RADIOLOGICAL SAFETY PRACTICES EXPERIENCED IN HANDLING OF RADIOACTIVE SOURCE DURING RADIOGRAPHIC TESTING, CALIBRATION AND RESPONSE CHECK OF INSTRUMENTS DURING THE PROJECT STAGE OF 500 MWe PROTOTYPE FAST BREEDER REACTOR (PFBR)

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ABSTRACT

The presence and effect of ionizing radiation is detected and measured only with the help of radiological instruments as radiation is non-sensory. The radioactive half-life of the radionuclide bears significance in assorting the radiation protection measures. The efficiency and resolution of the radiation detection instrument is influential in detection of the contamination present on the surface of the equipment and other materials lying on the floors and walls of the buildings emitting alpha (α), beta (β), gamma (γ) radiations, neutron and gamma leaking out of reactor systems. Thus they play a vital role in choosing the appropriate instruments to put into use for detection. The efficiency of the instrument stands prompt to detect the presence of contamination and the resolution helps identify the radionuclide which produces that contamination. The radiological instruments which would consist of ion chamber, proportional counter, Geiger Muller tube, plastic scintillator etc., need to be calibrated with a known radioactive source of appropriate strength of activity depending upon the range of the instrument finalized. Preservation of radioactive source of any strength of activity and handling of the same require the strict compliance to the radiation protection
procedures. In a nuclear power plant, where there is the routine use of radiological instruments, larger equipment and radiological testing are a regular concern, the preservation of radioactive sources and strict vigil of the handling the same is pivotal. The paper brings out the practical experiences of handling of radioactive source of strength of various ranges for various activities carried out at the project stage of Prototype Fast Breeder Reactor (PFBR).

**Key words:** Radiological Instruments, Non-Sensory, Efficiency, Resolution, Contamination And Radioactive Source

**INTRODUCTION**

The Prototype Fast Breeder Reactor (PFBR) is a Uranium Oxide–Plutonium Oxide fuelled fast neutron reactor, which employs liquid sodium as coolant, currently under construction at Kalpakkam, near Chennai in India. Argon is used as the cover gas in the reactor. PFBR is the first of its kind technology in power production in the nuclear industry in India and through which our country is entering into the second stage of nuclear power programme.

There is a tremendous application of radiological source in nuclear power plants, medical, agriculture, radiographic testing of the equipment, piping etc., considering the following scenarios. As the nuclear industry involves the radioactive elements as fuel and the associated activation and corrosion products emitting gamma rays, fission neutrons and photo neutrons as the sources of radioactivity arising during operation of the reactor, it needs to be checked that all the instruments have been calibrated with a known strength of radioactive source. The areas where the radioactive sources have been handled in PFBR during the pre-start up activities of commissioning of PFBR are:

- **Radiographic Testing (RT):** The option of handling of radioactive source involves testing of components which are welded; to check the healthiness of the weld joints and compliance to specifications as they are supposed to be leak tight.
- **Response Check of in-core components:** The application of radioactive source emerges while irradiating the components which have to measure the neutron field inside and outside the core. Such important components need to be calibrated and this also requires a response check with a radioactive source (neutron or gamma).
- **Response Check of Radiation Monitors:** The area radiation monitors which are installed inside the plant are also required to be calibrated with the appropriate strength of source before put into operation.
- **Response check and calibration of Health Physics Laboratory Instruments:** The radiological instruments in the Health Physics laboratory like survey meters, contamination monitors, dosimeters, teletectors, neutron rem counters, etc., need to be calibrated with the periodicity of time.

It becomes essential to identify the correct radioactive source, the required strength as per the range of dose level to be fixed by the instrument. Further to these, the preservation of the radioactive source, transportation of the radioactive source, careful handling of the source from not falling down, missing etc., are to be strictly adhered to as per the stipulations and safety guidelines of the Atomic Energy Regulatory Board (AERB).

