OCT 16 1967

IN-1116

September 1967

MASTER

MANUAL OF PROCEDURES FOR EFFECTING CONTROL OF SS MATERIALS AT STATION JWB

F. H. Tingey and B. S. Lewis

IDAHO NUCLEAR CORPORATION
NATIONAL REACTOR TESTING STATION
IDAHO FALLS, IDAHO

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

U. S. ATOMIC ENERGY COMMISSION

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, express or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

IN-1116
Special Distribution
Issued: September 1967

LEGAL NOTICE

This report was prepared as an account of Government sponsored work. Neither the United States, nor the Commission, nor any person acting on behalf of the Commission:

A. Makes any warranty or representation, expressed or implied, with respect to the accuracy, completeness, or usefulness of the information contained in this report, or that the use of any information, apparatus, method, or process disclosed in this report may not infringe privately owned rights; or

B. Assumes any liabilities with respect to the use of, or for damages resulting from the use of any information, apparatus, method, or process disclosed in this report.

As used in the above, "person acting on behalf of the Commission" includes any employee or contractor of the Commission, or employee of such contractor, to the extent that such employee or contractor of the Commission, or employee of such contractor prepares, disseminates, or provides access to, any information pursuant to his employment or contract with the Commission, or his employment with such contractor.

MANUAL OF PROCEDURES FOR EFFECTING CONTROL OF SS MATERIALS AT STATION JWB

BY

F. H. Tingey
B. S. Lewis

IDAHO NUCLEAR CORPORATION

A JOINTLY OWNED SUBSIDIARY OF
AEROJET ALLIED
GENERAL CHEMICAL
CORPORATION CORPORATION

U. S. Atomic Energy Commission Research and Development Report
Issued Under Contract AT(10-1)-1230
Idaho Operations Office

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED
Peg

CONTENTS

I. INTRODUCTION	1
1. NUCLEAR MATERIALS CONTROL FUNCTIONS AND RESPONSIBILITIES	1
II. STATION JWB NUCLEAR MATERIALS CONTROL TECHNOLOGY	3
1. SCOPE	3
2. CONTROL OF MATERIAL FLOW AT STATION JWB	5
2.1 Material Balance Area Accounting	5
2.2 Cold Fuel Storage MBA	8
2.3 Hot Storage MBA	8
2.4 Gamma Facility MBA	9
2.5 Experimental Items	9
III. RECORDS AND REPORTS	11
1. RECORDS FUNCTION	11
1.1 Receipt of SS Material	11
1.2 Shipping SS Material	14
2. EXTERNAL SOURCE DOCUMENTS	15
2.1 AEC -101, -284	15
2.2 Form AEC-388	17
3. INTERNAL SOURCE DOCUMENTS	19
3.1 Form ID-164	19
3.2 INC-249	21
4. INFORMATIVE DOCUMENTS	23
4.1 Form ID-109	23
4.2 Form ID-110	24
5. JOURNALS AND LEDGERS	26
5.1 Out-of-Area Transfer Journals	26
5.2 Within-Area Transfer Journals	28
5.3 Material Balance Summary Ledger	28
5.4 Adjusting Journal Entry Form	30
5.5 Loss Journal	31
6. REPORTING	32
6.1 Semiannual Material Balance and Inventory Report	32
6.2 Composition of Ending Inventory	32
6.3 Project Inventory Reports	33

7. RAW DATA PREPARATION	.34
7.1 Transfer Journal and MBR Raw Data Preparation	.34
7.2 COEI, Project, and Custodial Inventory Raw Data Preparation	.35
8. MISCELLANEOUS PLANT INVENTORY ADJUSTMENTS	.36
8.1 Normal Operational Losses	.36
8.2 Accidental Losses	.37
8.3 Writeoffs	.37
8.4 Material Unaccounted For	.38
9. INVENTORY AND MATERIAL BALANCE CUTOFF PROCEDURES	.38
IV. MEASUREMENT TECHNOLOGY	.39
1. INTRODUCTION	.39
2. VERIFICATION OF URANIUM LOADINGS FOR FABRICATED FUEL ITEMS	.39
2.1 Scope	.39
2.2 Procedures	.39
2.3 Establishing U-235 Loading for Plate Standards	.40
2.4 Establishing Measurement Uncertainty for Plate Standards	.40
2.5 Calculation of U-235 in the Unknown	.41
2.6 Measurement Uncertainty of the Unknown	.41
2.7 Assigning U-235 to Fuel Elements Only	.42
3. GROSS POWER CALCULATION	.42
3.1 Temperature-Differential x Flow Calculation	.42
4. CALCULATION OF U-235 DEPLETION	.44
4.1 Total Burnup Computation	.44
5. ETR POWER RECORDING INSTRUMENTATION	.45
5.1 Flow Rate Measurement	.45
5.2 Dynatherm Bridge	.45
5.3 Power Calculating Unit	.46
5.4 Calibration	.46
6. MTR POWER RECORDING INSTRUMENTATION	.48
6.1 Flow Rate Measurement	.48
6.2 Differential Temperature Measurement	.48
6.3 Power Recorder	.48
6.4 Power Level Calculations	.43
6.5 Instrument Calibration	.49
V. FORECASTING AND DISTRIBUTION OF SPECIAL NUCLEAR MATERIALS	.50

1. FORECAST REQUIREMENTS	50
1.1 Annual Schedules	50
1.2 Revised Forecast Schedules	50
1.3 Supply Agreement Considerations	50
2. SPECIAL NUCLEAR MATERIALS SUBJECT TO FORECASTING	51
3. FORECAST QUANTITIES	51
4. COMPLETING FORM AEC-408	52
VI. SEMIANNUAL REVIEW	53
1. AUDIT INSPECTION AND INVENTORY VERIFICATION	53
1.1 Semiannual Review	53

FIGURES

1. Organizational chart	4
2. Fuel element flow at station JWB	5
3. Experimental item flow at station JWB	6
4. NMM control material balance areas established for control of reactor fuel movements at TRA	7
5. Records diagram for reviewing fuel at station JWB	12
6. Records diagram for shipping fuel from station JWB	13
7. Nuclear material transfer document, form AEC-101	16
8. SS material transfer receipt, form AEC-284	17
9. SS material transfer form -- leased material (form AEC-388) ...	18
10. SS material transfer sheet, form ID-164	19
11. SS materials expended in research, INC-249	22
12. Radioactive material shipment record, ID-109	23
13. Waste disposal request and authorization form, ID-110	25
14. IBM transfer sheet output sample	26
15. IBM raw data work sheet	27

16. Station JWB SS materials ledger	.29
17. Loss journal	.31
18. Printed sample of material balance report	.32
19. Printed sample of material balance report	.33
20. Typical schedule for single line entry backup	.33
21. COEI inventory report	.34
22. Sample of prepared IBM report	.35
23. COEI, project, and custodial inventory raw data preparation	.35
24. ETR power calculator resistance bridge for determination of ΔT	.43
25. Gentile flow tube	.46
26. Block diagram of the ETR power calculator	.47
27. Forecast of special nuclear material requirements	.51

I. INTRODUCTION

This manual presents the basic principles, philosophies, and techniques which have been found necessary for the establishment and maintenance of an adequate control system for all nuclear materials used in the research and test reactors at station JWB. The fundamental basis of the system described in this text is to assure the efficient control of nuclear materials by attempting to measure accurately and provide proper identification for the receipt, issue, use, and inventory of all such materials.

The specific nuclear materials which are placed under the control system include source and fissionable materials and may also include other special material if so specified by the Atomic Energy Commission. Concerning source materials, the Atomic Energy Commission Manual, Chapter 7401-051, states, "Source materials means uranium or thorium, but excludes (a) ores containing by weight less than one-twentieth of one percent (0.05%) thereof and (b) special nuclear material". Chapter 7401-052 defines special nuclear materials as "plutonium, uranium-233, or uranium enriched in the isotope 235". Therefore, for the purpose of this manual, SS material will be defined as a collective term which includes source materials, special nuclear materials, and those materials to which, by direction of the AEC, the provision of AEC Manual, Chapter 7400, apply.

Rigid control of nuclear materials is mandatory in view of their intrinsic value and, in some cases, strategic importance. This high monetary unit value assigned to these materials is not the only primary motive for rigid control systems. This is a predominant factor but must not be interpreted as the only means toward our specific goal. In addition, and by far just as important, is the consequence of health hazards, criticality hazards, and the hazard of application of some specific fissionable materials to military uses. The seriousness of these hazards together with the high monetary unit value motivates the necessity for strict and rigid control systems.

1. NUCLEAR MATERIALS CONTROL FUNCTIONS AND RESPONSIBILITIES

It is the duty of the Nuclear Materials Control accountant (station representative) to implement and enforce procedures applicable to the receipt handling and shipping of SS materials associated with the Test Reactor Area. The procedures are implemented through Idaho Nuclear Corporation management channels by the issuance and enforcement of INP 8.15.

All material balance and inventory reports required by AEC Manual, Chapter 7401, are submitted directly to the Idaho Operations Office without Idaho Nuclear management approval. The correctness of these reports places a direct responsibility on the Chief of the Nuclear Materials Control group to Idaho Nuclear management. This responsibility is transmitted from the Idaho Operations Office in the form of an annual Survey Report on the Nuclear Material Control system in existence at station JWB. The internal control and record system is also subject to review by the Idaho Operations Office, SS Materials Management officer. Therefore, any deviation or alteration from

AEC-approved procedures places a direct responsibility on the Nuclear Material Control group for corrective action. Such action in many cases may require Idaho Nuclear management attention.

Inventory management functions including SS materials forecasting, utilization; and safeguard handling are assigned to the Nuclear Material Control group. In all cases actions pertaining to these functions are approved by Idaho Nuclear management before transmittal to the Atomic Energy Commission.

The Nuclear Material Control office is also responsible to Idaho Nuclear management to perform audit inspection of the internal control systems and safeguard handling practices. The auditor in charge of these surveys is required to report periodically to Idaho Nuclear management all results pertinent to the audit findings. Corrective action needed is, therefore, brought to Idaho Nuclear management attention for the implementation, alteration, or enforcement of existing procedures.

II. STATION JWB NUCLEAR MATERIALS CONTROL TECHNOLOGY

1. SCOPE

The research and test reactors at station JWB are designed to accommodate large numbers and varieties of experiments subjected to high neutron fluxes over extended periods of time. At present this SS station includes the MTR, ETR, and ATR REACTOR PROJECTS. The complex also includes additional reactor facilities for mocking up reactor cores and studying gamma irradiation effects on experimental items. These facilities include the Advanced Reactivity Measurement Facilities (ARMF), ETR Critical Test Facility (ETRC), ATR Critical Facility (ATRC), and Gamma Irradiation Facility.

It is evident that a nuclear material control inventory at this station will, therefore, consist mainly of that contained in fuel elements and experimental items. The fuel elements dominate the inventory. Therefore, considerable effort is justified and directed toward devising and implementing measurement and control procedures for these items.

Fuel elements received must be properly identified, inspected, tested, measured, and stored. Verification of receipt (by fuel number and prefix) is accomplished by comparing original shipping documents with fabricators' specification sheets. Stringent inspection procedures for determining U-235 loadings are employed to comply with contract specifications. After inspection, a portion of the accepted fuel is transferred to the Reactor Critical Test Facilities for core mock-up tests. Here the elements are arranged in prescribed critical arrays for neutron and flux measurements. Measurement data obtained from the critical facilities are later used to apply burnup apportionment factors to each reactor core. The elements are then returned to be stored in a critically safe security vault.

