INTERNATIONAL TRAINING COURSE ON IMPLEMENTATION
OF STATE SYSTEMS OF ACCOUNTING FOR
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SESSION 9: TYPICAL IAEA OPERATIONS AT A FUEL FABRICATION PLANT

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I. INTRODUCTION

In this session the IAEA operations performed at a typical Fuel Fabrication Plant will be explained. To make the analysis less general the case of Low Enriched Uranium (LEU) Fuel Fabrication Plants will be considered. Many of the conclusions drawn from this analysis could be extended to other types of fabrication plants. The safeguards objectives and goals at LEU Fuel Fabrication Plants will be defined followed by a brief description of the fabrication process. The basic philosophy behind nuclear material stratification and the concept of Material Balance Areas (MBA's) and Key Measurement Points (KMP's) will be explained. The Agency operations and verification methods used during physical inventory verifications will be displayed.

II. SAFEGUARDS OBJECTIVES AND GOALS AT LEU FUEL FABRICATION PLANTS

In general terms the primary objectives of safeguarads are outlined in paragraph 28 of INFCIRC/153 as "Timely detection of diversion of significant quantities of nuclear material from peaceful nuclear activities to the manufacture of nuclear weapons and deterrence of such diversion by the risk of early detection".

For the specific case of LEU fuel fabrication plants the significant quantity was set as 75 kg U-235. Because the nuclear material involved in such plants is not directly convertible to metallic components for an explosive device, the detection time of a significant quantity has been set at one year.

The Agency's goals also in general terms are specified in paragraph 30, "The technical conclusion of the Agency's verification activities shall be a statement, in respect of each material unaccounted for over a specified period giving the limits of accuracy of the amounts stated."

The object of this lecture is to explain how to achieve the above mentioned goals based on the Agency's practical experience in safeguarding this kind of bulk facility.

III. PROCESS-OVERVIEW

A simple block diagram of the basic process is shown on Figure 1. It consists of converting UF_6 to UO_2 powder, pressing the powder in UO_2 pellets and sintering the pellets, loading the pellets into cladding tubes to form fuel rods, and inspecting the rods and combining them into fuel assemblies. There is a scrap recovery plant for purifying and converting scrap to UO_2 for recycle back to the pellet pressing operation. Solid and liquid wastes are processed and prepared for shipment offsite. Samples are analyzed in the analytical laboratory and archive samples are kept as references.

IV. STRATIFICATION OF NUCLEAR MATERIALS

Based on the above explained process one way of stratifying the nuclear material in LEU conversion and fuel fabrication plants appears in Table 1. The two strata with asteriks may require further break down. For example the in-process inventory at the fabrication plant can be considered as the sum of the following strata:

1. UO_2 Powder
2. Green Pellets
3. Sintered Pellets

Quite often burnable poison material (e.g., Gadolinium) is added to the LWR fuel. In this case a new stratum with different chemical and physical properties (UO_2, Gd_2O_3) should be considered. When more than one enrichment is involved the stratification should also take this into account.

