WASTE ASSAYING AND RADIATION MONITORING EQUIPMENT AT THE WASTE MANAGEMENT CENTRE OF NPP LENINGRAD

by

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The waste accumulated in the past at the Nuclear Power Plant Leningrad has to be sorted and packed in an optimal way. In the area of waste treatment and management, the completeness and quality of direct monitoring are of the outmost importance for the validity of, and confidence in, both practicable waste management options and calculations of radiological impacts. Special monitoring systems are needed for this purpose. Consistent with the scale of work during the waste treatment procedures and the complexity of the plant, data have to be collected from characteristic parts in various treatment stages. To combine all the information, a tracking procedure is needed during the waste treatment process to characterize the waste for interim and/or final disposal. RWE NUKEM GmbH has developed special customer-tailored systems which fulfil the specifications required by plant operation and by the authorities.

Key words: waste management, radiation monitoring, radiological impact, gamma camera, drum monitoring system

INTRODUCTION

The waste accumulated in the past at the Nuclear Power Plant Leningrad has to be sorted and packed in an optimal way. Different waste categories were stored at the plant during a long period of time, without taking into consideration different disposal possibilities, including sorting and treatment procedures. In the area of waste treatment and management, the completeness and quality of direct monitoring are of the outmost importance for the validity of, and confidence in, both practicable waste management options and calculations of radiological impacts. Special monitoring systems are needed for this purpose. The main data which must be evaluated are the dose rate at the surface of the waste package and at a distance of 1 m, as well as the radiological inventory and mass.

Furthermore, the collected data have to be readily available for further use in quantitative evaluations and easily accessible for analysis. Consistent with the scale of work during the waste treatment procedures and the complexity of the plant, data have to be collected from characteristic parts in various treatment stages. To combine all the information, a tracking procedure is needed during the waste treatment process to characterize the waste for interim and/or final disposal. RWE NUKEM GmbH has developed special customer-tailored systems which fulfil the specifications required by plant operation and by the authorities.

SORTING PROCEDURE AND FINAL CHARACTERISATION

Due to their application at the Waste Management Centre of NNP Leningrad, two monitoring systems play a special role. The waste in the plant has to be sorted in categories I and II, given in tab. 1. This is done through a combination of the Gamma camera RAYMOS and dose rate measurement systems. After the sorting process is fin-

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Table 1. Specification of waste categories I and II

	Waste of category I	Waste of category II
Specific β-/γ-activity	up to 3.7 10^6 Bq/kg	3.7 10^6 to 3.7 ^{9} Bq/kg
Dose rate in 10 cm from surface	0.3 to 300 Sv/h	0.3 to 10 mSv/h

ished and the waste incinerated and/or compacted, it is placed in 200 l drums, its final packaging. The final waste characterisation is made by a Drum Monitoring System for gamma ray measurement, DMS. All the data necessary for the declaration requested by the authorities are measured and evaluated with this RWE NUKEM monitoring system. The final results are given in purpose-made data sheets.

The said procedure is a remote controlled, radiological sorting procedure, in which the waste of categories I and II are separated from each other.

The solid waste of category I is first cut and then sent to the sorting facility where it is separated into following categories:

combustible solid waste, and
compactable solid waste.

The drum monitoring system is used for the measurement of drums filled with radioactive waste, for data evaluation and for the preparation of outgoing data sheets with measurement results. After this final measurement, the drums are delivered to the customer to be transported to the storage facility.

SPECIFIC MONITORING SYSTEMS

Gamma camera RAYMOS

RWE NUKEM GmbH has developed the Gamma camera RAYMOS [1-5] for waste pre-characterization (quantity and distribution of activity) or for checking the filling procedure *i. e.* waste sorting, in this case into categories I and II. The camera is a computer controlled device assigned for imaging gamma emitters together with an optical image. It is used for searching and identifying radioactive sources and measuring contamination profiles at distances between 0.5 -100 m.