Nuclear materials control of reactor fuel requires continual observation of fuel assembly movements and systemized procedures for inventory verification. This control is effected through the combined efforts of nuclear materials control, operations, security, and technical personnel. The Nuclear Material Control organizational structure now in use at station JWB is outlined in Figure 1. It should be noted that as a section of operations analysis, the Nuclear Materials Control group reports directly to the project manager. This group is therefore able to cross organizational lines to implement its procedure. The Nuclear Materials Control group is also void of direct responsibility for the physical assignment and handling of nuclear materials at the reactor site. This responsibility is assigned to operations and technical personnel who assume physical custody where applicable. Fuel transfers between areas are accompanied by transfer forms generated by the various custodians. The Nuclear Materials Control office, which receives copies of the transfer forms, periodically summarizes these data for material balance summary inventories. The data generated are scrutinized for qualitative and quantitative reliability and formulated into periodic reports.

In contrast to fuel elements, which contain significant quantities of nuclear material, some experimental items are received which contain, for the most

Fig. 1 Organizational chart.

part, small quantities of SS material. The majority of these items are encapsulated, canned, or fabricated into elaborately instrumented pilot-scale devices essentially ready for reactor insertion. Verification of SS material within these items is seldom possible. Therefore, the sponsor's uranium values are usually accepted upon receipt. Each experiment is recognized and verified by an item identification code. Following irradiation, these items are returned to the vendor at the same value as received; no report is made from the TRA reactor site regarding estimated fission loss or burnup.

Accountable control of experimental items is the primary responsibility of technical liaison personnel commonly called "project engineers" and other technical groups associated with laboratory analysis, fuel element development, and cross section and neutron assay. The technological value of the various experiments by the time they are prepared for reactor insertion is usually many times the nominal dollar value of the SS material content. Hence, observation of the precautions necessary to safeguard the experimental data is usually adequate for protection of the material content. It is for this reason, as will be seen later, that material balance area accounting is not warranted when controlling items of this nature. Rather than use this approach, the Nuclear Materials Control group assigns direct responsibility of these items to the respective personnel mentioned above. It is their responsibility to accept physical assignment and keep the necessary records concerning the location of these items.

2. CONTROL OF MATERIAL FLOW AT STATION JWB

2.1 Material Balance Area Accounting

The control procedures pertaining to fuel assembly movements are designed to maintain constant surveillance of fuel inventories in order to provide proper safety precautions, security control, and item identification. Experimental items, after receipt and inspection, are passed into the custody of the project engineer responsible for the experiment. This responsibility continues until the item is returned to the sponsor. The responsibility for fuel elements is transferred from custodian to custodian by designated material balance areas. The material flow in the TRA reactor complex is shown in Figures 2 and 3.

Fig. 2 Fuel element flow at station JWB.

Fig. 3 Experimental item flow at station JWB.

The control mechanism functions were purposely designed to reflect material balance areas on the book of accounts which are in direct agreement with geographical boundaries prescribed within the reactor test site complex. The method now in use at station JWB for subsidiary boundaries is shown in Figure 4. This particular subdivision is considered sufficient for controlling SS material transfers. Each material balance area is comprised of further

Fig. 4 NMM control material balance areas established for control of reactor fuel movements at TRA.

subdivided balance areas depicting the true nature of the operation. Rather than recording transfers within each subdivided area, only those transfers which affect the various major material balance areas are recorded to the MBA control accounts. IBM subsidiary accounting provides listings for each subdivided material balance area for inventory verification. These inventory control data listings are obtained from ID-164 transfer forms supplied to the NMM group

by the responsible custodians assigned to the various subdirected areas. Experimental items are discussed separately since the control mechanism required does not define material balance areas but rather defines direct assignment of custodial responsibility.

2.2 Cold Fuel Storage MBA

2.21 Inspection Vault. This fuel vault storage facility is under direction of the MTR Operations Superintendent. The vault custodian is responsible for issuing items for inspection, testing, scanning, etc. Safeguard procedures have been defined for limiting the total number of fuel elements and plates absent from the fuel vault at any one time. Material issues, other than reactor loading and critical mock-ups, normally are returned at the end of each working day. Therefore, in most cases a vault log serves as a sufficient control device for perpetual inventory accounting.

(1) Operational Fuel Vaults. These facilities were designed to store only fuel elements which have been inspected and prepared for reactor use. The responsibility for all SS materials within these areas are assigned to the MTR and ATR Operations group. Fuel elements are accepted into the vaults through the use of an internal transfer form (ID-164) issued by the respective custodians. Removals to the various reactors also are accompanied by the internal transfer form.

(2) Critical Testing. The critical testing facilities now in operation at the MTR-ETR reactor site are composed of the ETRC, ARMF-I, and ARMF-II. These test cores are designed to operate at zero power levels to provide neutron flux and reactivity data for proposed reactor core and experimental loadings. Fuel elements and experiments for the critical facilities are received from the inspection vault and off-site sponsors. Such transfers are accompanied by an internal transfer form. Each transfer form contains identification, date of transfer, and signatures of both sender and receiver. A copy of this form is forwarded to the Nuclear Materials Control office. Perpetual IBM inventory control accounting is effected through the use of internal transfer data and IBM data processing. Inventory verification for all fuel elements containing SS material at the critical facility areas is accomplished by comparing the printed IBM subsidiary inventory ledger with operational perpetual control boards. These boards contain identification and location of all fuel assemblies within each respective testing facility. Responsibility for SS materials in this area is assigned to the supervisor in charge.

2.3 Hot Storage MBA

2.31 Reactors. Fuel transferred from the operations vault to the reactors for core loading is accompanied by the internal transfer form generated by the operational vault custodians. A copy of the internal transfer form showing the assembly numbers of fuel elements transferred to the reactor is forwarded to the Nuclear Materials Control office.

2.32 Cooling Basins. Fuel elements discharged from the reactor are transferred to fuel storage grids located in the cooling basins. The storage grids are designed to accommodate an entire reactor core and are identified by a numerical and alphabetical system which can be read easily under 20 feet of water. Transfer data for elements transferred from the reactor core to the cooling basin are recorded on form ID-164. However, this form is used

for operational control purposes and is not transferred to the Nuclear Materials Control office. The reactor area account is carried on the IBM subsidiary records as "Hot Storage Fuel Inventory". At the end of each reporting period the IBM listing is subdivided into two categories, namely "reactor" and "hot storage". Reactor loading schedules are used by the Nuclear Materials Control office for separating reactor and hot storage inventories.

Inventory verification of the "Hot Storage" material balance is accomplished by comparing the printed IBM listings with panel board inventory data located in the respective cooling basins.

Off-site shipments from the cooling basins are effected also through the use of the internal transfer form. The Nuclear Materials Control group receives a copy of these transfers.

2.4 Gamma Facility MBA

Fuel element transfers to and from the gamma facility are recorded on the internal transfer form. The storage control requirements and perpetual inventory records kept by the operating personnel are identical to those described in the aforementioned material balance areas. Responsibility for SS items in this area is assigned to the supervisor in charge.

2.5 Experimental Items

Most experimental items are small and usually encapsulated and identified by outside markings. Control of these items must be rigid because they frequently are difficult to identify after removal from the reactor. Identification markings are smeared or corroded in the process of irradiation.

The traffic of experimental items used in research reactor installations is shown in Figure 3. All experimental items are received from the sponsor by a receiving agent. This agent is under direct supervision of the Project Engineering group. Smaller encapsulated items are photographed by the receiving agent. Experiment identification is placed on a card directly below the item and is photographed with it. If the items are misplaced after irradiation, the photographs can be reviewed for proper identification. Experimental items to be inserted in out-of-pile loops are not photographed. These items are usually large in size and can be readily identified.

Experimental items discharged from the reactor are stored in the cooling basin in either wall racks or special containers (inventory buckets). In either case, the storage is identified by markers large enough to be seen from the basin rail. The experiment number and location are marked on the inventory control panel discussed under the Section II-2.32, "Cooling Basin".

In accounting for experimental items, geographic locations are ignored in order to simplify the recording mechanisms. Experimental item locations are readily identified by reviewing operational control data. The Nuclear Materials Control group maintains sufficient control by assigning experimental items to the project engineer (by signature). The engineer is not relieved of physical responsibility until the experimental item has been shipped off-site or transferred to another custodian. In either case he must initiate the internal transfer form, forwarding a copy to the Materials Control group. It must be

noted that the Nuclear Materials Control group does not become responsible for physical assignment but remains a mere agent and an original information source for supplying data on item identification and SS content.

III. RECORDS AND REPORTS

1. RECORDS FUNCTION

The accounting records used at station JWB were designed to perform four major control functions: (a) to provide an efficient recording mechanism for the receipt of source and special nuclear material (b) to provide a perpetual accounting of all SS materials while they remain at station JWB (c) to provide an efficient recording mechanism for shipping SS material to other AEC installations, and (d) to provide an efficient means of categorizing SS material by type, location, and composition for reporting transfers and inventories which are consistent with requirements outlined in the AEC Manual Chapter 7401.

The above functions are explained in diagram form in Figures 5 and 6. The source data, journals, and ledgers have been included on these charts for the purpose of presenting a pictorial outline of the record system. The flow of source data through the books of accounts is indicated by solid lines accompanied by arrows signifying the direction of data flow. Dotted lines signify independent control mechanisms for verifying subsidiary inventory accounts with the master control ledgers.

A more detailed description of the accounting system is necessary to explain the various procedures required to maintain the book of accounts. For this purpose, the flow charts have been subdivided into numerical categories and discussed logical sequence.

1.1 Receipt of SS Material (Figure 5)

(1) SS material received at station JWB is accompanied by an external source document (AEC-101 or -388). The AEC-101 transfer form designates transfers of SS material between SS stations. The AEC-388 designates transfer of SS material between licensee contractors or between an SS station and a licensed contractor.

It should be noted here that only SS material received on form AEC-388 which indicates a return to AEC channels will be entered into the station records. SS material shipped to station JWB on form AEC-388 which does not indicate a "a return to AEC for credit" is handled as licensee material and does not enter the AEC facility records.

"Other receipts" include documentation of material received via procurement invoices. These receipts are transferred to the (Procurement -- other) transfer journal account.

The data on this transfer form are verified by the custodian receiving the material when he generates internal transfer form ID-164 (see Figure 5). For instance, when fuel elements are received at the fuel inspection vault, the SS material custodian records on the internal transfer form all data pertinent to the receipt and identity of the shipment. The form is signed by the custodian and forwarded to the Nuclear Materials Control office for verification of transfer data form AEC-101. When experimental items are received, the procedure is reversed. The Nuclear Materials Control office initiates the internal transfer form from data received on form AEC-101 and forwards it to the SS materials custodian for verification and signature. This routine was established for experimental items which are sponsor-owned and must be returned after irradiation study. The experiments themselves are assigned to Idaho Nuclear Corporation

Fig. 5 Records diagram for reviewing fuel at station JWB.

