MASTER

ABSTRACTCALCULATED INVENTORY DIFFERENCES - A POTENTIAL
SAFEGUARDS AND MATERIAL CONTROL TECHNIQUE

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by

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For Presentation at the Institute of Nuclear Materials Management
Twelfth Annual Meeting
June 29-July 1, 1971
Palm Beach Shores, Florida

Work Performed Under
Contract No. AT(30-1)-68
Between the Atomic Energy Commission and the General Electric Company

General Electric Company
Breeder Reactor Development Operation
Pleasanton, California

CALCULATED INVENTORY DIFFERENCES - A POTENTIAL
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The use of Calculated Inventory Differences as a potential material control measure has been tested at the General Electric Vallecitos Plutonium Laboratory as part of the Integrated Safeguards Experiment. (1) During the fabrication of 48 mixed oxide (urania and plutonia) fuel rods (2) material balances around individual process stations were calculated based on weights of materials transferred in and out of the system. Since the fabrication program was conducted in a series of process campaigns for individual fuel enrichments, it was possible to clean all processing equipment between enrichment levels and calculate material balances for each process station. The amount of material calculated to be remaining in the individual process stations after the between-enrichment clean-outs is termed the Calculated Inventory Difference. The oxide weight of material transferred in and out of each process station was used for one set of material balance calculations, while the "SS weight" (metal weight of material after correcting for oxygen and moisture) was used for a second set.

The resulting Calculated Inventory Differences for individual process stations were -0.6 to 2.1 percent for oxide and -0.6 to 1.0 percent for metal (uranium plus plutonium). The sum of the Calculated Inventory Differences was consistent with the overall balances obtained for the fabrication line. A total throughput of 139.9 kg of oxide (or 121.1 kg metal) was processed during the test.

While the Calculated Inventory Differences were observed to vary greatly from process station to process station, they were reasonably consistent for individual process stations over several process batches. Thus, routine calculation of material balances based on weight offers the fuel fabricator a potentially useful tool for monitoring his materials accountability system and detecting unusual losses or diversion in a timely manner.

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- (1) The Integrated Safeguards Experiment program is sponsored by USAEC Office of Safeguards and Materials Management. Technical administration is provided by Brookhaven National Laboratory - Technical Support Organization with technical assistance provided by the National Bureau of Standards.
 - (2) The fuel rods were fabricated under the joint General Electric Company-Edison Electrical Institute program on the Utilization of Plutonium in Boiling Water Reactors - Phase II.

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ABSTRACT

The use of Calculated Inventory Differences as a potential material control measure has been tested at the General Electric Vallecitos Plutonium Laboratory as part of the Integrated Safeguards Experiment. During the fabrication of 48 mixed oxide (uranium and plutonium) fuel rods material balances around individual process stations were calculated based on weights of materials transferred in and out of the system. Since the fabrication program was conducted in a series of process campaigns for individual fuel enrichments, it was possible to clean all processing equipment between enrichment levels and calculate material balances for each process station. The amount of material calculated to be remaining in the individual process stations after the between-enrichment clean-outs is termed the Calculated Inventory Difference. The oxide weight of material transferred in and out of each process station was used for one set of material balance calculations, while the "SS weight" (metal weight of material after correcting for oxygen and moisture) was used for a second set.

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While the Calculated Inventory Differences were observed to vary greatly from process station to process station, they were reasonably consistent for individual process stations over several process blends. Thus, routine calculation of material balances based on weight offers the fuel fabricator a potentially useful tool for monitoring his material accountability system and detecting unusual losses or diversion in a timely manner.

