ADVANCED CA TECHNOLOGIES AND REMOTELY CONTROLLED MANIPULATORS USED FOR THE DECONTAMINATION OF THE A-1 NPP JASLOVSKÉ BOHUNICE, SLOVAK REPUBLIC

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Abstract. This paper deals with the main activities and results of the Nuclear Power Plants Research Institute (VÚJE) Trnava in the fields of development of remotely operated manipulators and robots for decontamination and dismantling. D&D of the Active Water Purifying Station (AWPS) of A-1 NPP Jaslovské Bohunice was chosen as a pilot project for the application of advanced CA technologies and manipulators for D&D tasks.

The presence of radioactive, toxic or hazardous materials limits personnel access to facilities. Very often there are not enough up-to-date drawings of the installed technology. Therefore, in preparation phase of decontamination, a 3D Laser scanner and software 3Dipsos were involved as modelling technology and civil construction of the facility. Examples of acquired data and created 3D models are presented.

Many D&D tasks have to be performed remotely. This paper describes the main features of developed remotely controlled manipulators. A movable manipulator MT–15 is dedicated for recognition and analysing tasks in hostile environment. A general purpose manipulator MT–80 is used for heavy duties in D&D. A long reach manipulator DENAR-41 was developed for the decontamination of underground waste storage tanks.

Mock up tests of the afore-mentioned manipulators were performed before they were used in D&D tasks. Moreover the software EUCLID and IGRIP are used for simulation, analysing and optimisation of decontamination or dismantling tasks. This procedure leads to safe and more effective realisation of decontamination and dismantling tasks. The obtained results are also used for future development of suitable manipulators.

The description of the initial and present state of contamination and radiation level in AWPS is presented in this paper. Experience with utilisation of advanced CA technology for acquiring as built models, development of manipulators and simulation of D&D tasks are described.

INTRODUCTION

At present there are 6 NPP units in operation in the Slovak Republic (1st and 2nd unit of V-1 NPP, 1st and 2nd unit of V-2 NPP and 1st and 2nd unit of Mochovce NPP), 2 units are under a temporary construction stop (3rd and 4th unit of Mochovce NPP). All these reactors are of Russian design WWER-440, type V-230 and V-213.

The unit of the A-1 NPP (reactor cooled by CO_2, moderated by heavy water and using as a fuel natural uranium) is in the process of decommissioning. The nuclear power plant A-1 was in operation from 1972 to 1977 and was finally shutdown after an accident (level 4 according to the International Nuclear Event Scale). The reactor unit of the A-1 NPP is in the preparation stage for decommissioning of its components. All the spent fuel from the A-1 NPP was transported to Russia. The part of the turbine building is used for processing and storage of radioactive waste. Liquid radioactive waste, except water in the spent fuel pool, was reprocessed and some intermediate radioactive waste from the main production unit was partially treated [2].

VÚJE Trnava, Inc. has been chosen as a main counterpart for the A-1 NPP Decommissioning Project. The main goal of the project is to obtain radiologically safe status. The project should give the

complex solution of problems related to NPP decommissioning, mainly in Slovakia, but also for other European NPPs with WWER reactors.

The presence of radioactive, toxic or hazardous materials limits personnel access to facilities and, therefore, it is necessary to use advanced CA and remote technologies for decontamination and dismantling [3,4].

General-purpose manipulators as well as manipulators for spatial tasks were developed for decontamination purposes. The software EUCLID is used for 3D modeling of facilities and remotely operated robotic systems. In addition it is used for 3D simulation of operations of robots during decontamination and dismantling. The software IGRIP is involved in improveing a simulation result. The 3D SOISIC scanner and software 3Dipsos is used for acquiring a real state of civil constructions and equipment in the A-1 NPP.

D&D of the Active Water Purifying Station of the A-1 NPP Jaslovské Bohunice was chosen as a pilot project for application and verification of advanced CA technologies and manipulators for D&D tasks.

