Development and testing of procedures for carrying out emergency physical inventory taking after detecting anomaly events concerning NM security

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ABSTRACT

In the State Scientific Center of Russian Federation – Institute of Physics and Power Engineering (SSC RF - IPPE, Obninsk), which is under Minatom jurisdiction, the procedures for carrying out emergency physical inventory taking (EPIT) were developed and tested in cooperation with the Brookhaven National Laboratory (USA). Here the emergency physical inventory taking means the PIT, which is carried out in case of symptoms indicating a possibility of NM loss (theft). Such PIT often requires a verification of attributes and quantitative characteristics for all the NM items located in a specific Material Balance Area (MBA).

In order to carry out the exercise, an MBA was selected where many thousands of NM items containing highly enriched uranium are used. Three clients of the computerized material accounting system (CMAS) are installed in this MBA. Labels with unique (within IPPE site) identification numbers in the form of digit combinations and an appropriate bar code have been applied on the NM items, containers and authorized locations. All the data to be checked during the EPIT are stored in the CMAS database.

Five variants of anomalies initiating EPIT and requiring different types of activities on EPIT organization are considered. Automatic working places (AWP) were created on the basis of the client computers in order to carry out a large number of measurements within a reasonable time. In addition to a CMAS client computer, the main components of an AWP include a bar-code reader, an electronic scale and an enrichment meter with NaI -detector – the IMCA InSpector (manufactured by the Canberra Company). All these devices work together with a client computer in the on-line mode. Special computer code (Emergency Inventory Software – EIS) was developed. All the algorithms of interaction between the operator and the system, as well as algorithms of data exchange during the measurements and data comparison, are implemented in this software. Registration of detected anomalies and generation of reports on EPIT results can be also performed with the help of the EIS code.

Since EPIT procedures in their essence are supposed to be used infrequently but suddenly, and taking into account that additional personnel should be involved, much attention was paid to the creation of a user-friendly interface.

The effectiveness of the developed procedures, AWPs and EIS was confirmed by the exercise carried out at IPPE. All the anomalies specially created for this exercise were detected during the exercise.

INTRODUCTION

When preparing to the work within the task, available Russian and American regulatory documents were reviewed concerning the issues of responsibility, preparation, organization and carrying out activities in case the possibility of NM loss can not be excluded. Conceptually the approaches for carrying out emergency physical inventory taking are discussed in several documents [1-9, 15]. The basic requirements are described in [8]. Emergency PITs are carried out for the purposes of an unscheduled check of actual inventory of NM in an MBA and for collecting information about the presence of NM in case of an abnormal event.

An Enterprise-level document [10] requires that for each MBA "the list of measures and actions should be prepared and documented for the case of detection of abnormal situations with NM ". The situations considered as anomalies in the use of nuclear materials are specified in further sections of this paper.

In Russian regulatory documents the requirements on details of NM item-characteristic checks are described in a very general way, thus leading to the need to specify, at the Enterprise level, particular measurements. In comparison with a periodical PIT, EPIT requires a check of presence of all the NM, which is registered in accounting documents and in the computerized MC&A system database (if it is available) for the specific MBA. Carrying out a comprehensive PIT for thousands of items in a reasonable period of time (several or tens of working shifts) requires very thorough preliminary preparation.

TEST MBA AND ITS CHARACTERISTICS

Based the considerations above, one of the most prepared MBAs of IPPE was proposed as the MBA for development and testing of EPIT procedures. This MBA is that of an IPPE critical facility (B215 CF).

Short description of the B215 CF MBA.

There are five sub-MBAs in the B215 CF MBA:

- Sub-MBA No.1 - basic storage No.1 (code 1501).
- Sub-MBA No.2 - basic storage No.2 (code 1502).
- Sub-MBA No.3 - hall of critical facilities (code 1503) including B215 CF critical assembly, but except for operational storages No.1 and No.2.
- Sub-MBA No.4 - operational storage No.1 (code 1504).
- Sub-MBA No.5 - operational storage No.2 (code 1505).

In these sub-MBAs, all authorized locations of lower levels (racks, shelves, positions on shelves, positions in the core, etc.) have unique identification numbers given in accordance with the IPPE identification system.

Characteristics of NM items

In the B215 CF MBA nuclear materials are used and stored in the form of items containing 80% and 90% enriched uranium oxide or nitride. The items can be divided into five strata. Three of these strata (each contain thousands of items) include items in the form of clad disks and rods. These items are usually placed in special containers. Two other strata contain nuclear material in bulk form placed in several hundred containers. The total number of items (clad items and sealed NM containers) in the B215 CF MBA is many thousand. According to IPPE requirements, the labels with unique identification numbers (both in the form of digit combinations and bar codes) were applied on all the containers, items and authorized locations of all levels. All TIDs also have unique identifiers both in the digital form and in the form of bar codes.