INTRODUCTION AND SUMMARY

The Calculated Inventory Difference is a simple material balance method that is potentially useful for measuring the effectiveness of safeguards control systems on nuclear material. The method was recently demonstrated under the AEC's Integrated Safeguards Experiment* conducted at General Electric's Plutonium Laboratory. The purpose of the Integrated Safeguards Experiment was to study the effects of safeguards control of material balances based completely on measurements. Previous work by Brookhaven⁽¹⁾ indicated that safeguards controls were most effective when applied at the unit process level at frequent intervals. The unit processes of a plutonium facility are arranged in glove boxes which are periodically emptied between enrichments. A 48 rod mixed oxide fuel fabrication campaign was selected for study. Careful material balances around individual unit operations were made for two difference enrichments using only the weight of material transferred in and out of each unit process. The Calculated Inventory Difference can be used as a safeguards control index which is simple to calculate yet effective for monitoring unusual process losses and sensitive to a wide variety of control parameters. The method is simple to administer, requires no special equipment, and responds quickly to shifts in accounting capability.

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DESCRIPTION OF THE PROCESS

Fuel fabrication was accomplished at the General Electric Company's Plutonium Laboratory located near Pleasanton, California during the fabrication of 48 urania-plutonia fuel rods for the Edison Electric Institute Program on the Utilization of Plutonium in Boiling Water Reactors-Phase II. In the GE facility, a unit process is generally performed in an isolated alpha enclosure known as a glove box.

In the process studied, fissionable material moves from one unit process to another under a blend control system. This means that a quantity of material defined in the powder blending step is given a unique name and this blend becomes the accountable item throughout the entire process. The process consists of physically mixing plutonia and urania powders in the necessary quantities, pressing this material into pellets, firing the pellets in a reducing atmosphere, inspecting the pellets for conformance to specifications, and rod loading. Throughout the process, the material is measured on a weight basis at the completion of each step. Because of oxygen and moisture in the powder, the weight is not in itself descriptive of the nuclear material being transferred and samples are withdrawn at various stages of the fabrication process to determine the composition by chemical analysis. The isotopic composition of the metal in the plutonia-urania mixture is assumed to be constant, but the oxygen, the chemical composition, and the metallic impurity content are affected during processing in both a random and systematic manner.

At the beginning and end of each unique enrichment campaign, all process equipment, prefilter systems, and the interior surfaces of each box were cleaned as thoroughly as possible. Material balances based on the measured weight of oxide moved into and out of each box were then calculated.

Since mixed oxide is not stoichiometric, the oxygen-to-metal ratio (O/M) can vary from a low of perhaps 1.98 to as high as 2.20. In addition, the moisture content and other volatiles may vary as much as two percent. The O/M is reduced and the moisture is driven off during the sintering operation. As a result, a significant weight change occurs which does not represent a true loss of metal.

During the ISE experiment, the O/M and moisture content were measured at various process stages using a thermogravimetric method⁽²⁾. As a result of these measurements, a second set of material balances were calculated on metal weight basis. The difference between these two sets of material balances reflects to some degree the volatile and moisture components removed during processing.

During this study, special records were kept of batch identity, the weight of each material transfer, the scale calibrations and adjustments. These records were used to calculate the inventory difference for each enrichment (clean-to-clean) for each unit process.

MATHEMATICAL MODEL

Figure 1 presents the data elements that would be forthcoming from the processing of one enrichment of material broken down into m blends through n unit processes.

Let us assume that each unit process takes the same amount of time, and that as one blend passes through a unit process the next is introduced. At the beginning of time period 1, blend 1 will be measured into Process 1 and at the end of time Period 1, Blend 1 will be measured out of Process 1. Since all of Blend 1 has apparently cleared Process 1, we can calculate an inventory difference (CID) based on the fact that the physical inventory of Blend 1 in Process 1 consists of the holdup in Process 1 and any unmeasured operational losses in Process 1. This is entered in Figure 1 as M_{11} .

At the beginning of Time Period 2, Blend 1 is measured into Process 2 and Blend 2 is measured into Process 1 and the two blends are measured out of their respective processes at the end of the time period. Hence, two more calculated inventory differences are determined M_{12} and M_{21} . In addition, a calculated inventory difference, $\sum_{j=1}^n M_{1j}$ is available.

