Qualification setup for systems for measuring nuclear and radioactive material

M. Risse, W. Berky, H. Friedrich, J. Glabian, T. Köble, O. Schumann, S. Ossowski
Fraunhofer INT, P.O. Box 1491, 53864 Euskirchen, Germany

1 ABSTRACT

In various types of application, systems for measuring nuclear and radioactive material are used. During the purchase decision-making process, the information given by the manufacturer will be taken into consideration. In other application areas several well established standards exist which have to be fulfilled and in relation to which the devices are tested in qualified laboratories. In the field of measurement systems for nuclear and radioactive material no test laboratories in Europe were established for this kind of devices yet.

In the Illicit Trafficking Radiation Detection Assessment Program + 10 (ITRAP+10) dedicated testing procedures, test equipment and test methods have been developed based on ANSI and IEC standards. The corresponding tests have been performed at the European Joint Research Centre (JRC) in Ispra (Italy) and in several national labs in the US.

The next step is to enable laboratories in Europe to verify an instrument's compliance to these standards. This is currently carried out in ITRAP+10 Phase II in work package 2. The Fraunhofer INT is one of the participating organizations and has conceived and built a test environment to perform the corresponding dynamic and static test measurements using neutron and gamma sources.

This paper deals with the development of the testing facility at Fraunhofer INT consisting of a guide rail system with roller carriages carrying the measurement systems. A lifting device controlled with pressurized air lifts the radioactive sources from inside a shielding case up to a position in front of the measurement systems. The system is completed by a data acquisition system which includes video data collection. This enables the analysis of the time response even for systems without data storage capabilities. The setup is quite flexible and offers many options.

The development phase as well as first experience with the system and first investigations of measurement systems are presented.

Key words: guide rail system, test procedure for nuclear and radioactive measurement devices, illicit trafficking, neutron sources, gamma sources

2 INTRODUCTION

The measurement setups are outlined in the following section 3. This includes the setup for the static measurements which was already used for qualifying measurements as well as the current state of the dynamic measurement system. Both setups use the same holder system for the radioactive sources which is also described. Section 4 deals with the data acquisition system which comprises a video system and documentation tables.

Static measurements concerning the test procedures for PRD and RIID systems from the project ITRAP+10 Phase II have been performed. They are based on the ITRAP+10 project results [1]. First results obtained for a device, the D3S from kromek, are given in section 50.

3 MEASUREMENT SETUP

For characterization measurements it is necessary to have appropriate measurement setups which allow qualified examinations and therefore enable the user to gain reliable results. In the testing procedures and standards for different device classes, static measurements and partly dynamic measurements are intended. The developed static system is described in section 3.1 and the current status of the ongoing installation of the dynamic system is described in section 3.2. The source holder and shielding material are used for both setups and described in section 3.3.

3.1 Static Measurements

Figure 1 shows the setup of the static measurement system with two representative measurement devices for illustration purpose. The system consists of a central cube for placing the radioactive sources. While not needed for the measurement the source is lifted down and shielded with a combination of lead and polyethylene, both borated and normal. Polyethylene is inserted for neutron sources used. A maximum shielding with a thickness of 15 cm and a height of 30 cm can generally be placed around the source using 5 cm x 10 cm x 20 cm bricks. If other thicknesses are needed, individual solutions can be realized. The figure shows in green one row of lead bricks, they are visible due to an opening in the outer shell of polyethylene bricks (in white).

Figure 1: Setup of the static measurement system. Central cubic: in yellow: source, green: lead bricks, white: polyethylene bricks. Two guide rails with roller carriages with one detector each.

On three sides of the cube guide rail systems can easily be attached and held by lateral guides. We have four guide rails which can each be placed on the sides of the cube or can be placed in a row in order to enlarge the distance from the source. The length of each guide rail is 1.5 m.

In Figure 1 two guide rails are attached, each has a roller carriage placed on it and holds a measurement device. Their height can be adjusted which enables us to bring the center of the detectors to the same height as the center of the source. The roller carriages are fully adjustable via setting wheels. The roller carriages and the guide rails are equipped with scales for measuring distances.

In order to measure the time behavior e.g. time to alarm or time to stabilize a measurement value, it is necessary to have a short lift up time for the radioactive sources. Intended times are below 0.5 s. Therefore a lift up mechanism based on compressed air was chosen for the lifting device. The resulting lift uptime is about 0.35 s. Figure 2 shows the whole setup and the lifting height in detail on the right side. It is 0.38 m. The thicker black tubes are transporting the compressed air. The thinner ones are cables for the time measurement system.

