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FIELD TEST OF SHORT-NOTICE RANDOM INSPECTIONS FOR INVENTORY-CHANGE VERIFICATION AT A LOW-ENRICHED-URANIUM FUEL-FABRICATION PLANT: PRELIMINARY SUMMARY*#

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ABSTRACT

An approach of short-notice random inspections (SNRIs) for inventory-change verification can enhance the effectiveness and efficiency of international safeguards at natural or low-enriched uranium (LEU) fuel fabrication plants. According to this approach, the plant operator declares the contents of nuclear material items before knowing if an inspection will occur to verify them. Additionally, items about which declarations are newly made should remain available for verification for an agreed time.

A six-month field test of the feasibility of such SNRIs took place at the Westinghouse Electric Corporation Commercial Nuclear Fuel Division. Westinghouse personnel made daily declarations about both feed and product items, uranium hexafluoride cylinders and finished fuel assemblies, using a custom-designed computer "mailbox". Safeguards inspectors from the IAEA conducted eight SNRIs to verify these declarations. Items from both strata were verified during the SNRIs by means of nondestructive assay equipment.

The field test demonstrated the feasibility and practicality of key elements of the SNRI approach for a large LEU fuel fabrication plant.

1. INTRODUCTION

Short-notice random inspections (SNRIs) for inventory change verification were first analyzed theoretically by Gordon and Sanborn [1] based upon a suggestion by Brenner [2]. They and others were studying schemes for the verification of inventory changes at centrifuge enrichment plants [3].

For fuel-fabrication plants dealing only with natural or low-enriched uranium, the basic idea is that safeguards inspectors of the International Atomic Energy Agency (IAEA) could verify the feed to and production of a plant by conducting a number of short-notice or unannounced inspections that are scheduled by random selection throughout the material balance period. If certain conditions were met and the results of the SNRIs supported the declarations of the State and plant operator, then the declarations could be accepted for the entire material balance period--not just for the nuclear material present at inspections.

SNRIs offer a significant increase in effectiveness when compared to equal numbers of scheduled inspections that do not provide complete coverage of inventory changes during a material balance period. This is so even if the diversion detection probability, which depends on several factors, is small.

The Westinghouse Electric Corporation Commercial Nuclear Fuel Division Fabrication Facility, located in Columbia, South Carolina, U.S.A., was the site of a field test to determine the procedural feasibility of this approach [4]. Nuclear reactor fuel assemblies are made there from natural and low-enriched uranium hexafluoride.

By agreement, the field test concentrated solely on verifications of uranium hexafluoride cylinders and finished fuel assemblies, by far the major part of the transfer verifications required by the Safeguards Criteria [5] for fuel fabrication plants.

This paper is a preliminary summary of a much longer report describing the field test and its underlying theory [6].

2. THEORY OF SHORT-NOTICE RANDOM INSPECTIONS: INFERENCE CONDITIONS

Three conditions must be met for the validity of a statistical inference based on verification of a random sample [1,5]:

(1) All items in the population must be available for selection for verification.

(2) The plant operator must declare to the Agency values for the nuclear-material content of items before knowing which items will be verified.

(3) The operator must not alter item identity or content after learning that an item is chosen for verification and before the verification actually occurs.

To fulfill condition (1) for a flow stratum encompassing inventory changes, an SNRI approach incorporates a set of possible inspection dates. These opportunities should be frequent enough to allow verification of all items. Actual inspection dates are randomly chosen from these opportunities.

The "mailbox" concept is used to fulfill condition (2) [1-2,7-8]. Mailbox declarations are unalterable operator statements of accountancy values against which IAEA inspectors can compare the results of verification measurements.

Thus, condition (2) is satisfied by virtue of a mailbox to which the plant operator is regularly submitting inventory change data. Condition (1) is satisfied if some residence time for verification remains after the mailbox declaration for each item, and if this remaining residence time overlaps with an inspection opportunity. If, additionally, condition (3) can be met by adequate measures, then IAEA inspectors can select a random sample to verify during SNRIs and, based on the verification results, make statistical inferences about the entire population [1,5,9-12].

These points are graphically explained by Fig. 1. After mailbox posting of their nuclear material content, only batches 11 through 13 of fuel assemblies were in residence for possible verification at the time of the beginning of the second inspection; these batches would constitute the population for random sampling during the second inspection. Batches 14 and 15 could be verified at a third.

