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METALS AND CERAMICS DIVISION

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AN INTEGRATED SYSTEM OF NUCLEAR MATERIALS CONTROL
AT OAK RIDGE NATIONAL LABORATORY

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OAK RIDGE NATIONAL LABORATORY
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ABSTRACT

Current emphasis on development of fuels for breeder reactor application has necessitated frequent intermixing and copressing of ^{233}U , ^{235}U , and ^{239}Pu isotopes. To provide the highly accurate control system that assures safe operation of the facilities, all criticality, accountability, and radiation safety controls were integrated into a centralized system managed by a coordinator designated the Nuclear Materials Controller. Emphasis was placed on minimizing the spread of contamination and reducing the potential for a nuclear incident while at the same time maintaining a smooth, uninterrupted flow of materials with a minimum of paper work.

The centralized system is composed of three integrated units: (1) the Criticality Control Board - a visible, current record of all nuclear materials under control of the system, with magnetic, color-coded indicators that reflect values, location, and type of isotope in each approved laboratory to the nearest 1/2 g; (2) the Nuclear Materials Flowboard - a modified, color-coded, industrial indicator that visibly reflects each temporary movement of the materials and their current location during processing; and (3) the Flip-Sheet Ledger system - a concise version of the columnar accounting sheet that permits a great number of accounts to be filed and worked on overlays in an 8 1/2 x 11-in. ledger book.

The system has effectively and efficiently met all control requirements and provided both necessary and desirable safeguards without hindering the processing of materials; in several instances it has expedited production. The detailed records of materials on hand by type and location provide a detailed, current inventory that has resulted in savings of time and money on materials procurement and that has brought to attention valuable, inactive quantities that could be returned to production channels.

INTRODUCTION

During the spring of 1968, program-planning discussions between the Atomic Energy Commission and the Oak Ridge National Laboratory indicated a concentrated research on fuel materials for fast breeder reactors. In general, the effort in fiscal year 1969 would involve investigation of uranium oxides, nitrides, and carbonitrides that contained dispersions of plutonium.

Although the Metals and Ceramics Division at ORNL had extensive experience in fuels research and handling of fuels, it was recognized that mingling of the uranium and plutonium isotopes in significant total quantities increased the possibility of nuclear accident, not only from the standpoint of criticality but also from the standpoint of radiation safety because of the increased potential for contamination and toxicity from the dispersed plutonium. It was obvious that a strong secondary control system that would link the primary systems in our various research laboratories was mandatory.

SPECIFIC PROBLEM

Although relatively less nuclear material is involved in the operation of a pilot-plant for fuels research than one would expect to find in a commercial production plant, the problem of control was still large and complex.

The Metals and Ceramics Division included 350 research and support personnel on the immediate site engaged in research on a mixture of about 85 nuclear and nonnuclear programs. This situation resulted in what is best described as a "honeycomb": "cells" of the mixed nuclear materials are dispersed among other "cells" of nonnuclear materials that can influence their hazard potential through reflection, moderation, absorption, or transmutation. Unlike a normal production situation, our operation had no straight lines that could be premapped for a control base. For maximum efficiency of personnel and equipment, complete flexibility of movement between nuclear and nonnuclear materials within the operation was a necessity. Further observation of our particular

situation indicated an additional contamination factor - the internal movement of 2- to 5-kg quantities of undispersed plutonium broken into small, fast-moving quantities.

CONTROL SYSTEM

To satisfy all requirements and regulations imposed by the hazards of this type of operation and to maintain a smooth flow of materials with as little delay as possible, we developed a unique visual system that we believe works well for our situation and is applicable to similar problems. We integrated the controls for the three basic areas of nuclear operation: criticality, radiation safety, and accountability, in that order of importance.

Orientation

The control system is oriented around two bases: (1) the functional organization and (2) the Nuclear Safety Review.