The code of radiation protection is to minimize the exposure to personnel and environment due to ionizing radiation. Thus handling of the source and adopting adequate radiation safety measures in keeping the radiation exposure As Low As Reasonably Achievable (ALARA) to the working personnel becomes the primary responsible of the Health Physicist of the plant. Keeping the above points in view, the following activities are being carried out in Prototype Fast Breeder Reactor.
INDUSTRIAL RADIOGRAPHY AT PFBR-RADIOGRAPHIC TESTING

The integration of the components at every stage involves welding. As the components in the nuclear power plant are required to contain radioactivity and hazardous substance as no leakage is permitted through the walls of the equipment or through any gaps that are left unwelded. The flawlessness of the welding needs to be established before accepting any component. The weld joints are checked for their healthiness by industrial radiography. In this process, ionizing radiation is used to view the zones of the objects or joints in an equipment that cannot be seen otherwise. The purpose of radiography does not alter the equipment dimension or does not make interaction with the material of the equipment; but helps to view the presence of foreign materials inside an equipment and ensure the perfection in the welding. Industrial radiography in other words is an element of non-destructive testing. It is a method of inspecting instruments or materials for any hidden flaws by using X-rays or gamma rays. These ionizing radiations would penetrate through the materials and identify the flaws if any present. Gamma radiation sources of Iridium-192 and Cobalt-60 are commonly used to inspect a variety of materials.

The healthiness of the pipelines can also be checked using Selenium-75 radioactive source of strength of 80 Ci (Curie) and above. The techniques involved in the testing are single wall-single image, double wall-double image and double wall-single image. The method and technique will be suitably decided based on the dimension of the equipment and pipelines. The person who is carrying out the test is accompanied by the Radiological Safety Officer, certified by The Bhabha Atomic Research Centre, Mumbai.

In project phase, there will be a number of personnel working in the day time involving various jobs. As a radiological safety measure, in order to avoid the exposure due to ionizing radiation to a larger group of people, the testing at site will be carried out during night time when there will be only limited number of personnel available in site. The testing area will be cordoned off to keep the availability of the personnel from the centre of the radioactive source by keeping a minimum distance. Since the testing process is continuous, the area gamma monitors are mounted in the location to measure the background levels. The Thermo Luminescent Dosimeters have been issued to the personnel involved in the testing.

RESPONSE CHECK OF IN-CORE COMPONENT: BORON COATED CHAMBER - IN PFBR

Boron Coated Chamber (BCC) is the in-core component used during initial fuel loading of PFBR. The BCC is used for detection of neutrons during the first criticality of PFBR. Boron-10 Coated proportional Counters (BCC), with a sensitivity of 12cps/nv, are used in Control Plug during initial fuel loading and first approach to criticality. To enhance the core monitoring, when the fission chamber assembly attached to start up Neutron-Detector Handling Mechanism is lifted up and moved away from the core region, in the control plug, during fuel loading. In case of long shut down, if shut down count rate becomes <3cps, BCC with a sensitivity of 4cps/nv are used in control plug to monitor the core during fuel loading and start-up. Before the counters are introduced in the core, they need to be checked for response by neutron.
**Fig 1:** Control Plug  
(Project inside reactor from top shield)

**Fig 2:** PFBR Reactor Assembly

1. Main Vessel  
2. Core Support Structure  
3. Core catcher  
4. Grid Plate  
5. Core  
6. Inner Vessel
7. Roof Slab
8. Large Rotatable Plug
9. Small Rotatable Plug
10. Control Plug
11. Absorber Rod Drive Mechanism
12. Transfer Arm
13. Intermediate Heat Exchanger (IHX)
14. Primary Sodium Pump (PSP)
15. Safety Vessel
16. Reactor Vault

SYSTEM DESCRIPTION

The Boron coated proportional counter has the detector diameter of 63mm and the detector length is less than 1000mm. The neutron sensitivity is 12cps/nv.

SOURCE AND INSTRUMENTS

Americium-Beryllium source of strength 37 GBq (Giga Becquerel equivalent to 1 Curie) was used to check the response of these detectors. The source provides neutron flux of 250 n/cm^2/s when placed with the detector on contact. The neutron rem counter is used to measure the neutron dose rate and the associated cumulative dose if any. Gamma radiation survey was carried out in the testing area using gamma survey meter before opening the source as well as after source was removed from the shielding flask.

MEASUREMENTS

Following radiological levels were observed during the functional check of these detectors using Neutron rem counter and gamma survey meters of two different make. The neutron field and the gamma field at the distance of 1m from the source and on contact with source are measured.

