How Useful Are Imaging and Remote Sensing Technologies in Decontamination & Decommissioning? – 17363

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ABSTRACT
The examples of application of imaging and remote sensing technologies during decontamination & decommissioning works in nuclear environment at Kurchatov Institute site are presented. The systems which realized these technologies are: radiometric system installed on mechanical arm of Brokk remote controlled vehicle, collimated scanning spectrometric system and portable gamma cameras of different types. Objects of application: facilities of research reactors at characterization and under dismantling, temporal radwaste storages during discharge and remediation.

INTRODUCTION
The systems for remote measurement of dose rate or activity distribution at objects in nuclear environment are used wildly in recent years. They may solve different tasks. Different manufactures give long list of these tasks.
CANBERRA says about applications of portable gamma-cameras [1] for:
1. Localisation of Sources
2. Monitoring of Decontamination Processes
3. Estimation of Shieldings
4. Decommissioning of Radioactive Plants
5. Localisation of Hot Spots in Waste
6. Emergency Situations

16 ways of using for portable gamma-camera Polaris-H at NPPs are given by Dr. Z. He [2]

From our experience we can propose some applications of gamma-ray imagers in symbiosis with remote controlled mechanisms for:
1 Examinations of rooms and contaminated facilities
2 Work inside and discharge of waste storage
3 During cutting of non-uniformly contaminated tubes, aggregates, etc.

The examples of application of imaging and remote sensing technologies during decontamination & decommissioning works on MR research reactor at Kurchatov Institute are presented in next sections.

EFFECTIVE SOLUTION - REMOTE MEASUREMENTS
During more than 10 years activity in D&D at Kurchatov Institute site different systems for remote measurements were developed and used for:
- ✓ Gamma scanning
- ✓ Gamma-ray imaging
- ✓ Collimated dosimetry & high resolution video imaging

Objects of application: decommissioning and dismantling of research reactors, remediation of temporal radwaste storages at Kurchatov Institute, Moscow [3-8].

Instrumentation for remote measurements

The most active using during D&D works at Kurchatov Institute site have three systems for remote measurements: Gamma-pioneer system (G_P), Gamma-Locator system (G_L) and different portable gamma-cameras, named in Russian "Gammavizor" (G_V) (see fig 1).

Gamma-pioneer Gamma-Locator Gamma-camera "Gammavizor"

Fig. 1. Instrumentation for remote measurements.

The description of these systems and ways of their applications during D&D are presented in next sections.

MEASUREMENTS WITH GAMMA-PIONEER SYSTEM

Gamma-pioneer is a radiometric system for application with Brokk-90 (remote controlled robot). System includes two scintillation detectors (collimated to angle about 12^{o} and detector without shielding), video camera and has WiFi or LAN connection with control unit. The measuring range: 0.4 mSv/h to 8.5 Sv/h.
Its appearance and detector's construction are presented in figures 2 and 3.
Application Tasks of G_P:

- ✓ The survey of high-level objects;
- ✓ Dose rate measurements of high-level objects;
- ✓ Additional dose rate and video control during high-level objects manipulation

The system was used in survey of elements from temporal near reactor radwaste storage, preliminary scanning of activity distribution along elements, video and dose rate characterization of SNF elements and arrangements.

Fig. 2. System G_P installed on arm manipulator of robot Brokk.

