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Final Report on the Control of
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Final Report on the Control of
CPD Product Materials

by

D. F. Shepard, C. G. Hough, R. C. Burke, K. B. Stewart

Operations Research & Synthesis Operation
HANFORD LABORATORIES OPERATION

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CHEMICAL PROCESSING DEPARTMENT CONTROL STUDY
Final Report on the Control of
CPD Product Materials

I. Introduction

The purpose of this report is to present the conclusions and recommendations obtained during the course of the CPD Control Study and the conceptual framework upon which they are based. Primary emphasis has been given to the control of product materials. The study of this particular problem has not indicated any over-all improvement in the ability to account for product material; rather a disturbing decrease in this ability is apparent. The operating trends toward increased throughputs, conversion to continuous rather than batch operation, increased inventories, and the blending of materials to provide uniform feeds have increased the difficulty of adequate material control. What constitutes effective product material control depends upon the criteria used as measures of effectiveness, the time periods involved (fiscal year, month, immediate) and the level of control to be exercised (container - vessel, production plant, department, operation). There appears to be a divergence of opinion as to what constitutes adequate control and the procedures and techniques to be used in establishing, maintaining, and demonstrating it.

In order to logically present the background for the definition and delineation of an appropriate CPD Control System, Section III of this report discusses a control system in the following manner; (1) the description of the control system information requirements, (2) the definition of the conceptual framework of product material control, (3) the discussion of the interrelationships of production scheduling, process control and accountability, and (4) the methods for the effective utilization of control system information. Section IV utilizes this conceptual framework in order to enable a logical presentation of a proposed product material control system for the CPD. A summary of conclusions and recommendations is included in Section II. The Appendices consist of discussions of specific analyses conducted during the study. Other related reports that have been issued during the course of the study are included in the references.

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II. Summary of Recommendations and Conclusions

A. Responsibilities and Interrelationships

A basic requirement of any control system is information which provides a description and/or measurement of (1) the state of a process at any specific instant and (2) the changes in the state of a process. The logical definition and delineation of an information system depends upon (1) the total amount of information that is potentially available and (2) the amount of information actually needed by each function. In order for each function to effectively exercise the type of control for which they are responsible, means must be provided for (1) supplying each function with the information they need and (2) communicating the effectiveness of the control achieved. Thus, an information system designed to assemble and distribute the information needed for immediate and periodic control should be operated strictly as a service function independent of other responsibilities.

Based upon an analysis of the interrelationships within the CPD Control System it was realized that:

1. While the production scheduling, process control, and accountability functions may be readily distinguished administratively and from the viewpoint of desired objectives, in actual day-to-day operation they are inseparable.
2. An over-all product material control program which has more efficient production scheduling, process control and accountability as products inherently depends upon the procedures, techniques, and actions developed by the engineer.
3. The responsibility for successful accountability cannot be effectively exercised by an independent group that is administratively remote from the intimate contact necessary to effect solution of the problems.

In order to enable the engineer to effectively discharge this responsibility it is recommended that the SS Accountability Operation provide CPD with more detailed material balance reports that describe the material flow within primary and secondary control areas according to material type and origin. These reports should incorporate the ending inventory estimate that results in B-PID's with minimum variance (Section IV, D, 2). Since there are so many independent units making up the CPD complex it is also recommended that a central administrative function be formed to effectively discharge CPD's responsibility for control of product materials. This function might consist of representatives from each facility, SS Accountability, the Process Chemistry and Production Operations. Details are included in Section IV, D and IV, A, 7 respectively.

B. Product Material Control - Plutonium

Based upon an analysis of the plutonium material control system it was realized that:

1. Absolute flow control areas should be based upon the concept of logically defined process divisions that are capable of being surrounded by an "iron ring" of reliable absolute measurements.

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2. The number of absolute flow control areas should be maintained at the minimum required to describe the system, since control becomes more difficult each time additional areas are included. However, it may be necessary to rely upon some secondary control areas in order to achieve good primary control.

Consequently, it is recommended that the Chemical Processing Department be divided into the following primary and secondary control areas:

1. CPD Primary Control Area
2. CPD Shipper-Receiver Variance Area
3. Redox Processing Area
4. Purex Processing Area
5. Nitrate Shipper-Receiver Variance Area
6. Plutonium Processing Area
7. Fabrication Processing Area
8. Salvage Shipper-Receiver Variance Area
9. Research and Engineering Area

Programs should be developed to (a) further review each of the primary and secondary flow control measurements (b) provide future continuous control of these measurements and (c) maintain documented evidence of each review effort, all future control standards, and all basic control data that communicates the status of the control system.

With respect to absolute flow control in Shipper-Receiver Variance Areas it should be noted that:

1. Absolute flow control is demonstrated through the regular transfer slip transaction, while physical control (custody) is demonstrated through item control, a distinct and separate system.
2. The B-PID's resulting from absolute flow control would be the responsibility of the CPD administrative function, while responsibility for physical control (custody) remains with the facility in possession of the material.
3. Successful resolution of IPD-CPD and Redox, Purex-Z plant differences, hinge upon the installation of an acceptable receiver nitrate measurement in Z plant.

With respect to absolute flow control in processing areas it should be noted that:

1. Existing areas such as feed storage, metal solution preparation, extraction, recycle storage, analytical control, product storage, dissolving, and metal recovery would no longer exist as separate flow areas.

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2. Dissolving and metal recovery areas should be considered as temporary holding areas (measuring stations) where absolute flow values are determined prior to absolute transfer-transactions, and should be included in the Plutonium Processing area.
3. The transfer of by-product materials to a measuring station is accomplished by transferring physical control (custody), through item control, to this station while retaining absolute inventory control within the generating process area.
4. In order to obtain valid estimates of the amounts of by-product materials accumulating within processing areas it will be necessary to adopt a strict LIFO policy.
5. Due to the mixing of by-product materials at the measuring stations it will be impossible to "close-up" the Fabrication, Salvage, and Plutonium Processing areas unless some type of plan can be devised which will result in the assignment of valid flow control values according to material type and generating area. Without effective solution of this technical problem it is felt that the only other remaining alternative is to combine the Fabrication, Salvage, Plutonium Processing and HLO control areas into a single area.

Since B-PID variations are primarily dependent upon the precision of periodic physical inventory measurements it is recommended that CPD:

1. emphasize the development of improved methods of estimating plant inventory,
2. maintain plant physical inventories at as constant a level as possible,
3. adhere to consistent physical inventory practices,
4. establish a double-check system for each month's inventory so as to minimize errors.

C. Product Material Control - Uranium

Conclusions and recommendations for the control of uranium product materials are basically the same as those for plutonium, except there would be no need to maintain variance areas in the uranium control system.

D. Use of Other Control Tools

Methods similar to those currently used in the Analytical Control Quality Program should be developed for the control of volume and sampling measurement errors.

*See next page for
list of items
to be reviewed
and approved
by the
Quality
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Committee*

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III. Description of a Control System

A. Control System Information Requirements

One of the basic requirements of any control system is the generation of information which will provide a description and/or measurement of (1) the state of the process at any specific instant (static) and (2) the changes in the state of the process (dynamic). The static description of the process could be portrayed at predetermined intervals such as monthly, weekly or daily. The most desirable situation would be to have the ability to press a button at any convenient time and obtain this description in some graphic language. Pressing the button often enough would automatically give the dynamic, as well as the static, description of the process. Conversely, if we had the ability to accurately measure and sum the instantaneous changes we would automatically know the state of the process. If both methods were completely accurate and precise they would both arrive at the same measure of the process status. Due to the inherent inaccuracies associated with any physical device used to implement either method, it would be impossible to obtain identical descriptions of the process. Hence, there will always be a region of uncertainty associated with the ultimate information system used to describe a process, i.e., there will always be a difference between what is actually taking place within the process and the indications communicated by the information system.

In actual practice it is usually unnecessary to know everything about the process. The information requirements can usually be narrowed down to a relatively small percent of the total amount of information that could be obtained. This selection of information permits the design of practical systems for obtaining the required information. The purpose for which the information system is used, and the characteristics of the process being controlled, to a major extent determine the type, design, and effectiveness of the information system. The selection of the measurement points and methods, the conversion of these measurements to a common basis, the data processing to a defined numerical result, the comparison to another result or standard, and the communication of the resultant information are all a function of both the process and the over-all purpose of the information system. The purpose of the information system may vary depending upon the particular process activity concerned (process control, production scheduling, accountability, maintenance, etc.). Consequently, the information system must be designed so as to provide the information needed by all functions.

In order to logically define the extent of the information system, one must determine (1) the total amount of information that is potentially available and (2) the amount of information actually needed by each function. Decisions can then be made as to the best methods of obtaining the required information. The types of information required may vary from auditable SS accountability

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information to radiation exposure, maintenance, and manpower information. This information can be used to create all required types of control. Several of these types of control can be classified according to a common requirement which is "product material control"; namely, production scheduling, process control and accountability. While it is recognized that a good information system must include the demands for all types of control, the remainder of this discussion will be restricted to the control of product materials. A better understanding of the requirements of a complete information system may be obtained by referring to Appendix A.

B. Product Material Control

1. Physical Control

Physical control requires the description and/or measurement of the state of the process at a given instant. This may take two forms, (1) inventory control and (2) item control. Inventory control requires the measurement of the absolute amount and location of product materials. Item control requires the description of types and location of product materials. Item control is not concerned with knowing the absolute amount of product material; however, it is concerned with knowing that there are ten containers of a specific type of material. Item control is of primary interest in the day-to-day control of the process. It serves as the basis for obtaining inventory control through the assignment of absolute values to each container. Both types of physical control are necessary to production scheduling, process control, and accountability. Production scheduling is primarily concerned with item control on a day-to-day basis, i.e., the number and location of cask cars, buckets, cans, pieces, boxes, and cartons. In addition, production scheduling may require an approximate estimate of the absolute content; however, these estimates should be identified so as to distinguish them from measured estimates of absolute amounts. At the immediate processing level, production scheduling becomes an integral part of process control where the primary emphasis tends to change to inventory control. Here, estimates of absolute amounts become more important in order to avoid critical mass incidents, etc. Again, these estimates may be approximate and should be distinguished from measured absolute statements of inventory. At this level of application, time is so important that an approximate estimate today is more valuable than an accurate estimate tomorrow. Consequently, accuracy is not as important as precision. Accountability is concerned with both item and inventory control, but only at prescribed periodic intervals (monthly, fiscal year). Item control is useful in detecting the physical loss or misplacement of those materials that can be individually identified or counted. Inventory control is of use in obtaining periodic statements of absolute amounts and locations of materials. Both are a direct requirement of the AEC.

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2. Flow Control

Flow control requires the description and/or measurement of the changes in the state of the process. This may also take two forms, (1) absolute control and (2) relative control. These two forms parallel the connotation of inventory and item control presented in the discussion of physical control. Absolute and relative control are concerned with the dynamic changes in the state of the system while physical control was concerned with the static state of the system at any specific instant. Relative control requires the description of the changes in the instantaneous rate of flow of product materials in and out of the process. Absolute control requires the measurement of the total absolute amounts of product material flowing in and out of the process during some specified time interval. Relative control is of primary interest to production scheduling and process control (tons/day, cans/batch, etc.). Where a particular flow in or out of a process is restricted by certain limitations (critical mass, exposure, etc.), some absolute measure of the flow (grams/can, grams/batch) may also be necessary for process control. However, this absolute measure may only be approximate and should be distinguished from the relatively unbiased measures implied by absolute control. As in physical control, precision is more important to production scheduling and process control, while the lack of long term bias is more important to accountability control. The main reason for this distinction is that production scheduling and process control require immediate knowledge of the changes taking place in the process. For example, such knowledge may be required about the input and output for specific vessels. Since this input and output may be based on some relative measure it is of little value to accountability. In order to achieve absolute control to meet accountability requirements the process must be divided into logical areas that can be surrounded by "closed sets" of absolute measurements.

Absolute control can be exercised at several levels. For purposes of discussion and future reference the primary control area is defined as consisting of the over-all process complex input and output measurements. Secondary control areas are defined as consisting of input and output measurements surrounding areas within the primary control area. This type of nested definition of control areas may be continued to as many levels as are required to adequately define the process complex in question. However, all such control areas are based upon the concept of logically defined process divisions that are capable of being surrounded by an "iron ring" of reliable absolute measurements. Such nesting of control areas within control areas may be desirable because of

- (a) administrative requirements,
- (b) logical differences between specific process units within the over-all complex and,
- (c) the need to supplement higher level control areas due to inherent weaknesses in one or more of the higher level measurements.

Each time a lower level area (second, third, etc.) is introduced, control of the complex becomes more difficult. Each additional lower level measurement must be controlled to the same extent as primary measurements. Usually, each time a lower level control area is introduced, various recycle stream measurements are required and must also be accurately controlled if the control area is to provide useful information.

C. Interrelationships of Production Scheduling, Process Control and Accountability

The interrelationships of accountability, production scheduling and process control, in regard to product material control, are extremely complex. While these three control functions may be readily distinguished administratively and from the viewpoint of desired objectives, in actual day-to-day operation they are inseparable. All three are attempting to control the same physical process and often use the same basic data. However, the difference in objectives, augmented by administrative separation, sometimes hampers effective coordination of effort. An over-all product material control program which has more efficient production scheduling, process control and accountability as products inherently depends upon the procedures, techniques and actions developed by the engineer. These procedures, techniques and actions result in day-to-day control of (1) the amount of product material received, in inventory, and removed from the process and (2) the reliability of the absolute values assigned to this product material. While good production scheduling and process control do not of necessity result in good accountability, it is extremely difficult, if not impossible, to have good accountability without the assistance of production scheduling and process control. Whenever a material control problem arises that affects process control, it will also affect production scheduling and accountability. Hence, successful accountability must necessarily depend upon the actions determined by the engineer, and this responsibility cannot be exercised by an independent accountability group that is administratively remote from the intimate contact necessary to effect solution of the problem.

D. Effective Utilization of Control System Information

So far, the types of control necessary to effect the control of product materials, the requirements of an information system which generates the information needed by each function, and the interrelationships and responsibilities of the functions utilizing these types of control have been presented. In order for each function to effectively exercise the type of control for which they are responsible, a means must be provided for (1) supplying each function with the information they need and (2) communicating the effectiveness of the control achieved by each function.

