

Site-Wide Physical Inventory Taking at IPPE*

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Abstract

As part of the US-Russia Cooperative Program of Material Protection, Control and Accounting, staff members of the Institute of Physics and Power Engineering (IPPE) have implemented procedures for taking physical inventory of nuclear materials at many of the facilities within the IPPE site. These include both large facilities, with substantial inventories and requiring dedicated inventory equipment and computers, and small facilities, with smaller amounts of material and subject to inventory by portable equipment. The experience to date demonstrates good progress toward the goal of regular PITs for the most attractive nuclear materials at IPPE.

Introduction

Physical Inventory Taking (PIT) is an important part of nuclear materials protection, control and accounting (MPC&A) system performance at the Institute of Physics and Power Engineering (IPPE). PIT includes ensuring that all nuclear material items on inventory are included in the facility records and that the content of items corresponds to the recorded values. PIT provides strong testing of the whole material control and accounting (MC&A) system, since all major subsystems are involved in the PIT. This includes computerized accounting, nuclear material measurements, material control, automated data collection, statistical sampling plans and

underlying threat analysis, PIT procedures, and training of personnel. For this reason, much attention has been paid to PIT at IPPE both for the important results it gives, and as an incentive for implementation of a well-balanced MC&A system.

For four years upgraded PIT procedures have gradually been implemented at more and more IPPE facilities. The implementation of the PIT procedures and development of corresponding supporting subsystems are influenced by specific features of the IPPE site and the concurrent performance of other programs (such as the nuclear material consolidation program and the tamper-indicating device program).

Specific Features Of IPPE And Conditions For Upgrade Of Its MPC&A System

IPPE is a major scientific research and development laboratory located in Obninsk, Russia. It is under the jurisdiction of the Ministry for Atomic Energy of the Russian Federation and its research and development specialties focus on nuclear power engineering, fundamental and applied investigations, and nuclear technologies for civilian sectors of the national economy.

At most of the IPPE facilities, nuclear materials such as highly enriched uranium (HEU) and plutonium are used or stored in item form. Those facilities include reactors, critical assemblies, accelerators and other research installations. The total number of fissile nuclear

* This work performed under the auspices of the U.S. Department of Energy, Contract No. DE-AC02-98CH10886.

material items on the IPPE site is very large, and they are distributed among several facilities. In addition, nuclear material in bulk form is handled at some facilities where nuclear material processing or reprocessing of irradiated fuel is carried out.

The cooperative work of IPPE with US Department of Energy national laboratories on improvement of the IPPE MPC&A system started in 1995; the U.S. has supplied equipment, financing, and technical support. In 1995 some uncertainty existed about the operational program of IPPE facilities. As a result of significant changes in the IPPE research program, some facilities were to be re-oriented to new activities or closed and decommissioned. The new structure of material balance areas (MBAs) at IPPE still had not been determined. So in 1995-1996 the first prototypes of improved MPC&A systems were only implemented at a few facilities. After the first upgrades were demonstrated in some MBAs, it was realized that allocation of nuclear materials at the site should be optimized not only because of decommissioning of some facilities, but also for more effective safeguarding of the nuclear materials. The whole, improved MPC&A system could most sensibly be established with a new structure of MBAs at the IPPE site.

For this reason, it was decided to initiate a special program of consolidation of nuclear materials at IPPE. The purpose of the program is to decrease the number of facilities with the most attractive nuclear materials, to decrease amounts of nuclear materials at some facilities and to decrease the total cost of MPC&A upgrades at IPPE.

Project Of IPPE Nuclear Material Consolidation

At the time of initiating the consolidation program, there were at IPPE 35 material balance areas located in 22 buildings. Three different options of nuclear material consolidation were considered:

In the first option the nuclear materials were to be transferred from closed facilities to the existing Central Storage Facility (CSF). However, because of the limited capacity of the existing CSF, the number of MBAs could only be decreased from 35 to about 30.

The second option was construction of a new building specially designed as a new CSF. In this case the number of MBAs could be decreased from 35 to about 17, but the cost would be high and the expected time of construction would be long.

The third option was reconstruction of one of the existing research facilities as a new CSF. In this case the number of MBAs could also be decreased from 35 to about 17. However, during the period of reconstruction, some nuclear materials from this facility were to be temporarily transferred to other facilities.