Lu, Teichmann and Lu [13] have emphasized another possibility for conducting SNRIs to satisfy condition (1).

3. FIELD TEST RESULTS

The mailbox proposal implemented for the field test consisted of a redundant system of an IAEA computer mailbox at Westinghouse supplemented by telefax transmissions to Vienna. The computer was a Gateway 2000 486/33 desktop. It sat inside a specially fabricated anodized aluminum containment box that was sealed shut. One penetration permitted access to the "B" floppy disk drive and another permitted access for the power cable and the communications cable between the computer and the monitor. The keyboard for the computer remained inside the containment.

For the duration of the field test, Westinghouse staff daily turned the mailbox computer on and responded to an automatically executing program to submit inventory change data by diskette. During the entire six-month period, the mailbox recorded about 2700 transactions involving about 1000 assemblies. (Details of these results primarily concern assemblies.)

Four transaction events were specified as useful for the mailbox data: "births", "changes", "deaths", and "shipments". Dates, identifications, and accounting information were submitted for each event, and the computer mailbox itself also dated each entry. Cylinder receipts and assembly production consituted births; connection of cylinders to the plant process and packing of assemblies constituted deaths; item accounting amendments constituted changes; and shipments applied to assemblies only.

One criterion for the success of SNRIs is the promptness of mailbox declarations. For assemblies produced after February, 1993, about 80% of the entries were made one day after the event and about 15% three days after the event. The latter corresponds to the delay occurring because of weekends, when submissions were not made. Were the declarations delayed, items might be physically "dead" before "birth" declarations. This did not happen. Indeed, the data indicated "deaths" and "birth" declarations on the same day for only about ten assemblies--about 1%--during the testing period.

From March through August 1993, Agency inspectors conducted eight SNRIs at the Westinghouse plant, arriving unannounced. Great efforts were made to avoid premature disclosure.

During SNRIs, Agency inspectors unsealed the computer mailbox containment and obtained access to the keyboard. They thereupon extracted the mailbox data entered since the previous SNRI. Finally, they closed and sealed the containment.

With this data, the Agency inspectors began operating special SNRI preprocessing software on a portable computer; it combined the mailbox data with the physical inventory determined at the previous SNRI to yield a new physical inventory for the SNRI in progress. The software highlighted those items whose residence time extended through the beginning of the SNRI in progress. From them, the inspectors randomly selected several for verification.

"Armed" with the mailbox inventory, plus the facility physical inventory listings (PILs) requested immediately after arrival, the Agency personnel then went to the two relevant locations, the uranium hexafluoride storage pad and the fuel assembly storage area; Westinghouse personnel escorted them. They performed item counts and identifications and affixed temporary seals to the available items selected for measurement verifications. Most of the measurement verifications took place after the first day of the SNRIs.

From the time of arrival at the plant, the inspectors took about three hours on average (not including the SNRIs when this activity was deferred until the second day) to identify the fuel assemblies to be verified. Plant personnel supplied the PILs in about 1.25 hours on average.

The inspectors compared the mailbox data to the PILs and to the actual items on inventory. Discrepancies arose because of the dynamic nature of the plant at the time of the SNRIs, preprocessor software limitations, the inaccesibility of certain items and data errors. To understand the discrepancies, the Agency personnel examined source documents and received additional information from the Westinghouse staff.

An important factor under study was the achieved residence time for verification, i.e., the number of days between assembly production and packing (Fig. 2). About 1.5% of the assemblies that were packed during the field test had a residence time of one day; about 20% had a residence time of four days or fewer; and about 40% had a residence time of 7 days or fewer. If used on an *a priori* basis, these achieved values permit the calculation of detection probabilities as a function of future SNRI frequency [13]. Planning values for the residence times for verification were 7 days for

February through June and 4 days for July and August. These planning values were not met as minima because of plant operational needs.

On average about 160 fuel assemblies were on inventory at the SNRIs according to mailbox data. For about 24 of these assemblies, the actual residence time had not yet exceeded the planning value selected for the SNRI. These were identified in the assembly storage area by tag check and, sometimes, serial number. A sample of them was further verified, about three by attributes nondestructive assay (NDA; gamma ray check), and about two by variables NDA (neutron collar [14]).

4. CONCLUSIONS

Safeguards inspectors from the IAEA conducted eight test SNRIs at the Westinghouse plant from March through August, 1993. The inspectors appeared completely unannounced and within a short time began inspection procedures that lasted two or three days.