Assume that all the required information is accumulated at some central assembly point. The data must then be sorted and distributed to the various functions (maintenance, radiation monitoring, accountability, etc.). Some functions will need the data for immediate action and others will need it for periodic indications of control. In regard to the control of product materials, production scheduling and process control will need much of the information to effect day-to-day control of the state and the changes in the state of the process. The types of control that they will use were defined above as item control and relative control. The personnel responsible for processing the data must be capable of assembling the information needed for immediate item and relative control into

forms that can be used by production scheduling and process control for immediate action. The resulting information should now be in a form where it can be conveniently summarized into daily and other periodic reports that will communicate the dynamic and static state of the process to management. (It is felt that this is one of the main inadequacies of the present CPD system.) In addition, the information which was used for immediate control purposes and the original information which was not needed for immediate control purposes, must be routed to other functions as source data from which they can generate the type of control information for which they are responsible.

Up to this point the process function generating the information must also be responsible for the central processing and distribution of the information, unless the speed with which the information is capable of being processed is rapid enough that an independent group could integrate and communicate the desired information. Since the demands of immediate item and relative control can vary considerably from day-to-day, such an independent group must be capable of meeting these changes in demand upon notice, and would be required to operate strictly as a service function independent of other responsibilities. In addition to communicating the immediate item and relative control information to the production scheduling and process control functions, this group must also be capable of simultaneously communicating all data required by other functions that do not specialize in immediate types of control.

In the case of accountability, data is received and converted into inventory and absolute control information (defined above). In some cases the information may already be in an absolute form. Accountability then performs the necessary summations according to the logical primary and secondary control areas which were defined in the original formation of the control system. The reports generated should describe the state and changes in state of the product material control system in absolute terms. These reports should:

1. Communicate the degree of control maintained during a specified time period. The index of the reliability of product material control is the B-PID. This represents the difference between the static state of the process at the beginning and end of some specified time period (beginning inventory minus ending inventory) compared to the difference between the summation of the dynamic changes that occurred during the specified time period (receipts minus removals).
2. Communicate the state of the process at the end of the time period (composition of ending inventory) according to absolute amounts, material type and location.
3. Communicate the changes in state of the process (schedule of receipts and removals) according to absolute amounts, material types, source and disposition. (It is felt that this is another main inadequacy of the CPD system.)
4. Receive the distribution necessary to communicate the status of the process to all concerned with the control of product materials. This is particularly true of the primary report which describes the state

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of the over-all process complex. The primary report should serve as the main indicator of the state of the process complex and provide the main basis for decisions affecting the control of product materials.

5. Summarize this information over longer time periods so as to provide a basis for the comparison of present performance against past performance.

Items 1-5 are necessary in order to supply those who are responsible for the operation of the complex with the information that will allow complete analysis and understanding of the state of the system. Before effective decisions can be made that will result in the desired degree of control, convenient access to all information that effectively describes the state of the system must be available to those responsible for its control.

In large process complexes there may be so many individual units making up the complex that a central administrative function may be required to effectively analyze the integrated information coming from all control functions. Such a group should be capable of analyzing and coordinating the efforts of the individual units so as to determine the most effective course of action that will lead to the desired control of the over-all complex. This group would also be in a position to evaluate the desired degree of control against the cost of obtaining such control. In order to evaluate the effectiveness of the system over the long term, this group should establish means of determining whether absolute flow and inventory controls or relative flow and item controls are more effective. Continuous evaluation must be made in order to determine the degree of effort that should be expended in both fields.

IV. Discussion of CPD Product Material Control System

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A. Plutonium

1. Introduction

A detailed analysis of the plutonium B-PID history since Redox startup is included in Appendix C in terms of units. A separate report⁽¹⁶⁾ contains the same information in terms of percent. Appendix B contains the discussion, conclusions and recommendations associated with the Z plant material control problems. Reference should be made to these reports as they provide the basis for the over-all recommendations for the control of the plutonium system presented in this section.

Due to the complex interrelationships between physical and flow control (defined above) it would be difficult to individually present the application of each type of control in a discussion of a plutonium control system. Consequently, the discussion of plutonium (and uranium) control will be presented by first establishing logical primary and secondary control areas. Once these have been defined, a framework will have been established to discuss both physical and flow control within and between these areas, in both relative and absolute terms.

2. Primary Control

Primary control within CPD is defined as consisting of the 100 Area and offsite inputs, inputs and outputs from HLO, and all product and waste outputs from all plants. No distinction is made between the individual units or plants that make up the over-all system. The most important consideration in measuring these inputs and outputs is the control of bias, i.e., the ability to distinguish between real loss and measurement bias. At present the B-PID for this primary area amounts to about 240,000 units since Redox startup in January, 1952. Most of this has accumulated during the past two years since the startup of Recuplex and Tasks I and II (see Appendix C). We are unable to state whether this represents a real loss or a measurement bias. Assuming that it is considered worthwhile to establish this distinction, it is suggested that programs be developed to

- (a) thoroughly review each of the primary control measurements,
- (b) provide future continuous control of these measurements once the mechanics of each measurement and the potential sources of error have been determined,
- (c) maintain documented evidence of each review effort so that the work will not have to be duplicated in the future, and
- (d) maintain documented evidence of all future control standards that are adopted to prevent potential sources of primary measurement bias, and all basic control data that will in anyway communicate the status of the control system.

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There are programs (item a) within CPD that are attempting to evaluate 100 Area input by special dissolutions and the use of a Pu/U ratio method. These are discussed in more detail under secondary control. Other offsite inputs (war reserve) were probably quite accurate and possibly would not require extensive examination. An extensive product specification program already exists for shape and button output. Input and output from and to HLO has reached significant proportions and should be examined carefully. A much needed waste output review is currently in progress. Possibly the best example of good continuous control of a primary point (item b) are the methods used for control of final product purity specifications. The same type of approach, if applied to other primary points, should result in a good primary control system. Items c and d simply amount to good communications so that all concerned will have a better understanding of the over-all problem.

It was mentioned in section III that a central administrative function might be desirable for large process complexes that are made up of many individual units. It was intended that the responsibilities of such a group would include items a - d. Such responsibilities would enable the group to analyze the information and arrive at decisions that would lead to the most effective control of the over-all complex.

3. Secondary Control

Secondary control is defined as consisting of all internal measurements surrounding internal balance areas such as Redox, Purex and Plutonium Processing. Sometimes secondary control areas are further classified into third level control areas, e.g., feed storage, metal solution preparation, extraction, recycle storage, product storage, etc. Each time a secondary (or third level) area is introduced, control of the system becomes more difficult. Each secondary (or third level) measurement must be controlled to the same extent as primary measurements. Usually, each time a secondary (or third level) area is introduced, various recycle streams are introduced which must also be controlled accurately if B-PID's are to have meaning.

In the establishment of uranium control areas it was recommended⁽⁹⁾ that secondary control be maintained at a minimum, third level control be eliminated and increased emphasis be placed upon primary control. In order to achieve good primary control for plutonium it may be necessary to rely upon more secondary and third level controls for the following principal reasons:

- (a) the inherent uncertainty of the CPD receipts from the 100 Areas and their dependence upon the amount measured in CPD;
- (b) the variety of plutonium products received and removed from CPD;

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- (c) the desire to maintain administrative identity between Redox, Purex, Plutonium Processing, Fabrication and Research and Engineering;
- (d) the generation and storage of scrap materials that are difficult to quantify.

However, secondary (and third level) control areas are of little value unless they (1) can be surrounded by a "closed set" of reliable measurements, and (2) are true control areas in the sense that they indicate the degree of control between an input and an output. Many of our existing control areas do not fulfill these requirements, e.g., Redox Feed Storage, where the input is the same as the output resulting in a zero B-PID area, does not satisfy the second requirement. Such an area might be required for inventory control (defined above) which is separate and distinct from primary and secondary control. Consequently it may be necessary to create some new control areas and to eliminate some that currently exist.

4. Secondary Control - Redox and Purex

A secondary control area will be necessary to provide additional backup for establishing the validity of CPD input from the 100 Areas. Three main methods have been considered:

- (a) direct dissolver analysis or improvement of existing H-7 and E-5 measurements;
- (b) L-6 and L-9, 10 loadout based upon firm re-evaluation and control of preceding waste outputs, recycle inputs and physical inventory;
- (c) Pu/U ratio at dissolvers or H-7 and E-5.

It is generally accepted that the existing metal solution measurements do not reflect the true receipts from the 100 Areas. Improvement of this method has been discussed before and is generally considered to be impractical at the present time.

The success of the second method would depend upon good control of the preceding waste outputs, recycle inputs and physical inventory. At the present time it is felt that this is the best existing method; however, it is recognized that even though waste output and recycle input are firmly established there would still be reluctance to accept this measure of CPD receipts due to uncertainties in the physical inventory. Even so, as the time period increases (fiscal year) the effect of physical inventory uncertainties diminish.

The Pu/U ratio seems to offer the best possible chance of providing an acceptable measure of receipts from IPD provided the following limitations⁽¹⁷⁾ are eliminated or controlled:

- (a) the 2.7 percent uranium measurement bias associated with the Purex E-5,

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- (b) the effects of plutonium recycle added prior to the E-5 and uranium bearing recovered acid used in dissolver operations,
- (c) the effects on the Pu/U ratio caused by the ICF factor, E-5 radioassay and Am-Cm analytical biases,
- (d) the effect of the physical inventory preceding the point at which the ratio is established.

Items (a) and (b) are quite important in that most of the 100 Area input will pass through Purex and because the potential biases associated with recycle, recovered acid and the E-5 measurement itself could conceivably introduce considerable bias if not properly controlled. Without proper control the measurement may be no better than the present system. Control of item (c) is intended to be accomplished by the application of analytical bias corrections. Due to the radioassay and ICF factor relationships the evaluation and control of the associated biases may be difficult. Consequently, it is felt that the development of an independent plutonium assay method at E-5 (e.g. controlled potential coulometer) and the installation of a receiver nitrate measurement in Z plant would be desirable. The independent plutonium assay at E-5 would make the Pu/U ratio completely independent of the L-9, 10 nitrate measurement. This might also eliminate the need for an accurate ICF factor at L-9, 10 since it would then be needed only for waste and recycle streams where an approximate ICF factor, based upon periodic composite analysis, would probably be adequate. It would also eliminate the need for an Am-Cm correction. The installation of a receiver nitrate measurement in Z plant would help insure the absence of bias in the L-9, 10 measurements prior to the development of an independent plutonium assay.

At this time it seems highly unlikely that the development of a reliable independent plutonium measurement at the E-5, suitable for routine operation, will be forthcoming in the foreseeable future. Consequently, the installation of the receiver nitrate measurement at Z plant should be developed with the idea in mind of creating a measurement that would be accepted as the basic CPD plutonium measurement. This measurement would then provide a firm starting point for relating back to the 100 Areas through the Pu/U ratio and forward through Z plant by establishing an accepted input to this facility. Only the future will determine whether the Pu/U ratio will provide an acceptable measure of CPD receipts from the 100 Areas.

Reference 18 indicates the following precision comparison between the various methods of verifying CPD receipts from IPD:

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	<u>Monthly Basis</u>	<u>Yearly Basis</u>
Dissolver Solution Assay	$\pm 6.0\%$	$\pm 2.0\%$
Separations Loadout	$\pm 5.0\%$	$\pm 0.4\%$
234-5 Plant Loadout	$\pm 10.0\%$	$\pm 3.0\%$
Pu/U Ratio Method	$\pm 0.5\%$	$\pm 0.1\%$

Although these precision estimates indicate that the Pu/U ratio is superior, the graphs of reference 18 indicate remarkable agreement between the corrected dissolver solution assay, the separations loadout and the Pu/U ratio over the 16 month period. For the most part, however, the separations loadout indicates more plutonium received in CPD than does the Pu/U ratio (especially if the 15 kilograms recovered in Redox during November is considered). If the Pu/U ratio is accepted as being the most reliable, then the L-6 and L-9, 10 loadouts and/or the E-3A and L-16 recycle must be biased resulting in overstatements to Z plant. Consequently, it is doubtful that the verification of IPD receipts can be completely resolved before the installation of an acceptable receiver nitrate measurement in Z plant.

Assuming the adoption of the Pu/U ratio the secondary control areas prior to Z plant would consist of the CPD Shipper-Receiver Variance area, Redox, Purex, and the Nitrate Shipper-Receiver Variance area. There would be no third level control areas within Redox and Purex. Redox and Purex would be considered as individual processing areas. The CPD Shipper-Receiver Variance area would consist of the predicted receipts from the 100 areas as input and the Pu/U ratio measurement as output. The Redox and Purex processing areas would consist of the Pu/U ratio and recycle measurements as input, and the L-6 and L-9, 10 product and waste measurements as output. The Nitrate Shipper-Receiver Variance area would consist of the L-6 and L-9, 10 measurements as input and the Z plant receiver nitrate measurements as output.

Existing areas such as feed storage, metal solution preparation, recycle storage, analytical control and product storage would no longer exist. The feed, recycle and product storage accounts are nothing more than inventory control accounts which were established for convenience in taking periodic inventories. The input and output measurements are the same resulting in zero B-PID accounts that give no indication of material control. Since the Pu/U ratio would be applied prior to the dissolver charge and because it is generally recognized that the current H-7 and E-5 measurements are unreliable, there is no need for continued distinction between metal solution preparation and extraction areas. Analytical control areas are considered to be part of the parent plant process areas. The inputs and outputs to analytical control, for the most part, are relative and are not absolute measurements, i.e., number of samples received times some estimated value per sample equals receipts.

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Analytical control transactions are basically internal to the plant. The only controls necessary are those of day-to-day item control and periodic inventory control.

The Nitrate Shipper-Receiver Variance area would operate as follows. When an L-6 or L-9, 10 measurement occurs on a loadout batch a regular transfer slip transaction would constitute a removal from the parent plant process area to the variance area without going through a product storage area. This would constitute an absolute flow control transaction, but indicates no physical control (custody). Physical control (custody) would be demonstrated through item control, a distinct and separate control system. For example, each can within a batch could be serially identified with two-section tags. When the can is physically transferred the shipper would retain half the tag as certification of shipment. The receiver would retain the other half as certification of receipt. Other similar tagging methods could be devised using shipping papers, IBM cards, etc. The items would remain within the variance area until measured at the Z plant facility. A similar flow control transfer transaction would automatically constitute a removal from the variance area and a receipt to the Z plant processing area. The periodic inventory necessary to "close up" the variance control area would simply be the summation of the tags still within the custody of the shipper and receiver.

In addition to product nitrate flow, the variance area would also receive and ship any other material (recycle) transferred between facilities whether it be Z plant to Redox and Purex, Purex to Redox and Z plant, etc. A B-PID would be obtained for each type of material. The sum of all the B-PID's in the variance account would represent the B-PID for the net flow of material. Physical custody for each type of material would be similar to that described for product nitrate. Responsibility for the B-PID's generated in this variance area would not belong to any individual facility but to the central administrative function previously discussed. A similar situation would occur within the CPD Shipper-Receiver Variance area, eliminating the need for feed storage areas.