The third option was considered as rather attractive and, after selection of which facility could be reconstructed and where its nuclear materials could be temporarily moved, the third option was accepted. One «box» (roughly speaking, a material access area) of the selected facility that formerly housed a critical assembly is now being prepared for reconstruction. This building where the new CSF will be located is near another MBA with a large amount of nuclear materials, the BFS critical facility.

In accordance with the accepted program, there will be 17 MBAs located in 14 buildings after completion of the consolidation of nuclear materials. They can be classified into five types depending on specific features of nuclear material usage and specific features of technological processes and nuclear material handling:

Type A. At these facilities, nuclear materials are used in item form and the number of items is relatively small. Movements of nuclear materials within the facilities are rather rare. No processing of materials occurs, so no wastes are produced. Shipments of nuclear materials from the facilities and receipts of fresh nuclear materials are also relatively rare. Examples of Type A facilities are research reactors, small critical assemblies, and accelerators.

Type B. These facilities also use nuclear materials in item form; however the number of items is large. Examples of Type B facilities are large critical assemblies. At most of the item facilities, the major technological events are periodic movements of large numbers of items within the facility. The typical example

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is the BFS critical assemblies; many items can change their locations during one day, when construction of a simulated core with new composition or disassembly of an old core is carried out. On the other hand, shipments of nuclear materials from the facilities and receipts of nuclear materials are normally rare.

Type C. Facilities where unirradiated nuclear materials are processed constitute the third group. Materials are used both in item form and in bulk form at these facilities. Regular material transfers within the facility are essential for the technological processes. Characteristics of nuclear materials are changed during processing of nuclear materials. As a result of nuclear material processing, scrap and wastes are produced.

Type D. The fourth group includes facilities for storage of unirradiated fuel, particularly the CSF. At these facilities all nuclear materials are normally treated in item form. Materials in bulk form are stored in containers, which are not usually opened in the storage facility. As a rule, the storage facilities contain a rather large variety of nuclear materials. Movements of nuclear materials within the facilities are rare, while transfer of materials between IPPE facilities can be very intensive. All external shipments and receipts are carried out through the CSF.

Type E. Facilities where irradiated nuclear materials are reprocessed or stored form the fifth group. It includes facilities with hot laboratories or for the storage of irradiated fuel.

- Precise locations are identified by 11-digit identifiers.
- Nuclear material items are identified by 10-digit identifiers.
- TIDs are identified by 8-digit identifiers.
- Containers are identified by 6-digit identifiers.

Technologies used for applying bar codes depend on object type and working conditions. Printed polyester labels are used for most locations and containers (Figure 1) and for some nuclear material items. However, the polyester labels are not appropriate for marking those nuclear material items used in critical assemblies for simulating fast reactor cores and other core compositions in which hydrogen must be avoided. In order to limit the amount of additional hydrogen introduced into a core by bar codes, direct ink jet printing onto the items is done after a preliminary surface preparation of their cladding (Figure 2).

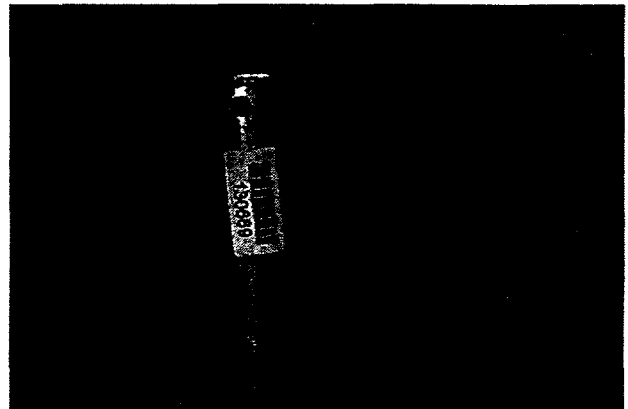


Figure 1. Nuclear material tube with polyester-label bar code

Site-Wide Nuclear Material Item Identification

At IPPE, the large numbers of nuclear material items, containers, authorized locations, TIDs and other objects of the MC&A system necessitate using an automated data collection system during PIT. For this purpose, bar coding of all these objects is carried out in accordance with a refined system of object identification.