Daily throughout the test period, Westinghouse staff members supplied to the Agency data about inventory changes for feed uranium hexafluoride and product fuel assemblies. Data were both transmitted to the Agency by facsimile and submitted to a custom-designed computer "mailbox" located at the Westinghouse plant. Both data routes functioned well.

The evaluation of the SNRI field test is not yet complete. Nevertheless, these accomplishments show that two main elements of the SNRI concept--the SNRIs themselves and the mailbox--are feasible and practical for a large low-enriched-uranium fuel-fabrication plant.

The field test results also lead to many recommendations concerning the further development and possible implementation of SNRIs for inventory change verification. These recommendations encompass policy considerations, SNRI concepts and procedures, and mailbox hardware and preprocessor software.

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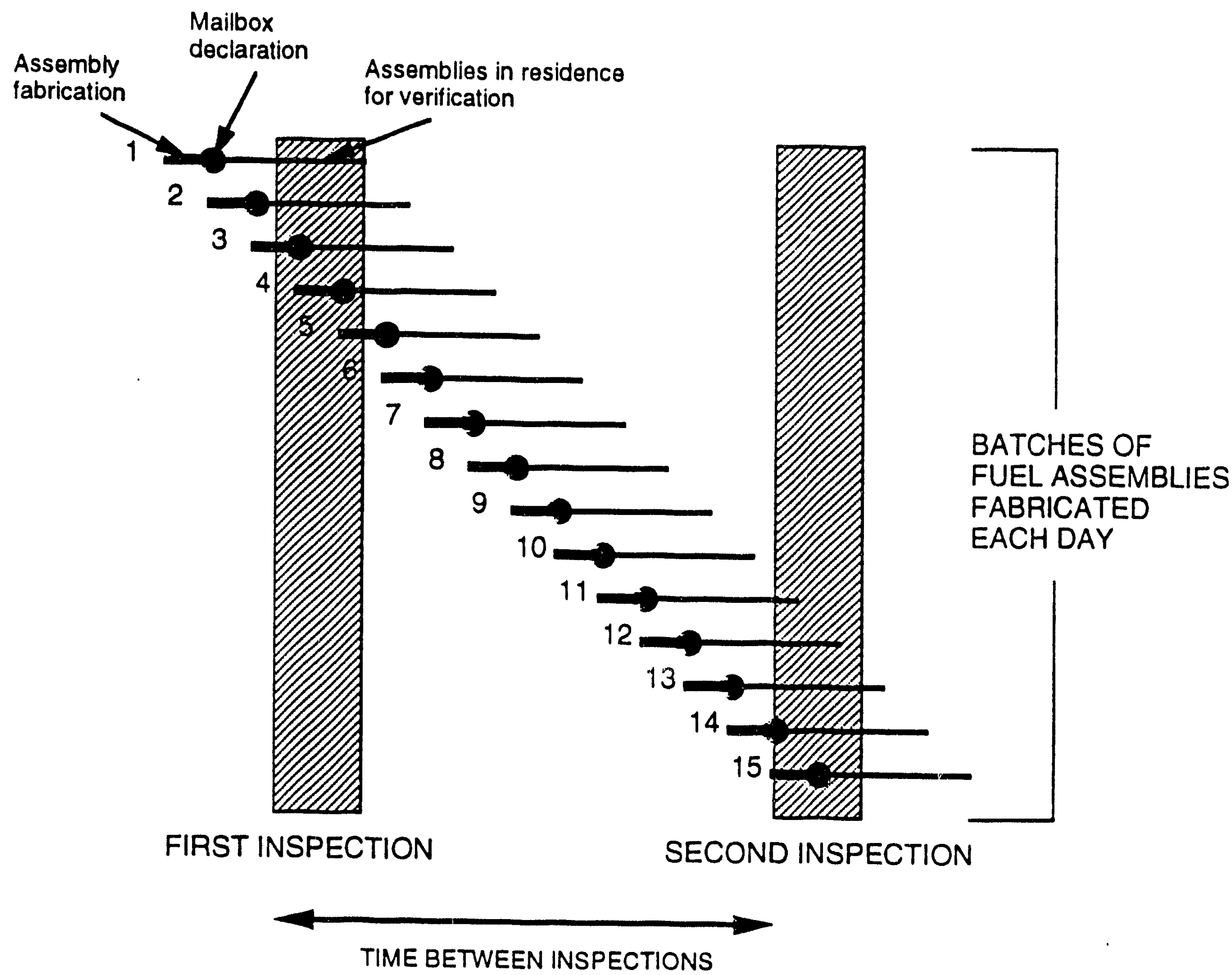
This paper is dedicated to the memory of Leon Green, who led the International Safeguards Project Office at Brookhaven National Laboratory from 1978 through 1991.