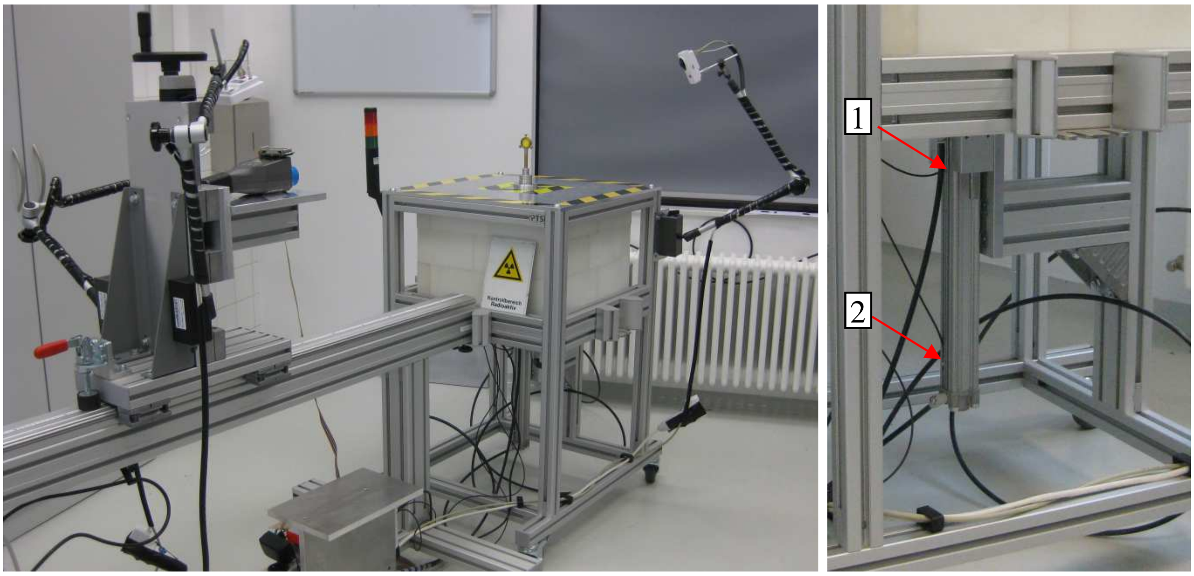

Figure 2: Setup with auxiliary systems. Left: Safety systems: alarm light (showing a red light when the source is outside the shielding), alarm tape at the cube, radiation protection sign; three video cameras resp. video camera holder. Right: lifting height with contacts for the time measurement: (1) upper and (2) lower end.

Several accessories are needed to perform qualified, safe, reproducible and reliable measurements. Therefore we have equipped the static measurement system with several auxiliary systems which are described in the following subsections.

3.1.1 Time Measurement System

To observe the time behavior of measurement devices, it is necessary to have an appropriate time measurement system. Our system has contacts at the beginning and the end of the lifting height. Figure 2 shows the position of the contacts. Passing by one of the contacts starts and respectively stops a clock. The current time in seconds as well as the previously obtained value (lift up or lift down time, measurement time) is displayed, see Figure 3. The time display and the display of the device which is qualified are filmed simultaneously. Therefore a correlation can be determined. In here a typical handheld device for illustration purpose is shown.

Figure 3: Display of the time measurement system in combination with a typical handheld device for illustration purpose. Left: display mounted on the detector filmed by the video camera (white box on the right). Right: LCD display upper line: previous measurement result (here: lift up time, 342 ms), lower line: actual measurement time; the last digit changes its position on the display on every update in order to compensate the slow LCD-refresh time. All times are given in seconds.

3.1.2 Distance Measurement and Adjustment

In general the distance between detector and source is defined by a predetermined dose rate value at the point of the detector. The dose rate and the correlating distance are determined by a measurement with a reference detector (see left side in Figure 4). Therefore it is necessary to switch between the reference detector and the measurement device. The general requirement towards reproducibility and reliability, the need to act fast in the area of radiation due to radioactive protection, and the aforementioned changing of the devices makes it necessary to measure the distance between source and detector precisely and have an easy and fast possibility to place the devices.

For the positioning of the devices we have either utilized special mounting plates or alignment tools. Left side of Figure 4 shows the plate for the reference detector below the detector. For devices which are only temporarily at our facilities we do not have special plates but alignment tools. One of those is shown in the Figure 4 on the right side.