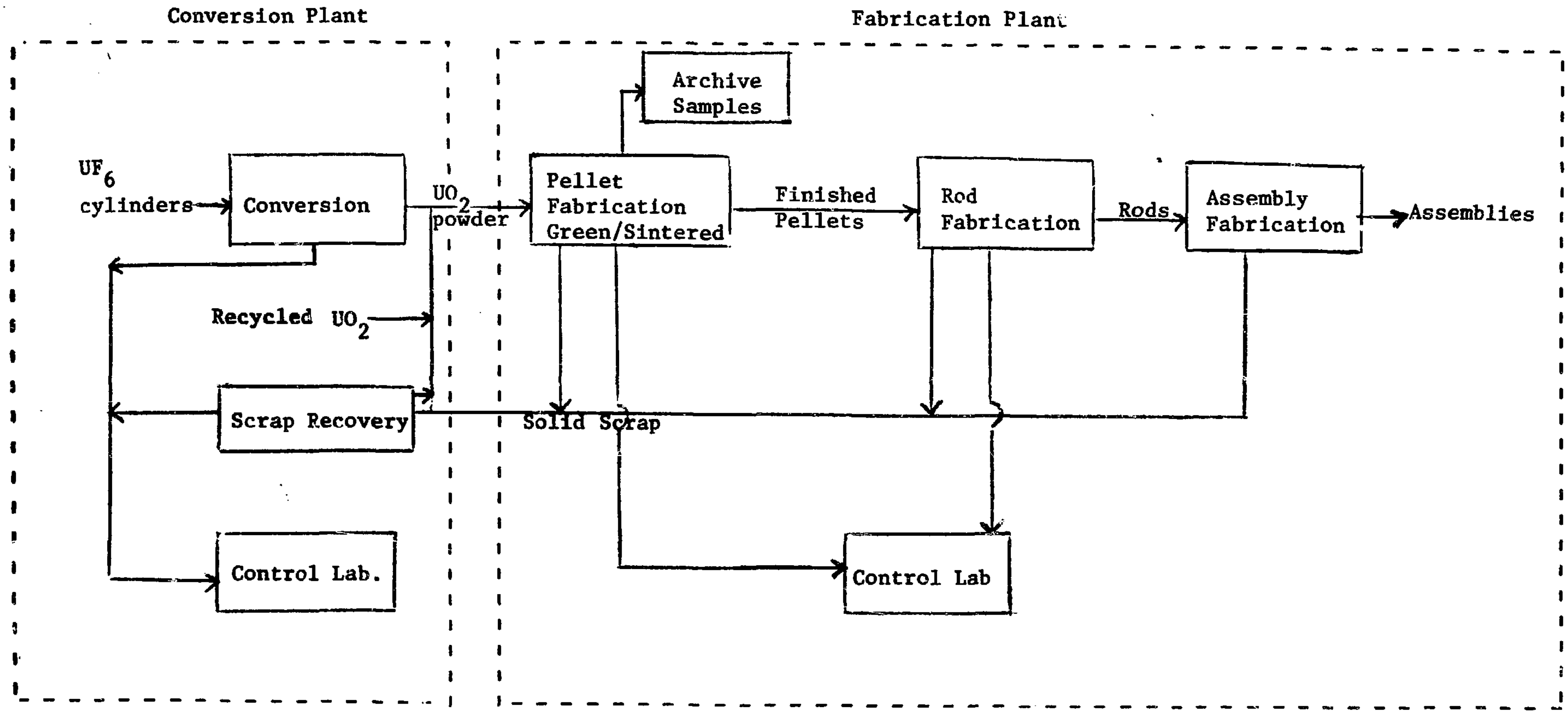


Figure 1. Process Overview

TABLE I STRATIFICATION OF NUCLEAR MATERIAL AT LEU FUEL CONVERSION AND FABRICATION PLANTS

I) CONVERSION PLANT

1) UF_6 Cylinders
2) In-Process *
3) Control Lab.

II) FABRICATION PLANT

1) UO_2 Powder
2) In-Process *
3) Finished Pellets
4) Rods
5) Bundles
6) Solid Scrap
7) Archive Samples
8) Control Lab.

V. *MATERIAL BALANCE AREAS (MBA's) AND KEY MEASUREMENT POINTS (KMP's)*

After nuclear material stratification and to make the task of nuclear material accountancy more manageable the facility is divided into areas - so called material balance areas - where the quantity of nuclear material in all inputs, outputs and the inventory can be determined. The boundaries of MBA's are chosen whenever possible to facilitate the measurement of all nuclear material transfer relevant to Safeguards and help ensure the completeness of flow measurements. Coupled with the concept of MBA's are the Key Measurement Points (KMP's) which are the locations where nuclear material appears in such a form that it may be measured to determine material flow (inputs, outputs, measured discards) or inventory.

VI. VERIFICATION METHODS

In order to achieve the Agency's goals (MUF, σMUF) a careful consideration should be given to the verification methods. In fact the verification methods are the corner stone for all the safeguards activities in these bulk facilities, since:

1. The measurement errors associated with these verification activities contributes directly towards the principle parameter σMUF;
2. the acceptance or rejection of a certain stratum on site which was subject to attribute verification is based on the 4 σ criterion (σ is the systematic and random components of the measurement errors of the verification technique used).