The identification system requires that unique identifiers mark all objects of the MC&A system both in human readable form and in bar code form. General requirements for identification of some major type of objects are as follows:

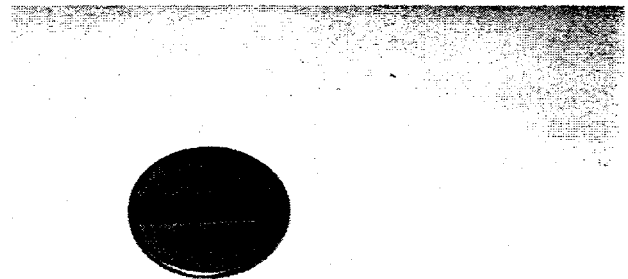
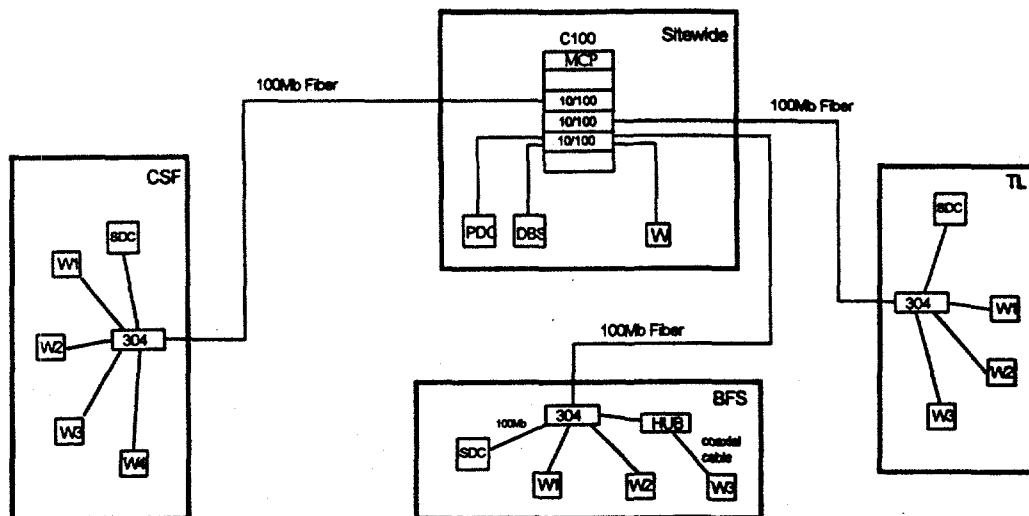


Figure 2. BFS fuel disk with bar code applied by ink jet printer



C100 - Network controller "Centillion 100"
MCP - Master module
10/100 - Switching module
304 - Ethernet switch
HUB - Ethernet link builder

PDC - Primary Domain Controller
DBS - Central Data Base Server
SDC - Combined Server & Domain Controller
W - Workstation

Figure 3. Diagram of Current Configuration of Site-Wide Computerized Accounting System

Applying printed labels is a simple and convenient technology, so it was used during the early preparatory stages for PIT activities at IPPE facilities. The use of this technology will continue in those MBAs where it is acceptable. Bar coding nuclear material items with the ink jet printer will take more time. The bar coding of the first large batch of nuclear material items was completed in 1998. It is expected that in 1999 the number of items bar coded with the ink jet printer will increase dramatically. The total number of items to be bar coded with ink jet printers at IPPE will be very large. This work should be completed in the year 2001.

PIT Strategy For IPPE Facilities By Means Of Stationary Material Accounting Equipment

PIT implementation first started at three IPPE facilities where the MC&A system was established on the basis of stationary equipment:

BFS Critical Facility: This is a typical item MBA of type «B». The number of nuclear material items before the start of the consolidation program was already large. After additional amounts of

nuclear materials were transferred to this MBA within the framework of the consolidation program, the number of items increased significantly. In the BFS MBA, a computerized accounting system based on a local area network (LAN) was installed (Figure 3). A measurement system was established for mass, isotopic composition and fissile mass. Material control procedures were implemented with so-called plug seals developed at BFS as well as conventional seals. Bar coding of some MC&A containers and TIDs was also implemented.

Central Storage Facility (CSF): This is a type «D» facility. The total number of nuclear material items in the storage is large. Here stationary equipment was also installed, including a LAN-based computerized accounting system (Figure 3), measurement equipment, and bar coding equipment. Material control procedures were also implemented.

Technological Laboratory (TL): This type «C» facility has been used in recent years for re-cladding of some nuclear material items from the BFS critical assemblies. The stationary equipment installed in TL also includes a LAN-based computerized accounting system (Figure 3), bar

coding equipment, and measurement equipment.