By the time the whole enrichment is processed (at the end of $m + n$ time periods), there is a calculated inventory difference for each blend, B_j , and a calculated inventory difference for each process, P_j . In addition, a calculated inventory difference for

the whole enrichment exists, E^1 . If at the end of the enrichment some waste or scrap material is removed from any process and this is separately identified and measured an adjustment, h_j , can be made to the process MUF, p_j , resulting in an adjusted calculated inventory difference, P_j , and an adjusted calculated inventory difference, E .

The characteristics of these calculated inventory differences are evident. Assuming unit process losses are negligible each M_{ij} ($i = 2, 3, \dots, m-1$), B_i ($i = 2, 3, \dots, m-1$), and P_j ($j = 1, 2, \dots, n$) will have an expected value close to zero and each M_{mj} and B_m will have a negative value if some attempt is made to move as much of the holdup through the plant as possible prior to the introduction of the next enrichment.

Additional useful parameters come from the $j-1$ values of $\sum_{j=1}^{n-1} M_{ij}$ ($i = 2, 3, \dots, m-1$) and the $m-2$ value of $\sum_{i=2}^{m-1} M_{ij}$ ($j = 1, 2, \dots, n$) ($n = 2, 3, \dots, n$) all of which should have an expectation of zero, on the assumption that the losses are negligible.

A similar argument to the above can be applied between enrichments. The enrichments, like the blends, could also be maintained as calculated inventory differences both across processes and by campaign. When the plant finally cleans out the line, removes filters, etc., a true material balance based on a clean to clean plant can be calculated. This final value is no longer a calculated inventory difference since the physical inventory is now either zero or measured and the adjusted value is the traditional MUF figure.

Referring to Figure 1, we see that each horizontal column represents a blend. When all rows have been completed for an individual column, the blend has been processed and material balances made. The mean value ($\bar{x}$) and the standard deviation (s) of these values can then be calculated. The mean value describes the average gain or loss for the blend. The standard deviation describes how variable one process step is from another. If the total process is in statistical control, one would expect every blend to gain or lose about the same amount of material during processing. In addition one would expect the standard deviation to be centered about some nominal value. One could use subjective judgment and visual inspection of the variation in the mean value from blend to blend to determine if a particular value appeared out of line. In practice, this decision process can be systematized by the use of control chart techniques which are described in many elementary statistical texts. The use of properly set control limits to signify when investigative action should be taken by management will minimize false alarms while retaining the sensitivity to detect significant shifts at the earliest moment.

In Figure 1, the first vertical row represents the Calculated Inventory Difference for each blend processed through Process Step 1. A mean value ($\bar{x}$) and a standard deviation of this mean value (s) for Process 1 can be calculated from these data.

Process 2...n are calculated in a similar manner. For each process,

UNIT PROCESS AREAS

<u>BLENDS</u>	1	2	3	j	n	<u>TOTAL</u>
1	M_{11}	M_{12}	M_{13}	M_{1j}	M_{1n}	$\sum_j M_{1j} = B_1$
2	M_{21}	M_{22}	M_{23}	M_{2j}	M_{2n}	$\sum_j M_{2j} = B_2$
.						
i	M_{i1}	M_{i2}	M_{i3}	M_{ij}	M_{in}	$\sum_j M_{ij} = B_i$
.						
m	M_{m1}	M_{m2}	M_{m3}	M_{mj}	M_{mn}	$\sum_j M_{mj} = B_m$
TOTAL ENRICHMENT	$\sum_i M_{i1} = P_1$	P_2	P_3	P_j	P_n	$\sum_i B_i = \sum_j P_j = E^1$
ADJUSTED ENRICHMENT	$P_1 - h_1 = P_1$	P_2	P_3	P_j	P_n	$\sum_j P_j = E^1 - \sum_j h_j = E$

FIGURE 1

MATRIX OF CALCULATED INVENTORY DIFFERENCES BY PROCESS AREA

The $\bar{x}$ value is an estimate of average gain or loss for that step over the period of study. In like manner, the S value is a measure of the normal statistical variation inherent for that process step. The mean value varies between process steps because of the type of work done in different unit processes. Because of the nature of the work, the Powder Blending step has a higher mean loss value than say, the Pellet Inspection step. By the same reasoning, the loss value for the sintering operation may be unlike any other fabrication step.