It is also important to mention that the stratification of nuclear material should be performed keeping the verification methods under consideration.

Table 2 shows the verification methods that are used in LEU fuel fabrication plants.

VII. DIVERSION ROUTES

a. Diversion Possibilities

In a low enriched fuel fabrication plant few special precautions are required for the handling of material. The possibility exists therefore at all times and at all stages for material to be diverted simply by direct removal from storage or process.

b. Concealment Possibilities

Since containment and surveillance measures are impractical to detect diversion, reliance must be placed on materials accountancy The inspector's strategy must be to carefully compare the operator's claims for the amount of material received, shipped, stored or lost with his own observations. The operator's strategy could be either to

TABLE I VERIFICATION METHODS

	Strata	Identification	Weighing	NDA	Sampling & Analysis
	CONVERSION PLANT				
1.	UF_6 Cylinders	Yes	Yes	Yes	No
2.	In-Process	*	*	No	Yes
3.	Control Lab.	Yes	Yes	No	Yes
	FABRICATION PLANT				
1.	UO_2 Powder	Yes	Yes	Yes	Yes
2.	In-Process	Yes	Yes	Yes	Yes
3.	Finished Pellets	Yes	Yes	Yes	Yes
4.	Rods	Yes	Yes	Yes	No
5.	Assemblies	Yes	No	Yes	No
6.	Solid Scrap	Yes	Yes	Yes	Yes
7.	Archive Samples	Yes	Yes	Yes	Yes
8.	Control Lab.	Yes	Yes	Yes	Yes

rely on the failure of the inspector to detect discrepancies between records and inventories or to conceal the diversion by falsification of records. The scope for concealment can be analysed for each term of the material balance equation as follows:

i) Receipts of UF_6
   - Understating the shippers data in the records

ii) Shipments of fuel assemblies
   - Invention of shipment by producing false shipping documents
   - Overstating U content in records
   - Falsifying process measurements
   - Removal of declared material from the rods

iii) Inventory
   - Recording non-existing items.

The safeguards approach should therefore involve the following principal components:

- Audit of records
- Check of the operator's measurement system (scales or chemical analysis)
- Verification of the inventory
- Follow-up of the material under safeguards in the new MBA.