Fig. 6 Records diagram for shipping fuel from station JWB.

employees by the various sponsor representatives. In most cases the experimental items are encapsulated into specially designed insertion boxes which have been instrumented for reactor study. The signature of the custodian signifying the receipt of SS material places a direct responsibility upon that person for control of the material. In all cases a copy of the internal transfer form is forwarded to the Nuclear Materials Control office.

(2) All AEC-101 transfer data regarding the identity and receipt of an SS material shipment are first entered on the IBM raw data sheet. These sheets are forwarded periodically to the IBM group for card punching and verification. These data cards provide the necessary information for IBM computation of custodian inventory lists (COEI) and project inventory reports.

(3) In addition, raw data sheets are also used to record AEC-101 transfer data to punched cards for future computation (IBM computer) of the transfer journal. This journal is used to summarize receipts and shipments into various orders. A more detailed explanation of the use of the journal is included in Section III-5.1.

(4) Each month summary of the out-of-area transfer journal are posted to the material balance summary ledger. The summary totals are forwarded by station series to the station control account (at the extreme left) and to the particular balance area affected. For instance, receipted fuel element values will enter the "cold storage" balance area. Receipted values for experiments will enter the "experiments" column.

(5) The IBM cards mentioned in item (2), above, are first grouped into material type categories. Further grouping is then made by material balance areas. The source information for material balance area segregation is summarized in the within-area transfer journal outlined in Section III-5.2 of this manual. The summarized totals are transferred to the material balance summary ledger as (inventory accounts) to the respective material balance area accounts. The difference between these values and the computed book inventory is recorded as BPID.

(6) The semiannual inventory and material balance report (MBR) is formulated by an IBM computer program. The raw data cards necessary to formulate the MBR and supporting subschedules are comprised of the AEC-101 transfer journal cards plus additional IBM cards punched from the beginning inventory accounts and loss transfer journal (line entries Numbers 1, 38, 40, 60, 61, 62, and 63).

(7) As indicated in item (2), above, additional inventory reports are computed from a program deck and raw data cards originally punched for inventory listings. These reports are COEI, project inventory, MBA inventory listings, and individual custodian summaries.

1.2 Shipping SS Material (Figure 6)

(1) When the SS materials custodian transfers material off-site, he initiates internal transfer forms ID-164 and ID-109 and other supplementary information. The latter is usually a short description of material identity and quantity (packing list) which is included with the shipping parcel.

(2) Copies of forms ID-164 and ID-109 are transferred to the NMC office. At this time, the external source document (form AEC-101) is prepared.

(3) Periodically AEC-101 transfer data are transferred to IBM cards for IBM computations of the out-of-area transfer forward.

(4) Monthly, all AEC-101 transfer forms representing shipments to off-site areas are attached to the appropriate IBM cards pulled from the subsidiary control decks. If the values and the shipment description on each IBM card agree with the corresponding AEC-101 transfer data, the cards are detached from the AEC-101 and filed for future reference.

(5) Monthly summaries from the transfer journal are posted to the material balance summary ledger.

(6) Semiannual material balance reports are summarized from the out-of-area transfer journal transfer data. This is accomplished through the use of the IBM computer facility.

2. EXTERNAL SOURCE DOCUMENTS

2.1 AEC-101, -284 (Figures 7 and 8)

All transfers of SS material between SS stations are documented on SS shipping form AEC-101. This document records the transaction and is the medium for transferring the responsibility for SS material between SS stations. Therefore unless SS material is transferred physically to another SS station, form AEC-101 shall not be prepared; conversely, when responsibility for SS material moves between SS stations, form AEC-101 must be issued. Shippers should make every effort to dispatch form AEC-101 covering off-site transfers the same day the material is shipped.

Each shipper and receiver must measure independently the SS material transferred on each form AEC-101 to determine accurately the extent to which responsibility for the material is relieved or incurred. Any receiver who cannot measure independently the SS material content within ten days shall receipt for the material on a tentative basis within the ten-day period, using the SS material transfer receipt, form AEC-284 (see Figure 8), as an interim document pending measurement of the material and completion of the receiver's portion of form AEC-101. If the receiving installation does not determine the SS material content of its receipts within 60 days, it must accept unqualifiedly the shipper's SS material content unless the SS material received is scrap (irradiated or unirradiated). Distribution of AEC-101 is outlined in AEC Manual Chapter 7401.

As stated in the preceding paragraph, form AEC-284 may be used as an interim receipt. The principal purpose of this form is to provide a shipper with a signed acknowledgment that the proper receiver has obtained the SS material in those cases where the receiver cannot obtain a measurement within the ten-day limit and issue form AEC-101 showing his actual measured quantities. In cases where the receiver is unable to issue form AEC-101 promptly within the ten-day period, form AEC-284 shall be prepared and distributed by him. All receivers are cautioned not to show any classified security information on any form AEC-284 that may be issued. Form AEC-284 shall be distributed by the receiver as follows: one copy to the shipper, one copy to the shipper's operations office, one copy to the receiver's operations office (applies only when

Form AEC-101 (Rev. 8-64) U.S. Atomic Energy Commission AECM-7401						NUCLEAR MATERIAL TRANSFER DOCUMENT						1. TRANSFER NO.	
2. SHIPPER'S FACILITY CODE _____						3. RECEIVER'S FACILITY CODE _____						4. No.	DISTRIBUTION of COPIES
Name Address						Name Address Attention:						1	
												2	
5. SHIPPED FOR ACCOUNT OF (Facility Code) _____						6. SHIPPED TO ACCOUNT OF (Facility Code) _____						3	
												4	
Name Address						Name Address						5	
												6	
7. MATERIAL TRANSFERRED IS: (Check if applicable) Shipper Receiver a. Under Supply Agreement with AEC () ()						8. THIS TRANSFER: a. Initiates or Alters Financial Liability to the AEC () b. Does Not Initiate or Alter Financial Liability to the AEC ()						7	
												8	
10. TRANSFER AUTHORITY:						9. DOCUMENTATION (If document is classified) a. Page _____ of _____ Pages b. Copy _____ of _____ Copies c. Series _____						9	
												10	
11. MATERIAL TYPE AND DESCRIPTION						13. a. * (Signature of Receiver's Authorized Representative)						11	
												11	
12. TRANSFER DATA						*FOR OTHER THAN AEC COST-TYPE CONTRACTORS, COMPLETION OF BLOCK 13. a. CONSTITUTES ACCEPTANCE OF THE DATA IN BLOCK 12. IF THE RECEIVER INTENDS TO CONTEST THE DATA, BLOCK 13. a. SHOULD NOT BE COMPLETED AND THE SHIPPER SO NOTIFIED.							
a. The Quantities Listed Below Were Shipped On _____ 19____						AEC COST-TYPE CONTRACTORS MUST SHOW THEIR RECEIVER'S DATA IN BLOCK 13.							
(Signature of Shipper's Authorized Representative)													
b. Weight Units			c. From AEC Project No.			b. To-AEC Project No.			c. Date Material Received				
d. Lot & container no.	e. Gross weight	f. Net weight	g. Element weight	h. Weight % Isotope	i. Isotope weight	d. Gross weight	e. Net weight	f. Element weight	g. Weight % Isotope	h. Isotope weight			

* U.S. GOVERNMENT PRINTING OFFICE : 1964 OF-741-482

Fig. 7 Nuclear material transfer document, form AEC-101.

<small>FORM AEC-284 (11-57)</small>			
UNITED STATES ATOMIC ENERGY COMMISSION			
SS MATERIAL TRANSFER RECEIPT			
SS MATERIAL ON TRANSFER	FROM (STATION SYMBOL)	TO (STATION SYMBOL)	NO.
SHIPPING DATE		DATE RECEIVED	
MATERIAL HAS BEEN VERIFIED AS FOLLOWS (CHECK ONE): PIECE COUNT ☐ CONTAINER COUNT ☐ GROSS WEIGHT CHECK ☐ OTHER: _____			
SHIPPER'S WEIGHTS AND SS CONTENTS ARE ACCEPTED PENDING FINAL VERIFICATION MEASUREMENTS AND COMPLETION OF FORM AEC-101.			
BY _____ <small>(ACCOUNTABILITY REPRESENTATIVE)</small>			

Fig. 8 SS material transfer receipt, form AEC-284.

shipper and receiver are not under the same operations office), and one copy shall be retained by the receiver. No instructions are stated here as to method of preparation of form AEC-284 since the form is considered to be self-explanatory.

2.2 Form AEC-388 (Figure 9)

SS stations may receive authorizations and requests for distribution of SS material to a licensee (ie, one who receives, possesses, uses, transfers, stores, etc, the material subject to the Code of Federal Regulations and for which an allocation has been issued by the Division of Licensing and Regulation based upon Section 53 of the Atomic Energy Act of 1954, as amended) under a lease arrangement. When such SS material is distributed, it must be documented by use of the SS material transfer form -- leased material (form AEC-388). However, this form under no circumstances is to be used for (a) sales of SS material to licensees (recorded by means of the SS station's own invoice form) and (b) transfers of SS material for use by a "licensee" who has a contract to do work with the material for the AEC (such as recorded by means of form AEC-101 since the "licensee", in this case, is getting his material under an AEC program allotment pursuant to a contract or subcontract with the AEC and, thus, is required to be established as an SS station subject to the applicable requirements of AEC Manual Chapter 7401, Appendix.

16-76001-2

18

3. INTERNAL SOURCE DOCUMENTS

3.1 Form ID-164 (Figure 10)

Form ID-164 is a simplified transfer form which records the receipt, shipment, and internal movement of all SS material within station JWB. It is designed to control the movement of both fuel and experimental items, and assign custodial responsibility. The form is never used as an external source document for transferring material from one SS station to another. See Figure 7 for distribution.

FORM ID - 164 (7 - 66)	U.S. ATOMIC ENERGY COMMISSION IDAHO OPERATIONS OFFICE SS MATERIAL TRANSFER	REFERENCE: NONE	
DATE MATERIAL SHIPPED _____ DATE MATERIAL RECEIVED _____		EXPERIMENT NO.	
☐ U-233 ☐ U-235 ☐ NORMAL U ☐ DEPLETED U ☐ PU 239 ☐ TH ☐ OTHER			
REMARKS:	AEC FORM 101 NO.	ITEM NO.	ITEM NO.
SIGNATURE OF SENDER			
SIGNATURE OF RECEIVER			
WHITE - RECEIVER SIGN AND RETURN TO SENDER		* LIST EACH ITEM TO BE IDENTIFIED BY THE EXPERIMENT NO. ASSIGNED ABOVE.	
PINK - RECEIVER SIGN AND FORWARD TO NUCLEAR MATERIAL CONTROL		* LIST EACH ITEM TO BE IDENTIFIED BY THE EXPERIMENT NO. ASSIGNED ABOVE.	
YELLOW - RECEIVER'S FILE COPY		* LIST EACH ITEM TO BE IDENTIFIED BY THE EXPERIMENT NO. ASSIGNED ABOVE.	
GREEN - SENDER'S SUSPENSE COPY		* LIST EACH ITEM TO BE IDENTIFIED BY THE EXPERIMENT NO. ASSIGNED ABOVE.	
BLUE - SENDER FORWARD TO NUCLEAR MATERIAL CONTROL		* LIST EACH ITEM TO BE IDENTIFIED BY THE EXPERIMENT NO. ASSIGNED ABOVE.	

Fig. 10 SS material transfer sheet, form ID-164.