Table 1: Gamma and neutron field at 1metre distance from the source and on contact

<table>
<thead>
<tr>
<th>Source</th>
<th>Distance</th>
<th>Field using Survey meter</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Make 1</td>
</tr>
<tr>
<td>@ 1m from source</td>
<td></td>
<td>Make 1</td>
</tr>
<tr>
<td>Neutro</td>
<td>0.015 mSv/h</td>
<td>1.5</td>
</tr>
<tr>
<td>Gamm</td>
<td>-</td>
<td>3 µSv/h</td>
</tr>
</tbody>
</table>

FUNCTIONAL CHECK OF BCC DETECTOR

The neutrons emitted from the radioactive source is fast neutrons. In order to slow down the fast neutrons a thermalizing medium will be used. The High Density Poly Ethylene (HDPE) slabs are sufficient enough to do this. During the functional check of the BCC detector, two HDPE slabs each of thickness 3cm are used to thermalize the incident fast neutrons emitted from the Am-Be source.

There are various positions of source and thermalizing medium with the detectors are attempted and the output is observed in the electronics connected with the other end of the detector. The signal output is also viewed in the Cathode Ray Oscilloscope (CRO) attached to the electronics.
The pictorial representation of the placing of the source and the thermalizing medium are shown as below:

1. **Background** (absence of source)
The background counts are observed in the testing area using the gamma survey meters before the source is brought to the field for testing.

2. **Neutron Source – Thermalising medium – Detector** *(Contact neutron flux measurement)*

2.1 **Single Thermalising medium**:  
The source is placed in front of a Single HDPE slab and the emitted neutrons are allowed to pass through the HDPE which is acting as a thermalizing medium for the fast neutron and reaches the detector. The output signal is observed in the attached electronics.

![Fig 3: Single thermalizing medium set up](image)

Source (Am-Be)    HDPE    Detector

2.2 **Double Thermalising medium**:  
The source is placed in front of double HDPE slab and the emitted neutrons are allowed to pass through the HDPE which is acting as a thermalizing medium for the fast neutron and reaches the detector. The output signal is observed in the attached electronics.

![Fig 4: Double thermalizing medium set up](image)

Source (Am-Be)    HDPE    Detector

3. **Source – Detector – thermalising medium** *(Moderator outside)*

The thermalising medium (HDPE) was placed after the detector. The fast neutrons are directly hitting the detector and the escaped neutrons are backscattered by the thermalising medium and once again reaches the detector.
4. **On contact** (For fast neutron measurement):

The source is directly kept on the sensitive portion of the detector to observe the fast neutron interaction.

5. **Collimated arrangement**

5.1 For making the collimation arrangement of the source, the source is taken out and is directly put inside the shielding flask in the vertical direction and placed towards the sensible portion of the detector and the counts are observed for 10 seconds.

   The observed count rate was 26.5 cps (counts per second) in the collimated arrangement.

5.2 With the same arrangement stated above, a collimating pipe is placed in front of the mouth of the shielding flask of the source and thereby focusing the entire source to travel in one direction to reach the sensible portion of the detector.
The observed count rate was 29.5 cps in the collimated pipe arrangement.

\[ \Phi = \frac{S}{4\pi R^2} \text{n/cm}^2/\text{s} \]

\( S \) is Source strength (1 Ci = 2.5X10^6 n/s).

\( R \) is Thickness of HDPE slabs used for thermalisation; in our case was approximately 3cm

\( \Phi \) is the neutron flux

Substituting the values, we get,

\[ \frac{2.5 \times 10^6}{108} = 2.5 \times 10^4 \text{cps} \] (taking 10^8 as 100=10^2 for computation)

So, \( \Phi = 2.5 \times 10^4 \text{n/cm}^2/\text{s} \)

The value 2.5X10^4 cps corresponds to fast neutron flux. Due to thermalisation, 10% of the flux value might be slowed down. Total thermal neutron flux reaching detector volume = 2.5X10^3 n/cm^2/s.

Considering a 2\( \pi \) steradian, it is assumed that the 50% of the neutrons are reaching the sensitive portion of the detector and it is expected that half the value of the flux will be observed as counts. We shall have the 12cps sensitivity factor of the detector which corresponds to as 1 count.

So actual thermal neutron flux reaching detector =12500 n/cm^2/s. Hence, minimum value in the range of 12000 counts may be observed in electronics and the count rate is in the order of 1200 (as the counts are observed for 10 seconds). (The sensitivity factor = 12cps/nv for the detectors, 1 Count = 12cps).