The RAYMOS monitoring system, fig. 1, is based on extensive research by RWE NUKEM and RECOM and measurements realized in a realistic environment. The continuous optimisation of the parameters and selected components led to an improved system with increased sensitivity and angle resolution. The camera is a computer controlled device designed for imaging in hard X-ray and soft gamma ray energy regions.
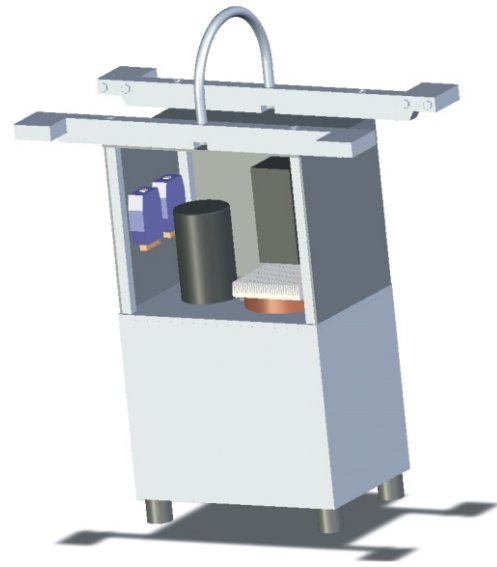
Figure 1. Gamma camera RAYMOS

For its application in waste treatment, RWE NUKEM has improved the system for nuclide identification, especially for hot spot analysis.

The imaging is based on the use of a conical collimator, a scintillation plate, an image intensifier as a detector, a CCD matrix as a readout device, and special digital processing to subtract the background and reduce the noise.

Description of the system

The imaging system is a combination of a collimator, a scintillation plate, an image intensifier and a readout device. A special CCD frame for digital processing is used to reduce the background by decreasing the noise level. In addition, RAYMOS includes a video-camera, a scanning unit, an integrated computer, and an external computer.

The pinhole camera principle is applied for the imaging process integrated into the measuring head. The gamma source is localised by superimposing gamma and video images. The integrated computer controls all imaging components of the system, as well as the data processing. The external computer controls the overall system, thus allowing for the camera to be operated by remote control.

As an option, the camera is equipped with NaI or CdZnTe gamma spectrometers, laser distance meters, and dose rate meters, depending on the required application.

The imaging in the measuring head is based on the pinhole camera principle. The two cone collimator produces an overturned X-ray or gamma image of the object on the plane of the scintillating plate. Different image intensifier systems (static tubes, MCP tubes) have been tested. The CCD ma-

trix is designed to read the optical image. Lead shielding reduces the background of gamma radiation that reaches the scintillator by passing through the shielding, *i. e*. that which does not come from the observed objects. The video camera records a similar frame of the observed objects in the visible spectrum range. Video images are used for gamma source identification. This is done by superimposing similar gamma and video images. Different techniques of data presentation are possible.

The equipment with the on-board computer is placed inside the body. The on-board computer is assigned to control all device systems for both preliminary processing and the compression of gamma images. The main computer which can be connected to the on-board computer *via* LAN or WLAN, is used for image readout, storage, displaying, detailed processing, and analysis of the images.

Further improvements

A conical collimator was implemented into the original system. A new development in the form of a coded mask collimator designed to reach a higher sensitivity was also achieved.

The application of coded apertures (CA) in gamma ray imaging systems for industrial technical applications originated, approximately, in the mid 1990´s, in astronomy. The basic purpose was to enhance the sensitivity of the systems, as well as high angular resolution. The coded mask of gamma ray imaging was suitable for solving these problems. It was, also, successfully applied in X-ray experiments with hot plasma. This application was the basis of the search for new masks of different patterns and geometry. Gamma astronomy demanded imaging in a range of energy higher than that of gamma radiation (from 10 MeV up to 100 GeV and above) and Compton telescopes and other new approaches were applied to these problems. In the case of the other applications of the masks, an overall objective concerning their usage resulted from information gathered on the depth of the image (radioactivity distribution). Thus, incidentally, a problem arose. The problem is connected with non ideal coding of images in the vicinity of the source, when the accident angle of gamma rays on the mask from the same source is varied along the mask and the transparency of the openings changes accordingly. The best values of the ratio between the unclosed and closed areas in the aperture are obtained depending on the value of a signal in a pixel, the background signal, the number of pixels in the image, and the type of the mask's pattern.

The comparison of the two systems shows that the new device locates activity distribution more completely and clearly. The new device is not only lighter, but also has a faster measurement time.

The system has the capability of being equipped with its own power supply. Wireless transfer of information by remote control operation is also possible.

Drum monitoring system for gamma ray measurement

The drum monitoring system for gamma ray measurement [2, 6-10] was developed to completely characterize the waste drums for interim and/or final disposal. This also includes the determination of the waste drum mass and dose rate (at the surface and at a distance of 1 m); the gamma emitters are identified and their source strengths stated. Furthermore, the maximum dose rate is marked on the outside of the drum and an automatic wipe test is carried out in order to discover possible contamination and provide evidence that surface contamination levels are below the accepted limits. The measurement system is constructed in such a way that, by using a few simple adjustments, the system can be transported through normal door openings. Measurement detector heads are fitted in such a way that it is possible to deal with cylindrical waste drums of different sizes by simple adjustment of mechanics. For measuring cubic boxes, the mechanics can be adapted without significant changes in the layout. The drum monitoring system is shown in fig. 2.