FIGURE CAPTIONS

Fig. 1. Schematic diagram of the availability for verification of fuel assembly batches at randomly timed safeguards inspections

Fig. 2. Achieved fuel assembly residence times (days from production to packing)



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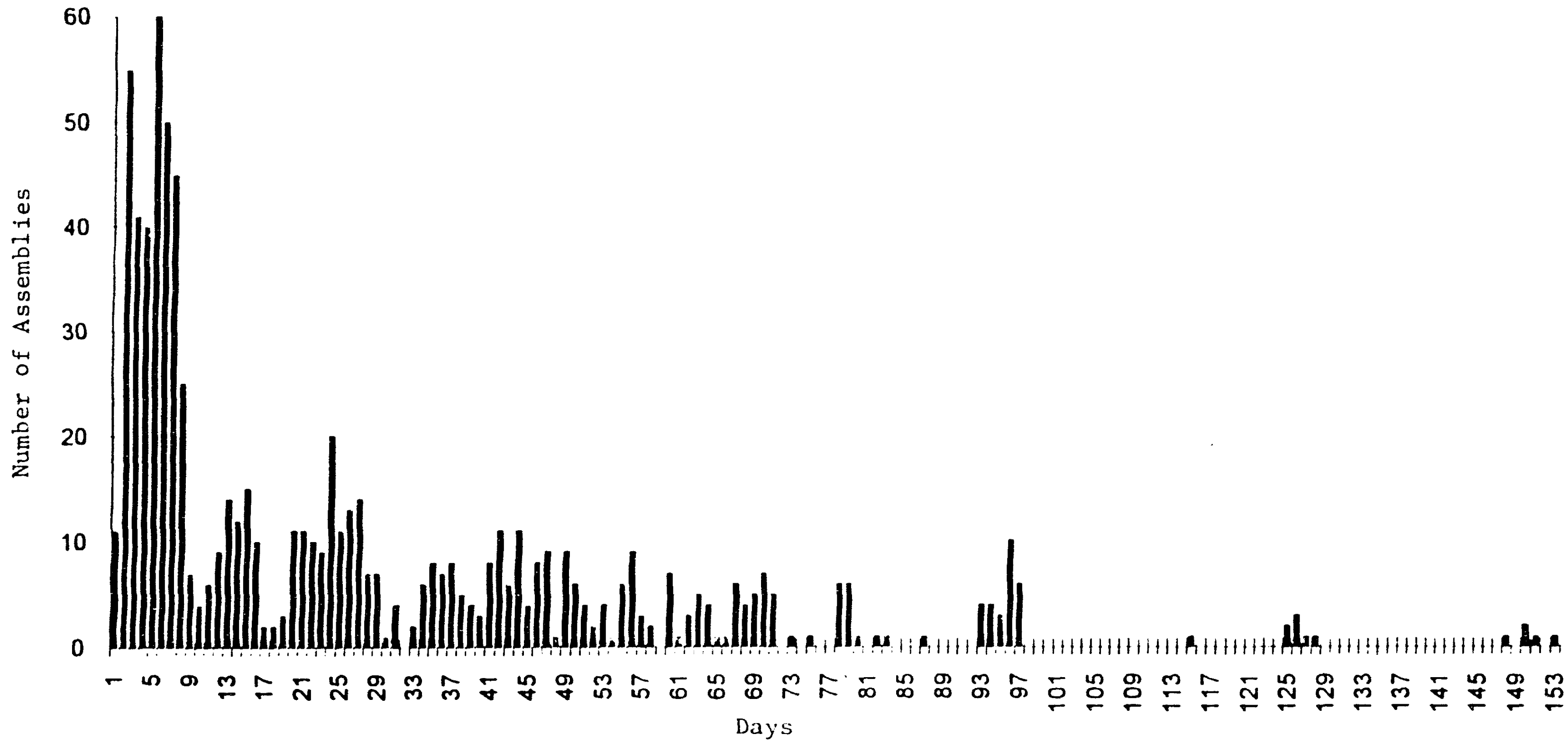

Fig. 2 Achieved Fuel Assembly Residence Times (days from production to packing)

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