5. Secondary Control - Z Plant

The factors which determine the generation of secondary control areas within Z plant are:

- (a) the variety of plutonium products received and removed,
- (b) the desire to maintain administrative identity between Plutonium Processing and Fabrication areas, and
- (c) the generation and storage of scrap materials that are difficult to quantify.

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The simplest secondary area to define is Fabrication. Due to the remoteness of the receiver it may be desirable to maintain a product storage area in order to distinguish between product produced and product shipped. Since it would be a zero B-PID area it would be independent of the main flow control system. The main difficulty associated with the Fabrication area is the absolute assignment of product content to by-products generated (casting fragments, briquettes, hood sweepings, etc.). It is felt that the simplest solution to this problem is to transfer physical control (custody), through item control, to the intended receiver while retaining absolute inventory control within the Fabrication area until the receiver establishes the absolute flow control value. At the periodic inventory time, if the material in the physical control (custody) of the receiver has not been assigned an absolute flow control value, the material will remain as part of the Fabrication area inventory based on the best estimate available from item control information. The problem associated with the assignment of a flow control value to Fabrication material, where the receiver mixes this material with other recovery material, will be discussed under Plutonium Processing.

In some cases the amount of by-product materials within the absolute inventory control of the Fabrication area may increase to large magnitudes due to the inability of the recovery operations to keep up with the accumulation. A strict policy of processing as much of the most recently generated material as feasible (LIFO) will be necessary in order to assign the best possible estimate to the unprocessed material that was generated during the same period. It should also be remembered that the fabrication area is of a different general nature than other processing areas in that item identity can be more readily maintained and product material control may be primarily dependent upon this characteristic. The techniques of item control are being studied by a separate task force (see Appendix A).

In some cases by-products generated within Fabrication, Plutonium Processing, HAPO and AEC in general, are types that cannot be economically recovered at the present time. There may be large amounts of other outside materials received (HLO, etc.) that would be inconvenient to process due to the desire to adhere to the LIFO policy within the main CPD flow complex. In order to handle these materials, so as not to disturb the main flow of material within CPD, it may be desirable to create a new secondary control area for the segregation and control of these types of materials. This area might be called the Salvage Shipper-Receiver Variance area. Any material received by this area must be assigned some item identification according to material type and shipper. Physical control (custody) would be accepted by the variance area at the shipper's best estimated flow control value. Periodic absolute

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inventory values would also be based on this estimate. The variance area could receive from any HAPO or AEC control area. Discards to waste could be based on the shipper's best estimated value. Whenever the Z plant recovery facilities have available capacity after fulfilling the LIFO policy associated with the current flow through the CPD complex, physical control (custody) of the variance area material could be transferred to the recovery facility until an absolute recovery value can be assigned. Only at this time would an actual flow transfer be made from the variance area. As with the other variance areas, the Z plant facility would not retain the responsibility for the B-PID variances generated in this area. The responsibility for physical control (custody) always remains with the facility actually in possession of the material.

The definition of the remaining secondary areas within Z plant is much more difficult. Conceivably, the remaining portion of Z plant could be divided into several areas, such as metal recovery, dissolving, extraction, plutonium processing (Tasks I, II and III), recovery feed storage, and analytical control. This is approximately the manner in which Z plant is currently divided. It was earlier stated that each time more secondary control areas are introduced, control of the complex becomes more difficult. This is certainly true of the above mentioned areas. (Appendix B). Although it is recognized there may be a desire to maintain administrative identity between some of these areas, it should be realized that the value of these areas is seriously limited unless absolute flow control in and out of these areas can be maintained. Even if this could be accomplished the value of these areas would still be limited unless current processing of by-product materials (LIFO) can be maintained. Due to the dynamic changes that continually occur within this facility it would be difficult to say with certainty that these conditions will ever be fulfilled. Consequently, it is felt that some combination of these areas must be realized in order to reduce the limitations caused by the need for absolute measurement of flow between areas. In order to establish a basis for determining a logical combination of areas, some discussion of the nature of these areas is necessary.

In regard to absolute flow control of product materials, areas such as metal recovery, dissolving and analytical control temporarily receive materials and perform some operation so as to arrive at some absolute measure of material content. This measure is usually considered to be the accepted absolute flow control value. These values when compared to the estimated input result in a B-PID that does not truly represent the state of control in the recovery facility. This indication of control truly belongs in the generating facility. Consequently, neither of the resulting B-PID's are true indicators of control. For example, during fiscal year 1958 the Task I, II and III B-PID was + 78,277 units. Through recovery activities the following amounts were estimated to have been overstated upon removal from the Task I, II and III area: dissolving,

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68,313; metal recovery, 13,166; feed storage, 8,959; resulting in a net adjusted Task I, II and III B-PID of -12,161 units instead of a + 78,277 units. So far, during fiscal year 1959 (4 months) these recovery facilities are charged with a B-PID of a -30,318 units. Obviously, this is not a true indication of the performance of these facilities.

One way that this situation might be corrected is to consider these facilities as being temporary holding areas where an absolute flow value is obtained prior to any indication of an absolute transfer transaction. In other words, physical control (custody) of material from other areas (Fabrication, Salvage, etc.) would be accepted in the recovery facilities while absolute inventory control would remain with the generating facility. The material would remain as part of the generating facilities inventory until an absolute value was obtained by the recovery facility. Only then would an absolute flow control transaction be indicated. The recovery facilities would be considered as absolute measuring stations. All emphasis would be placed upon methods and techniques to improve their ability to measure.

Transfers from a generating facility to analytical control would be treated in the same manner. The laboratory would accept physical control or custody by material type and source (item control) while the generating facility maintained absolute inventory control. When the laboratory returned the material to a measuring station only then would an absolute flow transaction be indicated. Of course, an absolute measure of laboratory waste removals would also have to be considered.

The extraction and plutonium processing areas (Task I, II and III) are the only true remaining "in process" areas within Z plant. The extraction area is very little different from a recycle or backcycle operation similar to those of the parent plants. Consequently, it seems logical to consider these areas as one process area. This is especially true when we consider the difficulty associated with establishing absolute flow control between these two areas. However, the problem of "closing" this area (Tasks I, II, III and extraction) still remains due to the large flow of by-products into the measuring stations. This problem would be substantially reduced if the measuring stations were considered to be part of this new area. All receipts to this new area would occur through either the Nitrate Shipper-Receiver Variance area (G-46 and the receiver product nitrate measurement yet to be established) or the recovery facilities where an absolute transfer would not actually occur until these measuring stations established a value. Removals would be restricted to output to waste, the salvage area, and button production. It may be desirable to continue to maintain a product storage area in order to distinguish between production and shipments, however, this would not be part of the flow control system since it would be a zero B-PID account.

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If it is administratively desirable to maintain a measure of extraction production for production scheduling and process control reasons, this can be continued separate from the main flow control system.

Due to the large amounts of by-products that may continue to accumulate due to the inability of the measuring stations to accommodate all the material it will be necessary to observe a strict LIFO policy as discussed above in connection with the Fabrication area. Only through the LIFO policy will it be possible to obtain reasonable absolute values for this inventory. Due to the dynamic changes that have continually occurred and are now planned, there is no reason to believe that continued changes will not take place in the future. Since these changes have always been accompanied by increased inventories, there will always be the possibility of accumulating large by-product inventories despite a policy to the contrary.

So far, the basic secondary control area structure necessary to establish good primary control of the CPD complex has been discussed and presented. It is felt that the only major technical problems so far encountered are those of establishing the Pu/U ratio and the Z plant Nitrate Receiver measurement. However, there is one other major problem that must be resolved before the described system, or any other system desiring absolute flow control, will be successful. This problem is caused by the mixing of by-product materials at the measuring stations. This mixing occurs in regard to material types (crucibles and powders, etc.) as well as between control areas (Fabrication, Salvage, and Plutonium Processing). Unless some type of plan can be devised which will result in the assignment of valid flow control values according to material type and generating area, it will be impossible to "close up" the Fabrication, Salvage, and Plutonium Processing areas. Even if such a plan were available, the value of these areas would still be limited unless the LIFO policy can be simultaneously maintained.

At the present time there are two plans which have been considered: (1) the use of neutron counting as a relative indication of material type content, combined with the absolute mixed output value to arrive at absolute individual input values, and (2) a statistical sampling (batch processing) of at least a portion of all the individual material types. Without further study no specific recommendations as to which plan or combination thereof offering the best chances for success can be presented. Resolution of this problem is technical in nature and will require the concerted efforts of the production scheduling and process control functions in order to effect a practical solution. Without effective solution of this problem, it is felt that the only other remaining alternative is to combine Fabrication, Salvage, Plutonium Processing and the HLO control areas into a single area. Even so, there would

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still exist a potentially large inventory to which the assignment of absolute values would be uncertain. The introduction of additional recovery capacity so as to maintain negligible by-product inventories without segregation of material types would still not provide absolute flow control between Fabrication, Salvage, and Plutonium Processing.

Assuming that these problems can be overcome the proposed CPD control system is graphically presented in Figures 1 and 2.

6. Physical Inventory Control

So far, the definitions of flow control areas and the distinction between absolute flow control and physical control (custody) have been presented. Item control was the main criteria for demonstration of physical custody. Item control may also serve as the main basis for establishing absolute inventory control in many areas. However, there are other areas to which item control may not be conveniently applied to establish absolute inventory control. All of the processing areas probably fall in this category, with the possible exception of the Fabrication area. Determination of the physical inventory in the other processing areas, in order to describe the static state of the processes at periodic intervals, is primarily dependent upon direct measurement at that time.

Inventory control is a precision problem rather than a bias problem as was the case with primary and secondary flow control. In order for the present average loss rate to have been caused by inventory bias we would have to be underestimating our inventory by an additional 2963 units each and every month. This is highly unlikely since this would have been an underestimation of 240,000 units for the 80 month period.* Thus, the CPD inventory would have to be underestimated by $240,000 + 2963$ units in September, 1958, $240,000 + 2(2963)$ units in October, 1958, etc. The average CPD inventory size since Redox startup has been about 285,000 units. It is currently averaging 610,000 units.

Thus, control of month-to-month inventory precision is the main inventory control problem if we expect to attach meaning to a monthly B-PID statement. No matter how much we improve the primary control measurements, the meaning that we attach to a monthly B-PID statement is no better than the precision of the inventory. Only after we have obtained a cumulative B-PID representing from several months to a year's operation does the effect of inventory precision diminish. Assuming it is desired to eventually reach a point where we can attach meaning to a monthly B-PID statement the following suggestions for control of CPD inventory are presented:

* See Appendix C.

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- (a) CPD should estimate what the average normal inventory level should be for each plant and establish reasonable maximum and minimum limits about that average. If the maximum limit is exceeded it would indicate an abnormal inventory accumulation which should not be allowed to continue. Exceeding the lower limit would probably result whenever it is necessary to flush in order to prevent critical mass or other process incidents. Allowance should be made for storage areas that are based upon firm measurements such as the Fabrication product storage area. In general the average inventory level should be as small as possible and the limits about that average as tight as possible. The main idea is to maintain as constant an inventory as possible, so as to minimize the fluctuations in the size of monthly inventories.
- (b) Improve methods of estimating plant inventory whenever possible. This might be accomplished by making use of methods such as were suggested in reference 6 for estimating the size of dissolver heels, red tagging a batch so that it can be measured at other points further on in the process, checking manometers over the entire range instead of just at zero, and adjusting the standard column holdup estimates each month based upon knowledge of process operating conditions that may have caused deposition or off standard buildups. The use of relative flow control methods may be useful in those process areas where the material flow is in powder form. Continuous weighing equipment utilizing electronic and pneumatic transducers may be useful in this regard. This is of particular importance in regard to plutonium since we are trying to control grams of material instead of pounds as with uranium.
- (c) Establish a double check system for each month's inventory so as to eliminate calculation errors, to make sure that transfers after the noon inventory do not introduce errors, to make sure that a vessel has not been left out, and to make sure that the best methods for estimating have been used based on the current months operating experience.
- (d) Reduce plant inventory for process reasons only (critical mass, flooding column, etc.). Whenever it is necessary to flush part of the process, do so during the middle of the month, if possible, so as to allow the plant inventory to build up to normal levels by month end inventory time.
- (e) Avoid the use of other inventory methods such as book inventories. In order to obtain meaningful monthly B-PID's, consistent physical inventory practices must be used.

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7. CPD Administrative Control Function

Throughout the report, reference has been made to the need for some over-all coordinating control effort. In large process complexes there may be so many individual units making up the complex that a central administrative group may be required to

- (a) effectively analyze the integrated information coming from all control functions and to maintain adequate records thereof, (9,11,12,13,14,16)
- (b) maintain emphasis upon primary flow control and physical inventory control methods,
- (c) arbitrate inter-process differences at a higher level in order to effect more timely and direct solutions in keeping with the over-all primary control concept,
- (d) effectively discharge CPD's responsibility for the control of product materials, and
- (e) evaluate the desired degree of control against the cost of obtaining such control through a good knowledge of the over-all system and its requirements.

It is felt that the CPD is responsible for the control of product materials within the CPD primary control area. Until now, it appears as though this responsibility has been limited to physical control (custody). There seems to be little recognition of responsibility for absolute flow control. Throughout this study it has been noted numerous times that the responsibility for control should not lie with one function when the physical ability to control lies with an operating function. Without the integration of the responsibility for product material control and the ability to accomplish said control, it will always be difficult to establish and maintain an effective control system. It is our belief that product material control and essential material control differ only by the higher value associated with product materials. Since essential material control is a recognized responsibility of the Production Operation, it seems only logical that product material control should be recognized in the same manner. Consequently the basic control system discussed throughout this report is presented in order to help establish a system that will provide CPD with the necessary information and decision structure that will allow the most effective control of product materials. The SS Accountability Operation maintains much of this information in order to fulfill the requirements of the AEC. Since the CPD has not clearly defined their information requirements, the accountability information and report system is primarily directed towards the needs of the AEC, which may not be the same as those of an effective CPD control system. Even though the needs might be identical, CPD does not currently receive the SS Accountability report to the AEC (21) that quite lucidly describes the state of the current system.