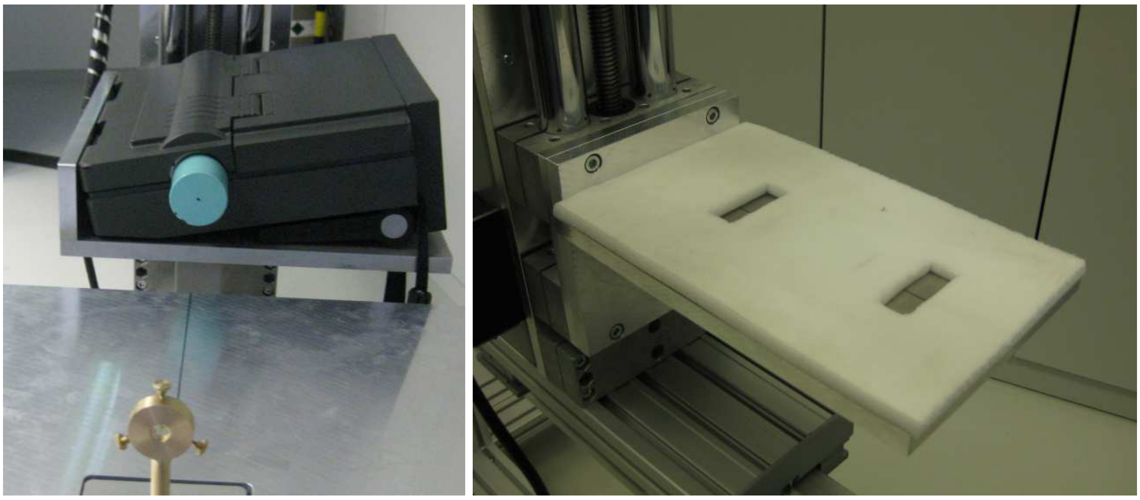

Figure 4: Positioning of the detectors. Left: reference detector with matching mounting plate; right: alignment tool for fast placing a detector.

The scales at the guide rails and the steering wheel enable us to adjust the height and distance rather fast. The measurement of the distance between the position of the source and the detector is done by a laser range finder. The distance is measured in absolute values for the documentation and relative to a reference point at the end of the central cube for rapid adjustment.

3.2 Dynamic Measurements

To perform dynamic measurements it is necessary that a radioactive source is passed by the measurement device to be evaluated. The velocity has to be variable depending on the class of devices. The test procedures of the ITRAP+10 Phase II project define a variety from 0.02 m/s up to 2.2 m/s. Also the height of the radioactive source has to be adjustable in order to pass it by in the complete active detection area. The dynamic system of the Fraunhofer INT is still under development, but will be realized by a carriage running on one track. The track is mounted on wooden plates which can be combined to enlarge or shorten the length of the track and to be flexible to use it on every place large enough. The carriage will be run by a motor which must have a large enough acceleration to reach the velocity in the available space.

The dynamic system will also be equipped with a video documentation system.

3.3 Source holder

Different gamma and neutron sources have to be used for the qualification measurements. The sources vary in size and geometry. The different source holders needed have to fulfill several requirements: due to the fast movement during the short lift up times the sources have to be properly fixed; to meet the radioprotection requirements the time for handling has to be short; for shielded measurements shielding material has to be placed easily and well fixed.

The source holders were divided in a basis for all holders and a special part for the individual source form. Figure 5 displays the source holder and shows the concept. In the left picture the basis made out of stainless steel is seen. This part is well fixed to the air pressure driven ground plate by the screws in the lowest ring. The next ring has a groove on the outside which is needed for the fixing of a shielding cylinder (see picture in the middle) using grub screws. The highest ring has three holes with grub screws which lead into a groove on the rod of the source part. The source can, for example, be mounted to the source part at a special working place with lead shielding and afterwards quickly placed in the basis.