3.11 Receiving Fuel Items.

- (1) The custodian having control of the storage inspection vault initiates form ID-164 showing the receiving date, number of each element, and signs as receiver.
- (2) The nuclear materials accountant compares form ID-164 with the corresponding form AEC-101. If in agreement, the nuclear materials accountant enters the AEC-101 transfer data into the Book of Accounts.

3.12 Receiving Sponsored Owned Experiments.

- (1) The nuclear materials accountant compares the document receipt, receiving report, or other data which are obtained through conversations with the custodian or sponsors with the information on form AEC-101. He initiates form ID-164 entering all data pertinent to the receipt and identification of the material involved, signs as the shipper, retains a suspense copy, and transmits the remaining copies to the custodian for verification and signature.
- (2) The custodian compares the data on form ID-164 with information from the shipper. Any additional information which is necessary to identify material is inserted on form ID-164 by the custodian. Copy 1 is returned to the Nuclear Materials Control group.
- (3) The nuclear material accountant reviews form ID-164 for any additional data which may have been added by the custodian. Changes are recorded to the IBM subsidiary control card. The suspense copy is removed from the suspense file and destroyed. Copy 1 is filed in the current ID-164 file. This file represents a perpetual accounting and SS material assignment of all experimental items on hand.

3.13 Internal Transfer of Material.

- (1) Custodian making transfer initiates form ID-164 as shipper and sends required copies to custodian receiving the SS material. Data on this form must include the following:

- Material type
- Date
- Material identification
- Material description
- Material balance areas involved
- Signature of sender.

- (2) Custodian receiving SS material signs as receiver and forwards a copy to the NMC office.
- (3) The nuclear materials accountant summarizes the forms by transfer series for posting to the Material Balance Summary ledgers. See Section III-5.2 for recording. The transfer of experimental items from one custodian to another does not constitute an internal balance area adjustment but only changes custodial responsibility.

3.14 Shipping SS Materials from Station JWB.

- (1) The custodian shipping SS materials from station JWB initiates form ID-164 showing identification number, estimated shipping

date, description of material, AEC-101 number associated with the receipt of the material, and signs as shipper. Pertinent copies are forwarded to the Nuclear Materials group.

- (2) The nuclear materials accountant compares form ID-164 with other shipping data received from shipping memos, ID-101's, courier receipts, and other off-site shipping documents.
- (3) When shipment takes place, the nuclear materials accountant signs the transfer form as receiver and inserts AEC-101 transfer series number in the "explanation" section. Copy 1 is returned to the custodian, and copy 2 is attached to the original ID-164 representing the receipt of the material. When the Number 2 copies of the transfer forms represent all SS quantities shown on the original receipt, all forms are transferred to the dead file.

3.2 INC-249 (Figure 11)

Form INC-249 is designed to record the expenditure or burial of SS material consumed in research. In most cases Sections I, II, and III must be completed prior to actual burial or material consumption. Section I is completed by the SS material custodian. It must be dated and signed by the person responsible for the expenditure. Copy 3 is retained by the custodian as a suspense copy. Copies 1 and 2 are forwarded to the Nuclear Material Control accountant for verification and signature. If the expenditure is reasonable and is within the allowable specified dollar quantity established and approved for station JWB (\$200.00 per month), the accountant will enter the authorization number provided for that purpose and notify the custodian that approval is satisfied. The custodian may then enter this authorization number on his copy of form INC-249 and take immediate action for disposal.

Should the quantities involved exceed the permissible allowance (\$200.00 per month), the Nuclear Materials Control accountant will transfer Copy 1 to the Idaho Operations Office after completion of Section II. The Idaho Operations Office will review the circumstances of the loss and recommend suggestions for salvage or outright disposal. If the latter is the case, the Nuclear Materials Control Chief of the Idaho Operations Office will complete Section III and transmit the original back to the INC Nuclear Materials Control office. The authorization number entered in Section III is transmitted by telephone to the SS Material Custodian. The latter may then bury or consume the SS material quantities stated on the request form.

SS MATERIALS EXPENDED IN RESEARCH

SECTION I (TO BE COMPLETED BY ORIGINATOR)

THIS IS TO CERTIFY THAT THE FOLLOWING SS MATERIALS WERE EXPENDED IN RESEARCH
DURING THE PERIOD _____ 19____ TO _____ 19____
(GIVE DETAILS AS TO IDENTITY, COMPOSITION, ENRICHMENT, QUANTITY ETC.)

THE MATERIALS ITEMIZED ABOVE WERE EXPENDED IN RESEARCH UNDER THE FOLLOWING
CONDITIONS. (PLEASE SUMMARIZE THE CONDITIONS SURROUNDING THE EXPENDITURE OF
THIS MATERIAL).

DATE

SIGNATURE _____
USER OF SS MATERIAL

SECTION II (TO BE COMPLETED BY INC MATERIALS CONTROL)

STATION SS MATERIAL REPRESENTATIVE _____
SIGNATURE _____

AEC, IOI REF. IF ANY

DATE

SECTION III (TO BE COMPLETED BY ID SS MATERIALS REPRESENTATIVE)

APPROVAL REPRESENTATIVE _____ DATE _____

SIGNATURE _____

AUTHORIZATION NUMBER _____

PREPARE IN TRIPLICATE
FORWARD ORIGINAL AND ONE CARBON COPY TO NMC OFFICE
ORIGINATOR RETAINS SECOND CARBON FOR HIS FILES

Fig. 11 SS materials expended in research, INC-249.

4. INFORMATIVE DOCUMENTS

4.1 Form ID-109 (Figure 12)

Form ID-109 is used to record shipping data and health physics monitoring results for all fuel or experiment shipments leaving station JWA. A copy of this form is routinely forwarded to the Materials Control office to serve as

FORM ID — 109
(REV. 1-63)
DPSU/ APR. 63/ 10M

U. S. ATOMIC ENERGY COMMISSION IDAHO OPERATIONS OFFICE

RADIOACTIVE MATERIAL SHIPMENT RECORD

ORIGINATOR	TO _____	
	FROM _____	
	VIA _____	COLLECT _____ PREPAID _____
	EXPERIMENT OR _____	CHARGE NO _____ CHARGE % _____
	PROJECT REF. _____	
	SHIP ON (DATE) _____	RADIOISOTOPES _____
	LOAD AT _____	RADIATIONS: ALPHA _____ BETA _____ GAMMA _____
	CONTAINER: TYPE _____	NEUTRON _____ CURIES _____
	SIZE _____ WT. _____	CHEMICAL CPD. _____
	NO. _____ ICC SPEC. _____	PHYSICAL FORM: SOLID _____ LIQUID _____
PALLETED FOR: ROAD _____ RAIL _____ AIR _____		
SECURITY CLASSIFICATION _____		
GRAMS: U-233 _____ U-235 _____ PU-239 _____		
DATE _____ ORIGINATOR _____		
LOADER	CONTAINER LOADED PER SHIPPER'S INSTRUCTIONS _____ DRAINED _____ CLEANED _____	
	CLOSURES SECURED _____ CHECKED FOR LEAKAGE AND CONTAMINATION _____	
	REMARKS, INSTRUCTIONS FOR HANDLING IN TRANSIT, ETC. _____	
	DATE _____ LOADER _____	
HEALTH AND SAFETY	ICC LABEL ON CONTAINER: (COLOR) _____ RADIATION UNITS OF PACKAGE _____	
	EXTERNAL RADIATION: CONTAINER SURFACE _____ MR/HR: AT ONE METER _____ MR/HR: _____	
	SURFACE CONTAMINATION _____ d/m/ 100 cm ² BETA-GAMMA: _____ d/m/ 100 cm ² ALPHA _____	
	DATE _____ HEALTH PHYSICS MONITOR _____	
	REMARKS _____	
	CONTAINER PALLETING APPEARS ADEQUATE FOR SAFE LIFTING AND/OR WEIGHT DISTRIBUTION. CONTAINER TIE-DOWNS AND CARRIER EQUIPMENT APPEAR SUITABLE FOR SAFE TRANSPORT OF CARGO.	
DATE _____ SAFETY INSPECTOR _____		
OPER.	APPROVED FOR SHIPMENT _____	
	DATE _____	SUPERVISOR _____
TRANSP.	RADIOACTIVE SHIPMENT CATEGORY _____ CONTAINER TYPE: A _____ B _____	
	CONTAINER SEAL NO. _____ APPROVED FOR NUCLEAR SAFETY BY _____	
	CONTAINER AND CONTENTS APPROVED FOR AEC BY _____	
	DATE RELEASED _____	SHIPPER'S AGENT _____

Fig. 12 Radioactive material shipment record, ID-109.

notification of all shipments leaving the area. Experiment numbers or fuel numbers may be compared on the form ID-164 issued by the shipper. After form AEC-101 has been issued, the AEC-101 numbers are transcribed across the face of form ID-109 to indicate that paper work on the shipment has been completed. Distribution of form ID-109 is made in accordance with instructions outlined in INP 8:10 and INP 8:15.

4.2 Form ID-110 (Figure 13)

The waste disposal request and authorization form is a very useful source of information for the Nuclear Material Control group. All SS material waste disposals must be accompanied by this form. All SS material approved for disposal, that physically remains at station JWB, will not be removed from the inventory records until form ID-110 has been completed in full.

4.21 Preparation and Distribution. The SS materials custodian requesting the disposal of the material originates four copies of form ID-110 and completes Section I. After completion, all copies are forwarded to AED Health and Safety for approval signature. The copies are then forwarded to the Nuclear Materials Control group for verification, signature, and date. The Nuclear Materials Control supervisor in turn transmits all four copies to the IDO Nuclear Materials Management Branch for completion of Section II. When the authorization number, signature, and date are entered, the IDO Nuclear Materials Management Branch forwards the original and first carbon to the IDO Site Survey Branch. The second copy is forwarded to the AED Nuclear Materials Control office files. Section III of the original and first carbon are completed by the IDO Site Survey Branch. Both copies are then forwarded to the AED Health and Safety Branch. The first carbon is retained in their files and the original is forwarded with the shipment to the burial grounds. Section four of the original is then completed by the burial attendant. The original is forwarded back to the IDO Site Survey Branch for filing.

The SS materials custodian originating form ID-110 is informed of the burial date by the AED Health and Safety man performing the actual burial. This information is forwarded by telephone or notegram to the Nuclear Materials Control office for write-off verification.

WASTE DISPOSAL REQUEST AND AUTHORIZATION

SECTION I - (TO BE COMPLETED BY ORIGINATING ORGANIZATION)		
ORIGINATING ORGANIZATION _____		
DESCRIPTION OF WASTE: (Complete applicable parts)		
Liquid _____	Solid _____	Volume _____ Weight _____
Radioactive: Yes _____ No _____ Curies _____		
Mr/hr at container surface _____ at one meter _____		
SS Material Type _____		Amount: Net _____ Isotope _____
Classification: Secret _____ Confidential _____ Category: I _____ II _____ III _____		
Composition: _____		
Capital Equipment No. _____		
Associated Hazards: _____		
CONTAINER: Type _____ Destroy _____ Save _____		
MODE OF TRANSPORTATION _____		
APPROVAL:		
Originator _____		
SS Account. Rep. _____		
HP Rep. _____		
(Signature)	(Title)	(Date)
SECTION II - (TO BE COMPLETED BY IDO SS MATERIALS SECTION IF SS MATERIALS ARE INVOLVED IN DISPOSAL OPERATION)		
Authorization Number _____		
(Signature)	(Title)	(Date)
SECTION III - (TO BE COMPLETED BY IDO HEALTH AND SAFETY DIVISION)		
Method of Disposal: _____		
Prescribed Precautions: _____		
APPROVAL:		
Site Survey Branch _____		
Analytical Branch _____		
S&FP Branch _____		
(Signature)	(Date)	
SECTION IV - (TO BE COMPLETED BY PERSON WITNESSING DISPOSAL)		
Disposal was made by means of _____		
at _____ on _____		
(Location)	(Date)	
(Signature)	(Date)	

Fig. 13 Waste disposal request and authorization form, ID-110.