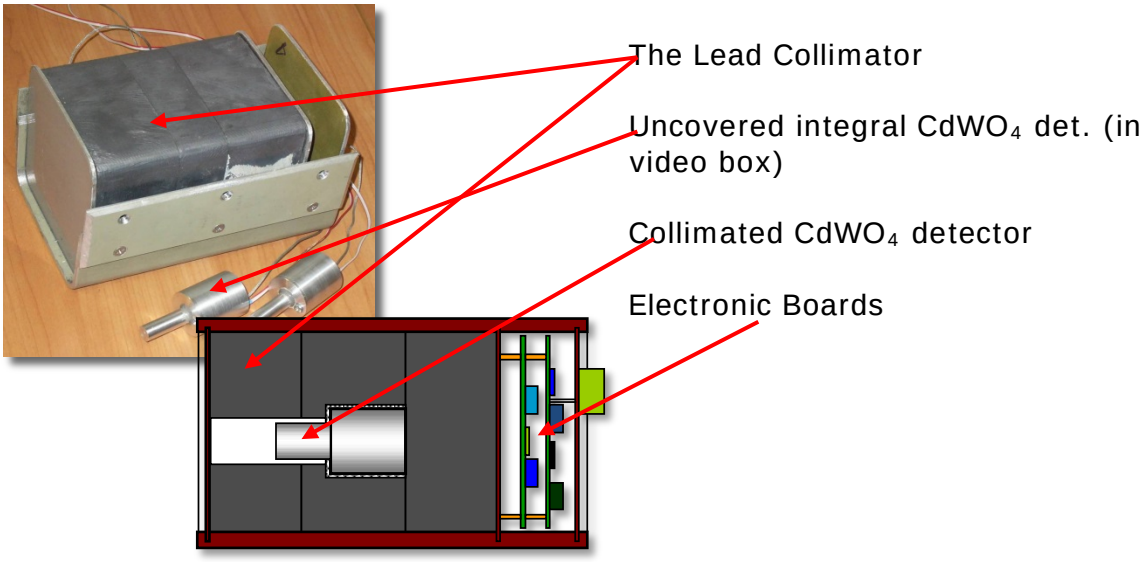


Fig. 3. The construction of G_P detectors.

The Survey of Radwaste Storages

The gamma- and video- scanning of spent fuel assemblies and cases with radioactive waste from temporary storages

Fig. 4. The gamma- and video- scanning of spent fuel assemblies and cases with radioactive waste from temporary storages.

Gamma-pioneer allows to look in details the content of cells and to measure the dose rate from surveyed objects.

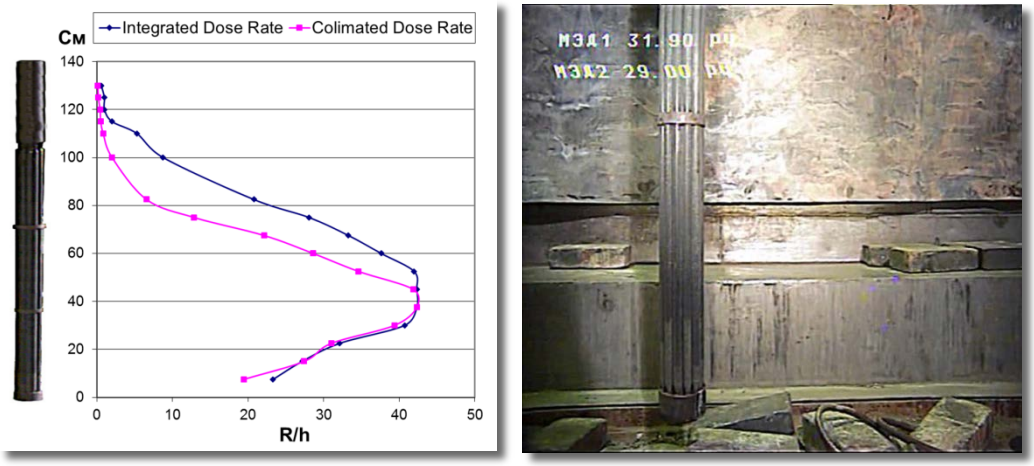


Fig. 5. SNF rods scanning . The distribution of integral and partial dose rate along the length of the object (left) and the image of rods on the control monitor during scanning (right)

Limitations of G_P performance – the absence of spectrometric characteristics of the studying objects was overcame by application of spectrometric G_L system.

MEASUREMENTS WITH GAMMA-LOCATOR SYSTEM

Gamma-locator is a remotely operated collimated spectrometric system. The appearance and construction of the system are shown in figures 6 and 7. The angular resolution of G_L is about 5^{O} , angular step during scanning procedures was in range 2 - 5^{O}.