EXPERIMENTAL DATA

Appendix A shows the material balances for 5 unit process stations in terms of "net weight". Appendix B shows the same data, expressed as "SS weight". The net weight material balance was obtained by summing individual transfer records of all materials moving into or out of each unit process. At various unit processes, samples were withdrawn and analyzed by thermogravimetric methods to determine the oxygen-to-metal ratio (O/M) and volatile content of the unsintered and sintered mixed oxide. These data are shown in Appendix C.

The following list shows the basis for the SS factor used to convert net weight to SS weight by unit processes.

<u>Unit Process</u>	<u>Basis for SS Factor</u>
37	Unsintered
38	Unsintered
39, 40, 41	Unsintered-In, Sintered-Out
42	Sintered
43	Sintered

To accommodate differences in blend size, all differences were converted to percent of the weight charged into each process step.

Example:

To convert 32401.8 grams of material charged into Box 37 with an unsintered SS factor of .881 to SS weight:

$$\begin{array}{rcl}
 (\text{Net Weight}) & (\text{SS Factor}) & = \text{SS Weight} \\
 (32401.8) & (.881) & = 28545.99
 \end{array}$$

Tables I and II summarize the losses (positive values) and gains (negative values) as percent of SS weight input to each unit process by enrichment and for the entire campaign.

The difference in the mean values for unit processes are shown in Table 1. The overall loss for each enrichment is of the same magnitude. Although the observed enrichment differences for unit processes are not identical, the 3σ control limits based on these data could be used to measure unusual deviations for future blends. The incorporation of additional data will result in better defined control limits.

Table I presents calculated inventory differences as a percentage of the material entering the unit process. Table II presents the absolute calculated inventory differences in grams for each unit process by enrichment. In some cases relative calculated inventory differences are preferable indicators; in other cases, the absolute calculated inventory differences might be preferred.

If the losses (gains) for a process are expected to vary with the amount of material processed then the relative calculations should be used. For processes where the losses (gains) are primarily dependent upon performing the process, they would not vary proportionately to the amount of material processed. Absolute calculations are preferable for processes with these properties.

If percentage calculations are used as the control parameter, certain cautions must be introduced. Sometimes it may become necessary to transfer material from later process stages to earlier ones, perhaps for criticality or process reasons. If this occurs, particularly if the transfers are in sealed cans which are not opened, the quantity of material entering the unit process is increased with no increase in the contribution to calculated inventory difference. Process controls must be instituted that either avoid such situations or that make the proper adjustments to the quantities used in determining the relative amounts of process loss (gain).

TABLE 1

Losses and Gains (CID) as % of SS Weight (in)

Material Balance	UNIT PROCESS					Delta
	37	38	39-41	42	43	
Enr. 1	-.02964	-.6426	1.0423	.1378	-.1207	.3857
Enr. 2	-.04625	.01581	.32068	-.0969	.1510	.3444
Camp 1	-.03857	-.29629	.6653	.0207	.0104	.3615
$\bar{x}$	-.03795	-.3141	.6815	.0205	.01515	.3650
*s	.01472	.5834	.6394	.2079	.2407	.0366

TABLE II

Absolute Losses and Gains in Grams (CID)

Material Balance	UNIT PROCESS					Delta
	37	38	39-41	42	43	
Enr. 1	-16.7	-362.6	632.8	81.8	-75.3	260.0
Enr. 2	-30.3	9.9	213.0	-57.3	87.8	223.1
Camp 1	-47.0	-352.7	845.8	24.5	12.5	483.1
$\bar{x}$	-23.5	-176.4	422.9	12.3	6.25	241.6
*s	12.0	330.0	371.9	123.2	144.5	32.7

*The standard deviation is estimated by multiplying the range by the appropriate constant for estimating σ from the range for $n=2$. This is at best a poor estimate of the standard deviation.