5. JOURNALS AND LEDGERS

5.1 Out-of-Area Transfer Journals

The out-of-area transfer journal is a book of original entry designed to reflect the summaries of receipts and shipments of SS material incident to each SS station. The chronological sequence of summaries and events is shown in the outline schedule below.

I. Material Type

A. Receipts

1. Summary by RIS by operational field office. Summaries include month and year-to-date totals for each RIS and its associated field office. Each field office is shown by monthly and year-to-date totals and includes a listed summary of its associated RIS symbols.

B. Shipments

1. Summary identical to that shown in I.A.1 above.

A sample of the IBM transfer journal output is shown in Figure 14. The data from the source documents (AEC-101, etc) are transcribed to IBM raw data work sheets prior to card punching. The work sheet is shown in Figure 15. The headings on the work sheet are self-explanatory. Therefore, the recording procedure need not be mentioned here.

FACILITY TRANSFER SUMMARY IDAHO NUCLEAR CORPORATION (JWB) FISCAL YEAR 1967				
DEPLETED URANIUM (KILOGRAMS)				
STATION TITLE	PERIOD SS NET	TOTAL ISOTOPE	YEAR-TO-DATE SS NET	TOTAL ISOTOPE
RECEIPTS				
07 02B-JWB 1 07-01-69	81	*		
07 TOTAL STATION 02B	81	*	81	*
07 TOT-AEC, IDAHO OPERATIONS OFFICE	81	*	81	*
RECEIPTS				
08 TOTAL STATION 02B			81	*
08 TOT-AEC, IDAHO OPERATIONS OFFICE			81	*
08 03-JWB 0 08-30-69	3	*		
08 TOTAL STATION 3	3	*	3	*
08 TOT-AEC, PROCUREMENT - OTHER	3	*	3	*

Fig. 14 IBM transfer sheet output sample.

5.2 Within-Area Transfer Journals

The within-area transfer journals are comprised entirely of summarized ID-164 transfer forms representing the internal transfer of SS material between two material balance areas. Each journal is comprised of summarized ID-164's representing a particular transfer series (MTR-cold to MTR-hot, etc). The total uranium values of each transfer series is forwarded to a recap sheet attached to the bound journal. These values are transferred to the material balance summary ledger at the end of each reporting period (monthly).

5.3 Material Balance Summary Ledger (Figure 16)

The material balance summary ledger is a book of final entry for recording the summaries of all transactions from the books of original entries (out-of-area transfer journals and within-area transfer journals) and all other special adjusting entries not usually recorded into the "original book of accounts". Such entries would include adjustments to individual material balance area inventories to record burnup, fission loss, write-offs, materials losses, etc.

The major material balance area designation and the supporting subsidiaries are listed below.

- (1) Cold Storage
 - (a) MTR-ETR-ATR inspection vault
 - (b) MTR-ETR-ATR operations fuel vault
 - (c) ETR critical facility
 - (d) ATR critical facility
- (2) MTR Hot Storage
 - (a) MTR reactor
 - (b) MTR canal
- (3) ETR Hot Storage
 - (a) ETR reactor
 - (b) ETR canal
- (4) ATR Hot Storage
 - (a) ATR reactor
 - (b) ATR canal
- (5) Gamma Facility
 - (a) MTR, ETR, ATR fuel
- (6) Experiments.

Data summarized in the MBS ledger includes: beginning inventories, receipts, shipments, within-area transfers, write-offs, expenditures, burnup and fission loss, material unaccounted for, and ending inventories.

MATERIAL TYPE _____

MONTH OF _____ 19 _____

REPORTING UNITS _____

[illegible]

Fig. 16 Station JWB SS materials ledger.

5.31 Posting Summarized Source Data to the MBS Ledger.

(1) Beginning Inventory. The beginning inventories for the station control and each respective material balance area for the current month are transferred to the ledger at values representing the ending inventories for the previous month. The arithmetic total of all material balance area inventories must be equal to the station control inventory value.

(2) Receipts. The total monthly receipts for the out-of-area transfer journal is transferred to the material balance summary ledger. The station code symbols are included in the explanation column for future reference. The SS material values are transferred to the station control column and the material balance area affected.

(3) Shipments. The total monthly shipment to each SS station summarized in the out-of-area transfer journal is posted to the material balance summary ledger in the same manner outlined for receipts. The posted values in this case will be either red or black with a negative sign indicating a deduction from the beginning inventory values.

(4) Within-Area Transfers. The within-area transfers affecting the individual material balance areas are transferred to the MBS directly from the summarized within-area transfer journals. Additions to a particular material balance area inventory are recorded in black. Removals are indicated by a red figure or a black figure with a negative sign. No entry is to be made to the MBS station control column from these journals.

(5) Write-off and Expenditures. Upon disposal, the approved write-offs or expenditures are transferred to the MBS ledger via the journal entry transfer form. Backup for the entry into this journal is obtained from the "expended in research" form, INC-249. Entries into this section of the material balance summary ledger include: normal operational loss, accidental loss, write-offs, and material unaccounted for. The latter could be an entry either decreasing or increasing an inventory account in the MBS ledger. The other accounts are normally recorded as decreases to a particular material balance area inventory summation.

(6) Burnup and Fission Loss. The burnup and fission loss values are obtained from IBM computer output for all reactor cycles occurring during a particular month. These data are explained in the measurement section of this manual. The loss values are entered into the loss journal via a journal entry transfer form. The entry is then transcribed to the loss section of the material balance summary ledger.

5.4 Adjusting Journal Entry Form

The adjusting journal entry form is a book of original entry used to document transfer data to the material balance summary ledgers which are not normally recorded from the out-of-area and within-area transfer journals. Such entries are necessary to record normal operational losses, accidental losses, write-offs, and material unaccounted for. The adjusting entry form is also used in rare cases to record and document shipper-receiver differences directly into the out-of-area transfer journal. These entries contain sufficient information regarding detailed AEC-101's involved including the shippers value tabulation and JWB

measurement data. Although the AEC-101 containing the receivers data is sufficient for transfer journal posting, the adjusting entry is made to backup the details involved in the S/R adjustment entry. A typical example of an adjusting entry to record NOL for a particular month is shown below. Note that journal entry number 7-1-67 corresponds to the first journal entry for the month of July in the year 1967. An entry for accidental loss, write-off, or MUF would be similar and contain journal entry numbers labled 7-2-67, 7-3-67, 7-4-67, etc.

Journal Entry 7-1-67	<u>Enriched Uranium</u>			
	<u>SS Net</u>	<u>U-235</u>	<u>SS Net</u>	<u>U-235</u>
Normal Operational Loss	10	9		
Cold Storage MBA Inventory			10	9

To record the normal operational losses occurring in the cold storage MBA inventory for the month of July 1967. This loss is authorized and documented by authorization form ID-187 received from the Idaho Operations Office.

5.5 Loss Journal (Figure 17)

As indicated in Section III-5.4, the inventory adjustment values transferred to the material balance summary ledger are documented by the journal entry transfer form. The accumulation of monthly and year-to-date values for each loss category (NOL, MUF, accidental losses, and write-offs) is summarized into the loss journal. A sample of this journal is shown in Figure 17. It is prepared monthly and distributed to Idaho Nuclear Corporation Finance, USAEC Idaho Operations Office, Materials Management Officer, and Idaho Nuclear Corporation Nuclear Materials Control. Losses requiring special ID authorization should be indicated with a footnote directly below each material type journal.

STATION _____				
SCHEDULE OF ACCIDENTAL LOSSES - NORMAL OPERATIONAL LOSSES, WRITE-OFFS, AND MATERIAL UNACCOUNTED FOR				
Material Type _____				
	Actual		Fiscal	Year-to-Date
	SS Net	U-235	SS Net	U-235
Accidental Losses	_____	_____	_____	_____
Normal Operational Losses	_____	_____	_____	_____
Write-Offs	_____	_____	_____	_____
Material Unaccounted For	_____	_____	_____	_____
<u>Total Plant</u>	=====	=====	=====	=====

Fig. 17 Loss journal.

6. REPORTING

All inventory and material balance reports mentioned in this section will be transmitted to the Idaho Operations Office, Materials Management officer, before or on the ninth working day following the end of the stated report period.

6.1 Semiannual Material Balance and Inventory Report

Semiannually (June 30 and December 31) the Idaho Nuclear Corporation Materials Management must prepare a summary of SS material transfer transactions concerning inventories, losses, write-offs, MUF's, and AEC transfer data. This report (MBR) is compiled and printed by the IBM computer facilities through the use of the out-of-area transfer journal data cards mentioned in Section III-5 of this manual. A printed sample of this report is shown in Figure 18 and 19. Lines 1, 38, 60, 61, 62, and 63 are not a part of the regular transfer journal data. Therefore, cards must be keypunched with SS material quantities applicable to each line number and inserted with the MBR program deck. The values for these cards are obtained from the material balance summary ledger (see Section III-5.3).

U. S. ATOMIC ENERGY COMMISSION					
MATERIAL BALANCE REPORT					
DEPLETED URANIUM(KILOGRAMS)		IDAHO NUCLEAR CORPORATION(IWB)		FISCAL YEAR TO DATE	
(TOTAL ELEMENT)	(ISOTOPE)			(TOTAL ELEMENT)	(ISOTOPE)
92	*	1. BEGINNING INVENTORY			
-----	-----	2. PROCUREMENT *RAW MATERIALS			
		3. *OTHER		11	
		4. PRODUCTION			
		5. DOD RETURNS *USE A			
		6. *USE B			
		7. *OTHER			
		8. FROM OTHER SS MATERIAL BALANCES			
		9. FIELD OFFICE -NEVADA			
		10. -ALBUQUERQUE			
		11. -BROOKHAVEN			
		12. -CHICAGO			
		13. -CLEVELAND SNPC			
		14. *DIVISION OF INTERNATIONAL AFFAIRS			
		15. *DIVISION OF NUCLEAR MATERIALS MGT			
		16. *DIVISION OF RAW MATERIALS			
		17. *GRAND JUNCTION			
		18. -IDAHO		81	
		19. -NEW YORK			
		20. -OAK RIDGE		815	
		21. *PITTSBURGH NAVAL REACTORS			
		22. -RICHLAND			
		23. -SAN FRANCISCO			
		24. -SAVANNAH RIVER			
		25. *SCHENECTADY NAVAL REACTORS			
		26.			
		27.			
-----	-----	28. TOTAL RECEIVED		907	
92	*	29. TOTAL TO ACCOUNT FOR		907	
-----	-----			-----	-----

Fig. 18 Printed sample of material balance report.