Functional Organization

Unlike the other research divisions at ORNL, the Metals and Ceramics Division is organized around functional laboratories rather than research programs. For example, all primary research on the joining of metals, regardless of program orientation, is performed in the Welding and Brazing laboratory, all nondestructive testing in the Nondestructive Testing laboratory, and so forth. Each laboratory is supervised by a technical specialist designated as its Laboratory Head. Primary control areas, called Subbalance Areas, are centered in each laboratory that requires nuclear materials. The Laboratory Head is responsible for the radiation safety and accountability associated with nuclear materials while they are in his laboratory work area.

These primary areas are grouped under a secondary control, designated as the Balance Area, which is under the supervision of a Nuclear Materials Controller, a staff assignee reporting (in a dual capacity) to the Division's Manager of Finance and Materials and Radiation Control Officer.

It is the responsibility of the Nuclear Materials Controller to maintain a complete and current record of the quantity, status, and location of all the nuclear materials in the Division and to monitor all movements, storage, processing, and other aspects of the nuclear materials work to ensure that approved procedures and quantities are observed.

Nuclear Safety Review

Before any materials may be handled or processed, the Laboratory Head must submit a detailed outline of the proposed activity, including the location and quantity of the various batches during the particular process. This proposal is reviewed by the Radiation Control Officer and forwarded to the ORNL Criticality Committee. When the Criticality Committee has reviewed and approved the proposal, a Nuclear Safety Review (NSR) number is assigned to the document, and copies are filed with the Nuclear Materials Controller, who records the limits assigned. If the laboratory has two or more operations in progress at the same time, the total quantity of material in the laboratory at any one time must not exceed the sum of the approved NSR totals.

Special Equipment

Three basic tools are used in this control system: (1) the Criticality Control Board, (2) the Nuclear Materials Flowboard, and (3) the Flip-Sheet Ledger. The first and third are unique, for they were originated and developed for use in this system; the second is a unique application of an old tool to a new and difficult problem.

Criticality Control Board

The Criticality Control Board, shown in Fig. 1, presents an instant, current report of the concentrations of nuclear material over the entire system by both type and quantity. It is divided into sections that represent a laboratory or location within a laboratory where the materials are stored and processed.

The board itself is a ferric metal plate, and the round indicators attached to it are standard bulletin-board magnets. The magnets are color-coded, and those not in service are filed in order in the lower right-hand section. The magnets are shown in detail in Fig. 2. The base color denotes the amount of material in grams that each magnet represents (i.e., white = 1 g, black = 10 g, blue = 50 g, etc.). The center stripe denotes the type of material that each magnet represents (i.e., red = Pu, green = ^{235}U , and yellow = ^{233}U).

When the Nuclear Materials Controller is notified of a movement of material, he plots the location, amount, and type by attaching representative magnets to the proper section. Upper limits for each material in each laboratory are on record with the Controller, and he will not permit any quantity to be delivered that will cause such limits to be exceeded. A total for the system (in this case, for the Division) is also maintained in magnet form in the lower center section. A few special 5-g designations are available adjacent to that section.

Nuclear Materials Flowboard

The Nuclear Materials Flowboard, shown in Fig. 3, singles out particular batches of material within the system that are moved very frequently between laboratories before processing is complete. It is a modification of a standard flowboard that uses retractable cords and pegs to indicate movements away from — but always back to — a central point. The first cord, for example, indicates that materials will frequently be moved from the central storage vault (cage) through the Nondestructive Testing Laboratory to the Ceramics Laboratory, back to the Nondestructive Testing Laboratory, and then back to the cage. The green pegs at the end of the cord indicate the number of grams in the particular batch. The red bar pegs indicate the location of the batch at any given time. The bar pegs are marked with the month in which the project is expected to be completed (this is the standard type of peg available with this particular board). Since these batch quantities stay in one location for only a short time (our limit is 24 hr), a great deal of time is saved in that no posting is made to the ledger. Should

LABS			
LAB 1	LAB 2	LAB 3	Lab 3 Birdcage STORAGE
3.45 Kg total	1.3 Kg total	1.6 Kg total	3 Kg total

Fig. 2. (Upper) Magnet Storage Section of the Criticality Board. Each magnet is striped with red, yellow, or green denoting the type of material. Base colors of the magnets representing quantity of material are shown in each column. (Lower) Blowup of an operational section of the board showing current quantities and types of material stored or in process within a single Sub-Balance Area.