ACTIVE WATER PURIFYING STATION

The Active Water Purification Station (AWPS) was used for purification of waste water and water from the special canalization system of the reactor's building of NPP A-1. The AWPS consists of a building, where the main equipment for receiving and treating waste water is placed and where the system of underground storage tanks is situated. Some equipment is still in operation after its reconstruction, i.e. evaporator, appropriate technological parts and tanks. Other parts of the equipment is out of operation after its incorrect use in the past. This equipment and the rooms where they are placed are generally very highly contaminated and it is necessary to decontaminate and dismantle them. The decontamination of underground storage tanks is the most urgent, because they are in direct vicinity of the environment and after several years of use their integrity could be broken.

The neutralisation tank of ion-exchangers, decontamination solutions and their pump tank constitutes the main equipment, which must be decontaminated and dismantled. This equipment is installed in the rooms No. 7 and 5, which are placed on the level – 8 m. The related pipe line, pumps and control valves are placed in adjacent rooms on the same level. Due to previous incorrect usage, this equipment is now out of operation. The significant amount of ion-exchanger and sludge which has remained in the tanks represents an important source of radiation in these rooms. Furthermore, there is a high level of contamination on the surface of this equipment and the walls of rooms where it is placed. The floors of these rooms are covered with sludge/dust contaminated with a very high level of α nuclides. Considerable sources of radiation are additional things, which were deposited in these rooms after their shut down. The insulation of the tanks is damaged and pipelines and control valves are highly corroded representing additional sources of radiation (see Fig. No.1). The level of radiation changes from 10 to 100 Gy/h and the surface contamination ranges from 600 $Bq.cm^{-2}$ to 950$Bq.cm^{-2}$.