The movement of the mechanical components is automatic and controlled by a PC. The data of the detector systems are registered and evaluated in a specified time grid, which allows a local interpretation of the gamma flux around the drum. The operation can be carried out from a shielded area and is controlled using menus in the specific language of the customer's country.

Figure 2. Drum monitoring system

In the analysis, the actual gamma spectrum is taken into consideration; in the determination of the dose rate and for the determination of gamma activity, the matrix and source position are taken into consideration.

The applied measurement methodology allows the use of high performance, tested and economical detector systems. These systems are in operation and long-term experience has proved their high reproducibility and reliability.

Proportional and GM counters are selected as dose rate measuring devices; they cover the necessary detection width from the lowest value to 5 Sv/h. The choice of detectors and the measurement region are fixed automatically. The gamma spectrometer chosen for the system consists of a very pure germanium detector with a response probability of 40%, a collimator system and corresponding nuclide software. The automatic wipe test is carried out at specified positions on the surface of the waste drum and at the lower edge of the waste drum positioning frame.

The movement of the mechanical components takes place automatically and is controlled and monitored by a PC. The data of the detector systems are registered and evaluated in a specified time grid. This means that the results of the measurements can be allocated locally. During the measurement, preliminary results and status information are presented clearly on a video monitor. After the measurement, a protocol is produced and the results transmitted to the main computer of the nuclear power plant.

The number of drum revolutions is fixed by the specific requirements for exactness. After the reference measurement, the results are examined for agreement (response probability and energy calibration). The test operation allows for the movement of single components and the registering of the single results of every measuring device at specified time intervals. This information, which is also stored during the routine measurement operation, can be presented on the video monitor using the menu option "presentation of single results" and is printed out on the system printer. The option "re-analysis of data" allows the user to obtain a renewed evaluation of the data with modified parameters. In the menu "parameter configuration" the operation and evaluation parameters can be changed so that waste drums which are new and were not in the initial planning can be measured.

Special error routines ensure a permanent surveillance of the mechanical setting and a reliable data transfer.

In data analysis, the actual gamma spectrum is taken into consideration for the determination of the dose rate; for the determination of gamma activity, matrix and source position are taken into consideration. The following source distributions can be analysed:

homogeneous source distribution,
heterogeneous distribution in axial and azimuthal direction, including "hot spots",
distribution on the outer surface of the waste drum,
distribution at the centre of the lid region,
distribution at the centre of the base region, and
distribution at the waste drum centre.

The parameters of the calibration curves for taking account of the matrix effects and the source distribution are determined in the calibration measurements.

CONCLUSION

The Gamma camera RAYMOS is an industrial system for gamma imaging and visualization. It can be successfully used in the sorting procedure for the characterisation of radioactive waste of those categories which arise in NPP Leningrad.

The present stage of the development of the Drum Monitoring System for Gamma Ray Measurement shows that compact equipment is available to determine all relevant parameters for characterizing the waste drums for interim storage and final disposal, as well as for transport, and that it is, therefore, suitable for checking waste drums.

The presented devices developed by RWE NUKEM GmbH allow complete waste characterisation of analysed waste at the Waste Management Centre of NPP Leningrad.

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СИСТЕМ ЗА КАРАКТЕРИЗАЦИЈУ И РАДИЈАЦИОНИ МОНИТОРИНГ ОТПАДА У ЦЕНТРУ ЗА УПРАВЉАЊЕ РАДИОАКТИВНИМ ОТПАДОМ НЕ ЛЕЊИНГРАД

Радиоактивни отпад у нуклеарној електрани Лењинград треба да буде сортиран и упакован на оптималан начин. У области руковања радиоактивним отпадом директан мониторинг је изузетно поуздана практична опција, посебно за прорачун радијационог утицаја. Специјални системи мониторинга су неопходни при оваквим применама. С обзиром на комплексност проблема подаци морају да се прикупљају у различитим етапама поступка и у различитим периодима. За комбиновање свих информација неопходна је посебна процедура (трекинг) за време обраде, карактеризације и дефинитивног паковања отпада. RWE NUKEM GmbH је реализовао посебне системе прилагођене захтевима клијента који задовољавају техничке спецификације електрана као и захтеве регулаторних комисија одређене земље.

Кључне речи: руковање отпадом, радијациони мониторинг, радијациони утицај, гама камера, систем мониторинга радиоактивних буради