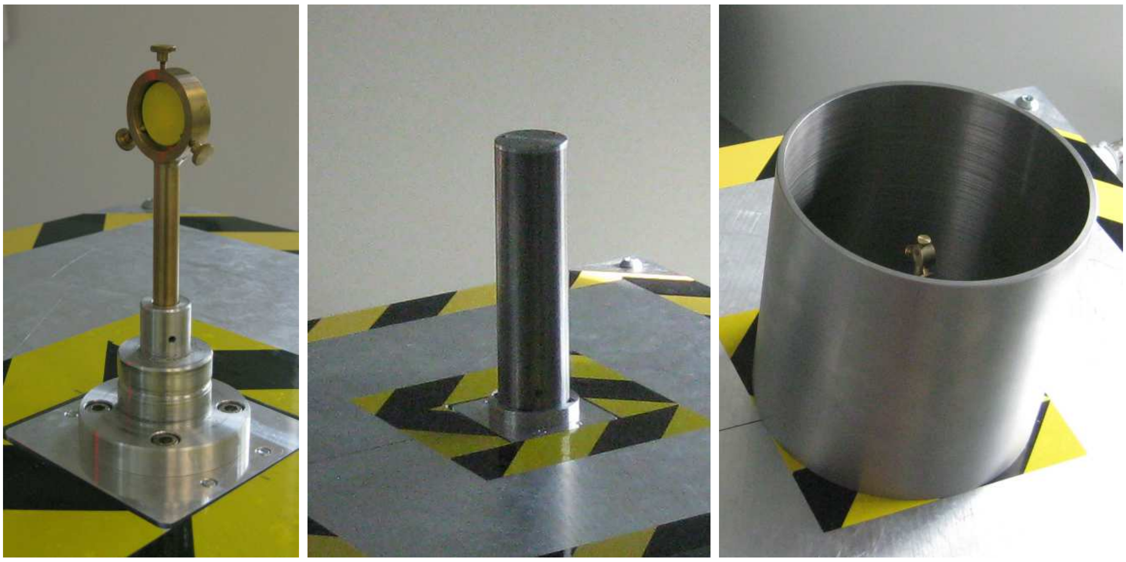

Figure 5: Source holder; <u>left:</u> basis (stainless steel) with holder for small plate sources; <u>middle:</u> lead (not visible) and steel shielding on the basis covering a neutron source; <u>right:</u> stainless steel shielding surrounding another sample holder.

For neutron sources it is generally required to have always a lead and steel shielding surrounding the source. Due to the step construction it is possible to have the shielding well fixed around the source while it is lifted up or down. For further shielding we have, for example, a cylinder of steel (see right picture in Figure 5).

Figure 6: A variety of source holders for different kinds of sources.

Because of the variety of source geometries it is necessary to have different individual source holder parts for the basis. The different holders are constructed to well fix the sources and place the center of the radioactivity always on the same height. Some of the holders developed in our workshop are displayed in Figure 6.

4 DATA ACCUISITION SYSTEM

4.1 Video System

Three aspects make it necessary to use a video system. Due to radioprotection it is not possible to observe the devices directly while the source is outside the shielding. The measured data are acquired in relatively short time which requires a possibility for a subsequent evaluation. The decision, for example, if an alarm was within 2 or 3 s after exposition towards the source cannot always be drawn directly. In addition the obtained videos enable us to have comprehensive data documentation.

Up to now we use three video cameras which can be seen in Figure 7. Two cameras are mounted at the roller carriage: one for the reference detector and one for the device display and the clock. The use of two separate cameras minimizes the time needed for adjustment of the camera. Having the device display and the clock on one video stream enables us to draw time correlations immediately, the display of the time since lift up of the source is extremely practical and saves time during data analysis.

The position of the source is documented by a separate video camera; see right part in Figure 7.

Figure 7: Video system. <u>Left:</u> roller carriage with camera observing the device display and clock and camera for the reference detector. <u>Right:</u> central cube with source observing camera towards the position of the extended source. The shown measurement device is a typical handheld device for illustration purpose.

The software Blue Iris processes the video data and controls the recording. Figure 8 shows the display of the appropriate laptop. The three cameras are shown in the colored frames. Enlarged is the view on the device and the clock. Which camera picture is enlarged can be chosen. The green and yellow frames/videos are used alternating depending on which device is used. The recording is triggered by the upper contact at the lifting height. Going upwards it starts the recording and going down it stops the recording. The recording starts and stops 5 s before and respectively after passing the contact. The video of the device (green frame) and the source (red frame) are both recorded and have the same time stamp to correlate the data. It is also possible to review the video while another recording is running.

Figure 8: Video system. <u>Green frame:</u> picture of device display and clock, <u>red frame:</u> picture of source, red light indicates the exposition, <u>yellow frame:</u> picture of camera for reference detector, not installed at that time.

4.2 Documentation tables

It is very reasonable to extract the data from the video and note the results directly by hand rather than to have a fully automated measurement system where the measurements are performed without observation and a subsequent analysis of the whole video records is needed afterwards. Problems or events which lead to a readjustment can directly be recognized and solved.

Table 4 - PRD

Tests successful:

Tests not successful:

Table 4: *5.2 Time-to-alarm: Photons results*

"Insturment" in search mode

By the Laboratory: Fraunhofer INT
Instrument: name, serial number, product number

Background Dose rate $\left[\frac{\mu Sv}{h}\right]$ with **MAB 500**:__________Position of Detector holder: Hight:____________Distance on Scale [cm]:____________.

Source: **Co-60**______________________Source ID: **MY 464**____________.

Activity at date of measurement [Bq]: **70 kBq**_______Source holder: **Plättchenhalter** Distance Detector Front side – Source [cm]:____________.