Three interchangeable spectrometric gamma-ray detectors are used in G_L: CdZnTe detector (60 mm^3) and two CsI(Tl) detectors - (5 and 20 cm^3) - see fig 7. The system was used at dose rates from 100uR/h (with scintillating detectors) to 3R/h (with detector CdZnTe)

1. Collimated spectrometric detector
2. Video camera
3. Control unit
4. Pan and tilt table

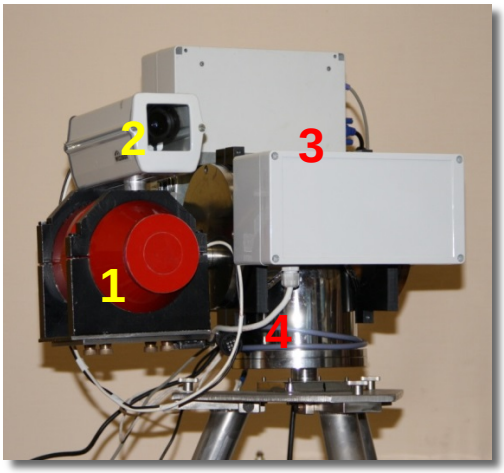


Fig. 6. Appearance of G_L system

Fig. 7. Detectors of G_L : CdZnTe detector CsI(Tl) detector

The system G_L was used for solving different measuring tasks during dismantling research reactor MR.

Survey of Central Reactor Hall to Control of Dose Rate Sources

The system G_L was installed in different premises of research reactor with contaminated facilities for scanning of contribution into the dose rate at position of the system from main sources. Results of scanning in reactor hall of MR are shown in fig. 8.

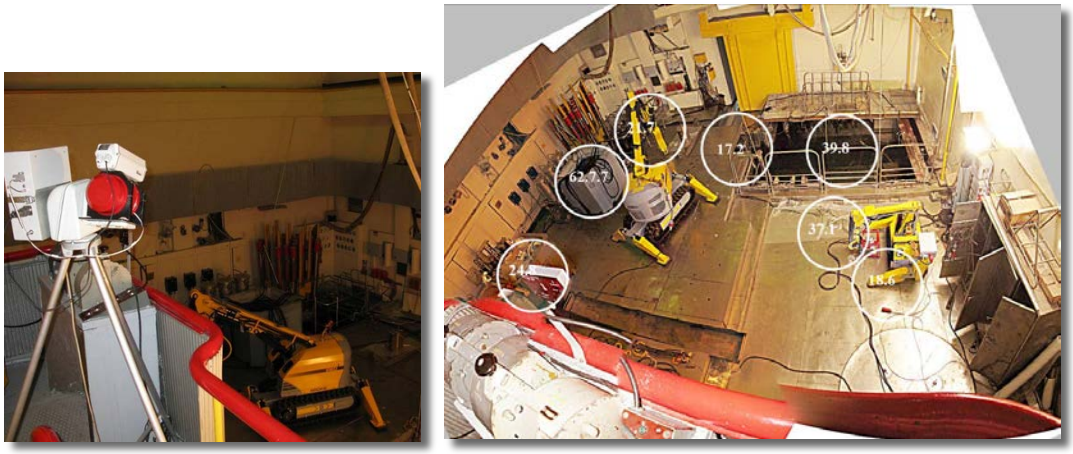


Fig. 8. G_L is installed for scanning main sources of dose rate in reactor hall of MR during D&D activity (left). Results of scanning - the contribution of the dose rate at device placement from the most active sources is printed in the circles(in uR/h).

Determination of Spent Fuel Presence in Radwaste

Research reactor MR had many undescribed elements of old facilities in local radwaste storages. They can contain the elements of spent fuel. G_L system was used to test possible presence of spent fuel using method of self-induced X-ray fluorescence of uranium [9].

