} \right]$

Fig. 6. Process and Crew Effectiveness vs Days Required for Cask (120 Rods) Processing.

Table 7. Summary of Equipment and Process Efficiency in Producing 1100 Fuel Rods.

[illegible]¹Replace scanner tube

²Cask Process Days = Cask Total Days – Campaign Days, e.g., 54–1 = 53, Cask Process Days.

³Rework Days = (Cask Total Days - Lost Work Time Days) $\times \frac{\text{No. of reworks}}{120 + \text{No. of reworks}}$, e.g., $(54-15.2) \times \frac{43}{120 + 43} = 10.2$, Rework Days.
$$^4 \text{Cask Crew Days} = (\text{Cask Total Days} - \text{Lost Work Time Days}) \times \frac{120}{120 + \text{No. of reworks}}, \text{ e.g., } (54 - 15.2) \times \frac{120}{120 + 43} = 28.6, \text{ Cask Crew Days.}$$
⁵Crew Effectiveness = $\frac{\text{Effective Cask Days at rod schedule}}{\text{Cask Crew Days}} \times 100$, e.g., $\frac{8.35 \text{ (7-rod day)}}{28.6} \times 100 = 29\%$
$$^6 \text{Process Effectiveness} = \frac{\text{Effective Cask Days at rod schedule}}{\text{Cask Process Days}} \times 100, \text{ e.g., } \frac{8.35 \text{ (7-rod day)}}{53} \times 100 = 16\%$$

Following production of 900 rods of the design shown in Fig. 3, 200 rods of the same design, but only 19 in. long, were fabricated. These are Nos. 901 through 1100. Elemental time values were not measured during the production of the short rods as manpower and time were not available. However, each subroutine listed in Table 1 was examined, and estimates of savings in time were made where appropriate. From these estimates, it was determined that the short rods required approximately 75% of the time required to fabricate a long rod. The crew and process effectiveness values in Table 7 were calculated assuming a 10 rods/day capacity; and the time values in selected subroutines were adjusted by the 25% time differential.

Examination of the operating experience and the equipment layout showed that the maximum daily rod production would be increased by 20%. The increase could have been accomplished by changes in the flow pattern, the equipment layout, and manpower assignments.

CONCLUSIONS

The Kilorod operation was divided into 28 subroutines composed of over 200 distinct production elements, some as small as 0.05 min and averaging approximately 0.5 min per application, and four technician routines. The maximum daily time requirements for three levels of rod output were determined.

Using the present layout and methods, the maximum daily production is limited to 15.5 rods; however, proper layout changes could increase this by 20% (ref. 4). To attain production rates above 40 rods/3 shift day will require extensive automation of the process equipment.

⁴Based on one 8-hr shift/day plus offshift ball milling as required.

Considerable progress was made in the efficiency of fuel rod fabrication. A comparison of the experience during the first shipment with the next six shipments shows:

1. increase in process effectiveness: from 16 to 82%
2. increase in crew effectiveness: from 29 to 87%
3. decrease in lost time from all causes: from 15.2 to 5.7 days
4. decrease in number of rods reworked: from 43 to 4.

The most efficient campaign in the complete operation yielded the following values:

1. process effectiveness: 82%
2. crew effectiveness: 87%
3. lost time from all causes: 3.7 days
4. number of rods reworked: 1

APPENDIX A

Elemental Time Values for Each Subroutine

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Subroutine 3	25
Subroutine 4	26
Subroutine 5	27
Subroutine 6	29
Subroutine 7	30
Subroutine 8	32
Subroutine 9	34
Subroutine 10	35
Subroutine 11	36
Subroutine 12	37
Subroutine 13	39
Subroutine 14	40
Subroutine 15	42
Subroutine 16	43
Subroutine 17	45
Subroutine 18	47
Subroutines 19 and 20	48
Subroutines 21 and 22	50
Subroutine 23	52
Subroutine 24	53
Subroutine 25	54
Subroutines 26 and 27	55

1

2

3

4

5

6

7

8

9

ENERGIZE EQUIPMENT; PICK UP LIQUID NITROGEN

<u>Element</u>	<u>Time (minutes)</u>
1. Throw all light switches to ON; energize equipment.	2.0
2. Leave cell 4, and return with liquid nitrogen for day's use.	10.

Total Cycle (all working) 12.0 Minutes

LOAD IN SHIPPING CASK

<u>Element</u>	<u>Time (minutes)</u>
Assist at hoist to load empty cask on rail truck.	
Remove sling from cask.	
Move rail truck loaded with cask toward cubicle.	
Assemble eye bolt to blind flange at loading end of cask.	
Position 1/2 ton hand hoist to eye bolt.	
Remove 11 1/2-inch cap screws from flange.	
Lift blind flange to clear cask.	
Remove bolt and pivot disk closure from cubicle opening.	
Move rail truck with cask to cubicle wall.	
Assemble (2) turnbuckles to cask and cubicle wall.	
Remove end plug from blind flange at closed end of cask.	
Use T-wrench and push rod magazine partially into cubicle.	
Replace end plug into blind flange.	