Dose rate at Detector reference point measured with MAB 500 $\left[\frac{\mu Sv}{h}\right]$:____________.

"Instrument": Position of Detector holder: Hight:____________Distance on Scale[cm]:____________.

γ-Alarm threshold:____________ n-Alarm threshold:____________.

Date:__________________ Performer:________________________.

Preparation: Begin:___________________________ End:___________________________.

Distance Det. Front side - Back side of source table: ____________

Time	No.	DR backg. [µSv/h]	DR source [µSv/h]	Alarm activation time [s]	Video file	step out time [s]	Comment	T [°C]	rf [%]	p [mbar]	Test succesfull? yes	Test succesfull? no
	1/30											
	2/30											
	3/30											
	4/30											

Figure 9: First page of the measurement table for time to alarm measurements.

For a complete documentation much information has to be noted down. For every measurement task documentation tables have been developed which can be used for immediate noting while the measurement is ongoing. The tables guide a person who is performing the measurement through all necessary steps. The first page of a representative table for the measurements concerning the time to alarm is shown in Figure 9.

5 TEST SYSTEM

Measurements according to the ITRAP+10 Phase II measurement procedures have been performed. We have started with qualification measurements of our own devices. The first one we had chosen was the D3S from kromek. The device can either function as a PRD or as a RIID and we tested it against both procedures.

5.1 D3S

The measurement system consists of a detection device and a smartphone for data collection and display.

Figure **10** shows the D3S, the detector part and the smartphone.

Figure 10: Test system D3S. <u>Left:</u> detector part, <u>Right:</u> smartphone with measurement running in search mode measuring a ^{226}Ra source. The left part shows the PCS significance over time, the right part the text box with status information, alerts, and measurement results.

The device has no defined reference point. As it is usually worn at a belt with the side seen in the figure to the outside, this side was placed towards the source. It can either be run in a search mode or in an identification mode. In the search mode every second a new measurement result is displayed, it gives a 3 s rolling average. The identification mode obtains measurements for 30 s. These times are fixed and cannot be changed.

In the text box the status information and results of the measurements are noted. When an identification result is obtained, it is displayed, as well as the event of an alarm. The alarm is given as vibration signal from the smartphone, as optical information in two forms: changing the background color of the box where the identification result is given (see Figure 10, Ra226 highlighted in red above the diagram), and as text in the text box. The acoustic information is a spoken text, in the case of the displayed example: “Alert, Radium-226 is detected”, “Alert, high gamma count” or “Alert, gamma count over range”. The latter two will not lead to any identification result, in the text box the user is guided to increase the distance to the source. The acoustic signal can easily be disabled by reducing the volume of the smartphone. If it is switched off and the vibration alarm cannot be realized, the optical alarm indication is not really obvious. It would be easier to realize the alarm if the vibration alarm was at the D3S detector part.

As far as it is observed up to now, in search mode the identification is possible up to about 0.7 µSv/h, above the “high gamma count” alert is given. The alarm settings cannot be set by the user.

5.2 False alarm

The first tests in the PRD test procedure are the false alarm tests. In here the device shall measure at a background radiation level for at least 10 h and have at maximum one neutron and one gamma alarm. The D3S passed this test without any alarm. During the test which was done during the night a battery capacity for the D3S between 10.5 h and 11 h was observed. The smartphone itself has a battery time of about 6 h, therefore it was connected to a power supply.

5.3 Time to alarm

The test procedures define a time of 2 s for PRD devices und 3 s for RIIDs in which the detector shall give an alarm after being exposed to the radioactive source. The time to alarm shall be estimated over the whole energy region, therefore tests with ^{241}Am, ^{137}Cs and ^{60}Co shall be performed. For all sources a dose rate of 0.5 µSv/h above the background shall be set. Up to now we have performed the measurements with ^{137}Cs. In all cases the nuclide was identified correctly. The time to alarm was in all cases below 3 s, which fulfills the criteria for the RIIDs. In 12 cases the time was between 2 s and 3 s. This means that the time to alarm criteria for PRDs are not fulfilled.

6 CONCLUSIONS

Test procedures for qualifying measurement systems for nuclear and radioactive material have been established. It is necessary to have test laboratories which can perform tests regarding these procedures. In this paper the development of such a testing facility is presented. For static measurements the setup is ready for operation already. The setup for dynamic measurements is under construction.

7 REFERENCES

[1] Joint Research Centre (European Commission): **Illicit Trafficking Radiation Assessment Program (ITRAP+10).** Test campaign summary report, 2016, DOI: 10.2788/895995, ISBN: 978-92-79-58986-7