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For the above reasons it is felt that there is a need for a central CPD group which can define the information requirements needed from each function (production scheduling, process control and accountability), maintain adequate records and history, analyze the information, arrive at the most effective decisions and evaluate the effectiveness of the system. As an example, the group might consist of representatives from each facility, SS Accountability, the Process Chemistry Operation, and the Production Operation. Responsibility for direction and for reports and statistics would lie with the Production Operation. Each facility representative should be well acquainted with analytical, volume, sampling and inventory measurement methods within their respective facilities. The facility representative would be responsible for implementing all procedures and techniques within the facility that were agreed upon by the central group. Representatives from the SS Measurements and SS Accountability groups would communicate the needs of the SS Accountability Operation in regards to fulfilling AEC requirements and receive communication of the information requirements of the CPD. The Process Chemistry Operation representative would provide an arbitrating service by conducting independent studies of the various problems. It may be desirable to include other disciplines such as statistical, systems, data processing, and facilities engineering. A typical CPD control organization embodying the concept of a central administrative group is presented in Figure 3.

B. Uranium

1. Introduction

A detailed analysis of the uranium B-PID history since Redox startup was presented in an earlier report⁽⁹⁾ which also included recommendations for control of the uranium system. For this reason and because of the similarity to the plutonium system already discussed, this section will only include a discussion of a few items that were not included in the earlier report.

2. Primary Control (reference 9, page 6)

There are no changes in this section except to reiterate the need for an over-all administrative coordinating effort to integrate and communicate the status of the control system.

3. Secondary Control (reference 9, page 8)

There are no changes in this section except to explain why it is felt that shipper-receiver variance areas, suggested for plutonium, may not be needed. The main reason for the CPD Shipper-Receiver Variance area was the inherent uncertainty of the CPD

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receipts from the 100 areas and their dependence upon the amount measured in CPD. This presents no problem for uranium, since the use of the Pu/U ratio accepts IPD uranium content as a certified input to CPD.

The situation which now exists in the storage areas between the parent plants and the UCO is different from that of plutonium. The main difference is that item control cannot be maintained since batches are mixed in a large storage area. The large variances associated with the physical inventory of this storage would tend to preclude the use of shipper-receiver variance areas between E-12 or K-6 and C-1. Consequently, it would seem desirable to establish controls about the C-1 and recovered acid measurements that would be acceptable to all facilities and retain E-12 and K-6 only to the extent necessary to fulfill process control requirements.

The decision as to whether a Salvage Variance area in the UCO would be beneficial or not would depend upon the degree to which inactive materials affect the current flow of CPD uranium material.

4. Physical Control

No further additions are necessary in this section due to the earlier report⁽⁹⁾ and because the corresponding section for plutonium applies equally well to uranium.

C. Use of Other Control Tools

1. The Standards Program

The Standards Program part of the Analytical Control Quality Program⁽¹⁵⁾ was initially intended to provide a basis for the control laboratories to determine the accuracy of analytical methods. However, from the beginning (October, 1954), it was recognized that it had the potential for broader application. This was realized in 1957 when the application of bias correction factors^(5,20) for the improvement of the reliability of source data was accepted. Since then there have been indications that better control has resulted.^(5,17,18) The Standards Program is primarily a bias control tool, consequently it is fundamental to the success of absolute flow control. Continued improvement in this field (better standards, etc.) will directly affect improvement of absolute flow control within CPD.

2. The Referee Program

The Referee Program part of the Analytical Control Quality Program was initially intended to provide a basis for determining the precision of analytical control methods. It was

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again realized from the beginning that the Referee Program had the potential for broader application. This has not been realized as was the case with the Standards Program. There has been one attempt to initiate this application, (19) but this attempt was discontinued in lieu of the need for an over-all CPD control study.

Since the Referee Program is concerned with the measurement of analytical precision it does not have direct application to absolute flow control. Its primary application is in the field of relative flow control and physical inventory measurement. Since relative flow control depends upon day-to-day or batch-to-batch measurements precision is of paramount importance. For example, if an engineer was attempting to control waste loss or DF through periodic analysis of nitric acid content and he received a result that indicated a deviation from his intended process average, he would be better equipped to make a decision to change the acid concentration if he knew what proportion of the total imprecision could be attributed to analytical, sampling and process variations. If the analytical variation were large, a rerun would be the logical decision, or it might indicate the need for a better analytical method. The same would apply to sampling variation. If the process variation is the most significant contributor, it might indicate that nitric acid content is not a good measure of the effectiveness of waste loss or DF control.

This influence of precision also applies to the measurement of physical inventory. Since nearly all inventory measurements are based upon one or two observations, knowledge of the proportionate contribution of each variance component may provide the information needed to improve that inventory measurement. This information is also needed for the estimation of the precision of the total inventory, which is the major source of variation in a monthly B-PID.

In addition to the indication of analytical precision provided by the Referee Program there is a need for further application of this program to provide protection against the occasional "flier." While an effective flier detection system is very difficult to establish, a knowledge of the number of analytical fliers that may occur would be useful in process control. Such information would provide a basis for establishing certain types of "risk" decisions.

3. Sampling Control Programs

It would be desirable to have a "Standards Program" to measure sampling bias and a "Referee Program" to measure sampling precision. Unfortunately, direct methods for measurement of sampling bias are not available since there is no convenient means of providing a reliable standard. An example of such a

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method would be to fill the Purex E-5 vessel with an accurately known solution similar to the normal process solution and then take samples for analysis. Indirect methods may have some application. An example would be the Pu/U ratio where 100 area uranium values serve as standard values. One must be sure that analytical bias is controlled. Even so, the apparent bias observed could be caused by volume measurement bias as well as sampling bias. Continued development of such methods is desirable in order to attain better absolute flow control.

As with analytical precision, the primary application of a knowledge of sampling precision is in the field of relative flow control and physical inventory measurement. Sampling referee programs similar to the analytical referee program can be devised and it is felt that this is necessary before the full potential of the analytical referee program can be realized. Wherever duplicate samples are routinely taken the necessary information is automatically available. Another method that may be useful would be to reduce the analytical referee program and replace it with a sampling referee program. Combined estimates of both analytical and sampling precision could thus be obtained; however, individual estimates of each could not be obtained. Any accomplishments in this field would lead to improved process control techniques.

4. Volume Measurement Control Programs

Volume measurement control is primarily of concern in absolute flow control and the measurement of physical inventories. Recent studies^(7,8) indicate that volume measurement bias may be one of the most significant factors in absolute flow control. Control of volume measurement bias requires the control of two factors, (a) the initial tank calibration and (b) the liquid level instrumentation used during routine operation. During calibration the measurement of the amount of water added must be accurate. Equally important, but more difficult, is the calibration of the liquid level instrument. During routine operation, methods must be developed to insure accuracy in the liquid level instrument comparable to that maintained during tank calibration.

In some cases, scales are used instead of liquid level instruments. This is particularly true of absolute flow measurements. Most existing weighing facilities utilize a "check weight" system. This should be considered when installing new facilities. It is felt that "check weight" data should be published in the same manner as analytical bias corrections for analysis purposes and to serve as a basis for demonstrating control.

There are the areas in which we have done little, & Dittler has rated CPD performance inadequate.

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D. CPD Requirements of the SS Accountability Operation

1. More Useful Reports that Describe CPD Performance

One of the main problems encountered in this study was getting the accountability data (receipts, removals, inventory, B-PID's) into a usable and composite form such that the necessary plant and control area analytical comparisons could be made. As a result considerable time was spent obtaining the data from the many "work sheets" which very adequately displayed all the necessary source data. Once we were able to explain what we needed the accountability groups readily provided all the information. In other words, the data and a good understanding of it are available. It is the time consuming integration of this data into a meaningful form that restricts timely analysis.

There is a need for a type of material balance report that describes the flow within primary and secondary control areas according to material type and origin. This essentially amounts to summarizing "work sheet" totals into material balance reports. Assuming that the CPD adopts a control system similar to the one described in this report, the above system will be used to describe the report system felt to be needed. This report system may or may not be the same as the one necessary to meet the requirements of the AEC. It merely defines the information needed by the CPD in order that they may operate an effective control system. The following is a listing of the absolute flow control reports needed for plutonium:

- (a) CPD Primary Material Balance Control Report
- (b) CPD Shipper-Receiver Variance Control Report
- (c) Redox Material Balance Control Report
- (d) Purex Material Balance Control Report
- (e) Nitrate Shipper-Receiver Variance Control Report
- (f) Plutonium Processing Material Balance Control Report
- (g) Fabrication Material Balance Control Report
- (h) Salvage Shipper-Receiver Variance Control Report
- (i) Research and Engineering Material Balance Control Report

Similar reports for uranium would include a, c, d, i, and the Uranium Conversion Operation Material Balance Control Report. Each report should contain the following general classes of information by month and fiscal year to date:

- (a) Total Material Balance
- (b) Composition of Ending Inventory
- (c) Book-Physical Inventory Differences
- (d) Schedule of Receipts
- (e) Schedule of Removals

The total material balance section is essentially the same as presented in current reports. It describes beginning inventory, receipts, removals, ending inventory and B-PID totals for each respective area. Composition of ending inventory is also the

same as in existing reports except that it should be broken down by material type and physical custody areas as demonstrated by Figure 4. The breakdown of Book-Physical Inventory Differences would only apply to the variance areas, since third level areas would no longer exist within second level processing areas. Figure 1 demonstrates the type of B-PID breakdown that should be included in the CPD Primary Material Balance Control Report. In some cases the schedules of receipts and removals can be included in the total material balance section (a) of the reports when material type activity is small. For example, the only other information needed in the Redox Material Balance Report for October, 1958, (HW-58132) would be a breakdown of the IPD receipts according to the generating reactor. Of course, in the proposed system this breakdown by IPD reactor would appear in the receipts to and removals from the CPD Shipper-Receiver Variance area. Material received by the Plutonium Processing area from Fabrication, Salvage, etc. should be broken down according to material types (briquettes, burnt turnings, powders, etc.). Figure 5 is a composite example demonstrating typical breakdowns that might appear in separate schedules of receipts and removals.

In summary, the principal changes recommended are:

- (a) a primary CPD report to include all the features of individual reports and the HAPO report to the AEC,
- (b) a more detailed breakdown of receipts and removals according to material type and physical custody areas,
- (c) a more detailed breakdown of composition of ending inventories according to material type and physical custody areas,
- (d) the inclusion of a cumulative fiscal year-to-date description of receipts, removals and B-PID's,
- (e) a Research and Engineering material balance report.

These are general recommendations that would be subject to revision as information needs change.

2. B-PID and Inventory Estimates with Minimum Variance

In the accounting structure as it now exists, the physical inventory for a month is always used as the ending inventory. The book inventory is equal to the beginning inventory (i.e., the ending inventory for the previous month) plus the receipts and minus the removals. The algebraic difference between the physical and book inventories is then used as a measure of discrepancy and is intended to detect diversion, measurement errors and accounting errors.

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The use of an alternative procedure for estimating the ending inventory,⁽⁴⁾ utilizing a combination of the book and physical inventory estimates results in certain advantages over the current method of utilizing only the physical inventory:

- (a) The alternative estimate of the ending inventory proposes using all the data in a manner which will give the unbiased estimate which has the smallest variance. Because of this, the resulting B-PID is more sensitive.
- (b) At present there is a strong dependence (negative serial correlation) between B-PID's for successive months in the sense that month-to-month fluctuations tend to be opposite in direction.⁽¹⁰⁾ This dependence tends to be eliminated by the alternative definition resulting in a B-PID that is less difficult to interpret,

On the basis of these advantages, the adoption of this method of computing B-PID's for CPD control purposes is highly recommended.

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FIGURE 1

	<u>Third Level</u>	<u>Secondary</u>	<u>Primary</u>
1. CPD Shipper Receiver Variance Area			
IPD - Redox B-PID	=====		
IPD - Purex B-PID	=====		
Offsite - Redox B-PID	=====		
Offsite - Purex B-PID	=====		
Offsite - Fabrication B-PID	=====		
Net CPD Shipper-Receiver B-PID		=====	
2. Redox Processing Area B-PID		=====	
3. Purex Processing Area B-PID		=====	
4. Nitrate Shipper-Receiver Variance Area			
Product			
Redox - Z Plant B-PID	=====		
Purex - Z Plant B-PID	=====		
Recycle			
Redox - Z Plant B-PID	=====		
Purex - Z Plant B-PID	=====		
Redox - Purex B-PID	=====		
Net Nitrate Shipper-Receiver B-PID		=====	
5. Plutonium Processing Area		=====	
6. Fabrication Processing Area		=====	
7. Salvage Shipper-Receiver Variance Area			
Res. & Eng. - Salvage B-PID	=====		
HLO - Salvage B-PID	=====		
Fabrication - Salvage B-PID	=====		
Pu Proc. - Salvage B-PID	=====		
Redox - Salvage B-PID	=====		
Purex - Salvage B-PID	=====		
Net Salvage Shipper-Receiver B-PID		=====	
8. Research and Engineering Area		=====	
<hr style="border-top: 1px dashed black;"/>			
<u>Primary Control</u>	☐	CPD Primary B-PID	=====

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FIGURE 2

FIGURE 3

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FIGURE 4

COMPOSITION OF ENDING INVENTORY

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1. CPD Shipper-Receiver Variance Area

Redox	Normal Metal	100-F, 100-H, 100-KW, offsite, etc.
Purex	Normal Metal	100-F, 100-H, 100-KW, offsite, etc.
Redox	E Metal	100-KW, 100-C, offsite, etc.

2. Redox Processing Area

In Process	MSP	Dissolver heels and charges, A-1 through H-7
	EXT	Columns, waste area, extraction vessels
	CONC	L cell holdup, L cell vessels

3. Purex Processing Area (Similar to Redox)4. Nitrate Shipper-Receiver Variance Area

Product Nitrate	Redox, Purex, Z Plant
Recycle	Redox, Purex, Z Plant

5. Plutonium Processing Area

In Process	Task 1	Hood x, y, z, etc.
	Task 2	Hood x, y, z, etc.
	Task 3	Hood x, y, z, etc.
	Extraction	Columns, receiving and blending, waste area, J4 canned nitrate, extraction vessels, etc.
By-products	Task 1	SN, Oxalate powder, etc.
	Task 2	Oxide, Fluoride powders, etc.
	Task 3	Fluoride powders, slag & crucible, B-3-S, etc.
	Extraction	Hood floor flushes, etc.
Product Storage	Offsite	Buttons, Nitrate
	Fabrication	Buttons

6. Fabrication Processing Area

In Process	Casting	Hoods x, y, z, etc.
	Machining	Hoods x, y, z, etc.
	Inspection	Hoods x, y, z, etc.
By-products	Casting	Skulls, casting fragments, etc.
	Machining	Briquettes, sweeps, etc.
Product Storage	Offsite	Shapes

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7. Salvage Shipper-Receiver Variance Area

Hanford Laboratories Operation	Quail briquettes, skulls, fragments, etc.
Research & Engineering	Skulls, fragments, sweeps, etc.
Fabrication	Waste cartons, polish residues, etc.
Plutonium Processing	Waste cartons, vacuum header holdup estimate, etc.
Offsite	ANL Waste, etc.
Redox	Waste cartons, etc.
Purex	Waste cartons, etc.