Note: Total net technician time could be as little as 18 minutes. Since routine is infrequent and requires two men on several elements a total of 21 minutes is given.

Total cycle (all working) - one man	12 Minutes
- other man	9 Minutes

CRUSHER

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Shout (to 3rd. level) for crystals.	.1
3. Wait for crystals.	2.5 *
4. Lower recycle hopper to recycle line.	.5
5. Glove hand to:	.2
6. Seat hopper to line.	.2
7. Open valve in line.	.2
8. Glove hand and,	.2
9. Use vise grip and open + 6 fraction valve.	.3
10. Ratchet, close -16 fraction valve.	.3
11. Walk up to second level.	.25
12. Check (visually) that crusher valve is open.	.2
13. Push button to:	
14. start classifier.	.15
15. start crusher.	.05
16. Receive two 5 kg. dumps of crystals.	3.0
17. Walk down to first level.	.2
<hr/>	
Total Cycle	8.45 Minutes
Working	5.95
Nonworking	2.50 *

RECYCLE

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center	0.1
2. Glove hand to:	.2
3. Close valve in recycle line.	.2
4. Raise recycle hopper to top of cubicle.	.7
5. Walk up to second level.	.25
6. Glove hand to:	.2
7. Seat hopper to flange.	.1
8. Ratchet, position valve to crusher.	.3
9. Glove hand and,	.2
10. Use vise grip, open hopper valve.	.3
11. Wait for dumping.	.1
12. Use vise grip, close hopper valve.	.1
13. Walk to first level.	.2
14. Lower recycle hopper to recycle line.	.5
15. Glove hand to:	.2
16. Seat hopper to line	.2
17. Open valve in recycle line.	.2
18. Wait	.1
19. Repeat elements 3 through 7 and 9 through 18	3.55
20. "	3.55
21. "	3.55
22. "	3.55
23. Repeat elements 3 through 7 and 9 through 16	3.25
24. Use vise grip, close + 6 fraction valve	.3

Total Cycle (all working) 21.9 Minutes

BALL MILL - 16 fraction

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Glove hand to:	.2
3. Open valve in recycle line.	.2
4. Ratchet, open -16 fraction valve.	.3
5. Toggle switch - vibrator to:	
6. ON	.1
7. Wait	.2
8. OFF	.1
9. Ratchet, close -16 fraction valve.	.3
10. Glove hand to:	.2
11. Close valve in recycle line.	.2
12. Raise recycle hopper to top of cubicle.	.7
13. Walk up to second level.	.25
14. Glove hand and,	.2
15. Seat hopper to flange	.1
16. Ratchet, position valve to Ball Mill	.3
17. Glove hands to:	.5
18. Position Ball Mill Barrel (BMB) for loading	.2
19. Hook fill line to BMB.	.1
20. Use vise grip, open BMB valve.	.3
21. Use vise grip, open hopper valve.	.3
22. Toggle switch - vibrator to:	
23. ON	.1
24. Wait	.1
25. OFF	.1
26. Glove hands and,	.5
27. Use vise grip, close hopper valve.	.3
28. Disconnect feedline.	.1
29. Use vise grip, close BMB valve.	.3

BALL MILL - 16 fraction

<u>Element</u>	<u>Time (minutes)</u>
30. Position BMB to Rollers.	.3
31. Remove hands from gloves and set electric timer for 2 hours - 15 minutes.	.4
32. Toggle switch rollers to ON	.1
33. Walk to first level.	.2
Wait out Ball Milling Operation (2 hrs. - 15 min.)	135. *
34. Go to work center.	.1
35. Walk to second level.	.25
36. Toggle switch rollers to OFF	.1
37. Glove hands, and	.5
38. Invert BMB to line	.2
39. Use vise grip, open BMB valve	.3
40. Vigorously rock BMB, remove hands from gloves	1.2
41. Walk to first level.	.2
<hr/>	
Total Cycle	145.2 Minutes
Working	10.2
Non-Working	135.0 *

BALL MILL -6/+16 fraction

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center	0.1
2. Lower recycle hopper to sample outlet	.5
3. Glove hand and,	.2
4. Use vise grip and position valve to SAMPLE.	.3
5. Turn Auto Weight Control Line Switch to ON.	.1
6. Toggle switch, -6/+16 ON	
7. Push FILL button	
8. Wait	
9. Push DUMP button	
10. Toggle switch, -6/+16 OFF	.25
11. Repeat elements 6 through 10	.25
12. "	.25
13. "	.25
14. "	.25
15. "	.25
16. "	.25
17. "	.25
18. Turn Auto Weight Control Line Switch to OFF	.1
19. Glove hand and,	.2
20. Use vise grip and position valve to BLENDER	.3
21. Do elements 12 through 33 of routine No. 5	5.45
(Wait out Ball Milling Operation 7 hours)	420.
22. Do elements 34 through 41 of routine No. 5	2.85
Total Cycle	432.10 Minutes
Working	12.1
Non-Working	420. *