The readings observed during the testing is tabulated as below:

**Observation of count rate for background, with application of single thermalising medium, double thermalising medium, on contact and outside the moderator with corresponding response inference**

<table>
<thead>
<tr>
<th>Detector No</th>
<th>Background cps</th>
<th>Single therm.</th>
<th>Double therm.</th>
<th>On contact</th>
<th>Outside moderator</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.1</td>
<td>-</td>
<td>1255.3</td>
<td>58.0</td>
<td>1372.3</td>
<td>positive</td>
</tr>
<tr>
<td>2</td>
<td>2.1</td>
<td>-</td>
<td>1421.2</td>
<td>69.5</td>
<td>1306.3</td>
<td>positive</td>
</tr>
<tr>
<td>3</td>
<td>2.2</td>
<td>-</td>
<td>1260.2</td>
<td>35.4</td>
<td>1427.0</td>
<td>positive</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
<td>-</td>
<td>1341.1</td>
<td>91.5</td>
<td>1340.0</td>
<td>positive</td>
</tr>
<tr>
<td>5</td>
<td>1.6</td>
<td>-</td>
<td>1228.8</td>
<td>70.2</td>
<td>1268.6</td>
<td>positive</td>
</tr>
<tr>
<td>6</td>
<td>1.8</td>
<td>-</td>
<td>1459.6</td>
<td>59.7</td>
<td>1287.3</td>
<td>positive</td>
</tr>
<tr>
<td>7</td>
<td>1.8</td>
<td>-</td>
<td>1331.7</td>
<td>52.3</td>
<td>1168.5</td>
<td>positive</td>
</tr>
<tr>
<td>8</td>
<td>1.5</td>
<td>-</td>
<td>1615.9</td>
<td>105.2</td>
<td>1385.3</td>
<td>positive</td>
</tr>
</tbody>
</table>
RADIOLOGICAL PROTECTION ASPECTS

The testing of a core component with a neutron source of 1Curie strength requires adequate radiological protection measures to avoid the exposure to the personnel in the testing area.

TECHNOLOGICAL MEASURES

The position of the detector and the output part was designed to be in opposite ends. The total length of the detector is 12metres. So the personnel working on the output end are available at the distance of minimum 11.5 metres from the position of the source. The efficiency of the survey meters are sufficient enough to observe the background counts and while the source is placed for testing.

ADMINISTRATIVE CONTROLS

- The testing location was so chosen where there is no routine access of the building.
- During the testing period, access to the testing area was restricted to essential persons only.
- The source was brought to the field after duly ensuring that the electronics of the detectors are responding well and calibrated.
- After every positioning of the source for a few seconds, the source was brought back inside the shielding flask, during the interpretation of the observed output signals in the electronics.
- The source was handled by a tong of 1m long.
- As the detector assembly is 12m long, the electronics of the system is kept at the other end of the sensible part of the detector.
- Despite all these only minimum people of the order of 15 were permitted to witness the response check at the electronics end. No onlookers to view the performance of the testing is strictly prohibited.
- The Health Physicists who were handling the source for the response check were issued with Neutron badge, TLD and a DRD (Thermo luminescent and Direct Reading Dosimeters).

FINDINGS

The high temperature Boron Coated Chamber (BCC) responded to the neutron source at varied settings of the instrument. Appreciable counts per second were recorded.

The dose exposure to the individual is NIL as per DRD issued to the personnel. The NIL exposure indicates the discipline and the adequate adherence to the radiation protection measures adopted and followed in our works and actions.

RESPONSE CHECK FOR RADIATION MONITORING SYSTEM AT PFBR

For the effective implementation of the design provisions for radiological protection for the occupational workers, public and to the public, a well-defined radiation monitoring programme is very much important. The radiation monitors which are designed under the Radiation Monitoring System (RMS), monitor the radiation levels in all the potentially active areas and initiate alarm/interlock actions as applicable. The RMS system is intended to measure, evaluate and record all radiation exposures that are emerging in the operation and maintenance of the reactor. It is an important activity of Health Physics Unit that all the radiation monitors are to be calibrated and checked for response with the appropriate strength of radioactive source.
RESPONSE CHECK OF DETECTORS USED IN STACK MONITORING SYSTEM