Fig. 3. Nuclear Materials Flowboard.

such quantities remain in one location for more than the 24-hr period, they do not qualify for a plot on the Nuclear Materials Flowboard and receive a regular paper transfer and internal plotting to the ledger.

Flip-Sheet Ledger

The Flip-Sheet Ledger, see Appendix, is a concise version of the more familiar double-entry, control-subsidary systems. A reversion to single-entry bookkeeping is used in combination with an overlay of the columns that contain the quantities in each transfer. Each gram quantity is posted to the proper subsidiary ledger sheet in the same column and line position as on the control sheet.

The quantity sheets have multiple columns (in this case, ten) so that any type of material may be recorded in chronological order of receipt or disbursement. This is important in the movement of the many batches of mixed isotopes common to the fabrication of breeder fuels. It also serves to condense the ledger system further by eliminating the need for separate ledgers for each type of material. This technique permits a single posting of the transfer identification and associated information for each control and subsidiary entry. This feature not only saves time, but also cuts in half the possibility of posting error, since there is no repeat posting of the identity information. The result is a complete control-subsidary system contained in a single document that accurately accounts for the nuclear materials by quantity and location. The control ledger is on top, and each quantity posting on a subsidiary is aligned in the same third-dimensional plane as its control counterpart, a feature that enhances the visual qualities of the system during inspection or audit.

We recognize that the document is limited in that its thickness increases with the number of subsidiary accounts, but by using a lightweight paper of suitable quality for the shorter forms, a relatively large number of pages may be included in each section without impractical bulkiness. If the form seems impractically bulky for a particular application, it is a good indication that the Balance Area is either too broad to be efficient or that the operation should be controlled by an

electronic data-processing system such as that described by Hazelton and Dunn.¹

SUMMARY

We have made two observations during the year that this system has been in active use. First, it has worked exceptionally well in providing the necessary current data with a minimum of paper work. The Radiation Control Officer is afforded an immediate comparison of the quantities on hand and the approved limits by a routine study of the boards each day. Indeed, with time, he develops a color-pattern psychology that enables him to sense problems or potential problems in a routine scan of the board. In addition, the special ledger also has a pictorial characteristic, since it is both compact and complete, and the Nuclear Materials Controller is able to maintain it with minimum effort both as a good accountability record and second-line check on quantity and location. Second, we believe that this system could provide adequate control for pilot-plant production quantities of nuclear material in a nonnuclear industry that wanted to enter the nuclear field on a trial basis while investing in a minimum of additional equipment. This latter observation would seem important if we are to involve small businesses in nuclear industry.

¹L. D. Hazelton and D. A. Dunn, "Automated Data Processing System for SS Material Control," pp. 89-128 in Proceedings of the Tenth Annual Meeting of the Institute of Nuclear Materials Management, Las Vegas, Nevada, April 28-30, 1969.

APPENDIX
FLIP-SHEET LEDGER

CONTROL

Date	(1)	Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
			U	235	U	235	U	233				
5-1		Bal Fwd	1000+	930+	1000+	100+	100+	94+	100+	10000+	50000+	50000+
-1 E		12862	250+	233+								
-2 E		13106			100+	3+						
-2 E		13841	100-	93-								
-3 E		14141								9000-		
-3 I		2742		+								
-4 E		14279					10+	9+				
-5 E		14381							100+			
-5 I		2743									+	
-6 E		14761			500-	50-						
-6 E		14915									25000-	
-8 E		15057	10-	9-								
-8 I		2744	+	+								
-9 E		15121	40-	37-								
-9 E		15346										47000-
-10 E		15721					10-	9-				
-10 I		2745								+		
-11 E		15947							100-			
-11 E		16104			100-	10-						
-12 E		MUF	30-	28-								
		Bal Fwd.	1070+	996+	500+	43+	100+	94+	100+	7000+	25000+	3000+

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.