Conclusions:

1. The concept of using calculated inventory differences (absolute or relative) as a potential safeguard control tool is illustrated by the use of 2 enrichments from a single campaign. Insufficient data prevents the development of limits based on long term results.
2. Calculated inventory differences based on SS weight (metal) are more uniform within a particular process step than between process steps.
3. The overall loss for each enrichment should be essentially a constant while the process is in control. This fact can be used to monitor when a shift does occur in the control of the process.
4. The results of this study suggest that plotting calculated inventory differences based on metal weight at each process station may be a worthwhile "early warning" device for a fuel fabricator for the timely control of his nuclear material inventory. The method is simple to administer, requires no special equipment, and result in quick responses to significant shifts in accounting data.

REFERENCES

1. Marcuse, W. and Williams, J.M. "Application of a Nuclear Process Simulation Model to an Integrated Safeguards Experiment," in Proceedings of a Symposium of Safeguards Techniques, Vol. II, IAEA-SM-133/56, IABA, Vienna, 1970.
2. GEAP-4271, "The Measurement of Oxygen-to-Metal Ratio in Solid Solutions of Uranium and Plutonium Dioxides," May 31, 1963.

APPENDIX A

NET WEIGHT MATERIAL BALANCE

NET WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 37 - BLENDING

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp.</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
M0094	32,401.8	31,791.2	3.0	---	401.8	15.6	190.2	.587
M0095	32,173.0	31,905.6	3.0	236.8	215.3	20.3	-208.0	-.647
Total for Enrichment	64,574.8	63,696.8	6.0	236.8	617.1	35.9	-17.8	-.028
M0096	32,586.8	31,881.4	5.0	---	604.8	2.3	93.3	.286
M0098	42,763.4	39,995.5	11.3	1,994.7	864.9	25.0	-128.0	-.299
Total for Enrichment	75,350.2	71,876.9	16.3	1,994.7	1,469.7	27.3	-34.7	-.046
Total for Campaign	139,925.0	135,573.7	22.3	2,231.5	2,086.8	63.2	-52.5	-.038

(1) $\frac{(\text{Z Grams Out})}{\text{Grams In}} \times 100$

NET WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 38 - SLOGGING & GRANULATION

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp:</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
M0094	32,257.7	32,608.8				14.9	-366.0	-1.135
M0095	32,408.6	32,439.2				19.9	-50.5	-.156
Total for Enrichment	64,666.3	65,048.0				34.8	-416.5	-.644
M0096	31,882.4	31,826.5				3.1	52.8	.166
M0098	40,133.5	40,143.1				31.6	-41.2	-.103
Total for Enrichment	72,015.9	71,969.6				34.7	11.6	.016
Total for Campaign	136,682.2	137,017.6				69.5	-404.9	-.296

(1) $\frac{(\Sigma \text{ Grams Out})}{\text{Grams In}} 100$

**NET WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOXES 39,40,41 PELLETIZING, SINTERING & GRINDING**

<u>Blend</u>	<u>In (2)</u>	<u>Out (3)</u>	<u>Samp.</u>	<u>Clean Scrap</u>	<u>Dirty (2) Scrap</u>	<u>Waste (3)</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
MO094	36,732.4	35,583.3			40.5	.9	1,107.1	3.016
MO095	32,858.0	32,422.4			83.0	9.3	343.3	1.045
Enr. 1	69,590.4	68,005.7			123.5	10.2	1,451.0	2.085
MO096	31,239.7	30,627.1				5.0	607.6	1.945
MO098	45,154.4	44,519.7			74.2	67.4	493.1	1.092
Enr. 2	76,394.1	75,146.8			74.2	72.4	1,100.7	1.441
Campaign 1	145,984.5	143,152.5			197.7	82.6	2,551.7	1.748