Each line entry shown on the material balance report for lines 2 through 27, 30 through 37, and 42 through 59 is further supported by an attached RIS -- Operational Office summary subschedule. A typical schedule for a single line entry backup is shown in Figure 20. The period and year-to-date totals for each RIS within a particular operations office is summarized showing the uranium values incident to that operations office. The summary is separated by material type and further subdivided by "receipts" and "shipments".

6.2 Composition of Ending Inventory

Composition of ending inventory must be prepared quarterly (December 31, March 30, June 30, and September 30). In essence, the total JWB inventory is segregated into specific categories or line number designations into which each

		30.			
		31.	EXPENDED IN SPACE PROGRAMS		
		32.	SALES		
		33.	DOD -USE A		
		34.	-USE B		
		35.	-OTHER USES		
		36.	EXPENDED IN AEC TESTS		
		37.	ROUTINE TESTS (ALBUQUERQUE AND SAN FRANCISCO)		
		38.	NUCLEAR LOSS		
		39.	DECAY		
		40.	SHIPPER-RECEIVER DIFFERENCE		
		41.	TO OTHER SS MATERIAL BALANCES		
		42.	FIELD OFFICE -NEVADA		
		43.	-ALBUQUERQUE		
		44.	-BROOKHAVEN		
		45.	-CHICAGO		
		46.	-CLEVELAND SNRC		
		47.	-DIVISION OF INTERNATIONAL AFFAIRS		
		48.	-DIVISION OF NUCLEAR MATERIALS MGT		
		49.	-DIVISION OF RAW MATERIALS		
		50.	-GRAND JUNCTION		
		51.	-IDAHO		
		52.	-NEW YORK	815	2
		53.	-OAK RIDGE		
		54.	-PITTSBURGH NAVAL REACTORS		
		55.	-RICHLAND		
1		56.	-SAN FRANCISCO	1	*
		57.	-SAVANNAH RIVER		
		58.	-SCHENECTADY NAVAL REACTORS		
		59.			
1		60.	ACCIDENTAL LOSSES		
		61.	NORMAL OPERATIONAL LOSSES	1	*
		62.	WRITE-OFFS		
		63.	MATERIALS UNACCOUNTED FOR		
-----	-----			-----	-----
2		64.	TOTAL REMOVALS	817	2
-----	-----			-----	-----
90		65.	ENDING INVENTORY	90	*
-----	-----			-----	-----
92		66.	TOTAL ACCOUNTED FOR	907	2
-----	-----			-----	-----

Fig. 19 Printed sample of material balance report.

FACILITY TRANSFER SUMMARY IDAHO NUCLEAR CORPORATION (JWB) FISCAL YEAR 1967				
DEPLETED URANIUM (KILOGRAMS)				
RECEIPTS				
STATION TITLE	PERIOD TOTAL SS NET	ISOTOPE	YEAR-TO-DATE-TOTAL SSNET	ISOTOPE
STATION 3	-----	-----	11	*
TOTAL USAEC, PROCUREMENT -- OTHER	-----	-----	11	*
	-----	-----	-----	-----

Fig. 20 Typical schedule for single line entry backup.

inventory item must fall. Each line number or description is further subdivided into material type and enrichment range outlined in IAD 7401-10. A sample of an actual COEI inventory report is shown in Figure 21. Note that the first two line numbers on the "composition" are reserved for reporting project and non-project inventory quantities. The total of these two line numbers must be in agreement with line 190 on the COEI inventory report.

6.3 Project Inventory Reports

Semiannually (June 30, December 31) the Idaho Nuclear Corporation Nuclear Materials management is responsible for the issuance of a station inventory report showing project or nonproject quantities at station JWB. This report is segregated by material type, project code, and enrichment ranges so specified by the Atomic Energy Commission. A sample of a prepared IBM report is shown in Figure 22. The raw data cards used in conjunction with the project inventory

8. MISCELLANEOUS PLANT INVENTORY ADJUSTMENTS

As previously mentioned, the AEC-101 transfer form is a media through which total plant inventories are decreased or increased. However, the total plant balance can be affected by recording losses due to fission, accidental spills, rounding errors, physical loss, intentional write-off, normal routine, or anticipated losses and measurement uncertainty. The latter (measurement uncertainty) generally creates a "material unaccounted for" loss or gain which may be generated by the measurement error problem and regarded as a shipper-receiver difference. An independent receiver measurement value applied to replace a previous value supplied by the shipper can result in a MUF. This MUF value is equal to the existing shipper-receiver difference and cannot be removed from the total plant material balance until a corresponding adjustment has been made to AEC-101 transfer data originally accepted. The adjustment is usually made by correcting AEC-101 values to coincide with those ultimately used by the receiver of the material.

A brief description of these miscellaneous inventory adjustments is listed below. The original document supporting these adjustments will also be noted. In all cases the values shown for lines 60, 61, 62, and 63 are transferred to the MBS and MBR through the J. E. system.

8.1 Normal Operational Losses (Line 61)

Normal operation losses are generally defined as routine and anticipated in nature and thus become a regular part of the operational programs at the TRA site. Some examples would include losses occurring during the manufacture of test fuel plates, or losses occurring during the natural fission process. The latter is explained in some detail in the paragraphs below.

The MTR and ETR burnup and fission loss computations are performed at the end of each cycle. The Nuclear Materials Management representative pulls the IBM fuel cards from the "reactor MBA" deck and submits them to the IBM computer section for burnup application. The computer program assigns a burnup and fission loss value to each fuel element and punches the residual values onto a new "reactor MBA" card deck. The total burnup values for the entire core are listed as printed output to be used for inventory adjustment in the material balance summary ledger.

The apportionment values for fuel elements and control sections occupying the various positions in the core are contained in the IBM program deck as fixed values. The only variables fed to the program deck is the total cycle MWd value and the SS net and U-235 values supplied by the fuel (data) cards.

Consequently, the burnup and fission loss apportionment to each fuel element is evenly distributed to each fuel element in the core. The same theory applies to the loss computation for control fuel sections. The formulas for the MTR and ETR are listed below:

$$\begin{array}{lll} \text{ETR} & \text{Burnup per element} & = \frac{1.26 \text{ (MWd)} (0.873)}{\text{total fuel elements in core}} \\ & \text{Burnup per control} & = \frac{1.26 \text{ (MWd)} (0.127)}{\text{total control sections in core}} \end{array}$$

	Fuel Loss per element	= $\frac{1.06 \text{ (MWd)} (0.873)}{\text{total elements in core}}$
	Fuel loss per control	= $\frac{1.06 \text{ (MWd)} (0.127)}{\text{total control sections in core}}$
MTR	Burnup per element	= $\frac{1.27 \text{ (MWd)} (0.90)}{\text{number of elements in core}}$
	Burnup per shim	= $\frac{1.27 \text{ (MWd)} (0.10)}{\text{total shims in core}}$
	Fuel loss per element	= $\frac{1.07 \text{ (MWd)} (0.90)}{\text{total elements in core}}$
	Fuel loss per shim	= $\frac{0.07 \text{ (MWd)} (0.10)}{\text{total shims in core}}$

The above formulas therefore indicate that 90 percent of the total core cycle loss is apportioned to the MTR fuel elements (equally distributed) and 10 percent to the MTR shim rod sections. Likewise, the ETR fuel elements absorb 87.3 percent of the total core loss bearing 12.7 percent to be evenly distributed to the control fuel sections. These fixed values were obtained from summarizing reactor cycle data for several years to obtain an average MWd apportionment factor for fuel elements versus control or shim rods. Individually, the burnup and fission loss values assigned to each fuel element leave some margin for error. However, these values are only used to transfer irradiated fuel to ICPP and present no problem when fuel is dissolved on a core to core basis.

The ATR alpha values have not been established to date, making it impractical to assign burnup or fission loss to the ATR fuel elements. When these figures become available, an amendment will be made to this manual to include burnup and fission loss computation procedures. All normal operational losses with the exception of fission loss and burnup are documented by form INC-249. The fission loss adjustment is documented (as stated above) by the computer burnup output sheet.

8.2 Accidental Losses (Line 60)

Accidental losses are defined as inadvertent losses, spills, or burials occurring as the result of an incident of oversight. These losses can be neither routine nor anticipated in any manner. In all cases the custodian responsible for the loss must prepare INC-249 showing measured values or estimates. In the latter case the basis for measurement must be included.

8.3 Writeoffs (Line 62)

Writeoff is an accounting procedure whereby SS material is removed from inventory because it has been incorporated into an instrument or piece of equipment. The material must also be noneconomical or nonpractical to recover. Documentation of a writeoff is performed through the issuance and subsequent approval of form INC-249.

If it becomes necessary to ship SS material to another SS station which has been previously removed from inventory by a "Writeoff", the associated inventory item must be entered back in the records through the MUF account. The AEC-101 transfer form can thus be used to document the shipment.

Deviation from the above procedure requires approval from the ID Materials Management officer.

8.4 Material Unaccounted For (Line 63)

MUF is generally created through physical loss or by changing the value of an item which has been entered on inventory records. This change takes place if the receiver of the material is capable of generating an independent quantitative evaluation of the item in question. If so, he may elect to use that value, thereby creating a temporary "material unaccounted for" due to book physical inventory difference. This difference is eliminated if the original AEC-101 transfer data are corrected to reflect the receiver's measurements. This account may be used also for recording unbalances due to possible measurement error or rounding procedures.

9. INVENTORY AND MATERIAL BALANCE CUTOFF PROCEDURES

At the end of each reporting period (June 30 and December 31), all transfer source documents (AEC-101 and -388) must be entered into the out-of-area transfer journal which are associated with SS materials shipped by all other SS stations in the report period. Therefore, no "material in transit" will exist between any two SS stations. If anticipated receipts are evident, it is the SS representative's duty to contact the shipper and obtain posting values for IN-transit shipments and enter same into the transfer journal card deck. In these cases it will not be necessary to wait for AEC-101 transfer forms which could arrive after the period close out.

Likewise if the station representative for JWB issues an AEC-101 late in the reporting period, he should inform the receiver of the material that an in-transit exists which should be picked up on his records in the current report period.

In view of the above condition it is usually necessary for the SS representative to maintain an open book of accounts until all source data concerning shipments and receipts for the period have been received. Theoretically, this procedure assumes no in-transit condition and, therefore, requires no journal entry for in-transit items. However, data concerning AEC-101 transfer forms for material in-transit items are obtained by telephone conversation with the shipper. These data are transcribed to the transfer journal using AEC-101 transfer series data. The telephone conversation is documented and filed (AEC 101 File) for future reference.

IV. MEASUREMENT TECHNOLOGY

1. INTRODUCTION

The success of the reactor materials control system depends upon the generation of sufficient accurate data to permit the degree of control required. Because the nuclear material inventory must be continuously corrected for loss by burnup, certain reactor and reactor fuel measurements are necessary. These are the measurements of initial nuclear material content of the fuel, the total heat (integrated power) generated by the fuel in the reactor, and the distribution of the heat generation among the fuel elements.

The initial composition of the fuel elements usually can be measured most accurately during their fabrication. This is normally done by chemical analysis of melt samples coupled with individual weighings of the corresponding plate core punchings, which are subsequently clad and rolled into plates. Alternatively, the density of each plate core punching can be measured and related to the uranium content by an empirical calibration. When, as is usually the case, the reactor operator is not the fabricator, the former may be reluctant to accept the fabricator's stated content without performing independent measurements. Therefore, nondestructive assay techniques are of particular interest.

