Body Contamination Monitors - State of the Art and Future Development

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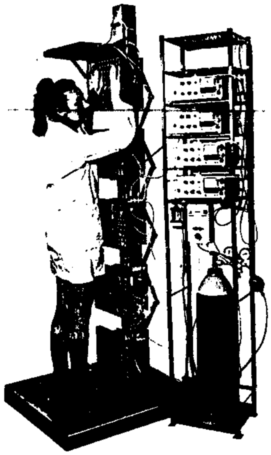
History

Since the introduction of large-area proportional counters in the mid-1960s, it is possible to efficiently test large parts of the body for contamination. Initially, simple hand/foot monitors were used with these detectors, but already by the end of the 1960s there were personnel contamination monitors for also measuring large parts of the body. These devices were constructed according to the materials available and with simple analogue electronics. Some of these devices are still in use today, more than 25 years later. Now personnel contamination monitors are a constituent part of monitoring controlled areas. Since their introduction they have been subject to massive on-going development in almost all sectors. Detectors can be manufactured with almost any dimensions to match requirements and with appropriate electronics are also suitable for simultaneous alpha measurement. The geometrical arrangement of the detectors has been improved so that almost all areas of the body are measured. The application of the extremely powerful computer techniques that are available nowadays has brought about substantial improvements in many respects: background subtraction, comprehensive service and calibration support, user guidance through the combination of modern sensor technology with monitor displays and speech output, networking and data storage.



Body Contamination Monitor
built in 1970

Classification and Application

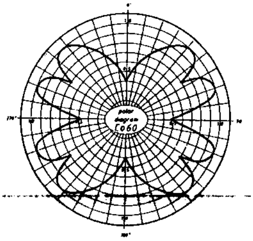
Personnel contamination monitors can be classified into three categories: **Hand/foot clothing monitors:** These just monitor the hands and feet simultaneously. The clothing must be measured with moveable clothing probes. The application extends to areas with a low throughput of personnel. **Pre-Monitors:** These also measure parts of the clothing simultaneously with the hands and feet, but normally only have a simple measurement geometry. The field of application covers checks within the controlled area with the objective of suppressing the spread of contamination. **Exit Monitors:** These measure the complete body with an optimum measurement geometry and are installed at the exits of controlled areas with high throughputs of personnel. The highest demands are placed on these monitors

Basic principles

In almost all countries there are laws and directives which stipulate the requirements for the monitoring of controlled areas. Here, the limits for the contamination monitoring are defined. This is mainly based on just the type of radiation or, as in Switzerland, is differentiated according to nuclides. The legal regulations are supplemented by standards such as the DIN standards in Germany or the IEC at an international level. Added to this, come recommendations from radiation protection commissions. Internationally the most important for personnel contamination monitors is IEC 1098 which was issued in 1992 ("Installed Personnel Surface Contamination Monitoring Assemblies for Alpha and Beta Emitters"). It regulates the minimum requirements on this kind of product and prescribes a range of tests with point and large-area sources.

- The determination of the uniformity of sensitivity is found with alpha and beta sources which are used for measuring the sensitivity distribution at specified measurement points within the measurement area of 15 x 10 cm^2 for hand detectors and 30 x 10 cm^2 for foot detectors. The sensitivity profile for the complete detector array is recorded for the body measurement (only beta). The horizontal profile based on a polar graph and the vertical profile based on an axial scan are recorded. An elliptical phantom with a 95 cm circumference and a 35 cm major axis is used as a basis.

- The sensitivity for the determination of the detection limits for the hand and foot monitors is made with large-area sources of 15 x 10 cm^2 (hands) and 30 x 10 cm^2 (feet). The mean of the axial and horizontal scans is used as the basis for the detection limits of the body measurement. Computational rules are also given for the determination of the detection limits in the quoted standard. However, a draft ISO standard (ISO 112929): "Determination of the lower limits of detection and decision for ionising radiation measurements")[1] already exists. In modern monitors with automatic adaptation of the measurement period the appropriate formulae in this draft standard are already taken into account.



Polar Response Diagram
according to IEC 1098
(Split -Delta Geometry)

Development and Problems in the Measurement Geometry

The fact that IEC1098 makes the measurement geometry a decisive quality feature due to the requirement for recording the polar and axial scan diagrams indicates how important geometrical properties have become. In actual fact the capability of a monitor to detect contamination reproducibly over as much of the body as possible mainly depends on the size and arrangement of the detectors. After all, the detector response is very dependent on the distance to the source. This particularly applies to low-energy radiation and K capture radiation.

Whereas formerly monitors monitoring the front and back of a person simultaneously in one measurement phase were common, monitors measuring the front and back sequentially have become more established due to a major problem with the one-step method. The advantages are obvious - in contrast to one-step monitors, the distances are noticeably shorter and more reproducible. In addition, the sides of the body can be measured with good sensitivity. With the one-step method this is not possible even with the important nuclides of ^{60}Co and ^{137}Cs due to the large distances. Substantially better results are also produced for the head. Forearm detectors are significantly easier to integrate in a two-step monitor. An optimum sensitivity distribution is obtained with a triangular geometry with mean vertical division (Split-Delta from Rados). The sensitivity profile of this geometry is also tolerant against different sizes of person.