BLENDER AND TRANSFER BOTTLE LOADING

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Glove hand, to:	.2
3. Rotate Blender to loading position.	.1
4. Set top seal to Blender.	.1
5. Glove hand, and	.2
6. Use vise grip and open Blender valve.	.3
7. Use vise grip and set sample valve to BLENDER	.3
8. Turn Auto Weight Control Line Switch ON	.1
9. Toggle switch, -6/+16 ON	
10. Push FILL button.	
11. Wait	
12. Push DUMP button.	
13. Toggle switch, -6/+16 OFF	.25
14. Toggle switch, Fines ON	
15. Push FILL button	
16. Wait	
17. Push DUMP button	
18. Toggle switch, Fines OFF	.25
19. Toggle switch vibrator ON	.1
20. Toggle switch vibrator OFF after 10 seconds	.2
22. Glove hand, and	.2
23. Use vise grip to close Blender valve.	.3
24. Unseat top seal from Blender.	.1
25. Toggle switch, Blender ON.	.1
26. Wait out Blender cycles (5 minutes)	5.0

While waiting out 5 minute blending cycle,
 using manipulator, move full T-bottle from
 below blender to scale; empty T-bottle from
 scale to below blender. Also weigh and record
 both full and empty T-bottles. (2 minutes working
 cycle; 3 minutes non-working cycle) *

BLENDER AND TRANSFER BOTTLE LOADING (contd)

<u>Element</u>	<u>Time (minutes)</u>
27. Go to work center	0.1
28. Toggle switch, Blender OFF	.1
29. Glove hand, to:	.2
30. Rotate Blender to dump position	.1
31. Use vise grip and position T-bottle to Blender	.3
32. Use vise grip and seat lower seal	.3
33. Use vise grip and open Blender valve	.3
34. Use mallet and jar blender thoroughly.	1.0
35. Use vise grip and close Blender valve.	.3
36. Use vise grip and unseat lower seal	.3
37. Use vise grip and lower T-bottle from Blender	.3
<hr/>	
Total Cycle	11.2 minutes
Working	8.2
Non-Working	3.0 *

SAMPLE

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Number (2) sample bottles.	.2
3. Cut length of polyethylene tubing for bagging	.2
4. Seal end of tubing (bag)	.3
5. Load sample bottles into bag.	.1
6. Remove "O" ring.	.1
7. Work down old bag, position new bag and "O" ring to port.	.2
8. Glove hands, to:	.5
9. Remove and deck old bag.	.2
10. Shelve sample bottles near Sample valve	.2
11. Use vise grip and position valve to SAMPLE	.3
12. Position bottle to Sample outlet.	.1
13. Remove one hand from glove.	.2
14. Toggle switch, -6/+16 ON	
15. Push FILL button.	
16. Wait.	
17. Push DUMP button.	
18. Toggle switch, -6/+16 OFF	.2
19. Aside bottle.	.05
20. Position second sample bottle to Sample outlet.	.1
21. Toggle switch, Fines ON.	
22. Push FILL button.	
23. Wait.	
24. Push DUMP button.	
25. Toggle switch, Fines OFF.	.2
26. Aside second bottle.	.05
27. Use vise grip and position Sample valve to Blender	.3

SAMPLE (Continued)

<u>Element</u>	<u>Time (minutes)</u>
28. Load sample bottles into bag.	.4
29. Seal bag with help of another technician ^I	1.0
	<hr/>
Total Cycle (all working)	5.0 minutes

^I Note that another technician is required for 1 minute to complete this routine (see sub-routine 9). A smaller portable sealing unit formerly used perhaps did not require the assistance of a second technician.

SEAL SAMPLES

<u>Element</u>	<u>Time (minutes)</u>
1. Assist another technician to seal samples (see sub-routine 8, element 29)	1.

DISPOSE OF OLD BAG

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Load old bag into new bag	.4
3. Seal bag with help of another technician ^I	1.0
4. Move out old bag to entrance to cell 4 and return to first level.	.6
<hr/>	
Total Cycle (all working)	2.1 minutes

^I Note that another technician is required for 1 minute to complete this routine (see sub-routine 11). A smaller portable sealing unit formerly used perhaps did not require the assistance of a second technician.

SEAL OLD BAG

<u>Element</u>	<u>Time (minutes)</u>
1. Assist another technician to seal old bag (see sub-routine 10, element 3).	1.