The gaseous effluents releasing from Reactor Containment Building (RCB) is discharged through 97.6m height stack which is closely located to Radioactive Waste Building (RWB). The stack location is provided close to RWB in order to reduce the length of exhaust duct. The gaseous effluents travel from low active zone to high active zone are collected at Reactor Containment Building (RCB) and through Radioactive Waste Building (RWB), it passes through the filters in the tunnel and discharged from the stack. The gaseous effluents of high value of radioactivity arises from Active Argon and fission gases released from Primary Argon Cover Gas Circuit, Cover Gas Purification System, Fission Gas Detection Circuit, Leak of cover gas containing fission product gases, if any, into Reactor Containment Building and various cells etc.,

To measure the flow concentration at isokinetic point, the sampling air line drawn at the height of 2/3 of total height of Ventilation stack is connected to the detectors in the stack monitoring room. The sampling air will pass through the particulate activity detector (beta particles-Strontium-90 is the representative radionuclide), Iodine activity detector (Iodine-131) and Stack Gamma detector (Fission Product Noble Gases (FPNG) and Argon Activity detector). The FPNG and the Argon activity indicates the gross gamma activity released during the operation of the reactor. The sketch showing the schematic of arrangement of detectors in the stack monitoring room is noted in Fig 9.

Stack Activity monitoring system consists of
i) Stack Particulate Monitor (Beta particles)
ii) Stack Iodine Monitor (Iodine -131)
iii) Stack Gamma Monitor (FPNG & Ar-41)

Fig 9: Schematic of Stack monitoring system
Table 2: Details of detectors used in the stack monitoring system

<table>
<thead>
<tr>
<th>S.No</th>
<th>Detector</th>
<th>Purpose of the detector</th>
<th>Details of the detector</th>
<th>Source used for response</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stack particulate activity monitor</td>
<td>To monitor the particulate activities released through stack</td>
<td>Particulate filter, Plastic Scintillation detector with Photo Multiplier Tube (PMT) along with Pre-amplifier, Lead shielding assembly and Electronic Processing and Display unit.</td>
<td>The radioactive source of Strontium -90 of 1Bq was used for the response check of the detector. While operating the ‘SYS RESET’ switch, the integral release and output voltage were verified.</td>
</tr>
<tr>
<td>2</td>
<td>Stack Iodine Monitor</td>
<td>To monitor the Iodine-131 activities released through stack</td>
<td>Charcoal filter cartridge, scintillation detector with photomultiplier tube, Lead shielding assembly and Electronic Processing and Display unit.</td>
<td>The radioactive source of Barium-133 (disc source) of 1Bq was used for the response check of the detector. While operating the ‘SYS RESET’ switch, the integral release and output voltage were verified. The test is repeated with Caesium-137 source.</td>
</tr>
<tr>
<td>3</td>
<td>Stack Gamma Monitor</td>
<td>To monitor the gamma activities released through stack- to monitor concentrations of FPNG activities and Argon-41 activity present in the air stream</td>
<td>Gas chamber, Scintillation detector with Photo Multiplier Tube, Lead shielding assembly and Electronic Processing and Display unit.</td>
<td>The radioactive source of Caesium-137 (disc source) of 1Bq was used for the response check of the detector.</td>
</tr>
</tbody>
</table>

Fig 10: Stack Monitoring system  
Fig 11: Electronics in Stack monitoring system  
Fig 12: Ventilation stack

RADIATION PROTECTION MEASURES ADOPTED DURING THE TESTING

The radiation protection measures were carried out through technical and administrative controls during the testing. They are discussed below:
TECHNICAL MEASURES

- The radioactivity of disc source as mentioned against each detector was used to check the response of the detectors.
- By design of the plant layout, the stack monitoring room is situated in an isolated building close to the Radioactive Waste Building (RWB).
- The testing was carried out inside the Stack Monitoring room itself, after enabling due power supply to the detector and the electronic cabinet.

ADMINISTRATIVE CONTROLS

- The area was cordoned off with a sign of radioactive testing is going on though it is an isolated location. Only essential personnel have been allowed to remain in the area to carry out the response test.
- The background at the place was initially measured before the source was brought with the presence of source at each and every detector was checked for the response. The response in the corresponding electronic cabinet is ensured for calibration.

FINDINGS

The exposure to the individual is NIL as per Direct Reading Dosimeter issued to testing personnel.

RESPONSE CHECK OF PORTAL SURVEILLANCE MONITOR:

The Portal Surveillance monitoring system is required for monitoring the contamination on personnel working in radioactive plant areas and to alert / alarm the personnel, on detection of contamination.