At these three facilities, implementation of PIT procedures started in parallel with the development of other MC&A system components, after preparatory activities were completed. The necessary preparatory activities included:

a. Analyzing technological characteristics of nuclear materials and the conditions of their use in each MBA.

b. Developing a system of authorized locations for nuclear materials, and applying identifiers (both in bar code and human readable form) onto authorized locations, containers, and TIDs. When possible, polyester labels were applied to nuclear material items. On nuclear material items that needed bar coding by the ink jet printer, original serial numbers provided by the fabrication plants were used until the items can be scheduled for bar coding.

c. Entering into the computerized accounting system database the accounting data for each nuclear material item. These data were usually taken from passports provided by fabrication plants.

d. Determining the real physical location of each item and entering this information into the same database.

e. Adjusting measurement techniques used during PIT to the conditions in the particular MBA.

f. Developing and documenting PIT procedures.

g. Training personnel.

In the MBAs with large numbers of nuclear material items (BFS and CSF), it takes a long time to complete the initial inventory activity «d» for all items since the personnel of the facilities are busy with facility operation. That is why the preparatory activities have been carried out for each stratum separately. Accordingly, nuclear materials have been encompassed into PIT on a stratum-by-stratum basis. Many items have been added to the BFS fissile materials database each year. At present most of the items have been entered in the BFS database and are involved in PIT. The same approach has been used at the CSF. At this facility many items have been entered in the

database and involved in PIT. It is planned that all BFS items will be entered in the database and involved in PIT by early 2000. All CSF nuclear materials should be involved in PIT in 2000.

Three more facilities are expected to use stationary equipment: one more critical facility, the new CSF and the Criticality Safety Experimental Building (CSEB). The initial inventory taking started at the additional critical facility in 1999; it is expected that all nuclear material of this facility will be involved in PIT within 1999-2000. The CSEB nuclear material will be involved in PIT in 1999. At this facility measurement equipment is stationary but portable computers will be used for computerized accounting of nuclear materials.

The routine PIT procedures at these item facilities are based on statistical sampling of nuclear material items. The procedure for each item includes verification of the correct location of the item and measurements of total weight, enrichment or isotopic composition by gamma ray spectroscopy, and, possibly, effective Pu-240 mass or U-235 mass by neutron coincidence counting. The sample size depends partly on material control measures (mainly seals) applied to the particular stratum of nuclear material.

The MBAs of type «C» usually do not contain many nuclear material items; for these MBAs inventory change events should be carefully tracked before PIT.

PIT Strategy For IPPE Facilities By Means Of Portable Material Accounting Equipment

It is too expensive to use stationary equipment in type «A» MBAs, with relatively small amounts of nuclear material and with rare changes in nuclear material disposition (shipments, receipts, internal movements, etc.). For this reason, several sets of portable equipment are used, which include (Figure 4):

- Portable computer with computerized accounting software,
- Gamma ray spectroscopy equipment, i.e., U-Pu Inspector or IMCA Inspector,
- Mass scale, and
- Portable bar code printing and reading equipment.

The portable computer can be connected to the network-based computerized accounting system and exchange data with one of the servers where the site-wide database resides (Figure 3). Normally data are not kept in the portable computer. Before moving to some particular MBA, a minimal fragment of the database, concerning only this particular MBA, is loaded into the portable computer to be used during PIT. After PIT, results are downloaded from the portable computer to the server and entered into the site-wide database.

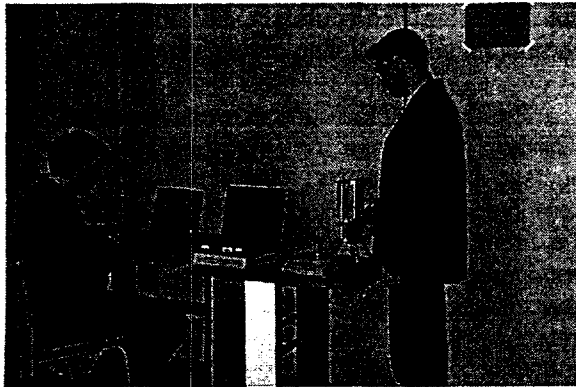


Figure 4. Nuclear material measurement conducted with portable equipment

It was planned at first to use these portable sets in five MBAs of type «A». However, the portable equipment can be also used in some MBAs of type «C» when the amount of nuclear material in the MBA is small. So the portable equipment will probably be used in eight MBAs.