COMPACTING

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.1
2. Glove hands, to:	.5
3. Raise rider rod and secure to zero position.	.1
4. Use T wrench and back off hold-down nut	.5
5. Use vise grip and open iris valve and lock.	.15
6. Lift rod clear of iris and compactor.	.1
7. Remove and aside feed tube adapter assembly.	.1
8. Remove and aside hold-down nut and split ferrule	.55
9. Scale depth to top of fuel bed.	.1
10. Assemble wood plug to open end of rod (including taping).	.2
11. Transfer plugged rod into welding wall.	.1
12. Remove gloves.	.2
13. Make data entries (feed and vibration times, d/m count, depth).	.3
14. Glove hands, to:	.5
15. Remove rod from dumb waiter.	.1
16. Assemble hold-down nut and split ferrule to rod.	.4
17. Assemble feed-tube adapter to rod.	.1
18. Insert rod through iris and seat firmly to feeder tube.	.2
19. Use vise grip and lock iris valve to rod	.15
20. Use T wrench and firmly secure hold-down nut to compactor adapter.	.7
21. Unglove hand.	.2
22. Start compactor (open pneumatic valve)	.1
23. Turn on feeder-vibrator (Syntron) and adjust to an approximate six minute feed rate.	.15
24. Feed powder into rod.	6. *

COMPACTING (contd)

<u>Element</u>	<u>Time (minutes)</u>
25. ¹ Stop feed-vibrator and continue compactor operation for an additional 5 minutes.	5.0 *
26. Close compactor valve	.1
	<hr/>
Total Cycle	16.7 minutes
² Working	7.5
² Non-working	9.2 *

¹ This cycle at present varies and often takes over five minutes due to trouble with compactor and incomplete understanding of compacting operation.

² Note that during last 5 minutes of compacting the following is accomplished:

25a Transfer full T-bottle from scale to radiation reading point.	.3
25b Transfer empty T-bottle from feeding position to scale.	.7
25c Read radiation scale.	.1
25d Transfer full T-bottle from radiation reading point to feeding position.	.7
	<hr/>
	1.8 minutes

TRANSFER PLUGGED ROD FOR SCANNING

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.2
2. Glove hand and grasp manipulator, to:	.2
3. Pass plugged rod from welding to	.1
4. scanner wall.	
5. Glove hand and grasp manipulator, to:	.2
6. Transfer rod from scanner wall	.2
to deck of cubicle	
Total Cycle (all working)	<hr/> .9 minutes

SCANNER CHECK (Gamma Densitometer)

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.2
2. Open chart door wider, throw chart toggle to ON, nearly close chart door, and dress chart through opening in door.	.3
3. Glove hand, to:	.2
4. Load <u>Standard</u> rod for scanning	.15
5. Slowly hand feed <u>Standard</u> to right, charting the 89 percent density section.	.6
6. Slowly continue hand feeding <u>Standard</u> to right, charting the 87 percent density section.	.6
7. Back out <u>Standard</u> and aside to deck of scanner cubicle.	.15
8. Remove hand from glove.	.1
9. Glove hand, to:	.2
10. Pick up plugged fuel rod from deck and load in traverse for scanning.	.2
11. Traverse toggle, to CCW (power feeding rod through scanning point).	.05
12. Chart toggle, to ON.	.05
13. Set dial to 46 (adjusting traverse speed to 8"/minute)	.1
14. ^I Scan rod (completed traverse stops automatically)	5.4 *
15. Go to center.	.1
16. Chart toggle, to OFF	.05
17. Traverse toggle, to CW; set dial to maximum (completed return - traverse stops automatically)	.1
18. Check chart for acceptable scan and tear charted run from roll.	.3

SCANNER CHECK (Gamma Densitometer) (Continued)

<u>Element</u>	<u>Time (minutes)</u>
19. Roll up charted section, tape, and store	.4
20. Glove hand, to:	.2
21. Remove scanned rod from scanner and transfer rod to cleaner wall	.35
<hr/>	
Total Cycle	9.8 minutes
Working	4.6
I Non-working	5.2 *
I While scanning, add to chart 89%, 87%, and rod number	.2 minutes

WELDING

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center	0.2
2. Glove hand, to:	.2
3. Assemble plug assembly to rod and load into fixture.	.15
4. Right fixture and latch, remove hand from glove.	.2
5. Raise rod into Bell Jar (BJ)	1.0
6. Evacuate BJ to 200 microns	5.5 Average *
<u>Meanwhile:</u>	
6a. Glove hand and transfer rod from scanner wall to welding wall.	.4
6b. Glove hands and remove tape and wood plug.	.7
6c. Wire brush O.D., I.D., and aside rod.	.9
6d. Seat end plug into rod in BJ	1.6
7. Purge BJ with helium.	.6
8. Evacuate BJ to 150 microns	4.4 Average *
<u>Meanwhile:</u>	
8a. Raise ram to clear torch.	1.3
8b. Position torch for welding.	1.0
9. Pressure atmosphere with helium and argon.	.6
10. Weld.	.5
11. Lower welded fuel rod (glove hand during last two minutes of cycle).	1.0
12. Remove rod and check with magnifying glass.	.3
13. Gage rod.	.35
14. File rod.	.3
15. Aside rod into cleaning wall. Remove hand from glove.	.2
<hr/>	
Total Cycle	15.5 Minutes
Working	11.5
Non-Working	4.0 *