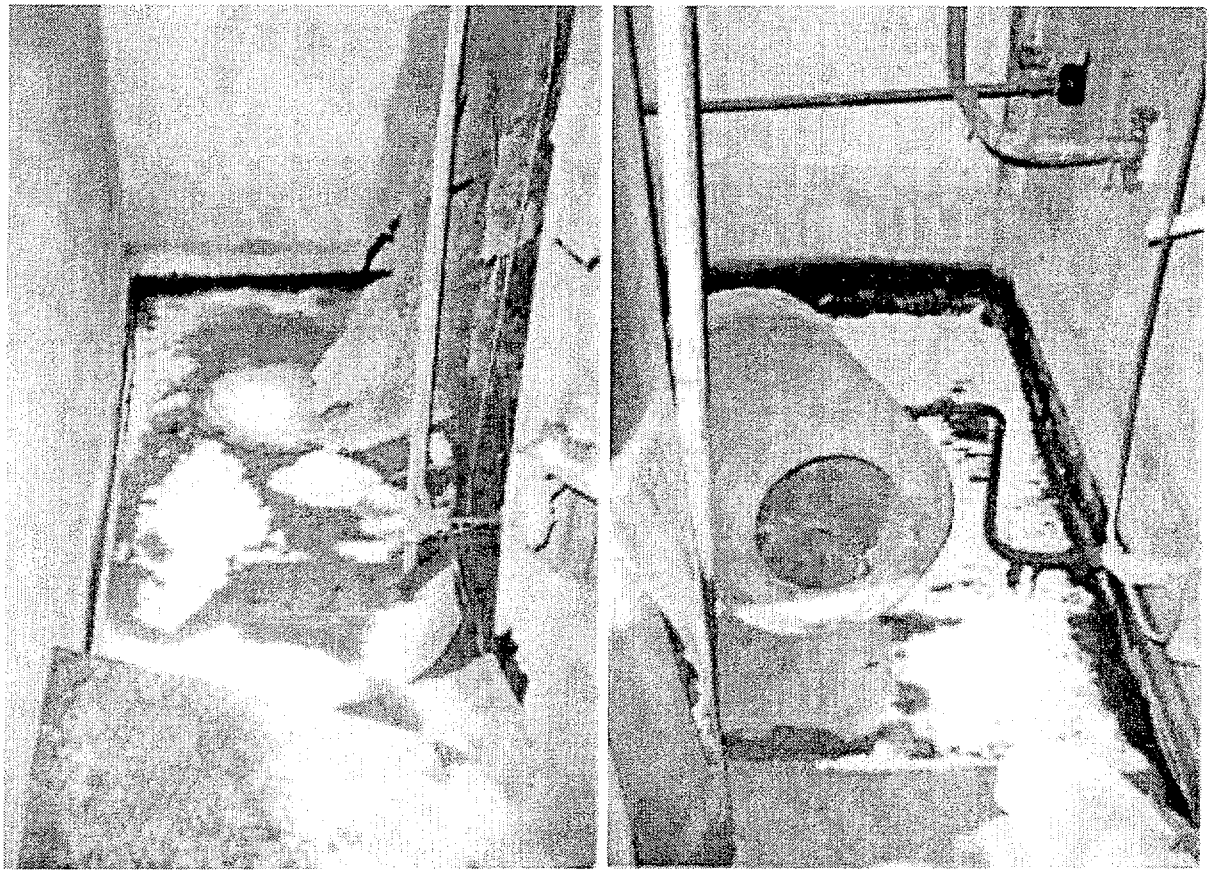

Fig. No.1 Initial state of the room No. 7 – Neutralisation tank.

The underground storage tank system is placed next to the AWPS building. It consists of 15 separate underground tanks. They collect different kinds of liquid waste from the reactor building of the A-1 NPP. The diameter of the tanks ranges from 6 m to 16 m. They are made of concrete with a special surface covering PESL (polyester glass reinforced laminate).

Generally, after several years of operation, there is a layer of sludge on the bottom of each tank and a separate layer of water. Often, there are different pieces of waste such as polyester foil, gloves and even more small flasks dropped in to tanks. In the inspection chambers there is also a lot of different wastes such as ledders, hoses, pumps etc. (See fig. No 2). All these pieces represent sources of contamination and therefore it is necessary retrieve them.

The level of radiation in the tanks changes from 0.5 up to 10 Gy/h. It is presumed that the covering of the tanks is damaged and there is a risk that liquid radioactive waste could leak into the environment. Therefore, it is necessary to pump out the liquid waste to the safe and/or decontaminated tanks and check their integrity.

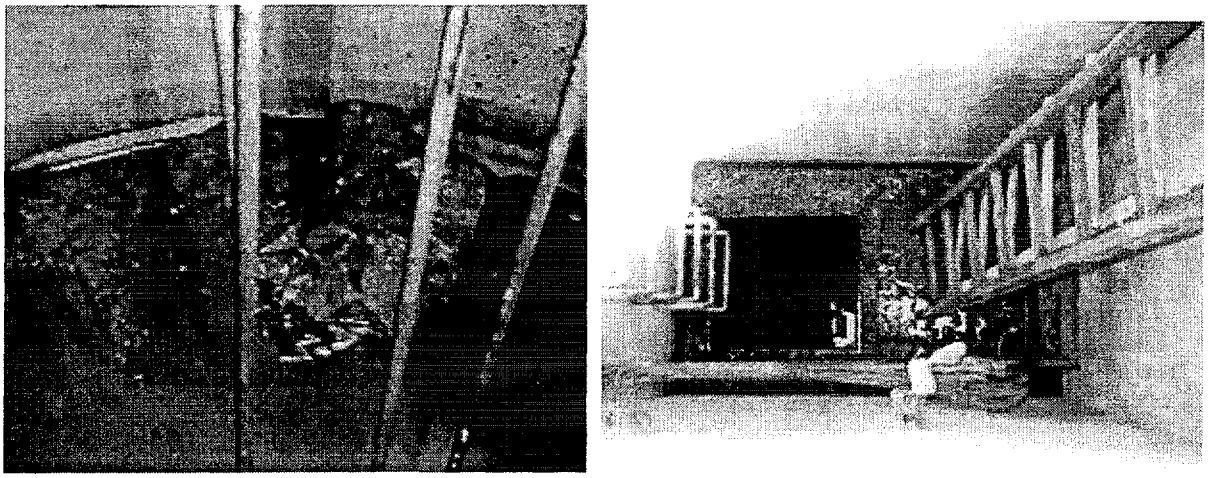

Fig. No. 2 Initial state of the underground storage tanks.