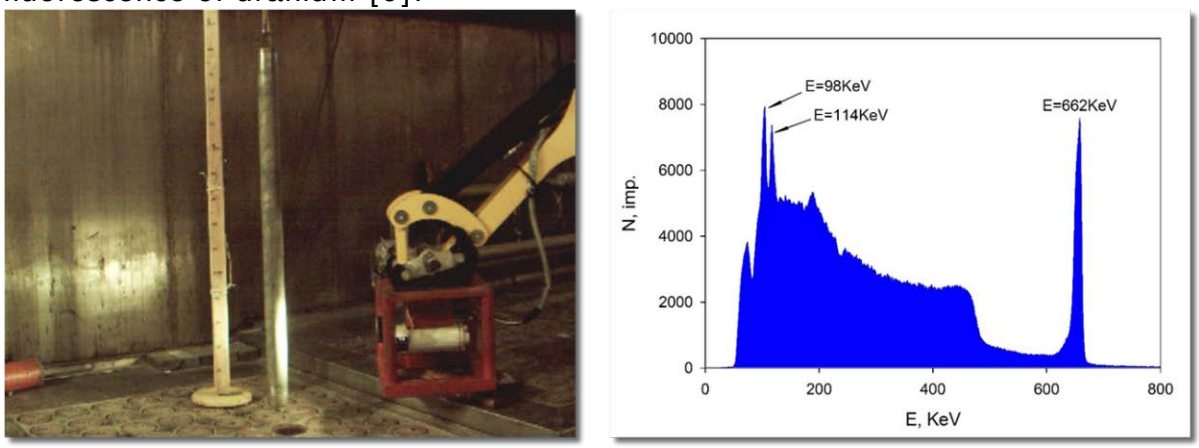


Fig. 9. Scanning of undescribed elements of research facility removed from the temporal radwaste storage with G_P and spectra of self-induced X-ray fluorescence obtained with G_L.

Criteria for Spend Fuel Availability:

✓ A peak Cs-137 exceeding background;

✓ Presence of uranium X-ray characteristic radiation peaks;

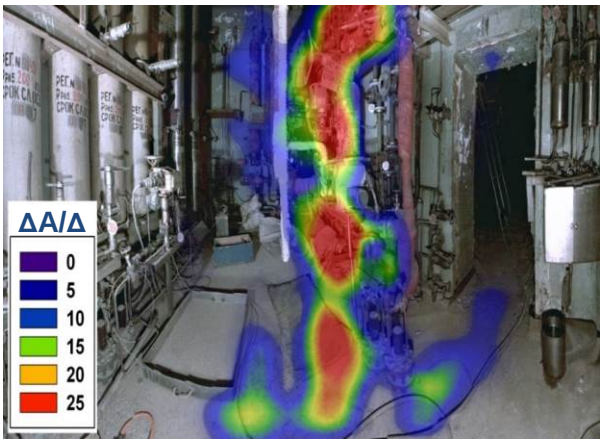
✓ Fulfillment of statistical conditions of presence validity of the characteristic radiation in the region of interest (~98 and ~113кэВ).

Limitation:

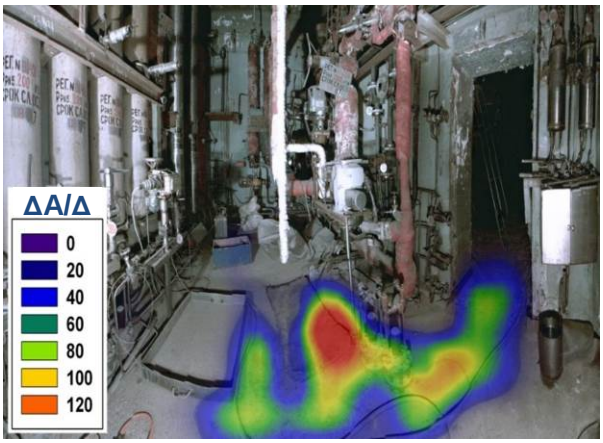
✓ The absorption of characteristic radiation inside neighboring waste and walls of case and scattered radiation.

Scanning of Rooms with Contaminated Facilities

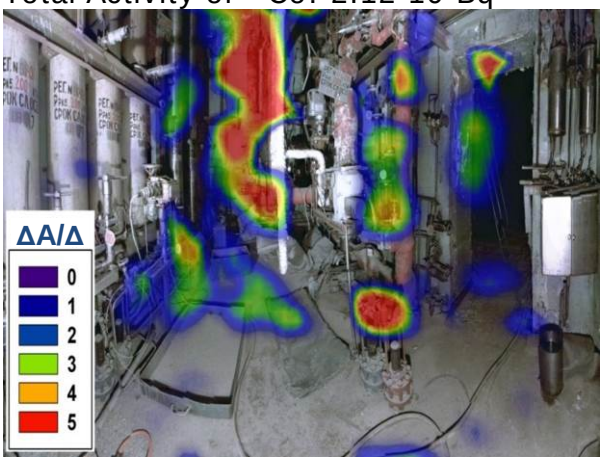
The scanning with system G_L rooms with contaminated facilities gives data on distribution of different gamma-emitting nuclides in element of facilities. It is possible to estimate the activity of radwaste removed from a room. Results of such measurements are presented in fig. 10.