ULTRASONIC CLEANING
(5 Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u>	
	<u>Manual</u>	<u>Automatic</u>
1. Go to work center.	0.2	0.2
2. Prepare Turco for vat.	1.0	1.0
3. Fill cleaning vat.	1.0	.05
Wait for fill.		.9*
4. Glove hand, open vat, and load rod to vat from welding wall.	.4	.35
5. Go to work center.	.2	.2
6. Glove hand and load rod to vat from welding wall.	.35	.35
7. Repeat 5 and 6.	.55	.55
8. Repeat 5 and 6.	.55	.55
9. Repeat 5 and 6 and close vat.	.60	.55
10. Turn knob to CLEAN (manual - also valve)	.1	.05
11. Ultrasonic Cleaning (Manual - soak only)	3.0*	3.0*
12. Go to work center.	.2	.2
13. Turn knob to drain (manual - also valves)	1.0	.05
Wait for drain.		.9*
14. Glove hand, open vat, load rod between centers, close vat.	.45	.4
15. Turn knob to SPRAY	.05	.05
16. Spray	1.5*	1.5*
17. Go to work center	.2	.2
18. Turn knob to DRY	.05	.05
19. Dry	3.0*	3.0*
20. Go to work center	.2	.2
21. Glove, hand, open vat, move rod to scanner wall.	.45	.4
22. Go to work center.	.2	.2
23. Repeat 14 through 22.	4.5* + 1.6	4.5* + 1.5
24. Repeat 14 through 22.	4.5* + 1.6	4.5* + 1.5

ULTRASONIC CLEANING (Contd)

<u>Element</u>	<u>Time (minutes)</u>	
	<u>Manual</u>	<u>Automatic</u>
25. Repeat 14 through 22.	4.5* + 1.6	4.5* + 1.5
26. Repeat 14 through 21.	4.5* + 1.4	4.5* + 1.3
Total Cycle	<hr/> 39.45	<hr/> 38.7
Working	13.95	11.4
Non-Working	25.5*	27.3*

For One Rod Only, Average:

Total Cycle	7.89	7.74
Working	2.79	2.28
Non-Working	5.10	5.46

NOTE: Observations made only on manual.

DRY, LEAK TEST, AND WEIGH
(5 Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.2
2. Glove hand and grasp manipulator, to:	.2
Move rod from cleaning to leak test area.	.5
3. Glove hands, to:	.5
4. *Wipe rod dry with cleaning pad.	.3
5. Remove lid from test chamber, load rod, replace lid.	.15
6. Remove gloves from hands.	.2
7. Repeat 1 through 6.	2.05
8. Repeat 1 through 6.	2.05
9. Repeat 1 through 6.	2.05
10. Repeat 1 through 6.	2.05
Bring in cleaning pads to cubicle (Turco Cleaning)	
Remove used cleaning pads from cubicle (Remove and	
Dispose of Used Pads).	-
11. Open valve to pumpdown test chamber	.2
12. Pump down to 20 X 1 scale reading	2.8*
13. Go to work center.	.2
14. Check out pressure with scale readings.	.1
15. Pressure test chamber with nitrogen.	.4
16. Glove hand, to:	.2
17. Remove chamber lid, remove rod and aside to scale	.2
18. Weigh rod and aside; replace lid; record data	.55
19. "	.55
20. "	.55
21. "	.55
22. "	.55
23. Transfer all data to Rod Fabrication Data Sheet	1.0
(Rod wt, net weight, leak test scale reading, and	
check off test vacuum).	

DRY, LEAK TEST, AND WEIGH (Contd)
(5 Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u>
24. Scotch tape sheet to cubicle for data recording	.2
<hr/>	
Total Cycle	18.3
Working	15.5
Non-working	2.8

*Pads already in cubicle - see Turco Cleaning, Sub-Routine 18.

TURCO CLEANING
(10 Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.2
2. Batch prepare Turco solution.	1.0
3. Load prepared cleaning pads through cold port (sub-routine).	3.5
4. Gloved hands, remove cover, get wet and dry pads from cold area below cubicle and replace cover.	.7
5. Get rod and wash, aside wet pad.	.25
6. Get dry pad and dry rod; aside pad and rod.	.20
7. Get another rod and wash with other side of wet pads, aside pads.	.25
8. Get dry pad and dry rod with other side of dry pad, aside pads.	.20
9. Repeat 4, 5, 6, 7, and 8.	1.10
10. "	1.10
11. "	1.10
12. "	1.10
<hr/>	
Total Cycle (all working)	10.7 minutes

For one rod only, average 1.07 minutes.

NOTE: Used cleaning pads disposed of by a separate routine.

Sub-Routine: *Get (12) pads to center and remove jackets	2.0
Saturate 5 pads with Turco solution	1.0
Dry hands	.2
Put (5) wet and (7) dry pads into cold area below cubicle	.3
<hr/>	
	3.5 minutes

*Two pads used in Dry, Leak Test, and Weigh, Sub-Routine 17.