The release of AWPS represents typical problems of D&D tasks:

- withdrawing of different parts of contaminated materials,
- dismantling of different parts of technology,
- pumping out and treatment of liquid radioactive waste,
- decontamination of storage tanks, and
- decontamination of different kind of surfaces.

The level of contamination and the extent of decontamination are rather mediate and this is the reason why D&D of the AWPS was chosen as a pilot project for testing advanced remotely operated manipulators and CA technologies.

DESCRIPTION OF ADVANCED CA TECHNOLOGIES USED IN THE D&D OF THE AWPS

Modelling of the facility ('as-built')

Knowledge of the physical configuration and contamination levels within the facilities is required for work planning, ALARA planning, cost estimates and workers' training for safe decontamination and dismantling. Drawings of the installed technology in the AWPS are not complete. Manual characterisation is difficult and time consuming. Advanced CA technologies are used for 3D modeling of the facility before planning the decontamination procedures.

A 3D laser SOISIC and the software 3Dipsos are used to ascertain the real state of civil construction and equipment in the AWPS. The SOISIC system uses a low-power laser beam, which is deflected by a scanning mirror to sweep across a given scene. A CCD camera detects the spot of the laser beam on the surface of the object. 3D coordinates are computed by triangulation at a rate of 100 discrete points per second. All measured points are transferred to the software 3Dipsos, which runs on a silicon graphics workstation. A consolidation procedure brings the 3D coordinates from different points of view to a common frame. After that, geometrical primitives (cylinders, cones, bends, planes, etc.) are fitted to operator-chosen groups of points using least squares adjustment algorithm. Finally, a 3D model of 'as-built' is obtained [5] (see Fig. 3). 'As-built' modeling is useful for updating the drawings of a facility.

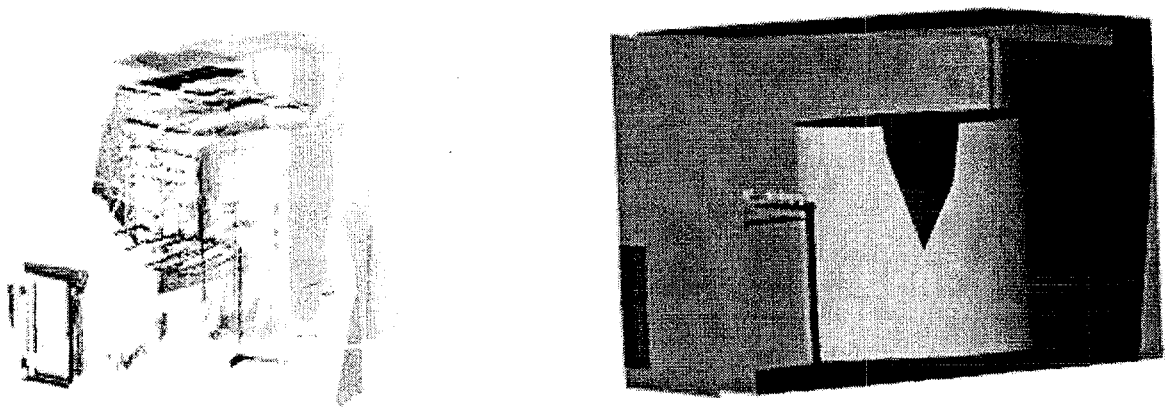

Fig. No. 3 Cloud of acquired points and created 3D model of as-built equipment of neutralization tank.