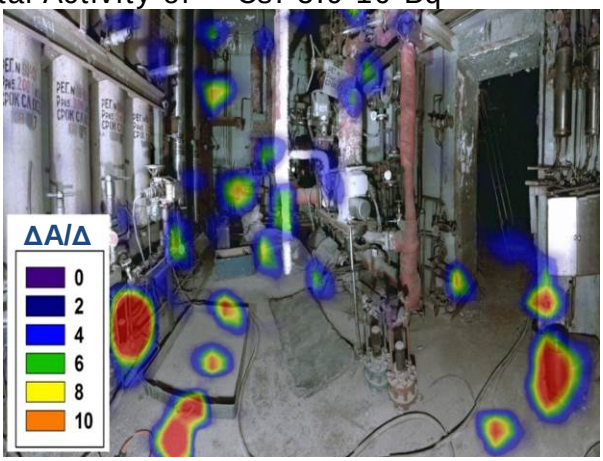
Total Activity of ^{60}Co: 2.12·10^{9}Bq



Total Activity of ^{137}Cs: 5.9·10^{9}Bq



Total Activity of ^{60}Co: 3.67·10^{8}Bq



Total Activity of ^{60}Co: 3.67·10^{8}Bq

(Results of modeling of dismantling works – removing the most active elements)

Fig. 10. Results of scanning of contamination in room with facilities of reactor research loop.

APPLICATION OF PORTABLE GAMMA CAMERAS

Portable gamma-cameras of different design were used actively for assistance of different operations during works on D&D of MR reactor. Different cameras were used. The angular resolution of gamma-ray imaging with cameras is from 1 to 2 degrees. The field of view is about 30 degrees. Gamma-ray images were obtained at dose rate at devise position up to 3 R/h. Results of applications are presented as gamma-ray maps in pseudo colors superimposed on video image of the scene in figures 11-14.

Measurements to assist remote controlled machines operations while radwaste storage discharge

Fig. 11. Remote controlled machine is removing canisters from historical radwaste storage (above) and gamma-camera images in different moments during work (bottom row)

Fig. 12. Test with G_V of residual contamination of radwaste storage after discharge - left. Gamma-ray image shows presence of small lost source on bottom – right.

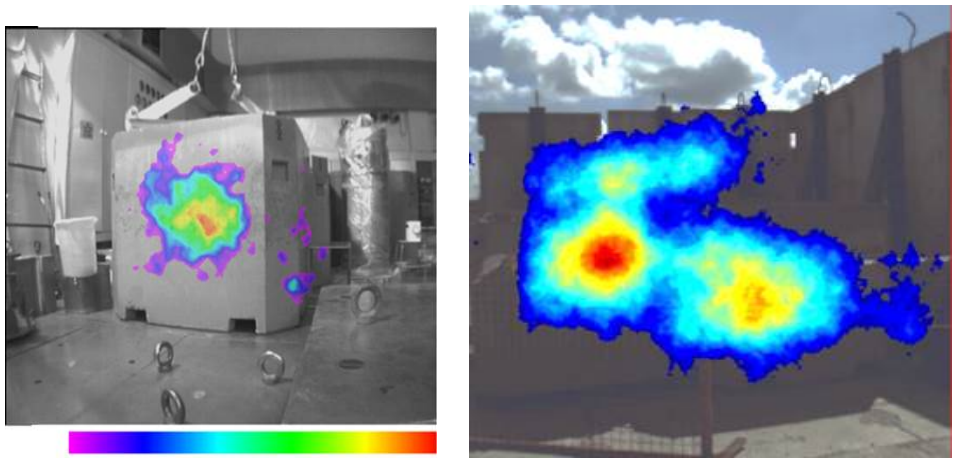


Fig. 13. Control of distribution of radwaste in containers by gamma-ray imaging with coded aperture gamma-cameras. Filled container in reactor hall – left, two containers and of Compton scattering on shielding by gammas from container.

Fig. 14. Extra-light gamma camera[10] (left) is used for control repacking of canisters with historical radwaste.

The remote-controlled gamma camera is applied to obtain a detailed distribution of contamination. For work at highly contaminated premises with non-uniform background radiation, this camera is equipped with rotating coded mask (coded aperture imaging).

THE SURVEY AND CUTTING OF LOOP CHANNEL ELEMENTS

Complex measurements of all three systems G_P, G_L, and G_V were carrying out during handling of contaminated elements of the loop channel's part. After obtaining gamma-ray image to see activity distribution along the element and the test on presence of uranium inside, these parts were cut to separate high and low contaminated part. The operations are presented in figures 15 and 16.