SMEAR

10 - Rod Cycle

<u>Element</u>	<u>Time (minutes)</u> <u>(Smear Man)</u>	<u>Time (minutes)</u> <u>(Cubicle Man)</u>
1. Go to work center.	0.2	0.2
2a Glove hands in cubicle		.5
2b Move smear discs to center	0.2	
2c Glove hand with disposable glove	.3	
2d Pick up rod and read out rod number		.15
2e Wait to get rod number	.15 *	
3a Record number on smear disc.	.1	
3b Passes hand with smear disc into cubicle	.15	
3c Hold rod, waiting to smear		.25
4a Rotate and hand feed rod through cupped smear disc and back out.		.15
4b Hold disc to rod for smear	.15	
5a Remove disc from cubicle and aside	.1	
5b Pick up another rod and read out number.		.15
5c Wait to get rod number	.05 *	
6a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
7a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
8a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
9a Repeat 3, 4, and 5	.5	.25
	.05 *	.30

SMEAR (contd)

Element	<u>Time (minutes)</u>	<u>Time (minutes)</u>
	<u>(Smear Man)</u>	<u>(Cubicle Man)</u>
10. Repeat 3, 4, and 5	.5	.25
	.05 *	.30
11a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
12a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
13a Repeat 3, 4, and 5	.5	.25
	.05 *	.30
14a Repeat 3 and 4	.4	.25
14b Repeat 5b		.15
15a Remove disc from cubicle and aside	.1	
16 Go to cell 4 entrance with smears	.4	
17 Check self through radiation	.2	
18 Check radiation instrument	.1	
19 Check smears through radiation and dispose of smears	1.0	
20 Return to first level	.4	
<hr/>		
Total Cycle	8.40	6.20
Working	7.80	6.20
Non-Working	.60 *	-
For one rod (average):		
Total Cycle	.84	.62
Working	.78	.62
Non-Working	.06 *	-

ASSEMBLE HANGER AND LOAD IN CARRIER

(10 - Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u> <u>(Hanger Man)</u>	<u>Time (Minutes)</u> <u>(Carrier Man)</u>
1a Go to work center.	0.2	0.2
1b Load cold area below cubicle with 10 hangers		1.0
1c Gloves hands in cubicle	.5	
1d Wait for hangers	.5 *	
2a Get hanger from cold area	.2	
2b Assemble hanger to rod	.2	
2c Read out rod number	.05	
2d Wait for rod		.45 *
3a Record rod number		.05
3b Hand rod through wall to carrier man	.1	
3c Get manipulator and move it to rod		.15
3d Wait for Carrier Man to grasp	.10	
4a Get rod with manipulator		.10
4b Hold rod for firm grasp by Carrier man	.10	
5a Position rod to first tube sheet		.3
5b Position rod to second tube sheet		.6
5c Seat rod in magazine		.3
5d Wait for Carrier man	.75 *	
5e Get hanger from cold area	.2	
5f Assemble hanger to rod	.2	
5g Read off rod number	.05	
6 Repeat 3, 4, 5, paying only .2 for 5b .35 for 5D	.75 + .35 *	1.1

ASSEMBLE HANGER AND LOAD IN CARRIER (contd)

(10 - Rod Cycle)

<u>Element</u>		<u>Time (Minutes)</u>	<u>Time (Minutes)</u>
		<u>(Hanger Man)</u>	<u>(Carrier Man)</u>
7	Repeat 6	.75 + .35 *	1.1
8	Repeat 6	.75 + .35 *	1.1
9	Repeat 6	.75 + .35 *	1.1
10	Repeat 3, 4, and 5.	.75 + .75 *	1.5
11.	Repeat 6	.75 + .35 *	1.1
12.	Repeat 6	.75 + .35 *	1.1
13.	Repeat 6	.75 + .35 *	1.1
14.	Repeat 3,4, 5a, 5b (.2), 5c, 5e, 5f, 5g	.75	1.1
Total Cycle		13.1 Minutes	13.45 Minutes
Working		8.65	13.
Non-Working		4.45 *	.45 *

For one rod (average):

Total Cycle	1.31	1.35
Working	.87	1.3
Non-Working	.44	.05

MARK, WEIGH, AND RECORD EMPTY ROD

(5 - Rod Cycle)

<u>Element</u>	<u>Time (minutes)</u>
1. Go to work center.	0.2
2. Pick up rod and electric tool and number one end.	.70
3. Number other end and aside rod and tool.	.75
4. Record weld number and all rod numbers.	.35
5. Repeat 2 and 3	1.45
6. Record weld number opposite rod number.	.1
7. Repeat 2, 3, and 6.	1.55
8. Repeat 2, 3, and 6.	1.55
9. Repeat 2, 3, and 6.	1.55
10. Remove cardboard sleeves from rod; discard sleeves	.4
11. Walk up from first level to scales on third level.	.7
12. Weigh rod and record	.6
13. Repeat 12	.5
14. Repeat 12	.5
15. Repeat 12	.5
16. Repeat 12	.5
17. Walk down to second level and port	.5
18. Tear open port, pass rods through, and reseal port with masking tape.	.8
19. Glove hands, load rods in dumb waiter and lower to first level.	.7
20. Walk to first level and Rod Data Sheet	.3
21. Transfer all data to Rod Data Sheet	.8