Key measurement points

Three key measurement points (KMP) have been organized and equipped in the B215 CF MBA. These measurement points are located in the hall of critical assemblies near the assembling table, in the basic storage No.1 and in the basic storage No. 2.

Development and implementation of integrated measurement system

Carrying out measurement procedures during EPIT involves repeated sequences of the same actions for each of the several thousand items. It is required to perform confirmatory measurements of, at least, gross weight and isotopic composition of each item, as well as some attributes, such as item identification number assigned by IPPE, item position in a container, container location and identification number of TID installed on the container.

The only method to ensure that the work is carried out in a fast and effective way is to use an automated system for carrying out measurements, data registration and control, as well as for preparation of reports. This system should have a user-friendly interface to decrease the probability of errors and to provide prompts for a user. The integrated system for carrying out EPIT, Integrated System for Emergency Inventory– (ISEI), was created. The system includes three automated working places for performing measurements. Each of these places is based on a client computer located in the B215 CF MBA and is connected to the database server.

The scheme of equipment integration in the system is presented in Figure 1. Special devices connected to each client computer are shown in this figure in addition to the computers of the CMAS network. The use of bar-code readers increases the speed and reliability of identification of MC&A system objects (NM items, containers, TIDs). The Mettler – Toledo scales provide gross weight measurements in the on-line mode. The IMCA InSpector gives on-line measurements of uranium enrichment in the verified items. These devices are connected to the client computer through COM-ports. Corresponding algorithms and software modules included into EIS software were developed in order to carry out data exchange.

In order to increase the efficiency of the work and to relax requirements on the skills of operators involved in the measurements, automated procedures were developed and implemented for the measurements of item gross weight and uranium enrichment. The comparison of the measurement results with the accounting data stored in the CMAS database is also carried out in the on-line mode. In software modules, established criteria are used for evaluation of agreement between measurement results and accounting data. Formats of messages on anomalies provided on AWP computer displays were implemented in the software, as were formats of anomaly registration in the database and in the reports.

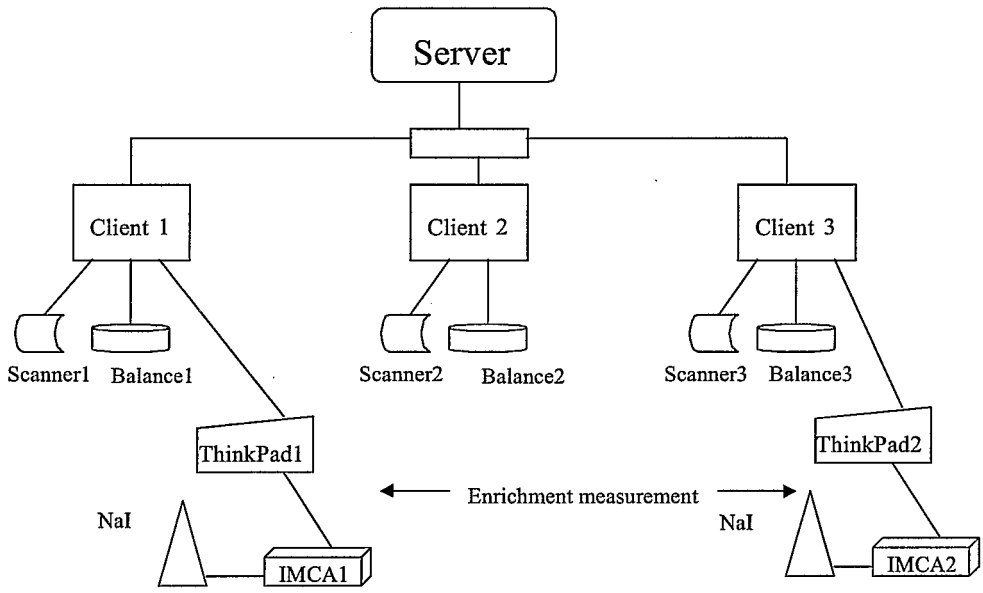

Fig. 1. Block-diagram of the system for data acquisition and analysis

Integration of measurement equipment into the hardware and software integrated system allows:

- Carrying out many measurements during a relatively short period of time;
- Quickly identifying what might be missing in content;
- Decreasing the impact of the human factor, which manifests itself in a large number of inadvertent errors when entering data and in violation of measurement procedures;
- Decreasing the radiation dose during the work with each single item, which is particularly important when many measurements are made;
- Relaxing requirements for skills of the personnel temporarily employed in the measurement procedures.