VIII. PHYSICAL INVENTORY VERIFICATION

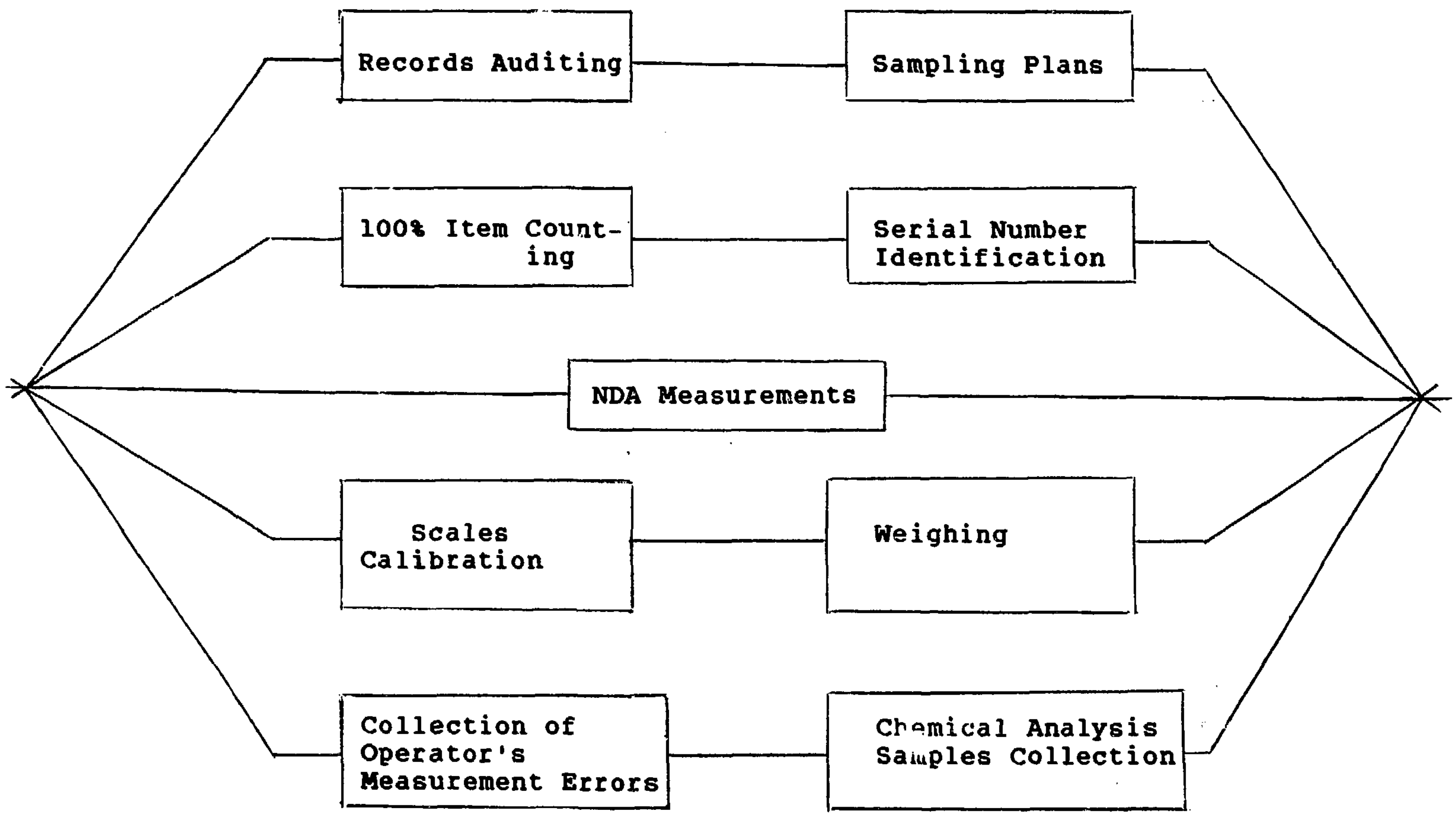
In this section the activities associated with physical inventory verification of a LEU fuel fabrication plant will be discussed.

a. Pre-inspection activities

For a bulk facility which has been under safeguards for some time, the nuclear material is already stratified and the verification techniques for attribute and variable verification are specified. Usually there is little to be done in connection with these activities. However, there is always room for improvements and developments but this is a rather long term activity that is not directly related to the routine of pre-inspection activities. However, a complete understanding of the philosophy behind stratification of nuclear material and its methods of verification is necessary.

The most important activities before Physical Inventory Verification are the calculations of sample size for attribute and variable verification, which are based on previous experience forecast for the material balance during a certain period, with breakdowns of the beginning, ending inventories and the changes occured and performed. These, together with the measurement errors standard deviations of the inspector and operator, are introduced to the existing computer codes at the Agency to produce an estimate of the sample size. This planning information proved to be of great help in the field. A hybrid combination of the planning information based on sophisticated computerial approach, the field experience and some simple calculation in the field will be very effective indeed.

Fig. 2. INSPECTION ACTIVITIES



b. Inspection Activities and Manpower Allocation

Figure 2 shows a block diagram of the different inspection activities, mainly:

1) Records auditing
2) Sampling plans
3) 100% item counting
4) Serial number identification
5) NDA measurements
6) Scales calibration
7) Weighing
8) Chemical analysis samples collection
9) Collection of operator's measurment errors

These interrelated activities are to be performed during a specified length of time. A Coordinator Inspector will insure the integrity of the whole inspection activities. The following is a typical distribution of the activities involved:

i) Coordinator Inspector: Integrity of the whole inspection plus sampling plans plus Record Auditing plus collection of Operator's measurement errors;
ii) Inspector 1: 100% item counting, serial number identification;
iii) Inspector 2: NDA Measurements;
iv) Inspector 3: Scales calibration plus weighing plus samples collection.

These activities are conducted in parallel and the coordinator inspector will ensure a proper timing for the occurrences of these events.