 Total Cycle (all working) 15.0 minutes

For one rod (average): 3.0 minutes

3-PIECE ROD END ASSEMBLY

<u>Element</u>	<u>Time (minutes)</u>
1. Set up work center for assembling 20 3-piece ROD ENDS.	1.2
2. Make 3-piece assembly.	.15
3. Repeat 19 times (.15 each $\times$ 19)	2.85
4. Position assemblies in welding chamber; aside extra pieces.	1.8
<hr/>	
Total Cycle (all working)	6.0 Minutes

REMOVE AND DISPOSE OF USED CLEANING PADS

<u>Element</u>	<u>Time (minutes)</u>
1. Make bag from polyethylene tubing.	2.0
2. Assemble bag to cold port.	1.0
3. Remove used pads to bag.	5.0
4. Remove bag from port and tape seal.	1.0
5. Dispose of bag at cell entrance and return to first level.	1.0

Total Cycle (All working) 10.0 minutes

Average per rod: 0.2 minutes

Total time to take care of:

50 pads used in Turco Cleaning, Sub-Routine 18, of 50 rods.

10 pads used in Dry, Leak Test, and Weigh Sub-Routine 17, for the same 50 rods.

LOAD OUT SHIPPING CASK

<u>Element</u>	<u>Time (minutes)</u>
Remove two (2) turnbuckles from cask and cubicle wall.	
Back out end plug from cask blind flange.	
With T-wrench, pull loaded magazine into cask.	
Replace end plug.	
Back rail truck with cask to clear cubicle wall.	
Close cubicle wall with pivoted dis, securing disk to wall with bolt.	
Use 1/2 ton hand crane and lower blind glange to cask opening.	
Secure blind flange to cask with 11 1/2" cap screws.	
Remove eye bolt from blind flange.	
Back rail truck with cask below hatch opening.	
Position sling to cask and large hoist.	
Assist hoist in removing loaded cask from rail truck.	

NOTE: Total net technician time could be as little as 18 minutes.
 Since routine is infrequent and requires two men on several elements, a total of 21 minutes is given.

Total Cycle (all working) - one man	12 Minutes
- other man	9 Minutes

APPENDIX B

Crew Time Calculations

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CREW TIME CALCULATIONS

Daily time, calendar and work, on subroutine cycle basis:

$$\frac{\text{Crew minutes}}{\text{Day}} = \frac{\text{minutes}^1}{\text{Rod}} \times \frac{\text{rods}}{\text{Day}} \times \frac{\text{crew}^2}{3.5}$$

$$\text{for: } 7\text{-Rod Day} = 89.22 \times 7 \times \frac{1}{3.5} = 178.4 \text{ minutes, calendar, "0", overall time}$$

$$= 53.18 \times 7 \times \frac{1}{3.5} = 106.4 \text{ minutes, work}$$

$$10\text{-Rod Day} = 88.71 \times 10 \times \frac{1}{3.5} = 253.5 \text{ minutes, calendar, "0", overall time}$$

$$= 52.67 \times 10 \times \frac{1}{3.5} = 150.5 \text{ minutes, work}$$

$$15\text{-Rod Day} = 88.31 \times 15 \times \frac{1}{3.5} = 378.5 \text{ minutes, calendar, "0" overall time}$$

$$= 52.27 \times 15 \times \frac{1}{3.5} = 224. \text{ minutes, work}$$

Daily time, calendar and work, on rod schedule basis:

$$\frac{\text{Crew minutes}}{\text{Day}} = \frac{\text{minutes}^3}{\text{day}} \times \frac{\text{crew}^2}{3.5}$$

$$\text{for: } 7\text{-Rod Day} = 656.4 \times \frac{1}{3.5} = 187.5 \text{ minutes, calendar}$$

$$= 441.2 \times \frac{1}{3.5} = 126.1 \text{ minutes, work}$$

$$10\text{-Rod Day} = 964.2 \times \frac{1}{3.5} = 275.5 \text{ minutes, calendar}$$

$$= 549.5 \times \frac{1}{3.5} = 157. \text{ minutes, work}$$

CREW TIME CALCULATIONS (Contd)

$$\begin{aligned}\text{for: 15-Rod Day} &= 1398.8 \times \frac{1}{3.5} = 399.7 \text{ minutes, calendar} \\ &= 840.8 \times \frac{1}{3.5} = 240.2 \text{ minutes, work}\end{aligned}$$

¹ From Figure 1, per rod totals for selected rod schedule.

² Crew size is 3.5, counting S (working supervisor) as 1/2 technician.

³ From Figure 1, daily time totals for selected rod schedule.