(1) $\frac{(\Sigma \text{ Grams Out})}{\text{Grams In}} \times 100$

NET WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 42 - PELLET INSPECTION

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp.</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
MO094	35,139.6	34,570.6	190.1	236.4			142.5	.406
MO095	32,177.8	31,735.2	200.1	254.3		38.3	-50.1	-.156
Enr. 1	67,317.4	66,305.8	390.2	490.7		38.3	92.4	.137
MO096	30,627.1	30,221.4	138.5	304.2			-37.0	-.121
MO098	36,613.8	35,886.3	277.5	258.7	202.0	17.4	-28.1	-.077
Enr. 2	67,240.9	66,107.7	416.0	562.9	202.0	17.4	-65.1	-.097
Campaign 1	134,558.3	132,413.5	806.2	1,053.6	202.0	55.7	27.3	.020

(1) $\frac{(\text{E Grams Out})}{\text{Grams In}} 100$

NET WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 43 - PELLET LOADING

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp.</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
MO094	39,600.2	35,901.0	32.7	3,818.4			-151.9	-.384
MO095	31,143.4	29,243.4	32.0	1,493.3	283.1	24.7	66.9	.215
Total for Enrichment	70,743.6	65,144.4	64.7	5,311.7	283.1	24.7	-85.0	-.120
MO096	50,221.4	26,232.5	35.8	3,963.5	29.7	0.2	-40.3	-.133
MO098	35,886.3	35,016.5	38.0	687.7		3.9	140.2	.391
Total for Enrichment	66,107.7	61,249.0	73.8	4,651.2	29.7	4.1	99.9	.151
Total for Campaign	136,851.3	126,393.4	138.5	9,962.9	312.8	28.8	14.9	.011

(1) $\left(\frac{\text{Grams Out}}{\text{Grams In}} \right) \cdot 100$

APPENDIX B

SS WEIGHT MATERIAL BALANCE

**SS WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 37 - BLENDING (BASED ON UNSINTERED SS FACTORS)**

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material. Unaccounted For (%) (1)</u>
MO094								
SS	28,184.1	27,652.9	2.6		349.5	13.6	165.5	.587
MO095								
SS	28,164.2	27,930.2	2.6	207.3	188.5	17.8	-182.2	-.647
Total for Err. 1								
SS	56,348.3	55,583.1	5.2	207.3	538.0	31.4	-16.7	-.030
MO096								
SS	28,311.4	27,698.6	4.3	---	525.5	2.0	81.0	.286
MO098								
SS	37,199.9	34,792.1	9.8	1,735.2	752.4	21.7	-111.3	-.299
Total for Err. 2								
SS	65,511.3	62,490.7	14.1	1,735.2	1,277.9	23.7	-30.3	-.046
Total for Campaign								
SS	121,859.6	118,073.8	19.3	1,942.5	1,815.9	55.1	-47.0	-.0386

(1) $\frac{(\text{X Grams Out})}{\text{Grams In}}$ 100

**SS WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 38 - SLUGGING & GRANULATION (BASED ON DETERMINED SS FACTORS)**

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (\$)(1)</u>
M0094								
\$S	28,058.7	28,364.1				-13.0	-318.4	-1.135
M0095								
\$S	28,370.5	28,397.3				17.4	-44.2	-1.156
Total for Emr. 1								
\$S	56,429.2	56,761.4				30.4	-362.6	-6.643
M0096								
\$S	27,699.4	27,650.9				2.7	45.8	.165
M0098								
\$S	34,912.1	34,920.5				27.5	-35.9	-1.103
Total for Emr. 2								
\$S	62,611.5	62,571.4				30.2	9.9	.016
Total for Campaign								
\$S	119,040.7	119,332.8				60.6	-352.7	-1.296