Figure 3 shows a schematic self-explanatory block diagram of the way the operator's records, accounting records and state reports are connected to the IAEA chain.

c. Post-Inspection Activities

With data based on the actual sample size chosen during the inventory verification together with the associated standard deviation of the measurement methods of the inspector and operator an estimate of σ_{MUF} could be obtained.

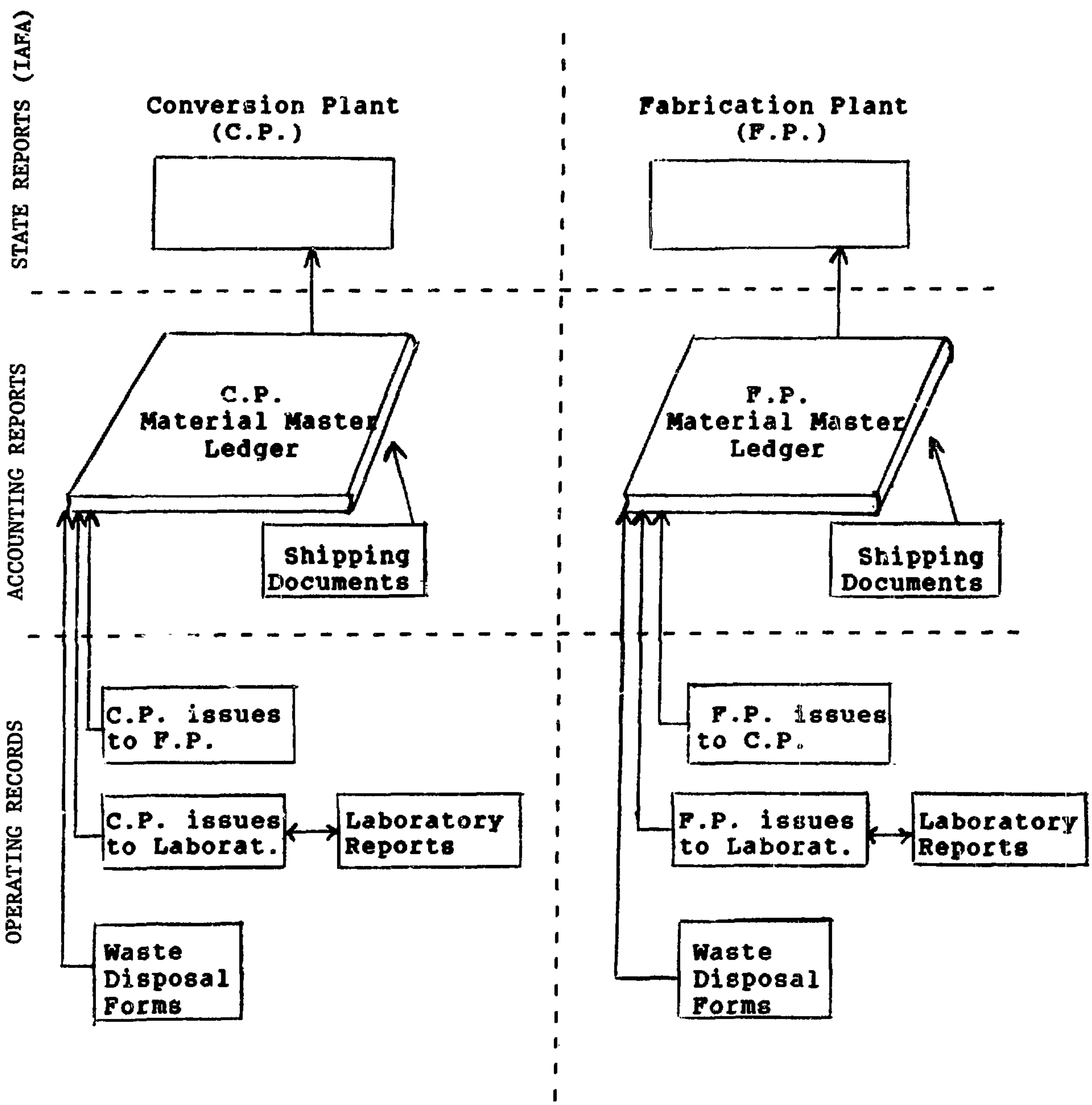


Figure 3. Inspection Activities: Records Auditing