3D modeling of a facility and simulation of a decontamination procedure

Once there are sufficient updated drawings, EUCLID is used for 3D modeling of the AWPS. If there are no drawings available, they will be produced in the above mentioned procedure. In this case the 3D models are transferred from 3Dipsos to EUCLID. EUCLID is capable of generating enables the generate 2D drawings and providing input for the database of facilities, which serves as a source of verified data for the preparation of D&D tasks.

EUCLID is also employed for the simulation of decontamination and dismantling performed by manipulators. Simulations are useful to optimize the manipulators' movements and to plan the decontamination procedures. Operators can find out how to maneuver manipulators to perform a given task (see Fig 4). With the help of EUCLID collisions between the manipulators and the equipment can be avoided. Simulation of manipulators' operations is also used to find the best location of the manipulators to carry out the decontamination and dismantling tasks in the most manner. Results of the simulations are used for the optimization of robot kinematics and their future development. In addition, IGRIP (Interactive Graphics Robot Instruction Program) from Delmia Corporation (formerly DENEB Robotics, Inc.) is used to cover all necessary aspects in development, programming, analyzing and simulating of robotic systems for the D&D of the AWPS (see Fig. 5).

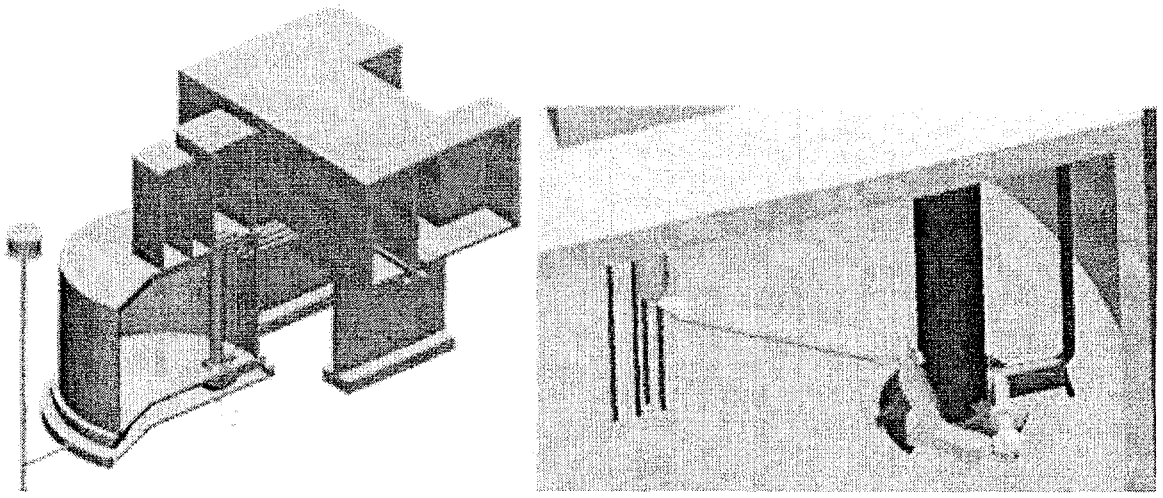

Fig. No. 4 3D modeling of underground waste storage tanks of the AWPS and simulation of dismantling task in software EUCLID.