8. Research and Engineering Area

Process Chemistry	Material types, etc.
234-5 Development	Material types, etc.
etc.	Material types, etc.

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FIGURE 5

SCHEDULE OF RECEIPTS AND REMOVALS

IPD Removals to Redox & Purex	Normal metal	100-F, 100-H, 100-KW, etc.
	E metal	100-KW, 100-C, etc.
HLO Receipts or Removals to any Area	Quail briquettes, skulls, frag- ments, etc.	
R & E Receipts or Removals to any Area	Skulls, frag- ments, sweeps, etc.	
Fabrication Removals to Plutonium Processing	Reject buttons, casting frag- ments, turnings, sweeps, etc.	
Salvage Receipts or Removals to any area	HLO	Quail briquettes, skulls, fragments, etc.
	R & E	Skulls, fragments, sweeps
	etc.	etc.
Waste Removals from any area	Stored	Coating waste, conc. waste, sumps, etc.
	Discarded	Cribs, sumps, etc.

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APPENDIX A
INFORMATION SYSTEMS

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The discussion of the CPD information system structure and requirements within the body of this report indicates a serious weakness that has a direct effect upon all the basic functions subject to this organization's control. It has been stated that the basic inadequacy of this system is its inability to maintain fundamental source information in a central location, or set of locations, where it can be integrated into as many combinations as are required to satisfy all functional needs. In other words, many of the units of information are in existence but randomly scattered throughout the various functions, prohibiting their efficient utilization.

It may be of help to interject an analogy at this point to illustrate the vital importance of the information system. If we choose any living organism and analyze its structure to determine how it accomplishes the sensing and interpretation of the environment in which it exists we find a specific system created for this purpose. Generally speaking, this is its total nervous system. For every organism there is a central signal processing organ, namely the brain. Almost every stimulus is consciously received and interpreted before action takes place. The remaining functions are usually referred to as reflexive. This is the portion of the system that has been found to be stable in nature, a static logical pattern of response to certain sets of stimuli.

In a sense, an organization assembled with the purpose of modifying the physical situation to accomplish a specific goal can be viewed in the same manner as the organism. The organization cannot survive without a complete and efficient communication or information system. There must be direct channels of communication from the physical processes to all segments of the organization to permit the organization to sense the status of the situation and to permit the creation of models which correlate the various stimuli in an understandable manner. This information system must have definable channels which are known. These channels must be as direct or short as possible consistent with established organization relationships and responsibilities. Above all, the lines of communication should not be interrupted during the time the organization is to function. The establishment of the information centers is also necessary to assure the acquisition, integration and proper dissemination of information. Actually,¹ in an exhaustive theory of organization, communication would occupy a central place, because the structure, extensiveness, and scope of organization are almost entirely determined by communication techniques.

It is important to distinguish between the physical entity for which an information system exists and the system itself. To do this the concept of models is important. For example, very few persons are in a position to change the physical plant in order to test a modification. In most cases a representative model is used. An engineer in this circumstance may use the process model (technical manual). Here a representation of the material to be processed

¹The Functions of the Executive; C. I. Barnard, Harvard University Press.

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is placed in the model, which in turn simulates the reactions to expect and produces a reliable answer as to the output. The fundamental difference is that the physical process is not subjected to any modification during the course of the test..

This method of simulating the existing process for measurement and modification purposes applies to each of the many functions established to exercise control of the physical processes. Therefore, there are innumerable models dependent upon the basic units of information emanating from these processes, and there are numerous uses to which the same set of information units must be put. An information system in its general sense is the over-all agglomeration of these models, their interpretation and use. The heterogeneous structure obtained is the foundation of the system. This structure is the best description of the many complex elements within and directly related to the physical processes at any point in time. However, it is far from complete and far from being precise. The structure of a functional model is dynamic. It is subject to change to improve its ability to simulate accurately to represent the changes that occur in the physical plant because of modification or repair, and to conform to administrative definitions established for measurement purposes..

In light of this over-all problem of adequate communication, a program directed toward defining the information system structure for the Z plant was initiated and is now in progress. The purpose of this program is to specifically identify the logical structure of the information system necessary to provide all administrative functions with basic control information.. This will be the task of defining the set of models from which selected segments can be integrated to provide the over-all logical structure required.

The study is being performed by a team comprised of members from the Z plant operations, CPD Research and Engineering, SS Accountability, and Operations Research & Synthesis functions. Each individual participating brings to this team the discipline and rationale required by such an activity. It should be pointed out that the initial phase of this program has been limited to the definition of production scheduling, process control, and accountability information requirements. This in turn limits the initial phase to defining the information system basic to the measurement of the physical process streams and entities directly related to these streams. No specific consideration will be given to the many other functions such as radiation protection, maintenance, and materials control during the initial developmental phase.

To date several principles have evolved as a result of this effort. One is that there must be a specific and unique name attached to each element for which information is required. This poses the problem of establishing a common language. Much progress has been made within the limits defined above. However, the expansion of this phase of the program to cover all information requirements will provide the acid test for this work.

A second principle is based on the requirement that an information system describe the activity occurring in the physical process to be controlled. Initially the study was predicated on a logical flow diagram depicting the

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sequence of technological steps in the process. This proved to be inadequate because it did not allow for the exceptions normally experienced. A study of this problem indicated that two criteria govern the activities in a physical process. The first is the process logic, i.e., the technological steps necessary to accomplish a specified end product. The second is the set of "assignments" that can be interjected at any point in the process logic. These assignments are used for many purposes, such as correcting for malfunctions in the process stream or closely associated entities, identifying the item by weighing or physical measurement, and placing an item in a known status while awaiting the next logical step.

The integration of these two principles into a workable model indicated the nature of an information system and some of its basic characteristics. To know and understand what is occurring at any time in the physical process, it is necessary to establish item control. The fundamental elements of item control are that the item must have a unique and specific name, its location must be known, and time at which an item arrives and departs from a specified location must be established. Unless the name, location and time of occurrence are related it is impossible to attach additional information units concerning physical, chemical or radiation characteristics to the item in question. Location as used here includes the point where a transition from one unique entity to another occurs. The information needed for item control is the foundation of the information system. This information also serves as the index for relating the many complex variables involved.

The determination of the relative or absolute amount of product materials is dependent upon the identification of the item and its experiences prior and/or subsequent to an absolute measurement. Specifically, this implies the establishment of a formalized system to acquire, integrate, and disseminate the information required for process control, production scheduling and other control functions. The relationships involved would be unique because such a system must identify and segregate each quantitative unit of information according to its relative, semi-absolute, or absolute value in order to prevent integration of data of different degrees of accuracy and designating the result as absolute.

All control functions depend on this information to some degree, either as basic information or as an index to the success of their efforts. In general, all functions are established to promote the best operation of the physical processes, whether they are responsible for proximate or remote manipulation of the systems required to accomplish this end. The complete evaluation of the organization's over-all efficiency in reaching specified goals is completely dependent upon relating these areas. It is the knowledge of the condition of the physical system that permits this correlation.

APPENDIX BPRODUCT MATERIAL CONTROL IN Z PLANT

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I. Discussion

Appendix C demonstrates that indicated HAPO losses are closely associated with the startup of recovery facilities in Z plant. It cannot be determined whether the indicated losses are real or a result of overstatement by 100 Area and the Redox-Purex nitrate measurements. The resolution of this problem depends upon improved product material control in Z plant. In order to gain an understanding of the indicated losses, Plutonium Recovery Operation data were examined for the period January-June, 1958. Table 1 presents fiscal year 1958 B-PID's for all of the Z plant material balance areas.

Prior to Task I, II, III, Redox and Purex balances indicated a 50.8 kg overstatement by the 100 Areas. Redox, Purex and Tasks I, II, III combined indicated that the 100 Areas are understating by about 27.5 kgs. However, the high cumulative gain in Tasks I, II, III may not be representative of the true performance in this area. If corrections are made for overstatement of Tasks I, II, III by-product materials as determined by metal recovery and dissolving operations it becomes apparent that Tasks I, II, III were actually underaccounted by about 12.2 kg's (Table 2).

TABLE 2Fiscal Year 1958

	<u>B-PID</u>	<u>B-PID</u>
Redox		-22,228
Purex		-28,635
Task I, II, III	78,277	
Metal Recovery Adj.	-13,166	
Dissolving, Adj.	-68,313	
Feed Storage Adj.	-8,959	
Adj. Task I, II, III		-12,161
100 Area to Button Production		-63,024

The presence of transfer biases of this order of magnitude limits the significance that can be attached to Task I, II, III B-PID's. The factors that contributed to the large dissolving adjustment were examined for the period January-June, 1958. This examination revealed good process stability in the dissolving operation to the extent that monthly dissolving B-PID's can be satisfactorily predicted by the following equation:

$$\text{B-PID} = (\text{Receipts}) (-0.25) \pm 1,670$$

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TABLE 1

Z PLANT B-PID's - FISCAL YEAR 1978

Month	Task I, II, III		Fabrication		Metal Recovery		Dissolving		Extraction		Anal. Control		Feed Storage		Z Plant	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
July 57	-6,839	-6,839	-1,188	-1,188	-1,263	-1,263	-1,211	-1,211	-132	-132	278	893	0	0	-11,631	-11,631
Aug.	-9,447	-16,286	-2,183	-3,370	-1,420	-1,420	-3,499	-4,710	-492	-584	491	893	-437	-437	-15,401	-27,032
Sept.	-16,292	-32,578	-2,055	-5,425	-453	-1,873	-2,721	-7,431	1,373	789	491	1,384	0	0	-19,030	-46,062
Oct.	-2,037	-34,615	-1,853	-7,278	-1,594	-3,467	-201	-7,632	-6,316	-5,526	218	1,602	90	90	-9,945	-55,607
Nov.	28,792	-5,823	380	-6,898	-1,034	-2,628	-842	-8,474	474	-5,052	218	1,820	0	0	27,588	-27,619
Dec.	16,816	10,993	43	-6,855	-568	-3,196	-7,935	-16,409	-7,937	-13,009	-267	1,335	62	62	7,694	-27,426
Jan. 58	23,065	34,058	595	-6,260	-1,747	-4,943	-12,566	-28,975	-5,564	-18,573	699	2,034	118	118	-800	-19,731
Feb.	10,803	44,861	-308	-6,568	-4,986	-6,733	-6,827	-35,802	873	-17,699	473	1,560	10	10	4,045	-20,531
Mar.	9,362	54,223	-1,671	-8,239	-1,464	-8,197	-6,905	-42,307	1,948	-13,099	273	1,833	-139	-139	15,082	-15,886
Apr.	11,069	65,292	-2,250	-10,489	-6,411	-14,608	-19,323	-61,630	-3,628	-11,111	0	1,833	-117	-265	-8,142	-30,968
May	-10,418	54,874	-3,428	-13,917	-2,062	-16,670	-4,742	-66,372	-1,948	-14,740	34	1,866	138	-118	10,482	-55,110
June	23,403	78,277	2,158	-11,039	-269	-16,939	-5,474	-71,846	-1,248	-15,988	34	1,866	-8,841	-8,979	10,482	-44,628

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This indicates that dissolving receipts are consistently overstated by $25 \pm 3.6\%$. Table 3 demonstrates this stability.

TABLE 3

	<u>Receipts</u>	<u>Obs. B-PID</u>	<u>Calc. B -PID</u>	<u>Obs.-Calc.</u>
January, 1958	51,591	-12,567	-12,898	-331
February	29,464	-6,864	-7,364	+500
March	25,626	-6,505	-6,406	-99
April	75,375	-19,322	-18,844	-478
May	22,816	-4,742	-5,704	+962
June	18,823	-5,475	-4,706	-869

The period July-September, 1958 does not appear to follow this relationship due to adjustments in the factors used to estimate plutonium content of Task I, II, III by-product materials.

TABLE 4

	<u>Receipts</u>	<u>B-PID</u>	<u>Calc. B-PID</u>	<u>Obs.-Calc.</u>
July, 1958	21,837	-8,011	-5,459	-2,552
August	10,740	-1,473	-2,685	+1,212
September	36,155	-4,359	-9,038	+4,679

However, it appears as though July receipts to dissolving were even more overstated than during the January-June period. August and September performance indicates that the factor adjustments did reduce the amount of the overstatements from about 25 percent to about 12 percent. The factor adjustments were based upon the assumption that dissolving measurements were unbiased and that past recovery data is representative of current by-product content. The factor changes applied to slag and crucible, and Task I, II powders. Table 5 demonstrates the effect of the July factor adjustments if they had been applied back to the January-June, 1958 period.

TABLE 5

<u>Period</u>	<u>Change in Slag & Crucible Receipts</u>	<u>Change in Task I,II Powder Receipts</u>	<u>Observed Dissolver B-PID</u>	<u>B-PID After Factor Adjustments</u>
Jan. 58	-1,633	-2,707	-12,567	-8,227
Feb.	-746	-3,819	-6,864	-2,299
Mar.	1,868	-3,645	-6,505	-4,728
Apr.	4,208	-11,557	-19,322	-11,973
May	2,180	-2,054	-4,742	-4,868
June	149	-1,792	-5,475	-3,832
Total	6,026	-25,574	-55,475	-35,927

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Thus it would appear that the January-June, 1958 dissolver receipts were still overstated by 35,927 units or about 16 percent.

The metal recovery adjustment was also examined. The relationship between metal recovery receipts and B-PID's is represented by the following equation:

$$B-PID = (\text{Receipts}) (-0.074) \pm 7,347$$

However, the large uncertainty of this relationship, as indicated by the $\pm 7,347$ precludes the use of the 0.074 constant as a valid estimate of the overstatement bias. This is further demonstrated by Table 6.

TABLE 6

<u>Period</u>	<u>Receipts</u>	<u>Obs. B-PID</u>	<u>Calc.</u>	<u>Obs -Calc.</u>
January, 1958	39,964	+1,447	-2,946	+4,393
February	41,601	-4,985	-3,067	+1,918
March	26,577	-1,464	-1,959	-495
April	32,192	-6,410	-2,373	-4,037
May	27,024	-2,063	-1,992	-71
June	19,326	-269	-1,425	+1,156
Average	31,114	-2,291		
Precision of one month		$\pm 7,558$		

The extraction area receives material at the values established in the dissolving and metal recovery areas, and at values established in certain direct measurement vessels (G-50, G-46, etc.). For the period studied, there appears to be no bias between receipts and removals in the extraction area. However, the month-to-month variation is excessive.