2. VERIFICATION OF URANIUM LOADINGS FOR FABRICATED FUEL ITEMS

2.1 Scope

Fabricated fuel items will be independently verified for uranium 235 content by nondestructive assay techniques. In all instances these techniques will be performed at the fabricator residence utilizing a portable gamma scanning instrument. Measurements will be concentrated on rolled fuel plate items prior to element fabrication. Sampling techniques and scanning procedures for each fuel plate type (for each vendor) will be designed to augment or complement fabricator production scheduling. In general, routine scanning procedures will be established and made uniform for all vendors. The sampling plan will be designed to be commensurate with measurement problems inherent at the fabricator with special interest focused on the number of plates that can be efficiently scheduled for loading verification.

2.2 Procedures

Under contract commitment, each fabricator will be reviewed by a member of the Idaho Nuclear Operations Analysis branch prior to production scheduling. This review will be focused on vendor's techniques used to determine U-235 loading of each fuel plate. When accepted, this technique will be further verified by nondestructive assay scanning with the portable scanning instrument. If the U-235 difference between the two measurement methods is within the two standard deviation limit applicable to both methods, production scheduling will be permitted.

Routine scanning (by sample method) will be performed on regular fabricated items. This verification will be conducted by an Idaho Nuclear resident inspector.

Fuel plate standards will be made available for each plate-type series and will be transmitted to the fabricator residence for the scanning process.

2.3 Establishing U-235 Loading for Plate Standards

2.31 Alloyed Fuel Plates. The U-235 loading content of alloyed fuel plate standards is determined by the following procedure. Several production fuel plates are selected and scanned for total gamma emission. The resulting count rates are observed to establish and select fuel plates within the group which exhibit and represent a sufficient range of count rates which could be applicable to regular production fuel plates. The selected fuel plates are scanned several times against an arbitrarily picked standard. The chosen standard in this case represents the approximate center of the range. The ratios of each plate relative to the standard are averaged to obtain a mean ($\bar{R}$) value. All these plates with the exception of the standard are dissolved and analyzed for total uranium and U-235 content. The chemical analysis is then related to the individual (R) values by using the method of least squares. From the regression, the values A (intercept) and B (slope) are obtained to form the equation $U = A + BR$.

2.32 Powdered Metallurgy Fuel Plates. The U-235 loading for fuel plates manufactured by powder metallurgy techniques is assigned at the fabricators plant. The Idaho Nuclear "resident inspector" observes the powder weighing for all fuel plates to be used as standards. After the inspector is satisfied that the weighings are correct, he will sample the powder (U_3O_8 , UO_2 , or U/Al_3) and transmit the sample to ICPP for analytical composition. This sample also may be transmitted to another qualified laboratory for independent verification.

2.4 Establishing Measurement Uncertainty for Plate Standards

2.41 Alloyed Fuel Plates. The variance associated with the estimated U-235 content of an individual fuel plate is

$$\sigma_{\mu}^2 = \sigma_r^2 \left(\frac{1}{n} + \frac{(R - \bar{R})^2}{SSD_R} \right) + B^2 \sigma_R^2 + \sigma_S^2$$

where

σ_{μ}^2 = variance of loading content of standard

σ_r^2 = residual variance from regression or variance of random analytical error

n = number of data points in regression

R = observed relative count from regression

SSD_R = sum of the squared deviates of R from the regression

σ_R^2 = variance associated with a given relative count rate

$\bar{R}$ = mean relative count from regression

B^2 = constant derived in regression equation

σ_S = variance of systematic analytical error.

2.42 Powdered Metallurgy Fuel Plates. The variance associated with the estimated U-235 content of an individual fuel plate is equal to the total variance associated with the analytical result variance assigned to the powder weighing at the fabricator is considered to be negligible and will not contribute to the overall variance.

2.5 Calculation of U-235 in the Unknown

The U-235 loading value assigned to an unknown fuel element or fuel plate as the result of scanning against the appropriate standard is expressed as

$$U_x = U_L + \Delta \left(\frac{C_x - C_L}{C_u - C_L} \right)$$

where

U_L = grams U-235 in low standard

Δ = difference in grams U-235 of upper and lower standard

C_x = total counts of unknown

C_L = total counts of lower standard

C_u = total counts on upper standard.

This formula assumes that a linear relationship exists between the upper and lower standards. The scanner counting drift observed during the scanning sequence can be interpreted as negligible because the greater portion of the drift is eliminated through the bracketing technique. Bracketing is defined as scanning the unknown between the upper and lower standards.

2.6 Measurement Uncertainty of the Unknown

The U-235 variance associated with the individual loading value of unknown plates and elements is expressed as

$$\sigma_u^2 = \sigma_{u_L}^2 + (R)^2 \sigma_\Delta^2 + (\Delta)^2 \sigma_R^2$$

where

$$\sigma_\Delta^2 = \sigma_{U_u}^2 + \sigma_{U_L}^2 + 2 \text{ CV } (U_u, U_L)$$

U_L = grams U-235 in low standard

U_u = grams U-235 in upper standard

$$R = \frac{C_x - C_L}{C_u - C_L}$$

2.7 Assigning U-235 to Fuel Elements Only

The Westinghouse scanning instrument will be used as a gross check to verify fuel element loadings obtained from individual fuel plate U-235 assignments. This check is assumed to be a operational safety factor rather than a contract accountability requirement. In some instances (MTR elements and ETR controls), the Westinghouse measurement will prevail as the true accounting measurement for control settlements. This procedure will apply only in those cases where it is difficult to establish and maintain a proper resident fuel plate scanning plan.

The assignment of U-235 and the associated limits of recognized uncertainty is performed in accordance with those procedures outlined in Sections IV-2.3, -2.4, -2.5, and -2.6 of this manual.

3. GROSS POWER CALCULATION

3.1 Temperature-Differential x Flow Calculation

For research and test reactors which accomplish heat removal by flowing gas or liquid through the reactor, the gross power can be calculated by using an expression of the form

$$\text{Power} = K(\Delta T)F$$

where

ΔT = the temperature differential of the coolant across the reactor

F = the coolant flow rate

K = a factor dependent on certain physical properties of the coolant at the existing conditions and energy conversion factors.

For purposes of burnup computation, reactor power is computed approximately once per hour from data generated by resistance thermometers located in the upstream and downstream sections of the main flow lines, and by a "Gentile" pressure differential flowmeter (Figure 24) across the primary flow tube.

There are three primary sources of uncertainty or error associated with the power calculation as determined in this manner. These are as follows:

- (1) The measurement error in the ΔT factor
- (2) The measurement error in the flow determination; this error results from:
 - (a) the measurement uncertainty in the differential pressure determination across the flow tube and
 - (b) The interpretation of differential pressure as flow

Fig. 24 ETR power calculator resistance bridge for determination of ΔT .

- (3) The error identified with the mechanism by which the differential temperature and flow are converted to power.

Usually the interpretation of differential pressure as flow is accomplished by means of a calibration. The error associated with this calibration is derived from data obtained under highly controlled conditions prior to installation of the flow tube. This should be a full scale calibration rather than one which would result from the application of dimensional analysis to scale up from smaller flow tubes. The conversion of the differential pressure to a flow reading is through instrumentation which is approximately, but not precisely, equivalent to the original calibration. Thus, the component (2)(b) above is in fact a composite of

- (1) The uncertainty to be associated with the original calibration
- (2) The bias or deviation between the flow indicated on the instrument and the calibration value for any given pressure differential.

Experience has shown that the uncertainty in the original flow tube calibration will dominate the uncertainty in the gross power calculation unless particular care is taken prior to installation to obtain an accurate primary flow tube calibration. Furthermore, the error in this particular component is nonattenuating (systematic) in any cumulated power computation and thus could be extremely serious.

The major problem in flowmeter calibration for high-power reactors using water as a coolant is associated with the high flow rates involved. This condition requires a pump sump with a capacity sufficient for several minutes flow. Test equipment must be installed on the sump tank to enable observers to read the drop in water level and the corresponding time intervals accurately. The tank must be carefully calibrated to ensure an accurate value for volume delivered between level readings. During each run the flow tube pressure differential is measured with a manometer. The data (flow rate versus pressure differential) are fitted by statistical regression analysis techniques to the functional form

$$F = a (\Delta P)^b$$

or

$$\text{Log } F = A + b \log \Delta P.$$

The error to be associated with the fitted equation when used for estimating flow from an observed pressure differential can be obtained from the regression analysis. Statistical regression theory would suggest that the individual calibration runs be concentrated at the end points of the range of anticipated application, but since the instrument response may not be linear, intermediate values probably should also be obtained to verify the form of the regression equation.

In the reactor, the temperature differential is measured by a multiplicity of resistance thermometers located in the main flow lines. These thermometers are located sufficiently downstream from the reactor to allow thorough mixing of the water. Temperature differential measurements contribute negligibly to the overall error in gross power measurement, particularly since accuracy control is easily accomplished at periodic intervals by submerging the upstream and downstream thermometer bulbs in controlled temperature baths, applying a predetermined temperature differential between the two baths, and recording the ΔT chart reading.

4. CALCULATION OF U-235 DEPLETION

4.1 Total Burnup Computation

Total burnup of fissionable material includes losses by fission and by conversion to other isotopes through nuclear processes. Thus, if U-235 is the fuel material, the burnup includes conversion of U-235 to U-236 by the n, γ reaction. The relationship of grams U-236 to grams U-235 fissioned is essentially equal to the ratio " α " defined as the capture-to-fission cross section ratio;

$$\alpha = \frac{\sigma(n, \gamma)}{\sigma(n, f)}$$

The gross loss by fission per fuel cycle can be computed by the relationship

$$\frac{\text{grams fissioned}}{\text{MWd}} = \left(\frac{\text{grams fissioned}}{\text{fission}} \right) \left(\frac{1}{\text{MeV/fission}} \right) \left(\frac{\text{MeV}}{\text{MWd}} \right)$$

By substituting appropriate values for these factors, a simple relationship relating fission loss to generated MWd can be obtained. For example, assuming that the energy released per U-235 fission is 198 MeV, the fission loss equals 1.06 times megawatt days (MWd). Thus, for example, for a thermalized reactor,

$$\text{Burnup} = (1 + \alpha) (\text{fission loss})$$

$$\text{Burnup} = (1 + \alpha) (1.06) (\text{MWd})$$

and for $\alpha = 0.185$, the spectrum average value,

$$\text{Burnup} = (1.26) (\text{MWd})$$

The apportionment values for calculating burnup and fission loss are shown in Section 8.1.

5. ETR POWER RECORDING INSTRUMENTATION

The power generation (MW) in the ETR reactor is calculated and recorded by the Foxboro power calculator. The power measurement is achieved by measuring the coolant flow rate and temperature rise and applying an appropriate conversion factor. The reactor power is recorded hourly, and an arithmetical mean of the power readings for each 24-hour period is calculated.