Computers of each KMP are the clients of the IPPE CMAS. The CMAS database contains all the data necessary for carrying out emergency physical inventory taking.

INITIAL EVENTS FOR CARRYING OUT EPIT

The following events are considered as those initiating the procedures of EPIT:

- Receipt of directives from higher authorities;
- Detection of anomalies during a periodical PIT;
- Detection of symptoms indicating violation of the rules and conditions of NM use and storage;
- Detection of unusual phenomena concerning the information about NM;
- Transfer of NM to a new custodian.

These events will lead to a decision to carry out EPIT. Differences in organization of EPIT after different initiating events would result in development of five different EPIT procedures. During EPIT, the NM handling activities are the major actions. Therefore the other accompanying activities are only described to a limited extent.

DEVELOPMENT OF PROCEDURES

EPIT procedures are complex structures with branching elements. All five procedures have different initiating events and a common core. Each of these procedures describes in detail the actions of personnel in accordance with the type of detected anomaly. After the detailed analysis of procedure contents, the decision was made to structure the procedures into four nested levels. This allows the descriptions of the procedures to avoid superfluous details and to emphasize key elements for participants at different levels.

The first, most general level describes actions on organizing EPIT after the event initiating EPIT takes place. It also includes reporting of EPIT results and actions carried out after Minatom review of the final report is received.

The second level includes the EPIT procedure (for B215 CF MBA) itself and describes usage of developed hardware/software ISEI system during the EPIT. At this level anomalies are detected and registered. The work with EIS software is also included in the second level procedure. Action steps on using bar-code reader, scales and computer subsystem for enrichment measurement to be performed by AWP operator during carrying out of EPIT are described in the procedure too. There could be a choice of what instruments to use and what the accuracy of the measurements should be.

The third level is a technical one and describes the work of handling a single container with NM items during carrying out EPIT.

The fourth level includes the procedure for measurement of gross weight of NM item and the procedure for uranium enrichment measurement.

The procedures of levels 2 to 4 are carried out with the ISEI hardware/software system and are supported by means of specially developed EIS software.

Titles of the developed procedures are provided below. Short identifiers of the procedures are given in brackets. Procedures were developed in accordance with the methodological guidance document [17].

1. Procedure No. 215-1. Procedure for measurement of item gross weight with Mettler–Toledo scales PB 601 and PB 8001. (**P1**).
2. Procedure No. 215-2. Procedure for measurement of uranium enrichment in items of B215 CF MBA with IMCA InSpector. (**P2**).
3. Procedure No. 215-3. Procedure for measuring and comparing to accounting data the characteristics of items located in a single container when carrying out emergency PIT in B215 CF MBA. (**P3**).
4. Procedure No. 215-4. Procedure of carrying out EPIT in B215 CF MBA. (**P4**).
5. Procedure No. 215-5. Procedure for organizing EPIT in B215 CF MBA in case a MINATOM order is received. (**P5**).
6. Procedure No. 215-6. Procedure for organizing EPIT in B215 CF MBA in case anomalies are detected during periodical PIT. (**P6**).
7. Procedure No. 215-7. Procedure for organizing EPIT in B215 CF MBA in case of symptoms of MC&A rules or storage condition violation. (**P7**).
8. Procedure No. 215-8. Procedure for organizing EPIT in B215 CF MBA in case of detecting anomalous events in the nuclear material information system. (**P8**).
9. Procedure No. 215-9. Procedure for organizing EPIT in B215 CF MBA in case of transfer of nuclear materials to a newly appointed custodian. (**P9**).
10. Procedure No. 215-10. Procedure of using EIS software for control of EPIT in B215 CF MBA. (**P10**).

PREPARATION TO THE EXERCISE AND CARRYING OUT OF THE EXERCISE

Any existing MC&A system in a specific MBA should be periodically tested under real conditions. The regular PITs can be also considered as a test of the system. However, because of the relatively small number of items measured on a random basis during a regular PIT, such a test is not very demanding. A demanding test for checking the system effectiveness is the use of hardware and software of the MC&A system for carrying out a complete PIT of thousands of items during a relatively short period of time in case of events requiring such activities - EPIT. During EPIT it is necessary to carry out measurements of characteristics and attributes of each NM item as well as to compare the data obtained with the data in the CMAS database. As a practical compromise, an exercise was designed that tested the EPIT procedures without requiring checks of every item.