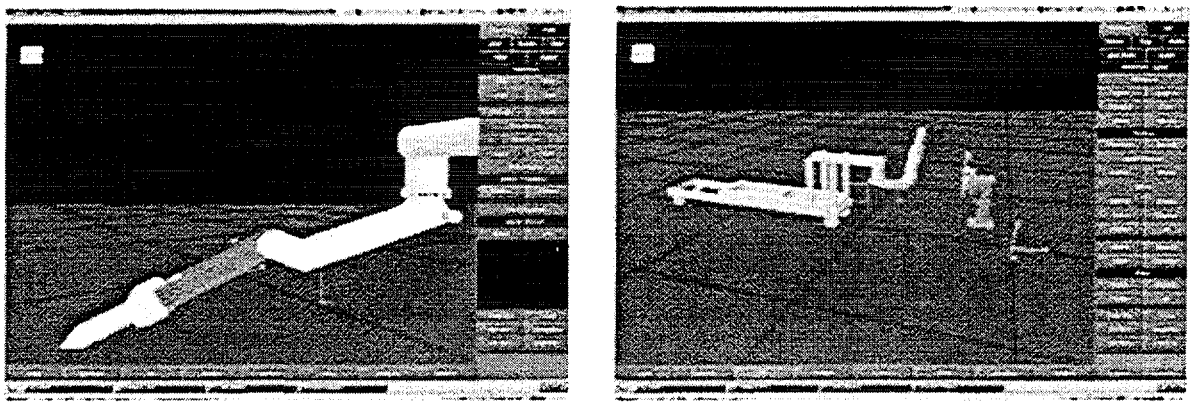

Fig. No. 5 Kinematics analyses of manipulator MT-80 in software IGRIP.

REMOTELY OPERATED MANIPULATORS USED IN THE D&D OF THE AWPS

As described above the presence of radioactive material and level of radiation limit access of personnel to the underground storage tanks and rooms of the AWPS. Therefore it is necessary to use remotely operated manipulators and robots for decontamination and decommissioning. VÚJE developed several different remotely operated manipulators and robots for decontamination and dismantling tasks [6].

The manipulator MT-15 is used in hostile and radioactive environments to recognize and analyse tasks, pick up radioactive samples, measure the contamination level and rate of radiation. MT-15 consists of a remotely controlled vehicle, which carries a manipulator and working unit. The vehicle has four separate cleated tracks, which can be tilted. The manipulator arm has 5 degrees of freedom.

The general-purpose manipulator MT-80 was developed for decontamination and dismantling tasks. The MT-80 is a hydraulic arm with 5 degrees of freedom and 1.8 m reach. It is made of special titan-dural alloy and the payload of the manipulator is 80 kg. A control unit allows laborious repeated tasks to be programmed, which are often used in decontamination or dismantling. The wrist of the manipulator can be equipped with any decontamination tools necessary.

One of the main priorities in the AWPS decommissioning is the decontamination of the underground storage tanks. For that purpose a special manipulator, DENAR-41, was developed. It is a long-reach hydraulic arm with a vertical bearing structure, which is placed over the storage tank. The main difficulties in the development of DENAR-41 were the large diameter of the storage tanks (up to diameter ∅ 16 m) and the small dimension of the hole in the inspection chamber (540 x 540 mm) through which the manipulator reaches into the tanks. DENAR-41 can also hold and manoeuvre the manipulator MT-80 or tools that are required to assist in waste retrieval.

Design and manufacture of manipulators were done. Initial mock-up testing was performed at the beginning of 2001 (see Fig. No. 7). At the time this paper was submitted, the manipulators are being used for their purpose in the active environment of AWPS.