EFFECTIVENESS CALCULATIONS FOR ESTABLISHING FIGURE 6

7-Rod Day

Maximum required routine *8.35 days

120 rods/7 rods per day = 17.14 available days for cask (120 rod) load.

$$\frac{8.35 \text{ days of routine}}{17.14 \text{ days available}} \times 100 = 48.7 \text{ percent, maximum effectiveness for } 17.14 \text{ days 120 rod cycle.}$$

10-Rod Day

Maximum required routine *7.62 days

120 rods/10 rods per day = 12. available days for cask (120 rod) load.

$$\frac{7.62 \text{ days of routine}}{12 \text{ days available}} \times 100 = 63.5 \text{ percent, maximum effectiveness for } 12 \text{ days 120 rod cycle.}$$

15-Rod Day

Maximum required routine *7.74 days

120 rods/15 rods per day = 8. available days for cask (120 rod) load.

$$\frac{7.74 \text{ days of routine}}{8 \text{ days available}} \times 100 = 96.8 \text{ percent, maximum effectiveness for } 8 \text{ days 120 rod cycle.}$$

15.5-Rod Day

Maximum required routine *7.74 days

120 rods/15.5 rods per day = 7.74 available days for cask (120 rod) load.

$$\frac{7.74 \text{ days of routine}}{7.74 \text{ days available}} \times 100 = 100 \text{ percent, maximum effectiveness for } 7.74 \text{ days 120 rod cycle.}$$

* 7-Rod Day - routine requires ¹ 630.92 minutes,

$$\text{or } 630.92 \times \frac{120 \text{ rods/cask}}{7} = 10,816 \text{ minutes per cask (less entries } 1, 2, 26, \text{ \& } 27.$$

$$\text{routines } 1, 2, 26, \text{ \& } 27 = 42, \times 1.18 \text{ delay} = 50 \text{ minutes for } 1, 2, 26, \text{ \& } 27.$$

Total routine load = 10,866 minutes per cask

$$10,866/1302 \text{ available crew min. per day} = 8.35 \text{ days, max. required routine.}$$

EFFECTIVENESS CALCULATIONS FOR ESTABLISHING FIGURE 6 (contd)

*10-Rod Day - routine requires ¹ 823.01 minutes,
 or $823.01 \times \frac{120}{10} = 9,876$
 $= \frac{50}{10}$
 $= 9,926$ minutes per cask
 $9,926/1302 = 7.62$ days, maximum required routine.

*15-Rod Day - routine requires ¹ 1253.45 minutes
 or $1253.45 \times \frac{120}{15} = 10,028$
 $= \frac{50}{15}$
 $= 10,078$ minutes per cask
 $10,078/1302 = 7.74$ days, maximum required routine.

¹ Summation of routine time taken from Figure 2, 3, 4 and 5 for crew:
 $169.69 + 171.6 + 202.1 + 87.53 = 630.92$ minutes for 7-Rod schedule
 $218.71 + 226.2 + 258.8 + 119.3 = 823.01$ minutes for 10-Rod schedule
 $348.5 + 341.4 + 377.4 + 186.15 = 1253.45$ minutes for 15-Rod schedule

APPENDIX C

Special Personal Allowance Breakdown

SPECIAL PERSONAL ALLOWANCE

	<u>Routines</u> ¹	<u>Minutes Required</u>
Reporting to Work	A	4.5
Two cigarette breaks	B x 2	6.
Two personal breaks	C x 2	9.
Two coffee breaks	D x 2	17.
Lunch	D x 1	8.5
Leaving work	E x 1	12.
		<hr/>
		57. Minutes,
		allowed 60

¹ <u>Routine</u>	<u>Minutes</u>
A Get into radiation clothing; go to cell entrance vestibule; put on shoe covers; descend to first level.	4.5
B Ascend to cell vestibule; go through radiation check; wash hands; replace shoe covers; return to first level.	3.0
C Ascend to cell vestibule; go through radiation check; go to wash room; wash hands; return to cell vestibule; replace shoe covers; return to first level.	4.5
D Ascend to cell vestibule; go through radiation check; go to wash room; wash hands; go to lunch room, through radiation check; return to cell vestibule; replace shoe covers; return to first level.	8.5
E Ascend to cell vestibule; go through radiation check; go to wash room; strip off clothing, properly dispose of radiation clothing; shower, redress into personal clothing.	12.

Special personal allowed due to work area being remote and radiation controlled. This is in addition to the allowed daily normal personal (48 minutes for personal and fatigue).

APPENDIX D

Ball Milling Frequency

Frequency Of Ball Milling -16 And -6/+16 Fractions

Fuel for rods must be approximately 45 percent fines and 55 percent -6/+16 fractions. The 10 kgs. of crystals processed through crusher and recycle renders approximately 6.8 kgs. of -6/+16 and 3.2 kgs. of -16 fractions.

After each recycle, the 3.2 kgs. of -16 fraction is converted by Ball Milling into fines. After every third recycle, an additional Ball Milling operation is made to convert 4 kgs. of -6/+16 fractions into fines.

The 3 each of Crusher, Recycle, and -16 fraction Ball Milling plus the one -6/+16 fraction Ball Milling renders approximately 13.6 kgs. of fines and 16.4 kgs. of -6/+16 fractions giving the proper proportion (45:55) of fines and -6/+16 fractions.

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