Also, modern geometries represent a compromise in detection characteristics, operating convenience and, not unimportant, costs. Improvements can still be achieved in the area of the shins, on the upper side of the feet and in the region of the upper arms, but with substantial extra expenditure. The measurement geometries now achieved have partial suitability for the detection of alpha contamination. Admittedly, a non-defined sensitivity profile is produced due to the extreme dependence of alpha radiation on distance, but, for example due to the split-delta geometry, large parts of the body and clothing come close enough to the detectors to enable good alpha detection.

Detectors

The market is currently dominated by large-area proportional counters for continuous operation. There are a number of reasons for this: They have high alpha and beta sensitivities with a low background, they can be produced economically in almost any dimensions and they can be easily repaired on site. Their main disadvantage is that they need a continuous supply of counting gas. Alternative sealed proportional counters only achieved limited success, because they exhibit practically no alpha sensitivity, have a noticeably lower sensitivity to low-energy radiation and, due to restricted dimensions, the devices constructed with enclosed detectors produce more dead zones. Added to this, much effort is required to replace the window foils so that they have to be more protected, giving a further reduction in sensitivity.

In principle, large-area plastic scintillation detectors are suitable, but there are still many fundamental problems to be solved. In particular, the detector material must be designed very thin (1 to 2 mm) so that it exhibits a low background with high beta sensitivity. Reading the light out from these types of plastics economical is still a problem, but if this can be achieved for a reasonable expenditure, then this type of detector would be a very interesting alternative to the proportional detector.

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[1] DIN 25482 is applied in Germany

Interference Effects and their Treatment

The measurement is disturbed by a number of external influences - varying background count rate, xenon and radon clouds, xenon and radon attached to the clothes or hair or contamination on the detectors. In contrast, in modern devices electromagnetic interference is no longer a problem.

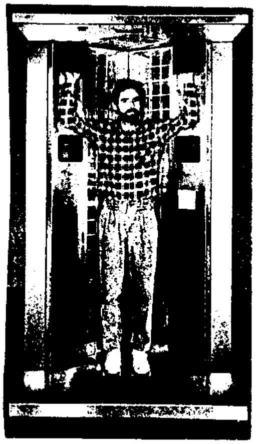
The most important ~~disturbing influence is the varying background count rate~~. It is caused by natural radiation (cosmic rays, building materials, etc.) and by artificial radiation sources (active piping, contaminated surfaces, etc.). Added to the normally slow changes in the background are those, for example, due to the large queues in front of the monitor. Often the field is also directional. There are a number of methods of background subtraction. Many of the methods are too slow or lead to extended downtime periods. A method specially developed for application in personnel contamination monitors operates with an exponential filter and two sliding median values. The two median values are formed from different numbers of pulses so that they have different response times. During the background measurement the signal from the exponential filter is checked for whether it is located within specified limits about the median values. Based on a range of criteria, the system decides which of the median values is regarded as the present background. With this method the monitor can adapt quickly to short-term changes in the background without downtimes and without sacrificing the required accuracy.

Xenon and radon clouds mainly behave as other background variations and are taken into account by the subtraction method. This is not the case with radon or xenon activity clinging to clothing. It only appears when the person enters the monitor. The large-area characteristic of this activity may give a clue, but is not sufficient to be used as a criterion in the classification as background, because contamination may also cover a large area. It is just these types of contamination that must not under any circumstances remain undetected.

The alpha channels also exhibit a background effect. This is situated in the region of 0.1 to 0.5 pulses/s, so that usual background subtraction methods cannot be used. Therefore, for the alpha background subtraction, methods are used which are specially developed for low pulse rates.

Data Processing and Networking

Whereas with the first generations of personnel contamination monitors the measurement data was lost after termination of the measurement, it is now possible to link the monitors distributed in the plant with a central computer where the measurement data can be collected. Practice shows that important conclusions can be drawn from this data, enabling for example, the origin of the contamination in the system or the presence of hot particles to be deduced. From this, appropriate measures for improving the radiation protection can be derived. The possibility of accessing information from the devices centrally also represents a significant alleviation in the workload for the servicing personnel so that it also increases the availability.



Modern Body Contamination Monitor RTM860TS with Split-Delta Geometry and powerful PC-Electronics

Future Prospects

Although personnel contamination monitors have now achieved a high technical standard, continual development will still take place in the future. Modern computer technology offers opportunities of improving the service friendliness and also the possibilities of networking and data evaluation have not yet been exhausted. An example here is the coupling with dosimetry. The latest developments show that progress can be achieved in the field of background subtraction. It is still to be seen whether the large-area proportional counters in use today can be replaced by other technologies. In any case however, refinements in the measurement geometry and the signal evaluation will produce further improvements in the measurement characteristics.