Fig. 15. Arrangement of remote controlled machine and measuring devises during operation on cutting of contaminated elements of the loop channel's part.

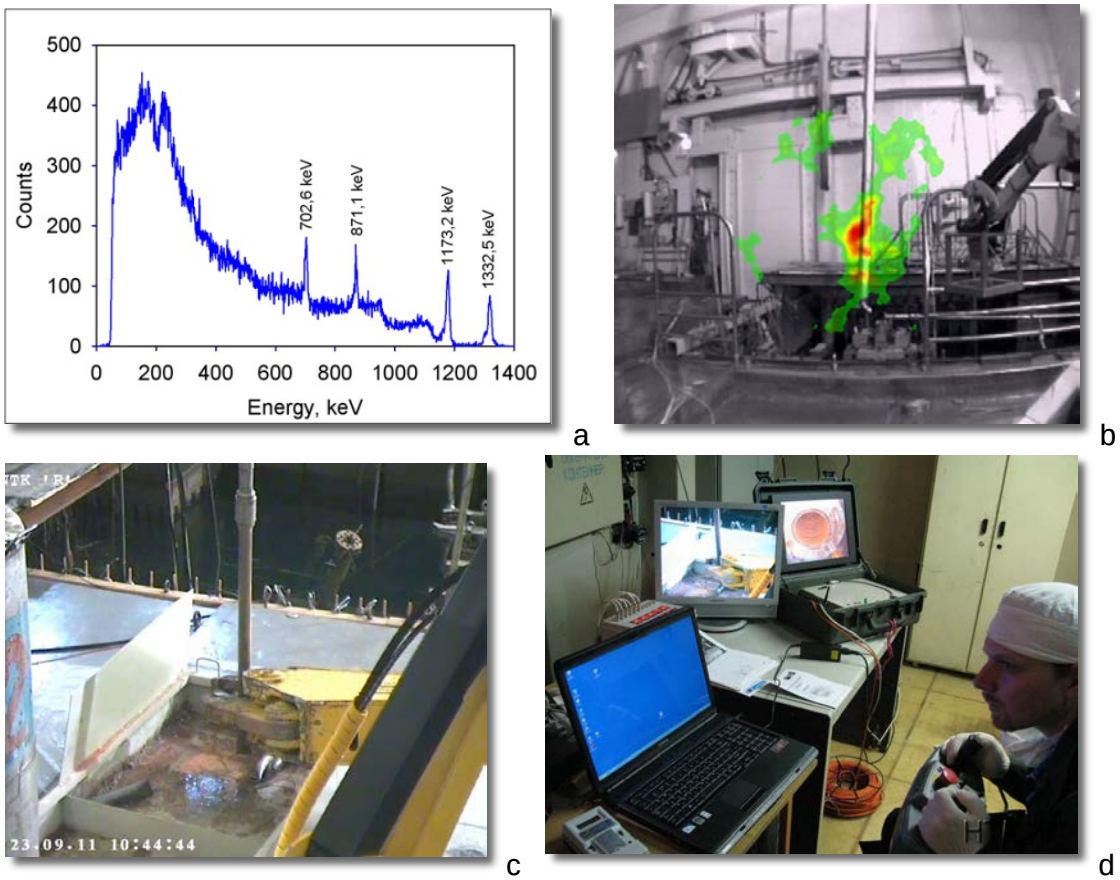


Fig. 16. Gamma spectra of highly contaminated part of element (detector CdZnTe)– a, gamma-ray image of element -b, view of element cutting by remote controlled machine – c, work of operator of remote controlled machine – d.

Completed analysis allowed to select of the most optimal scheme of cutting and packaging of the loop channel's elements depending on the activity.

CONCLUSIONS

- Application of remote-controlled systems for handling of contaminated components and devices for remote measurements has significantly reduced radiation doses for personal;
- The application of imaging and remote sensing technologies in decontamination & decommissioning of research reactor with a lot of undescribed elements (result of unprepared reactor shutdown at the beginning of the 90s) resulted in effective works on the project;
- Presented equipment for remote measurements can be used widely in the projects for decommissioning of shutdown reactors and reactor facilities, in elimination of emergencies on nuclear objects.

ACKNOWLEDGEMENTS

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