Selection of procedures for the exercise

In order to carry out the exercise, the procedure of the first level No. 215-7 ("Procedure for organizing emergency PIT in B215 CF MBA in case of symptoms of MC&A rules or storage condition violation" (**P7**)) was selected and approved by the US side. Procedures **P1, P2, P3, P4,** and **P10** were used as procedures of the lower level.

Training of personnel and organization of the exercise

For procedures of different levels, different approaches were used regarding procedure organization and personnel training. In addition, the accepted approaches required separation of training of employees performing organizational functions and employees performing routine operations of NM handling and measuring NM characteristics.

Specific features of EPIT resulting from these approaches were also taken into account in designating AWP and NM handling operators. Because of their specific nature, the EPIT procedures are supposed to be initiated by low probability events and thus they are expected to be performed rarely, compared to periodic PIT procedures. On the other hand, carrying out EPIT procedures would require a high intensity of work, and for this reason AWPs should be used during these procedures. So, in order to carry out the procedures of the lower levels it is necessary to involve temporarily personnel whose usual activities do not include regular carrying out of such procedures. The following requirements were considered when analyzing information about candidates to be trained as operators:

- An appropriate medical permit was to be obligatory;
- Skills and experience in NM handling had to be sufficient;
- Experience of participating in periodic PITs was required;
- User-level computer skills was required for AWP operators; and
- It must be possible to interrupt basic activities when EPIT is necessary.

The training of the personnel was subdivided into several stages. The first five were

- meetings and presentation of the full set of the procedures;
- individual acquaintance of participants with the procedures that they would be involved in;
- demonstration of the step-by-step measurement actions in accordance with the procedures P1, P2 and P10 to database administrator, CMAS operator and supposed AWP operators;
- training of candidates for AWP operator positions to carry out P1, P2 and P10 procedures under the supervision of persons responsible for development of AWPs;
- training of AWP operators together with NM handling operators and a custodian to carry out activities in accordance with procedures P1, P2, P3 and P10.

The complex training for carrying out procedures P4 and P10, as well as a check of procedure knowledge and skills acquired, was performed at the sixth stage. This training and check of knowledge were organized in such a way that operators were working as independently as possible. The persons responsible for development of procedures undertook some actions only in the cases when it was necessary to correct erroneous actions of an operator or to help operators in resolving some problems.

Special requirements for creating anomalies

It is obvious that desire to create real anomalies with a nuclear material comes into collision with stringent regulatory requirements for operations with NM. Therefore, as agreed with the Institute Directorate, a minimal group of persons created anomalies for the exercise that were recorded only in a special document, the content of which was only known to a limited number of persons. After the exercise was completed, the persons who created the anomalies eliminated them and restored the state of NM according to the correct documentation and database information. All the necessary and sufficient measures were taken in order to prevent real loss (or theft) of NM when creating anomalies for exercise purposes.

Carrying out the exercise

The exercise took three days. On the first day anomalies were created, the EPIT Commission was organized and the start of exercise was discussed with US observers. On the second day the US experts were present in the MBA and observed the personnel actions during the exercise. The exercise was also continued on the third day when US observers were absent. The content of four containers was checked. All the specially created anomalies (changed locations of containers and those of some NM items as well as substitution of NM item with

highly enriched uranium by an item with lower enrichment) were detected. No unexpected anomalies were detected. The exercise was terminated because of the positive results and because of the potential for significant radiation doses to the operators handling NM items. At the end of the second working day and until the moment of the exercise completion, intermediate reports were generated by the system. Final reports on the results of the verification were obtained after the completion of the exercise. All the necessary organizational measures were taken at the site level. After the exercise the Acting Chief Engineer held a meeting with the participation of the persons responsible for development of procedures, EPIT Commission members, B215 CF MBA manager, and Russian experts - evaluators of the exercise.

CONCLUSIONS

EPIT procedures based on anomaly symptoms (as opposed to procedures based on the events) were developed and tested. These procedures start when suspicion of NM loss arise. The automated system for data collection and analysis during EPIT was developed and implemented, personnel were trained to follow the procedures and the plan for carrying out the exercise was created and implemented. US members of the IPPE Project team who have experience in carrying out MC&A system exercises and development of response procedures in emergency situations provided necessary support to IPPE personnel. They also observed the process of the exercise demonstration. Procedures, principles and technical decisions developed for EPIT can be used for development of similar procedures for other sets of nuclear materials and measurement equipment.

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