The system consists of the Beta-Gamma Portal Monitor installed at the final exit point of the plant and is used for monitoring the Head, Feet and other parts of the body of the personnel leaving the areas prone to contamination. The system provides the local display of contamination data on all the channels on a LCD screen and gives alarm and display when contamination exceeds the present alarm level. In case of contamination, the system will also provide a contact output for external use. All the detectors assemblies shall have pancake GM tube detectors. Fig 13: Portal Monitor sensitivity of the detector is high for Beta and low for gamma. The radioactive source used for the response check is Strontium-90 with 3.7Bq (disc source). The detectors are placed for monitoring head, body, hands and feet of the personnel. Suitable optical sensor has been provided to sense the presence of the organs in the monitor. Suitable lead shields are provided to reduce the background radiation level. The detector is made with sensitivity that it should respond for contamination or clean within 3 seconds with 99% confidence level.
The radioactivity of Strontium-90 disc source with 3.7 Bq (Becquerel) was used to check the response of the detector. The testing was carried out inside the Nuclear Island Connected Building (NICB). The area was cordoned off with a sign of radioactive testing is going on. Only three personnel were allowed to remain in the area to carry out the response test. The background at the place was initially measured and with the presence of source at different chambers of the monitor have been checked for the response. The audio annunciation in the system to inform “Contamination” and “Clean” signals are verified.

**RADIOLOGICAL PROTECTION MEASURES**

The entire testing was carried out by following adequate radiological safety practices.

**TECHNICAL MEASURES**

- The radioactivity of disc source as required was used to check the response of the detectors.
- The location of the portal monitor is at the final exit point of the reactor. So the initial testing were done on a holiday.
- The testing was carried out at the instrument location itself, after enabling due power supply to the detector and the Electronic cabinet.

**ADMINISTRATIVE CONTROLS**

- The area was cordoned off with a sign of “radioactive testing is going on” though it is an isolated location.
- Limited number of personnel were only permitted to remain in the area to carry out the response test.
- The background at the place was initially measured before the source is brought
- With the presence of source the detector was checked for the response. The audio annunciation in the system to inform “Contamination” and “Clean” signals are verified.

**FINDINGS**

The exposure to the individual is NIL as per Direct Reading Dosimeter issued to them. The NIL value of the exposure represent the compliance to the highest standards of radiation protection practices adopted while carrying out the testing in above cases and the success of elaborate planning before any testing is initiated.
CALIBRATION AND RESPONSE CHECK OF HEALTHY PHYSICS LABORATORY INSTRUMENTS

The prime responsibility of Health Physicist group in every nuclear power plant includes the radiological surveillance. The Radiological surveillance in all zones is required to find the background radiation level in the particular area. To meet this requirement different types of radiation measuring instruments are procured, installed and calibrated. To measure the radiation levels in zone 1 and office areas, Micro R Survey meter will be used and in other zone areas teletector will be used for surveillance.

To identify the presence of contamination, Alscin (Alpha Scintillation Counter), survey meter cum contamination monitors are used. To measure the air activity in controlled areas, air sampler is used. The samples are analyzed using the filter paper in alpha counting and beta counting system and the respective activity is estimated. The radioactive instruments are calibrated initially by the supplier. However, the response check of the dosimeters will be done on procurement. The instruments like survey meters, teletectors, counting systems, dosimeter like Thermo Luminescent Dosimeter (TLD), Direct Reading Dosimeter (DRD) etc., need to be calibrated.

CALIBRATION AND RESPONSE CHECK OF ANALOG DIRECT READING DOSIMETER

The Direct Reading Dosimeters are issued to the occupational workers while carrying out jobs in high potential areas along with Thermo Luminescent Dosimeter (TLD). The dosimeters need to be calibrated and checked for response by exposing it to gamma radiation source. The dosimeter has to be adjusted to zero in the aligning scale with fiber pointer. After doing zero adjustment, it should be allowed for a minimum period of 24 hours to observe for any leak in the zero set point by the fiber pointer. This is the leak test to be done for direct reading dosimeter.
The initial reading after the leak test was noted and the dosimeter was exposed to the radioactive source of Caesium-137 of 1 Ci (Curie) strength for 20 minutes to get the Fig 17: Analog DRD exposure of 2mSv/h. This dose rate is achieved by keeping the dosimeter at a distance of 75cm from the centre of the source.