TABLE 7

<u>Period</u>	<u>Receipts</u>	<u>B-PID</u>	<u>Ending Physical Inventory</u>
January	89,694	-5,564	11,679
February	60,812	+370	10,721
March	54,787	+4,640	7,315
April	87,251	+1,948	9,944
May	40,422	-3,628	8,583
June	54,372	-1,248	12,532
Average		-580	
Precision of one month	95CL	$\pm 8,526$	

This variation could be caused by measurement errors in receipts, removals, or physical inventory. The data of Table 6 indicates no relationship between B-PID variation and physical inventory, hence the B-PID variation must be caused by measurement error in extraction receipts and removals. This

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can be further demonstrated by examining SN and VT receipts from Task I, II, III that were remeasured in the G-50 tank during the period March-June, 1958. The average value of the ratio between G-50 receipts and Task I, II, III removals was 0.67. A linear regression, assuming zero intercept, results in the following equation:

$$\text{G-50 Receipts} = (\text{Task I, II, III Removals}) (0.67 \pm 0.19)$$

As a result of the apparent bias between these measurements SS Accountability adjusted the monthly extraction receipts by the observed monthly ratio, assuming the G-50 to be unbiased. The following table illustrates the actual accountability adjustments and the adjustments that would have been obtained if the linear regression of all the data had been available.

TABLE 8

Period	Task I,II,III Measured Removals	Acctblty. Adjust.	Linear Regres. Adjust.	Extraction B-PID With		
				No Adjust.	Acc. Adjust.	Regres. Adjust.
Mar. 58	6,387	-4,075	-2,104	565	4,640	2,669
Apr. 58	7,099	853	-2,338	2,801	1,948	5,139
May 58	7,218	-3,896	-2,378	-7,524	-3,628	-5,146
June 58	5,660	-243	-1,864	-1,491	-1,248	373
Total	26,364	-7,361	-8,684	-5,649	1,712	3,035
Precision of Total 95 CL			$\pm 3,762$			

Either method of adjustment is valid. The precision of the total adjustment indicates that while correction is justified the uncertainty associated with the correction is so large that (1) good agreement between the two methods of calculating the adjustment cannot be expected, and (2) the adjustments do little to reduce the variation in the extraction B-PID's. The uncertainty associated with this single receipt to the extraction area, which is less than ten percent of the total receipts, limits the significance that can be attached to monthly extraction B-PID's.

PRO Feed storage consists of vaults containing plutonium solutions and solids awaiting recovery. Some of the materials exist in forms that are easily measured while others are in forms that are very difficult to measure. This storage area contains from 90 to 95% of the total physical inventory of the Product Recovery Operation and is two to four times as large as the average monthly throughput. The solutions received are normally processed within a month and constitute a relatively minor material control problem. Storage time for solids varies considerably. This variable storage time, and the uncertainty associated with plutonium content estimates prevent reliable determination of the actual amount of plutonium in PRO feed storage. Table 9 lists the estimated amounts of plutonium in PRO feed storage as of June 30, 1958 according to material types and the months in which the June inventory was generated. Table 10 demonstrates that most materials received in PRO feed storage are not

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TABLE 9

COMPOSITION OF JUNE 30, 1958 INVENTORY ACCORDING TO TIME RECEIVED (Kgs)

Material Type	MONTH IN WHICH JUNE 30, 1958 INVENTORY ARRIVED IN FEED STORAGE													Total 6-30-58 Inventory
	Pre-July	July	August	September	October	November	December	January	February	March	April	May	June	
Task II Powders					2.79		10.22	1.93	2.73	2.41	0.17		9.35	26.81
Task III Powders							0.42	0.11	0.15	0.05			1.13	4.23
Task IV-VII Sweeps						0.03		0.05			0.02	0.17	1.81	2.42
Reduction Fragments	7.73	0.46	0.10		0.05							2.04	2.55	12.96
Casting Fragments			0.15	0.01	0.68		0.05					0.38	0.07	0.50
Burnt Turnings														0.89
Solutions					3.83	7.47	2.25	0.61		7.05	0.16		10.10	32.87
Buttons		1.40			11.32	2.19	3.43	0.12					0.77	30.84
Skulls			6.37	6.64									0.72	0.72
Metal Samples									0.19			0.93	0.44	1.56
Briquettes					0.62				0.15					0.77
Shapes					1.55									1.55
Cast Metal														
Total	7.73	1.86	6.62	6.65	20.84	9.69	16.37	2.82	3.22	9.51	0.35	3.52	28.82	118.00

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TABLE 10

KILOGRAMS OF MONTHLY PRO FEED STORAGE RECEIPTS THAT WERE PROCESSED

Material Type	March		April		May		June		July		August		Total	
	Rec'd	Processed	Rec'd	Processed	Rec'd	Processed	Rec'd	Processed	Rec'd	Processed	Rec'd	Processed	Rec'd	Processed
Task II Powders	26.66	3.59	3.37	2.60	6.77	0	13.35	1.51	6.11	0.34	7.86	0.34	40.12	8.38
Task III Powders	3.57	0	0.72	0.72			1.13	0			1.15	0	6.57	0.72
Task IV-VII Sweeps			0.26	0	0.65	0	1.80	0	0.02	0.02			2.73	0.02
Reduction Fragments	2.97	0.35	2.19	1.52	6.00	0.22	2.47	0	4.55	0.01	4.55	0	22.73	2.10
Casting Fragments	0.06	0			0.10	0.07	0.07	0.06	0.90	0	1.17	0	2.30	0.13
Burnt Turnings											3.82	2.16	3.82	2.16
Solutions	0.53	0.31	0.47	0.20	0.26	0.26	12.93	10.90	0.69	0.69	11.58	11.09	26.46	23.45
Buttons	7.19	0	21.81	13.29	2.29	1.38	10.10	0			29.19	0	70.58	14.67
Skulls	3.17	0.11	7.22	5.96	5.16	5.08	3.41	2.69	7.51	5.20	6.52	4.27	32.99	23.31
Metal Samples	0.55	0	0.73	0.30	0.77	0.55	0.72	0	1.29	0	1.15	1.15	5.21	2.00
Briquettes					6.16	3.70	1.79	0.45	17.81	4.81	36.66	6.78	62.42	15.74
Shapes	12.93	12.62									0.23	0	13.16	12.62
Engineering	1.60	1.10	0.57	0.20	1.12	1.12	1.89	1.89	0.05	0.05	0.34	0	5.57	4.36
HLO	2.46	0			10.31	0.74			7.10	0	27.77	6.54	47.64	7.28
Total	37.69	18.08	37.34	24.79	39.59	13.12	49.66	17.50	46.03	11.12	131.99	32.33	342.30	116.94

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removed for current processing, but remain in storage awaiting future processing. Any over- or understatement of the amount of plutonium in these materials results in erroneous B-PID's for both the month in which the materials were generated and the month in which recovery took place. For example, the dissolving operation experienced a negative B-PID of 19,322 grams of plutonium in April, 1958 and of 5,475 grams in June, 1958. This difference of almost 14 kg is not attributable to less effective material control during April. It is a direct function of the higher April dissolving rate of 75,375 units as compared to 18,823 units during June. By concentrating recovery efforts on current material, a more reliable estimate of the actual amount of plutonium in by-products generated during the current month would be available. In addition, the estimation of the amounts of plutonium in by-products remaining to be processed would be more reliable. The use of current recovery data is required whenever a relatively high potential for under- or overestimation exists.

II. Summary

1. Due to the uncertainties associated with Task I, II, III area B-PID's, it cannot be determined whether indicated HAPD losses are due to overstatement by the 100 areas and Redox-Purex nitrate measurements, unmeasured inventory buildup, and/or unmeasured discards.
2. The basis for the resolution of possible overstatements by the 100 areas and Redox-Purex nitrate measurements can be established by installation of acceptable receiver nitrate and recycle measurements in Z plant. These measurements would provide a sound input basis for control of product materials in Z plant.
3. The use of past dissolving and metal recovery data, in order to establish current by-product content factors, does not appear to be valid.
4. Current factors established through the processing of at least part of current materials would provide better estimates of the true product content of by-product materials.
5. The establishment of reliable factors depends upon the ability to relate recovery data to individual material types.
6. The B-PID's resulting from variations in the estimation of by-product content should remain in the area of generation.
7. The PRO and Tasks I, II, III should be considered as one control area because a) the PRO is basically the same as backcycle operations in the parent plants, b) product material control becomes more difficult when internal control areas and their associated measurements are added, and c) the combined B-PID would be less variable and would result in a better indication of the true performance of the over-all area.

APPENDIX CANALYSIS OF PLUTONIUM B-PID HISTORY

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I. Introduction

An analysis of plutonium B-PID's was made covering the period since Redox startup. The enclosed tables and graphs present a fairly complete history of B-PID's and inventory status. Throughput data is not included for security reasons. HW-58647 presents the B-PID data of Table 1, 3 and Figure 1 in terms of percent. Section III includes a historical breakdown of the various events that affected changes in the B-PID trend periods of Table 3.

II. Discussion of Tables

Figure 1 presents the cumulative B-PID data of Table 1 in graphical form. This figure demonstrates that the apparent plutonium losses didn't really begin until about May, 1956. The losses that occurred between February, 1953 and October, 1954 can probably be explained by the use of the MWD-G/T relationship developed by Kinderman. Actually, HAPO losses probably began soon after the startup of Recuplex, Metal Recovery and Task I, but were not significant due to understatement of K reactor production. After K reactor production was corrected in June, 1956, the HAPO losses in Z plant became very noticeable. Since most of the early material processed through the Product Recovery Operation was scrap material that had accumulated over the years, it is reasonable to assume that HAPO has been losing material all along, but couldn't detect it until recovery facilities were available. This seems likely in view of the fact that heavy losses have continued even though the recovery facilities are now processing relatively current scrap materials. The gradual underaccounting across Redox and Purex since February, 1957, due to improvements and subsequent lowering in the parent plant nitrate measurements, indicates that some of the HAPO losses may be due to 100 Area overstatements. However, the recent recovery of L cell holdup at Redox brings Redox into good agreement with the 100 Areas. If a similar recovery should occur at Purex, as a result of the planned cleanout in L cell, it may indicate that the 100 Area prediction estimates are valid.

Table 2 and Figure 3 demonstrate HAPO inventory status. Most of the inventory increases can be explained by startup of new processes, the receipt of SRO and War Reserve materials, and large plant cleanouts. Since the startup of continuous equipment the fluctuations in inventory size have increased considerably due to repeated underestimation of Z plant inventory followed by cleanouts that recover the underestimations. Prior to this time the fluctuation in inventory size is not nearly as noticeable as it was for uranium. (9)

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Table 4 and Figure 2 demonstrate the variance from month-to-month in B-PID's. The yearly standard deviations in the extreme right hand column of Table 4 indicate that the B-PID's vary more and more each year. There is a significant increase in standard deviation beginning with the year 1956. This corresponds with the startup of Z plant facilities and the increased inventory problems that resulted. The erratic month-to-month standard deviations in the bottom of Table 4 can also be attributed to the 1956-1958 period.

III. HAPO Plutonium B-PID Trends

The following is a discussion of the trend periods indicated in Table 3.

A. January, 1952 - July, 1952

During this period 100 area production was based upon Larrick's G/T conversion relationship. Redox and T plant were based upon radioassay and ICF factors where the ICF factors were based upon the TPC/TU (total plutonium count per ton of uranium). In terms of percent the 6 kg loss at Z plant was significant, however, most of it was probably caused by overstatements at Redox and T plant.

B. August, 1952 - February, 1953

All plants except T plant showed gains during this period. There is very little indication of possible causes in available records.

C. March, 1953 - January, 1954

Two major changes took place in February, 1953. Kinderman's G/T relationship was adopted for prediction of 100 area production. This curve was also used to obtain F factors based upon MND/TU replacing the TPC/TU relationship. As a result significant losses appeared across the 231 building indicating that the Kinderman relationship was biased. In terms of percent, the 3.5 kg loss at T plant was not significant.

D. February, 1954 - November, 1954

During February, 1954, the use of Kinderman's F factors, for application to the radioassay of Redox and T plant nitrate products, were discontinued in favor of a direct laboratory assay by x-ray and coulometer. The 100 area production continued to be based upon Kinderman's curve. As a result the apparent loss shifted from the 231 building to Redox. T plant seems unaffected by this change of events. During September, 1954,

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the indicated HAPO B-PID reached a maximum. After this the HAPO percent B-PID began to increase almost as rapidly as it had been decreasing before. However, in terms of grams, the HAPO B-PID appeared to hold steady indicating that HAPO experienced no significant losses from about September, 1954, to about February, 1956. The change was attributable to the adoption of Gumprecht's curve during October, 1954, for the prediction of 100 area production.

E. December, 1954 - March, 1955

During this period the Z plant fluoride factor was changed resulting in overaccounting across the 231 building. Recovery of 1,294 units in the form of F-10-P sludge was obtained. The slag and crucible inventory was increased by 3,635 units due to the change in the fluoride factor. HAPO was credited with 3,787 units since the Oak Ridge recovery of HAPO slag and crucibles was higher than expected. The HAPO material balance appears much improved since the adoption of Gumprecht's curve and the laboratory F factor.

F. April, 1955 - December, 1955

Task I and 233-S started up in April. Recuplex started up during July. The initial charge to KE reactor occurred during April. This was an unstable period for Z plant. Losses appeared in Metal Recovery, Recuplex, and Tasks I and II. The Metal Recovery loss was probably due to overstatement of burnt turnings. Nearly all measurements surrounding Recuplex and Tasks I and II were considered unreliable. There was a one percent low bias in the F-10-P loadout scales and a high bias in the F-10-P coulometer analysis. Solids in the F-10-P resulted in a one kg accumulation in the 231 filters. The Z plant inventory began to increase significantly. Recuplex losses were explained by overstatements of plutonium powders that accumulated from numerous cleanouts.

G. January, 1956 - May, 1956

During January the KE and KW reactors were discharged and the Purex plant started up. T plant began production of Neptunium. Redox was significantly overaccounted due to understatement of K material. Cleanouts in Recuplex, T plant, Metal Recovery and Tasks I and II resulted in all plants being overaccounted during this period.