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LAB A

Date	(1) Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
		U	235	U	235	U	233				
5-1	Bal Fund	500+	465+	200+	20+	—	—	—	2000+	1000+	—
-1	E 12862										
-2	E 13106										
-2	E 13341	100-	93-								
-3	E 14141										
-3	I 2742										
-4	E 14279										
-5	E 14381							100+			
-5	I 2743									1000-	
-6	E 14761										
-6	E 14915										
-8	E 15057	10-	9-								
-8	I 2744	20-	20-								
-9	E 15121	40-	37-								
-9	E 15346										
-10	E 15721										
-10	I 2745								1000-		
-11	E 15947							100-			
-11	E 16104										
-12	E MUF	30-	28-								
	Bal Fund	300+	278+	200+	20+	—	—	—	1000+	—	—

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.

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LAB B

Date	(1) Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
		U	235	U	235	U	233				
5-1	Bal Fwd	500+	465+	—	—	—	—	—	4000+	—	—
-1 E	12862										
-2 E	13106										
-2 E	18841										
-3 E	14141								3000-		
-3 I	2742	250-	233-								
-4 E	14279					10+	9+				
-5 E	14381										
-5 I	2743									1000+	
-6 E	14761										
-6 E	14915										
-8 E	15057										
-8 I	2744	20+	20+								
-9 E	15121										
-9 E	15346										
-10 E	15721					10-	9-				
-10 I	2745										
-11 E	15947										
-11 E	16104										
-12 E	MUF										
Bal Fwd		270+	252+	—	—	—	—	—	1000+	1000+	—

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.

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LAB C

Line	(1)	Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
			U	235	U	235	U	233				
5-1		BA Fund			800+	80+	100+	94+	—	—	30000+	—
-1	E	12862	250+	233+								
-2	E	13106										
-2	E	13841										
-3	E	14141										
-3	I	2742	250+	233+								
-4	E	14279										
-5	E	14381										
-5	I	2743										
-6	E	14761			500-	50-						
-6	E	14915									20000-	
-8	E	15057										
-8	I	2744										
-9	E	15121										
-9	E	15346										
-10	E	15721										
-10	I	2745								1000+		
-11	E	15947										
-11	E	16104			100-	10-						
-12	E	MUF										
		BA Fund	500+	466+	200+	20+	100+	94+	—	1000+	10000+	—

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.

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LAB D

Date	(1) Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
		U	235	U	235	U	233				
5-1	Bal Fwd	—	—	—	—	—	—	100+	4000+	9000+	—
-1	E 12862										
-2	E 13106										
-2	E 13341										
-3	E 14141										
-3	I 2742										
-4	E 14279										
-5	E 14381										
-5	I 2743										
-6	E 14761										
-6	E 14915									5000-	
-8	E 15057										
-8	I 2744										
-9	E 15121										
-9	E 15346										
-10	E 15721										
-10	I 2745										
-11	E 15947										
-11	E 16104										
-12	E MUF										
	Bal Fwd	—	—	—	—	—	—	100+	4000+	4000+	—

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.

LAB E

Date	(1)	Transfer Doc. No.	Enriched U > 75%		Enriched U < 75%		Uranium 233		Plutonium	Normal U	Depleted ⁽²⁾	Thorium
			U	235	U	235	U	233				
5-1		Bal Fwd	—	—	—	—	—	—	—	—	100000+	50000+
-1 E		12862										
-2 E		13106			100+	3+						
-2 E		13841										
-3 E		14141										
-3 I		2742										
-4 E		14279										
-5 E		14381										
-5 I		2743										
-6 E		14761										
-6 E		14915										
-8 E		15057										
-8 I		2744										
-9 E		15121										
-9 E		15346										47000-
-10 E		15721										
-10 I		2745										
-11 E		15947										
-11 E		16104										
-12 E		MUF										
		Bal Fwd	—	—	100+	3+	—	—	—	—	100000+	30000+

The Flip-Sheet Ledger. The second column (1) shows movement of material to or from external source, E, or movement of material within the Balance Area, I. Internal movements do not affect the control balance and are indicated thereon only by + or - to designate line item and type of material. Depleted uranium (2) is carried only by total element and not by isotope unless it is in a special depletion range. The last line item, MUF, designates an authorized writeoff.