All PIT preparatory activities («a» to «g») are also necessary in those MBAs where the portable equipment is used. However, since these MBAs have smaller amounts of material, the preparatory work can be done fast and all the material in the MBA can be involved in routine PITs expeditiously. In MBAs with a small number of items, all items are measured during PIT. The PIT procedures include confirmation of the location of items, TID examinations, and measurements of item total weight and enrichment (or isotopic composition).

In 1998 the portable equipment was used for carrying out PIT at two type «A» facilities. One was the reactor of the First Nuclear Power Plant and the other was the Accelerator Building. The inventoried items contained:

- Uranium with U-235 enrichment in the range from low to very high
- Plutonium with Pu-240 abundance in the range from low to high
- U-Pu mixtures, or
- Other nuclear materials

The measurements indicated some problems not connected to the portability of the equipment. As for the use of portable computers for material accounting purposes, some procedures still need to be refined to ensure security of data. However, in general, the experience of using the portable equipment in MBAs with smaller amounts of nuclear materials was encouraging.

Current Schedule For Site-Wide PIT

In order to start regular PIT in all MBAs at IPPE, the preparatory work should be completed for all nuclear materials. In addition, for MBAs with large amounts of materials, the PIT procedures that were first implemented when only part of the materials was involved in PIT should be tested in full scale, evaluated and refined. A schedule for completion of preparatory activities and starting regular PITs has been developed at IPPE for each MBA. Scheduling problems occur if accounting data are not completely reliable for some materials and new accounting measurements should be carried out. In this case these particular materials will be entered in the database and involved in PIT with some delay. However these cases should not delay PIT of the rest of the material in the MBA.

In accordance with the current schedule, among five MBAs of type «A», two have completed their preparatory activities, performed their first PITs, and are starting regular PITs in the first half of 1999. One more MBA has completed all preparatory activities and will complete its first PIT in June 1999. It should be ready to start regular PITs late in 1999. Two more MBAs of this type should complete preparatory activities by the end of 1999 and start regular PITs in the year 2000.

The preparatory work at the three MBAs of type «B» is a multi-year task. Nevertheless, one of these MBAs (BFS) will complete the preparatory work early in 2000. In the spring of 2000 regular PITs with all material types should start. Preparatory work just started at the second

MBA of this group; it will be completed in the year 2000. Regular PITs should start there late in 2000 or early in 2001. The third MBA has less material than the two other MBAs. Preparatory work started in 1999 and will be completed late this year. Regular PITs should begin early in 2000.

Among four MBAs of type «C», one MBA (TL) is ready for regular PITs, including material balances, and will perform them when nuclear material is regularly processed in the facility. Others started preparatory work in 1999. Two of them are expected to complete the preparatory work in 1999 and can start regular PITs in 2000. The last one should complete the preparatory work in 2000 and start regular PITs late in 2000.

The existing CSF and new CSF are the only two MBAs of type «D». All preparatory work at the existing CSF should be completed in 2000. The regular PITs are expected to start in early 2001. Currently the new CSF contains no nuclear materials. Since all materials will be measured during the transfer to this new storage, regular PITs could start soon after nuclear materials are transferred there.

Three MBAs of type «E» contain irradiated nuclear materials. It has not yet been decided how these materials should be measured during PIT, so no schedule has been established for irradiated materials. In hot laboratories, separated material can be measured during PITs, so preparatory work for these materials will start in 1999 and these materials can be involved in regular PITs early in 2000.

Conclusion

Moving toward the goal of completing a site-wide PIT of all of its most attractive nuclear materials, IPPE has already implemented procedures for taking physical inventory of nuclear materials at many of its facilities. These include both large facilities, with substantial inventories and requiring dedicated inventory equipment and computers, and small facilities, with smaller amounts of material and subject to inventory by portable equipment. Plans exist to implement the PIT procedures at the remaining facilities, with the goal of encompassing all by the year 2001. The experience to date demonstrates good progress toward this goal.

Acknowledgements

We are grateful to the many staff members who have contributed to these efforts—both those of IPPE from BFS, TL, CSF and other facilities, and those of the other US DOE national laboratories, LANL, LLNL, SNL, and PNNL. We acknowledge and appreciate support and policy guidance from the MPC&A Program of the DOE Office of Nonproliferation and National Security, particularly from Michael Haase, and from the Minatom Department for Protection of Information, Nuclear Materials and Sites, particularly from Victor Erastov.

We also thank Tas Khan, Maryann Musso, and Grace Webster for helping with preparation of the manuscript.

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