**Table 3: Response Check of DRDs**

The readings are tabulated below:

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>DRD No.</th>
<th>LEAK TEST</th>
<th>RESPONSE CHECK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Initial Reading</td>
<td>Final Reading</td>
</tr>
<tr>
<td>1</td>
<td>293746</td>
<td>0</td>
<td>0.0</td>
</tr>
<tr>
<td>2</td>
<td>293747</td>
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</tr>
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</tr>
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<td>10</td>
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</tr>
</tbody>
</table>

**RADIOLOGICAL SAFETY ASPECTS**

The dosimeters are calibrated in the personnel calibration facility which is constructed as per the safety requirement of regulators. The radioactive source will be operated pneumatically. By setting the time of exposure in the control board and giving command for pneumatic operation of opening of source, the personnel can move out of the facility. After completion of the set time, the personnel can enter the facility and collect the dosimeters. Then the dosimeters reading can be seen for functionality of the dosimeter. Since the personnel are absent when radioactive source is spared, the exposure for the personnel is NIL.

The list of Health Physics lab instruments in PFBR and the periodicity of testing is as follows:
Table 4: Frequency for Surveillance for the Health Physics lab Instruments used in PFBR

<table>
<thead>
<tr>
<th>S. No</th>
<th>Monitor</th>
<th>Source used for calibration</th>
<th>Frequency of Check</th>
<th>Frequency of Test</th>
<th>Frequency of Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Survey meters (in use)</td>
<td>Cs 137</td>
<td>Daily (II shift)</td>
<td>---</td>
<td>Once in 3 months (General shift)</td>
</tr>
<tr>
<td>2</td>
<td>Survey meters (spares)</td>
<td>Cs 137</td>
<td>Monthly (General Shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>3</td>
<td>Teletectors (in use)</td>
<td>Cs 137</td>
<td>Daily (II shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>4</td>
<td>Teletectors (spares)</td>
<td>Cs 137</td>
<td>Monthly (General Shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>5</td>
<td>Rem counter</td>
<td>Am-Be</td>
<td>Daily (II shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>6</td>
<td>α counting system (in use)</td>
<td>Pu-239</td>
<td>Daily (each shift)</td>
<td>---</td>
<td>Once in a month (General shift)</td>
</tr>
<tr>
<td>7</td>
<td>α counting system (spares)</td>
<td>Pu-239</td>
<td>Monthly (General Shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>8</td>
<td>β counting system (in use)</td>
<td>Sr90-Y 90</td>
<td>Daily (each shift)</td>
<td>---</td>
<td>Once in a month (General shift)</td>
</tr>
<tr>
<td>9</td>
<td>β counting system (spares)</td>
<td>Sr90-Y 90</td>
<td>Monthly (General Shift)</td>
<td>---</td>
<td>Once in 6 months (General shift)</td>
</tr>
<tr>
<td>10</td>
<td>Gamma counting system (Single Channel Analyser)</td>
<td>Na-22 (disc source)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Gamma counting systems (Multi Channel Analyser)</td>
<td>Na-22 (disc source)</td>
<td>Daily (each shift)</td>
<td>Weekly (III Shift)</td>
<td>Once in a month (General shift)</td>
</tr>
</tbody>
</table>

CONCLUSIONS

The use of radioactive source and handling of radiation arising from the source has been optimized based on its requirement. The Radioactive source is to be stored, transported and handled with necessary precautions as per the radiological safety guidelines of the regulators of our country (AERB). The radiation protection procedure starts from the cordonning off the place and with necessary sign boards where such radiological testing is to be carried out, the measurement of background radiation level, the issue of dosimeters to log the individual exposure rate, safe handling of the source while testing, lesser time taken to complete the response check, minimum of 1 metre distance from the radioactive source during testing, etc. The above testings have been carried out with due care taken for all such radiation protection measures and resulted with NIL exposure experienced for the individuals. This successful completion of such testing with radiological source testing with due precautions and adhering to the safe radiological practices have given confidence in taking up further challenges in source handling by the crew or Prototype Fast Breeder Reactor obviously.
ACKNOWLEDGEMENT

The author sincerely acknowledges the efforts and the guidance rendered by her supervisor which has helped in dose reduction during construction stage and which has been reflected in the form of dose reduction measures in this paper. The author also acknowledges the efforts of personnel involved in all such radiological testing including BHAVINI and its contractors’ employees.

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