H. June, 1956 - February, 1957

Adjustments were made at Redox and Purex to correct the K reactor understatements. New prediction curves were prepared for the K reactors. Slug factor weights were also adjusted. T plant was shutdown during October. Recuplex recovery of a 3-year accumula-

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tion of casting fragments was only 30 percent of the input value. Metal recovery continued to lose due to overstatement of burnt turnings. Overstatement of Redox and Purex material processed through Recuplex and Tasks I and II was suspected. During this period HAPO began a very significant loss trend which coincided with the increasing capacity of the Product Recovery Operation. During February, the laboratories introduced a new plutonium standard for use in the calibration of the x-ray photometers.

I. March, 1957 - October, 1957

This period represented the most significant loss period to date. Neutron counters were introduced in May. Redox and Purex began a gradual downward trend. Z plant continued to lose heavily. The Redox and Purex nitrate measurements were carefully examined indicating very little overstatement in these measurements. The Purex F factor behaved erratically during this period. War Reserve and SRO material was received and processed. Continuous Task I and II started up in October and the Task I recycle measurement was transferred to Redox and Purex.

J. November, 1957 - March, 1958

Extensive cleanouts of old and new Z plant equipment resulted in the recovery of significant quantities of material. Redox and Purex scale and x-ray bias adjustments were made. Recuplex G-46, D-8 and D-9 vessels were recalibrated.

K. April, 1958 - August, 1958

Analytical bias corrections were introduced on a routine basis and adjustments back to July, 1957, were made. Most of the Z plant inventory backlog was processed by May, however, heavy losses continued indicating that a real physical loss may be occurring. Neutron counting indicated plutonium content of waste cartons was considerably higher than suspected. A book inventory method of estimating the size of Redox and Purex dissolver heels was introduced. Numerous slug types charged to reactors may require adjustment of prediction equations after suitable production test data is available. Since the introduction of the new laboratory x-ray standard Redox and Purex have shown a gradual downward trend. This tended to increase when Redox and Purex scale and x-ray bias corrections were applied. Assuming that the new standard and bias corrections have resulted in a better measure of plutonium nitrate leaving the parent plants, overstatement of reactor production may account for some of the over-all HAPO loss. However, recent

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flushes of the Redox L cell recovered nearly all of the Redox losses since startup resulting in good agreement between the 100 areas and Redox-Purex, except for the overstatements that occurred during the use of Kinderman's G/T relationship. The Pu/U ratio indicates that both the 100 area predictions and Redox-Purex nitrate measurements are overstated. Complete resolution as to which measurements are biased will depend upon the installation of an acceptable receiver nitrate measurement at Z plant. If the indicated losses are real they have probably existed for many years and did not begin to appear until extensive recovery operations began in early 1956.

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TABLE 2

CPD PLUTONIUM INVENTORY STATUS BY MONTH

	<u>B-T</u>	<u>Redox</u>	<u>Purex</u>	<u>231</u>	<u>Z Plant</u>	<u>CPD</u>
52	Jan. 20,981*	4,739			73,621	99,341
	Feb. 20,768*	13,775			71,678	106,221
	Mar. 31,382*	16,429			88,267	136,078
	Apr. 21,905*	18,064			103,034	143,003
	May 33,338*	24,611			99,191	157,140
	June 20,525*	19,136			99,101	138,762
	July 21,377*	23,368			69,811	114,556
	Aug. 13,007	21,388		7,563	98,200	140,158
	Sep. 8,115	16,605		8,901	103,746	137,367
	Oct. 7,826	21,948		7,489	117,943	155,206
	Nov. 8,170	21,002		12,635	117,958	159,765
	Dec. 10,939	22,656		17,917	115,897	167,409
53	Jan. 6,872	20,800		6,986	130,521	165,179
	Feb. 12,976	25,526		4,889	116,473	159,864
	Mar. 8,287	27,245		10,344	111,274	157,150
	Apr. 7,540	24,549		10,052	126,553	168,694
	May 8,559	12,105		18,495	123,207	162,366
	June 8,062	28,682		27,996	117,536	182,276
	July 6,304	22,602		17,050	135,350	181,306
	Aug. 5,469	31,328		13,891	112,106	162,794
	Sep. 7,125	25,990		24,788	107,920	165,823
	Oct. 7,667	29,104		26,212	148,414	211,397
	Nov. 7,183	20,982		11,035	136,229	175,429
	Dec. 12,433	28,127		17,125	147,454	205,139
54	Jan. 11,884	26,088		12,588	45,090 ⁽¹⁾	95,650
	Feb. 10,923	37,021		22,062	70,998	131,004
	Mar. 3,622	15,439		20,660	86,196	125,917
	Apr. 6,447	37,206		12,591	96,013	152,257
	May 6,752	43,047		29,584	102,223	181,606
	June 8,981	18,696		23,683	74,410	125,770
	July 7,863	38,234		31,262	58,379	135,738
	Aug. 11,215	37,614		5,620	79,453	133,902
	Sep. 8,630	30,007		24,472	96,477	159,586
	Oct. 12,437	35,854		30,095	79,488	157,874
	Nov. 11,596	27,796		21,587	91,777	152,756
	Dec. 13,092	22,834		22,191	126,877	184,994
55	Jan. 10,324	9,888		2,521	89,427	112,160
	Feb. 10,330	15,472		47,222	71,107	144,131
	Mar. 8,014	16,296		1,452	85,206	110,968
	Apr. 10,118	62,809		810	123,375 ⁽²⁾	197,112
	May 10,916	62,468		2,004	179,890	255,278
	June 13,347	53,554		4,954	207,005	278,860

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TABLE 2 Continued

	<u>P-T</u>	<u>Redox</u>	<u>Purex</u>	<u>231</u>	<u>Z Plant</u>	<u>CPD</u>
55	July 13,161	24,391		4,616	170,316(3)	212,484
	Aug. 13,627	21,455		6,875	155,583	197,540
	Sep. 12,583	19,926		2,748	263,510	298,767
	Oct. 10,213	26,582		2,815	244,639	284,249
	Nov. 10,351	58,852		3,203	177,550	249,956
	Dec. 6,631	3,715		2,635	249,980	262,961
56	Jan. 4,607	24,778	23,811	2,453	153,363	209,012
	Feb. 4,542	14,321	25,476	4,712	213,466	262,517
	Mar. 321	30,881	33,858	589	180,410	246,059
	Apr. 714	29,377	18,241	1,538	231,315	281,185
	May 391	33,913	27,506	13,499	211,202	286,511
	June 214	42,109	28,053	6,176	164,847	241,399
	July 156	43,199	80,764	715	141,104	265,938
	Aug. 31	14,202	95,106	670	276,436(8)	386,445
	Sep. 31	16,272	77,570	1,656	437,545(8)	533,074
	Oct.	19,795	66,516	2,546	328,959	417,816
	Nov.	22,237	59,166	1,651	329,004	412,058
	Dec.	8,182	54,817	4	276,535	339,538
57	Jan.	46,640	48,793		185,698	281,131
	Feb.	8,913	74,912		208,121	291,946
	Mar.	54,687	20,046		297,347	372,080
	Apr.	18,520	72,869		272,819(5)	364,208
	May	38,273	46,331		371,943	456,547
	June	20,525	54,557		470,104	545,186
	July	36,181	60,021		477,604(4,6)	573,806
	Aug.	44,777	54,361		722,118(5,6)	821,256
	Sep.	19,417	68,918		536,378	624,713
	Oct.	32,046	71,870		734,444(5)	838,360
	Nov.	49,429	49,465		901,838(7)	1,000,732
	Dec.	22,839	54,826		556,541	634,206
58	Jan.	35,190	63,510		458,186	556,886
	Feb.	26,881	62,977		419,540	509,398
	Mar.	17,471	70,526		423,711	511,708
	Apr.	14,697	71,087		441,599	527,383
	May	47,528	38,497		353,322	439,347
	June	45,121	80,649		348,437	474,207
	July	40,093	83,125		421,613	544,831
	Aug.	39,213	82,271		363,614	485,098

* Includes 231

- (1) Slag and crucibles shipped to Oak Ridge
- (2) Task I & II Startup
- (3) Recuplex Startup
- (4) Continuous Task II Startup

- (5) War Reserve Received
- (6) SRC Material Received
- (7) Old and New Task I & II Clean-Outs
- (8) Plant Clean-Outs

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TABLE 3

HAPO PLUTONIUM B-PID TRENDS IN GRAMS

<u>Period</u>	<u>B-T</u>	<u>Redox</u>	<u>Purex</u>	<u>231</u>	<u>Z Plant</u>	<u>Miscel- laneous</u>	<u>HAPO</u>	<u>No. of Months</u>	<u>Average Rate of Loss/Month</u>
Jan.'47-Dec.'47							2,720	12	227
Jan.'48-Dec.'48							1,951	12	163
Jan.'49-Dec.'49							-1,956	12	-163
Jan.'50-Dec.'50							3,688	12	307
Jan.'51-Jun.'51							4,027	6	671
July'51-Dec.'51							4,409	6	735
Jan.'52-July'52	2,097	1,857			-6,040	29	-2,054	7	-293
Aug.'52-Feb.'53	-214	3,234		1,067	287	1,682	6,057	7	865
Mar.'53-Jan.'54	-3,530	2,781		-18,673	-1,689	-3	-21,114	11	-1,919
Feb.'54-Nov.'54	-4,822	-16,574		-1,065	4,931	-6	-17,533	10	-1,753
Dec.'54-Mar.'55	-84	2,051		7,670	-7	-105	9,525	4	2,381
Apr.'55-Dec.'55	-658	3,565		843	-18,582	118	-14,713	9	-1,635
Jan.'56-May'56	2,557	8,531	1,065	177	3,490	-78	15,744	5	3,149
Jun.'56-Feb.'57	108	-5,379	-74	-1,025	-48,048	-582	-55,710	9	-6,190
Mar.'57-Oct.'57		-15,956	-7,709	-3	-70,227	-1,853	-95,748	8	-11,968
Nov.'57-Mar.'58		-1,116	-5,324		39,182	-27	32,715	5	6,543
Apr.'58-Aug.'58		-11,904	-19,345		-66,578	-1,671	-99,501	5	-19,900
Jan.'52-May'56	-4,654	5,445	1,065	-9,981	-17,610	1,637	-24,088	53	-454
Jun.'56-Aug.'58	-605	-34,355	-32,452	-1,028	-145,671	-4,133	-218,244	27	-8,083
Jan.'52-Aug.'58	-5,259	-28,910	-31,387	-11,009	-163,281	-2,496	-242,332	80	-3,029

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TABLE 4
ANALYSIS OF VARIANCE TABLE
HAPO PLUTONIUM B-PID's

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Sums	Ave.	σ (one month)
1952	537	-1,066	-479	502	1,181	-1,977	-752	2,665	1,250	-1,041	-403	2,198	2,615	218	1,412
1953	-4,301	5,689	-1,280	-409	-1,307	-257	-1,386	-1,198	-1,161	-2,661	-5,428	-2,583	-16,363	-1,364	2,699
1954	-3,363	-1,790	-1,847	710	-1,887	-2,970	-8,697	224	-3,686	4,585	-2,175	3,945	-16,951	-1,413	3,535
1955	3,207	744	1,629	-1,764	-2,621	-3,301	-35	-398	-4,723	3,414	-4,298	-986	-9,132	-761	2,713
1956	3,802	-1,291	4,422	6,849	1,962	-20,343	-8,345	6,845	-11,534	3,697	4,323	-25,287	-34,900	-2,908	10,955
1957	7,531	-12,597	5,385	-3,437	-6,105	-16,141	-20,519	-16,767	-11,181	-26,983	29,770	7,264	-63,780	-5,315	15,694
1958	-4,487	-6,426	6,594	-23,070	-35,100	14,546	-40,738	-15,139					-103,820	-12,978	19,354
Sums	2,926	-16,737	14,424	-20,700	-43,877	-30,443	-80,472	-23,768	-31,035	-18,989	21,789	-15,449	-242,331		
Ave.	418	-2,391	2,061	-2,957	-6,268	-4,349	-11,496	-3,395	-5,173	-3,165	3,632	-2,575		-3,029	
σ (one month)	4,663	5,757	3,422	9,432	12,985	11,382	14,738	8,993	5,222	12,021	13,256	11,666			10,113

DECLASSIFIED

TABLE 1
PLUTONIUM B-PID'S IN GRAVE
Redox Startup To Date

	B-T		Redox		Pures	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
52 Jan.	-490*	-490	-28	-28		
Feb.	1,321*	831	-442	-470		
Mar.	21*	852	-182	-652		
Apr.	1,039*	1,891	609	-43		
May	155*	2,046	335	292		
June	26*	2,072	762	1,054		
July	25	2,097	803	1,857		
Aug.	677	2,774	1,829	3,686		
Sep.	-493	2,281	2,140	5,826		
Oct.	171	2,452	-138	5,688		
Nov.	5	2,457	-785	4,903		
Dec.	-870	1,587	-379	4,524		
53 Jan.	-199	1,388	-1,301	3,223		
Feb.	495	1,883	1,868	5,091		
Mar.	96	1,979	1,798	6,889		
Apr.	-162	1,817	1,692	8,581		
May	494	2,311	-1,498	7,083		
June	-1,094	1,217	1,711	8,794		
July	-81	1,136	1,034	9,828		
Aug.	-159	977	148	9,976		
Sep.	-213	764	812	10,788		
Oct.	-435	329	-61	10,727		
Nov.	-1,299	-970	-2,603	8,124		
Dec.	96	-874	711	8,835		
54 Jan.	-773	-1,647	-963	7,872		
Feb.	-1,173	-2,820	-1,648	6,224		
Mar.	-839	-3,659	-451	5,773		
Apr.	654	-3,005	-1,285	4,488		
May	-1,144	-4,149	-465	4,023		
June	-1,213	-5,362	-2,446	1,577		
July	23	-5,339	-6,300	-4,723		
Aug.	-436	-5,775	-1,371	-6,094		
Sep.	-705	-6,480	-2,334	-8,428		

231
Monthly Cumulative

Task I & II
Monthly Cumulative

Task III-VII(1)
Monthly Cumulative

PRO
Monthly Cumulative

Tot
Monthly

			1,022	1,022		1,022
			-1,979	-957		-1,97
			-341	-1,298		-34
			-1,154	-2,452		-1,15
			801	-1,651		80
			-2,803	-4,454		-2,80
			-1,586	-6,040		-1,58
			299	-5,741		29
			-1,009	-6,750		-1,00
			80	-6,670		8
			858	-5,812		85
			108	-5,704		10
			-340	-6,044		-34
			291	-5,753		29
			181	-5,572		18
			183	-5,389		18
			-148	-5,537		-14
			310	-5,227		31
			-443	-5,670		-44
			-200	-5,870		-20
			1	-5,869		1
			-96	-5,965		-9
			-720	-6,685		-72
			-498	-7,183		-49
			-259	-7,442		-25
			-370	-7,812		-37
			-50	-7,862		-5
			1,673	-6,189		1,673
			157	-6,032		157
			42	-5,990		42
			-118	-6,108		-118
			35	-6,073		35
			-45	-6,118		-45