(1) $\left(\frac{\Sigma \text{ Grams Out}}{\text{Grams In}} \right) 100$

**SS WEIGHT MATERIAL BALANCE IN GRAMS FOR
BOX 39,40,41 PELLETIZING, SINTERING & GRINDING**

<u>Blend</u>	<u>In (2)</u>	<u>Out (3)</u>	<u>Samp.</u>	<u>Clean Scrap</u>	<u>Dirty (2) Scrap</u>	<u>Waste (2)</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%) (1)</u>
MO094								
SS	31,950.9	31,446.7			35.2	.8	468.2	1.465
MO095								
SS	28,763.9	28,518.5			72.7	8.1	164.6	.572
Total for Enr. 1								
SS	60,714.8	59,965.2			107.9	8.9	632.8	1.042
MO096								
SS	27,141.1	26,956.1				4.3	180.7	.666
MO098								
SS	39,279.8	39,124.4			64.5	58.6	32.3	.082
Total for Enr. 2								
SS	66,420.9	66,080.5			64.5	62.9	213.0	.321
Total for Campaign								
SS	127,135.7	126,045.7			172.4	71.8	845.8	.665

(1) $\left(\frac{\text{Grams Out}}{\text{Grams In}} \right) 100$

(2) SS Weight is Based on Unsintered SS Factor.

(3) SS Weight is Based on Sintered SS Factor.

**SS WEIGHT MATERIAL BALANCE FOR
BOX 42 INSPECTION (SINTERED SS FACTORS)**

<u>Blend</u>	<u>In</u>	<u>Out</u>	<u>Samp</u>	<u>Clean Scrap</u>	<u>Dirty Scrap</u>	<u>Waste</u>	<u>Material Balance</u>	<u>Material Unaccounted For (%)</u>
M0094								
SS	31,054.6	30,551.8	168.0	236.4			125.9	.40
M0095								
SS	28,303.4	27,914.1	176.0	223.7		33.7	-44.1	-.15
Total for Emr. 1								
SS	59,358.0	58,465.9	344.0	432.6		33.7	81.8	.13
M0096								
SS	26,956.1	26,599.1	121.9	267.7			-32.6	-.12
M0098								
SS	32,176.6	31,537.3	243.9	227.3	177.5	15.3	-24.7	-.07
Total for Emr. 2								
SS	59,132.7	58,136.4	365.8	495.0	177.5	15.3	-57.3	-.09
Total for Campaign								
SS	118,490.7	116,602.3	709.8	927.6	177.5	49.0	24.5	.02

(1) $\frac{(\Sigma \text{ Grams Out})}{\text{Grams In}} \times 100$

**SS WEIGHT MATERIAL BALANCE FOR
BOX 43 - LOADING (SINTERED SS FACTORS)**

Blend	In	Out	Samp	Clean Scrap	Dirty Scrap	Waste	Material Balance	Material Unaccounted For (%) (1)
M0094								
SS	34,996.7	31,727.5	28.9	3,374.5			-134.2	-.383
M0095								
SS	27,393.5	25,722.3	28.1	1,313.5	249.0	21.7	58.9	.215
Total for Enr. 1								
SS	62,390.2	57,449.8	57.0	4,688.0	249.0	21.7	-75.3	-.121
M0096								
SS	26,599.1	23,088.3	31.5	3,488.4	26.1	0.2	-35.4	-.133
M0098								
SS	31,537.3	30,772.9	33.4	604.4		3.4	123.2	.391
Total for Enr. 2								
SS	58,136.4	53,861.2	64.9	4,092.8	26.1	3.6	87.8	.151
Total for Campaign								
SS	120,526.6	111,311.0	121.9	8,780.8	275.1	25.3	12.5	-.010

(1) $\left(\frac{L \text{ Grams Out}}{\text{Grams In}} \right) 100$

APPENDIX C

SS FACTORS

SS FACTORS

<u>Factors</u>	<u>M0094</u>	<u>M0095</u>	<u>M0096</u>	<u>M0098</u>
Unsintered	.8698	.8754	.8688	.8699
Sintered	.8838	.8796	.8801	.8788