5.1 Flow Rate Measurement

The flow measurement is by a flow transmitter which measures and indicates differential pressure (ΔP) across a Gentile flow tube (Figure 25). The Gentile flow tube consists of a short spool piece, the inner circumference of which is equipped with two groups of nozzles, one group pointing upstream to the main flow and the other group pointing downstream. The nozzles are connected by pressure rings which are attached to the high and low pressure sides of the flow transmitter. The differential produced is the result of impact force differences rather than static pressure differences. Static pressure is cancelled out. This flow tube, which is 36 inches in diameter, normally has a flow of approximately 60,000 gallons per minute. The inlet and outlet pressure differential displaces mercury in the flow transmitter, and the resultant mercury float movement actuates the flowmeter arm. A mechanical linkage on the flowmeter arm actuates a transducer core via a square root cam to vary a 1000-cycle impulse, producing an electrical voltage on the transducer secondary which is proportional to the flow rate ($\sqrt{\Delta P}$). The signal is electrically cabled to the calculator unit.

5.2 Dynatherm Bridge

The dynatherm bridge is an electrical bridge circuit consisting of eight resistance bulbs and other circuitry. Four bulbs are installed in the inlet stream and four in the outlet. The bulbs are positioned at 90-degree intervals around the main flow pipe. Each bulb is inserted approximately six inches into the main flow duct. A schematic of the bridge circuit is shown in Figure 24. The bridge recovers the output signal of the flow transmitter, and the output voltage of the bridge is directly proportional to the product of the flow rate and Δt .

Fig. 25 Gentile flow tube.

5.3 Power Calculating Unit

The power calculating unit is outlined in Figure 26. Note that the unit is comprised of all components found within the boundaries of the dotted line. The flow transmitter signal, which is directly proportional to the flow rate, passes through an isolation amplifier which converts the high impedance signal of the flow indicating transmitter to low impedance without attenuating the flow rate signal. This provides the necessary impedance match to the dynatherm bridge. The signal is then transferred through a coupling transformer providing a ground for the bridge excitation circuit. This method of grounding produces a symmetrical capacitive balance to ground simplifying phase balancing of the bridge arms.

Electrical adjustments are provided on the computer unit to correct the apparent power signal for friction effects and shield losses. The friction-compensating unit subtracts a signal from the calculated power signal to compensate for the increment of temperature rise which is due to friction. The shield-compensating unit adds a signal to the calculated power signal to compensate for shield power losses. These adjustments are usually minor and could be considered as insignificant factors when computing power for burnup purposes. The correct power is electrically cabled to the power recorder unit which is calibrated to read power units directly in megawatts.

5.4 Calibration

Calibration of the electronic equipment is accomplished by the use of calibration standards which are housed within the calculator unit. By a switching arrangement, the flow rate and ΔT impulses can be removed from the circuit and standard impulse units injected. Replacement of the flow signal with the flow standard permits calibration of the flow recorder as well as the power

Fig. 26 Block diagram of the ETR power calculator.

recorders. Likewise, the temperature differential standard permits calibration of the dynatherm bridge. This standard is also used to calibrate the power recorder. These calibration checks are performed on the ETR instrument during each shutdown. More extensive calibration checks on all electronic equipment involving ΔT and water flow are performed annually. Calibration of the flow and ΔT sensing units was discussed previously.

6. MTR POWER RECORDING INSTRUMENTATION

Some reactor power calculators are not sufficiently accurate to permit use of the instrument reading directly for calculating burnup. In such cases, the power is calculated manually using differential pressure and temperature readings from the instruments. Such is the case of the MTR reactor, where the data are read and the power calculated once each hour.

6.1 Flow Rate Measurement

The flow rate measurement in the MTR reactor is similar to that described for the ETR. A Gentile flow tube is used for measuring differential pressure (ΔP), and the pressure impulse is transmitted to a Barton "Atcotran" differential pressure transmitter which converts the ΔP to a proportional electrical signal. The transmitter consists of a ΔP cell and a differential transformer. The ΔP cell consists of a bellows linked mechanically to the movable armature of the differential transformer. The position of the bellows, as determined by the pressure differential, results in a transformer core position which produces a corresponding voltage signal at the transformer secondary. This signal is transmitted to a strip chart recorder containing the appropriate components for conversion of the signal to a flow rate reading.

6.2 Differential Temperature Measurement

The ΔT measurement at the MTR is made by resistance thermometers in the main inlet and outlet flow ducts of the reactor. The resistance thermometer bulbs are arranged in a resistance bridge circuit which is balanced by a servo-operated slide wire. The slide wire position, which is directly proportional to ΔT , is recorded on a strip chart.

6.3 Power Recorder

The power recorder receives the electrical impulses from the ΔT and coolant flow recorders and provides a direct readout in megawatts. The main power recorder is located on the reactor control room console, but signals are retransmitted to four slave recorders located elsewhere in the reactor building. Because of their limited precision, the power recorder readings are used only for reactor operation. The power values needed for burnup calculation are calculated manually.

6.4 Power Level Calculations

The power level is calculated from ΔT , flow, and a factor based on inlet water temperature. The ΔT and flow are recorded hourly from their respective indicators. The factor merely converts gallons to pounds at the inlet temperature, and Btu per minute to megawatts. The calculated power is recorded on the hourly log sheet in megawatts to tenths of a megawatt.

The product of "time interval" in hours and power level is referred to as "interval megawatt hours". The "accumulated megawatt hours" is the sum of the "interval megawatt hours". The reactor operator calculates the total megawatt days produced each day by dividing the total accumulated megawatt hours for the day by 24. The sum of the megawatt days for a particular cycle is accumulated until the cycle has ended.

6.5 Instrument Calibration

Calibrations of MTR recording instruments are performed quarterly. Annual comprehensive checks are also made covering instrument electrical resets and chart calibration for all instruments associated with the ΔT and flow measurements.

V. FORECASTING AND DISTRIBUTION OF SPECIAL NUCLEAR MATERIALS

1. FORECAST REQUIREMENTS

1.1 Annual Schedules

By January 10 of each year the Nuclear Materials Control office is required to submit to the Idaho Operations Office a forecast of nuclear material withdrawals and returns which will cover the period July 1 of that year to June 30 of the following year. The forecast must be submitted by quarters and must be issued on form AEC-408 (Figure 27). The annual forecast must include all project numbers covering SS material on inventory or to be forecasted. In other words, if it is not anticipated that a withdrawal or return is required during the forecast period for a specific project, the inventory value of that project must be included in the forecast schedule. Inventories also must include all nuclear material outside projection channels which were withdrawn for the 04 allotment for use under contract AT(10-1)1230. Such project numbers are associated with the prefix "J".

1.2 Revised Forecast Schedules

By September 10 of each year the Nuclear Materials Control office is required to submit a revision to the third and fourth quarters included in the previous annual forecast. This revision will not include inventory values for project numbers but will include only the withdrawal and return estimates. Changes made to the third and fourth quarter forecast must be justified by using the explanation space located at the bottom of form AEC-408. In addition to this revision, an additional forecast is required which covers the first and second quarters of the succeeding fiscal year.

1.3 Supply Agreement Considerations

Withdrawals of SS materials under supply agreement must be included as forecast requirements regardless of the fact that such material is not assigned to a project program at the time of withdrawal. Assignment to a particular project is consummated upon conversion of the supply agreement material to fabricated items requested under the supply agreement fabrication contract. Under this procedure the excess requirements necessary for scrap generation are not requested in the total value reported in the withdrawal estimates. This requirement will be entered on a line immediately below the withdrawal estimates. It should also include sufficient requirement for the conversion losses.

Withdrawal estimates shown on form AEC-408 for supply agreement material should be entered on a line separate from that which shows withdrawal estimates for a particular project assignment.

Ending inventory estimates (column 13, AEC form 408) should be entered on project line totals only. The inventory should represent the estimated value for project quantities subsequent to conversion from supply agreement material. No ending inventory estimate is necessary to show supply agreement quantities not yet transferred to a project program.

[illegible]

2. SPECIAL NUCLEAR MATERIALS SUBJECT TO FORECASTING

- (1) Enriched U-235' -- all percentages
- (2) U-233
- (3) Plutonium
- (4) Pu-238.

51

- (1) Enriched uranium -- nearest full kg U-235
- (2) U-233 -- nearest full 100 grams
- (3) Plutonium -- nearest full 100 grams
- (4) Pu-238 -- nearest full 1 gram unit.

4. COMPLETING FORM AEC-408

Sections 1-5 Self explanatory.

- Section 6 The wt% U-235 is to be recorded to the nearest full 1/10 percent. Plutonium forecasts should be reported with regard to Pu-240 content to the nearest 1 percent whole unit.
- Section 7 This section is used to record the anticipated inventory for each project number on the first day of the forecasting period. This estimate will include present inventory values plus or minus withdrawal and returns prior to the inventory date.
- Section 8 This section includes quarterly estimates of anticipated withdrawals. Project quantities should include fabrication and conversion excess requirements. Supply agreement quantities should include only finished product requirements.
- Section 9 Total of Section 8.
- Section 10 Includes quarterly return estimates for each project number. This section must be divided into two categories signifying whether the material is to be returned to production channels in the form of cold scrap or irradiated fuel. Returns for fuel cores must include an allowance for U-235 burnup. This allowance is dependent on reactor cycle time expectancy and U-235 loading.
- Section 11 Total of Section 10.
- Section 12 Section 9 minus Section 11; this value can be negative.
- Section 13 See paragraph 1.3 of this section.
- Section 14 The remarks section is to be used to fully justify the withdrawal or return of each project listed.

VI. SEMIANNUAL REVIEW

1. AUDIT INSPECTION AND INVENTORY VERIFICATION

1.1 Semiannual Review

In accordance with INCP 8.15, each SS materials custodian will be subject to a semiannual review of his SS materials holdings. This review will be conducted by members of the Nuclear Material Control group.

1.11 Custodian Inventory Verification. Semiannually, the Nuclear Materials Control group will issue an IBM listing to each custodian showing the SS material items for which he is responsible. This list must be reviewed, verified, signed, and returned to the Nuclear Material Control office within seven working days after receipt. The custodian's signature (other than exceptions noted) will be a valid confirmation that he has knowledge of the existence of all items on the IBM listings. Prior misplacement of an internal transfer form (IC-164) will not relieve the custodian of the responsibility for a misplaced item if that item was indicated on an inventory list which has his signature. In other words, a signature on an IBM list is a valid confirmation of the existence and location of all items on that list and will be interpreted as a direct replacement of all ID-164 transfer forms related to the listings.

1.12 Inventory Sampling Requirements. After the conditions have been met the SS materials inventory for each custodian will be verified by members of the Nuclear Materials Control group. The sampling requirements are indicated in the paragraphs below.

- (1) A random sampling inventory verification will be conducted on all items containing less than 15 grams of SS content.
- (2) Where feasible, all items containing 15 or more grams of SS content will be verified by visual inspection. Unirradiated fuel elements and fuel plates are verified 100 percent by comparing each fuel element number with IBM subsidiary records. Reactor and storage basin inventories are verified by comparing operational control board data with the IBM subsidiary lists. Verification of the control board data is completed by spot checking various fuel numbers in the basin grids with those indicated on the control boards proper. Sampling procedures require that at least 10 percent visual inspection be conducted on items of this nature.

1.13 Custodian Records Review. The audit inspector will be required to review the record systems used by the various custodians. Each custodian must maintain a proper file of all ID-164 transfer forms to verify all inventory items assigned to him.

1.14 Review Findings. The nuclear materials control supervisor will be responsible for summarizing all review findings (semiannually) and report same to Idaho Nuclear Corporation management. This report will be made available to all SS material custodian department heads.