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Line	PRO		Total & Plant		Miscellaneous (2)		BAPD	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
22			1,022	1,022	33	33	537	537
27			-1,979	-957	34	67	-1,066	-529
28			-341	-1,298	23	90	-479	-1,008
32			-1,154	-2,452	8	98	502	-506
34			801	-1,651	-110	-12	1,181	675
40			-2,803	-4,454	35	23	-1,977	-1,302
41			-1,586	-6,040	6	29	-752	-2,054
50			299	-5,741	-60	-31	2,665	611
70			-1,009	-6,750	89	58	1,250	1,861
12			80	-6,670	-39	19	-1,041	820
04			858	-5,812	-28	-9	-403	417
			108	-5,704	1,599	1,590	2,198	2,615
44			-340	-6,044	78	1,668	-4,301	-1,686
53			291	-5,753	43	1,711	5,689	4,003
72			181	-5,572	18	1,729	-1,280	2,723
89			183	-5,389	92	1,821	-490	2,233
37			-148	-5,537	67	1,888	-1,307	926
27			310	-5,227	-9	1,879	-257	669
70			-143	-5,670	-31	1,848	-1,386	-717
39			-200	-5,870	-46	1,802	-1,198	-1,915
35			1	-5,869	-5	1,797	-1,161	-3,076
35			-96	-5,965	-7	1,790	-2,661	-5,737
83			-720	-6,685	7	1,797	-5,428	-11,165
			-498	-7,183	-53	1,739	-2,583	-13,748
42			-259	-7,442	-31	1,708	-3,363	-17,111
12			-370	-7,812	62	1,770	-1,790	-18,901
32			-50	-7,862	1	1,771	-1,847	-20,748
39			1,673	-6,189	37	1,808	710	-20,038
30			157	-6,032	-127	1,681	-1,887	-21,925
32			42	-5,990	-34	1,647	-2,970	-24,895
38			-118	-6,108	-2,021	-374	-8,697	-33,592
73			35	-6,073	2,101	1,727	224	-33,368
			-45	-6,118	-42	1,685	-3,686	-37,054

DECLASSIFIED

TABLE 1 Continued

		B-T		Redox		Purex		M
		Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	
54	Oct.	290	-6,190	511	-7,917			
	Nov.	-279	-6,469	-785	-8,702			
	Dec.	789	-5,680	-889	-9,591			
55	Jan.	-198	-5,878	1,749	-7,842			
	Feb.	-162	-6,040	-387	-8,229			
	Mar.	-513	-6,553	1,578	-6,651			
	Apr.	-352	-6,905	1,294	-5,357			
	May	-554	-7,459	-1,892	-7,249			
	June	-77	-7,536	-2,630	-9,879			
	July	814	-6,722	-1,520	-11,399			
	Aug.	466	-6,256	2,525	-8,874			
	Sep.	-814	-7,070	-501	-9,375			
	Oct.	271	-6,799	5,109	-4,266			
	Nov.	296	-6,503	-2,894	-7,160			
	Dec.	-708	-7,211	4,074	-3,086			
56	Jan.	-5	-7,216	308	-2,778	-5,521	-5,521	
	Feb.	291	-6,925	1,116	-1,662	-705	-6,226	
	Mar.	1,068	-5,857	4,871	3,209	272	-5,954	
	Apr.	1,039	-4,818	-1,621	1,588	8,684	2,730	
	May	164	-4,654	3,857	5,445	-1,665	1,065	
	June	-713	-5,367	-14,410	-8,965	-2,274	-1,209	
	July	48	-5,319	421	-8,544	-5,172	-6,381	
	Aug.	91	-5,228	2,806	-5,738	11,629	5,248	
	Sep.	0	-5,228	237	-5,501	-3,650	1,598	
	Oct.	-31	-5,259	0	-5,501	4,740	6,338	
	Nov.		-5,259	3,993	-1,508	1,454	7,792	
	Dec.		-5,259	-716	-2,224	-6,365	1,427	
57	Jan.		-5,259	-332	-2,556	10,030	11,457	
	Feb.		-5,259	2,622	66	-10,466	991	
	Mar.		-5,259	-3,024	-2,958	6,576	7,567	
	Apr.		-5,259	597	-2,361	-1,456	6,111	
	May		-5,259	-5,799	-8,160	-272	5,839	
	June		-5,259	4,313	-3,847	-6,652	-813	
	July		-5,259	-2,944	-6,791	-5,948	-6,761	
	Aug.		-5,259	-3,944	-10,735	3,923	-2,838	

231		Task I & II		Task III-VII (1)		PRO		Total 2	
Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Monthly
85	-17,635			3,678	-2,440			3,678	
1,036	-18,671			-71	-2,511			-71	
4,128	-14,543			-64	-2,575			-64	
1,896	-12,647			60	-2,515			60	
1,075	-11,572			0	-2,515			0	
571	-11,001			-3	-2,518			-3	
-226	-11,227	-2,594	2,594	99	-2,419			-2,495	
285	-10,942	-265	-2,859	599	-1,820			334	
216	-10,726	-2,256	-5,115	412	-1,408			-1,844	
-569	-11,295	2,266	-2,849	-591	-1,999			1,118	
-1,029	-12,324	-1,776	-4,625	-51	-2,050			-1,417	
-106	-12,430	-1,182	-5,807	33	-2,017			-3,494	
1,242	-11,188	-2,115	-7,922	-265	-2,282			-4,171	
468	-10,720	515	-7,407	119	-2,163			-6,766	
562	-10,158	-2,964	-10,371	-363	-2,526			-8,203	
219	-9,939	6,572	-3,799	1,492	-1,034			-7,353	8,914
-162	-10,101	-839	-4,638	85	-949			-8,426	-1,827
-260	-10,361	-385	-5,023	-997	-1,946			-8,497	-1,453
637	-9,724	524	-4,499	-802	-2,748			-10,219	-2,000
-257	-9,981	-63	-4,562	-581	-3,329			-9,719	-144
-146	-10,127	2,419	-2,143	-290	-3,619			-13,843	-1,995
338	-9,789	-60	-2,203	-1,199	-4,818			-16,650	-4,066
-563	-10,352	-3,806	-6,009	844	-3,974			-20,641	-6,953
-407	-10,759	-1,181	-7,190	-1,107	-5,081			-26,086	-7,733
-413	-11,172	2,120	-5,070	-211	-5,292			-28,556	-561
-1,538	-12,710	1,962	-3,108	-827	-6,119			-29,284	407
403	-12,307	-996	-4,104	-769	-6,888			-46,117	-18,598
1,301	-11,006	91	-4,013	-193	-7,081			-49,727	-3,712
0	-11,006	294	-3,719	2,003	-5,078			-56,861(3)	-4,837
-3	-11,009	1,610	-2,109	-737	-5,815			-55,915	1,819
	-11,009	1,057	-1,052	-1,187	-7,002			-58,347	-2,562
	-11,009	1,978	926	-903	-7,905			-59,487	-65
	-11,009	-3,837	-2,911	-3,195	-11,100			-66,266	-13,811
	-11,009	-6,656	-9,567(6)	-1,370	-12,470			-69,871	-11,631
	-11,009	-10,050	-19,617	-1,806	-14,276			-73,416	-15,401

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ive	PRO		Total Z Plant		Miscellaneous(2)		HAPO	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
440			3,678	-2,440	21	1,706	4,585	-32,469
511			-71	-2,511	-4	1,702	-2,175	-34,644
575			-64	-2,575	-19	1,683	3,945	-30,699
515			60	-2,515	-300	1,383	3,207	-27,492
515			0	-2,515	218	1,601	744	-26,748
518			-3	-2,518	-4	1,597	1,629	-25,119
419			-2,495	-5,013	15	1,612	-1,764	-26,883
820			334	-4,679	-794	818	-2,621	-29,505
,408			-1,844	-6,523	1,033	1,851	-3,301	-32,806
,999	-557	-557	1,118	-5,405	121	1,972	-35	-32,841
,050	-860	-1,417	-2,687	-8,092	326	2,298	-398	-33,239
,017	-2,077	-3,494	-3,226	-11,318	-75	2,223	-4,723	-37,962
,282	-677	-4,171	-3,057	-14,375	-150	2,073	3,414	-34,548
,163	-2,595	-6,766	-1,961	-16,336	-208	1,865	-4,298	-38,846
,526	-1,437	-8,203	-4,764	-21,100	-150	1,715	-986	-39,832
,034	850	-7,353	8,914	-12,186	-113	1,602	3,802	-36,030
-949	-1,073	-8,426	-1,827	-14,013	-5	1,597	-1,291	-37,321
,946	-71	-8,497	-1,453	-15,466	-79	1,518	4,422	-32,399
,748	-1,722	-10,219	-2,000	-17,466	115	1,633	6,849	-26,050
,329	500	-9,719	-144	-17,610	4	1,637	1,962	-24,088
,619	-4,124	-13,843	-1,995	-19,605	-808	829	-20,343	-44,431
,818	-2,807	-16,650	-4,066	-23,671	86	915	-8,345	-52,776
,974	-3,991	-20,641	-6,953	-30,624	-166	749	6,845	-45,931
,081	-5,445	-26,086	-7,733	-38,357	20	769	-11,534	-57,465
,292	-2,470	-28,556	-561	-38,918	-39	730	3,697	-53,768
,119	-728	-29,284	407	-38,511	8	738	4,323	-49,445
,888	-16,833(5)	-46,117	-18,598	-57,109	-11	727	-25,287	-74,732
,081	-3,610	-49,727	-3,712	-60,821	244	971	7,531	-67,201
,078	-7,134	-56,861(3)	-4,837	-65,658	84	1,055	-12,597	-79,798
,815	946	-55,915	1,819	-63,839	16	1,071	5,385	-74,413
,002	-2,432	-58,347	-2,562	-66,401	-17	1,054	-3,437	-77,850
,905	-1,140	-59,487	-65	-66,466	32	1,086	-6,105	-83,955
,100	-6,779	-66,266	-13,811	-80,277	10	1,096	-16,141	-100,096
,470	-3,605	-69,871	-11,631	-91,908	5	1,101	-20,519	-120,615
,276	-3,545	-73,416	-15,401	-107,309	-1,346	-245	-16,767	-137,382

DECLASSIFIED

TABLE 1 Continued

	B-T		Redox		Purex		Mc
	<u>Monthly</u>	<u>Cumulative</u>	<u>Monthly</u>	<u>Cumulative</u>	<u>Monthly</u>	<u>Cumulative</u>	
57 Sep.		-5,259	1,822	-8,913	5,982	3,144	
Oct.		-5,259	-6,977	-15,890	-9,862	-6,718	
Nov.		-5,259	-3,327	-19,217	5,116	-1,602	
Dec.		-5,259	8,397	-10,820	-1,351	-2,953	
58 Jan.		-5,259	-4,474	-15,294	-7,649	-10,602	
Feb.		-5,259	504	-14,790	-5,585	-16,187	
Mar.		-5,259	-2,216	-17,006	4,145	-12,042	
Apr.		-5,259	-1,306	-18,312	-6,177	-18,219	
May		-5,259	-5,034	-23,346	-5,753	-23,972	
June		-5,259	1,894	-21,452	2,418	-21,554	
July		-5,259	-4,623	-26,075	-7,894	-29,448	
Aug.		-5,259	-2,835	-28,910	-1,939	-31,387	

* Includes 231

- (1) Fluoride Powder to Final
- (2) 100 A Basins, Technical, HLO, etc.
- (3) Metal Recovery Transferred from Task III-VII to PRO
- (4) Task III Transferred from Task III-VII to Task I-II
- (5) Processed 3 Year Accumulation of Casting Fragments - 30% Yield
- (6) Continuous Task II Startup

231		Task I & II		Task III-VII (1)		PRO		Total
Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly
-11,009	-11,009	-15,720	-35,337	-1,509	-15,785	-1,801	-75,217	-19,031
-11,009	-11,009	-3,409	-38,746	10	-15,775	-6,147	-81,364	-9,544
-11,009	-11,009	27,751	-10,995	1,640	-14,135	-1,402	-82,766	27,981
-11,009	-11,009	15,029	4,034	1,562	-12,573	-16,398	-99,164	191
-11,009	-11,009	17,812	21,846	6,548	-6,025	-16,665	-115,829	7,691
-11,009	-11,009	11,969	33,815	-1,948	-7,973	-11,360	-127,189	-1,331
-11,009	-11,009	7,526	41,341	437	-7,536	-3,319	-130,508	4,641
-11,009	-11,009	11,979	53,320	-3,159	-10,695	-23,901	-154,409	-15,081
-11,009	-11,009	-9,446	43,874	-4,379	-15,074	-10,317	-164,726	-24,141
-11,009	-11,009	21,864	65,738	4,445	-10,629	-15,833	-180,559	10,471
-11,009	-11,009	-8,519	57,219(4)	-4,178	(4)-14,807	-15,437	-195,996	-28,131
-11,009	-11,009	-4,513	52,706	3,721	-11,086	-8,905	-204,901	-9,691

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	PRO		Total Z Plant		Miscellaneous(2)		HAPO	
	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative	Monthly	Cumulative
re								
35	-1,801	-75,217	-19,030	-126,339	45	-200	-11,181	-148,563
75	-6,147	-81,364	-9,546	-135,885	-598	-798	-26,983	-175,546
35	-1,402	-82,766	27,989	-107,896	-7	-805	29,770	-145,776
73	-16,398	-99,164	193	-107,703	24	-781	7,264	-138,512
25	-16,665	-115,829	7,695	-100,008	-58	-839	-4,487	-142,999
73	-11,360	-127,189	-1,339	-101,347	-6	-845	-6,426	-149,425
36	-3,319	-130,508	4,644	-96,703	20	-825	6,594	-142,831
35	-23,901	-154,409	-15,081	-111,784	-505	-1,330	-23,070	-165,901
74	-10,317	-164,726	-24,142	-135,926	-171	-1,501	-35,100	-201,001
29	-15,833	-180,559	10,476	-125,450	-241	-1,742	14,546	-186,455
37	-15,437	-195,996	-28,134	-153,584	-86	-1,828	-40,738	-227,193
86	-8,905	-204,901	-9,697	-163,281	-668	-2,496	-15,139	-242,332

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