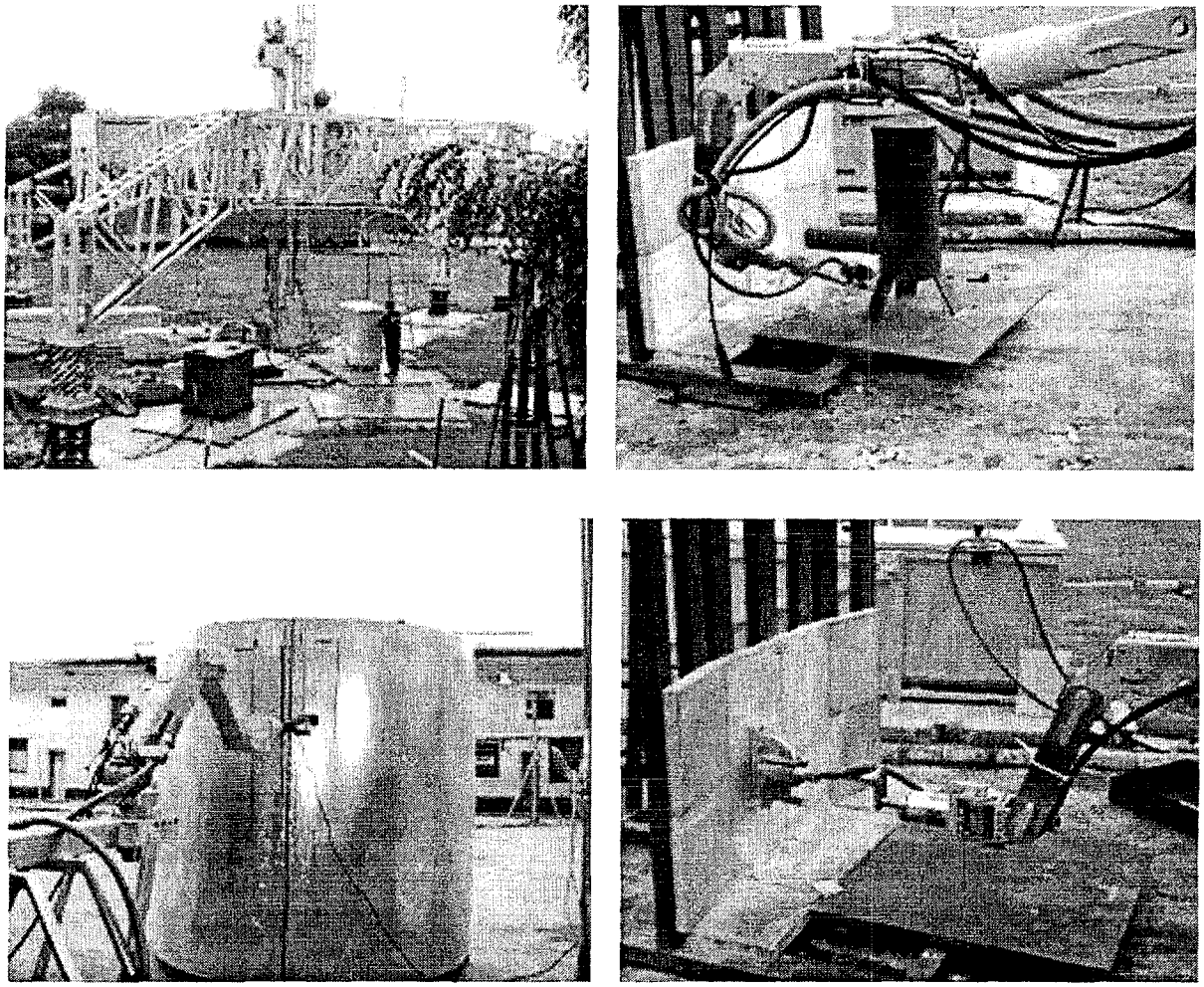

Fig. No. 7 Mock up testing of manipulators DENAR-41, MT-80 and developed decontamination tools.

RESULTS OBTAINED

Up to the present time the containment and all the necessary equipment (automatic ventilation system, decontamination and fragmentation tools and radiation level measurement tools) for decontamination of the room of neutralisation tanks (room No. 7) were installed. Things deposited like hoses, drums, flasks and small sources of radiation were withdrawn and treated in the existing waste treatment centre in the NPP Jaslovské Bohunice or deposited in safe conditions. All unnecessary armatures of the neutralisation tank were dismantled. The dry sludge from the floor of the room was vacuumed and treated. After these steps, the radiation situation was much improved (see Fig. No. 8). The mock-up tests of the manipulators MT-15 and MT-80 were performed. It is planned that they will be used for the dismantling of the insulation of the neutralisation tank and for cutting the pipelines in the room No. 7. It is planned that by the end of 2002 the neutralisation tank and room No 7 should be decontaminated. According to the result of the decontamination, it will be decided whether the neutralisation tank will be dismantled or will be reused.

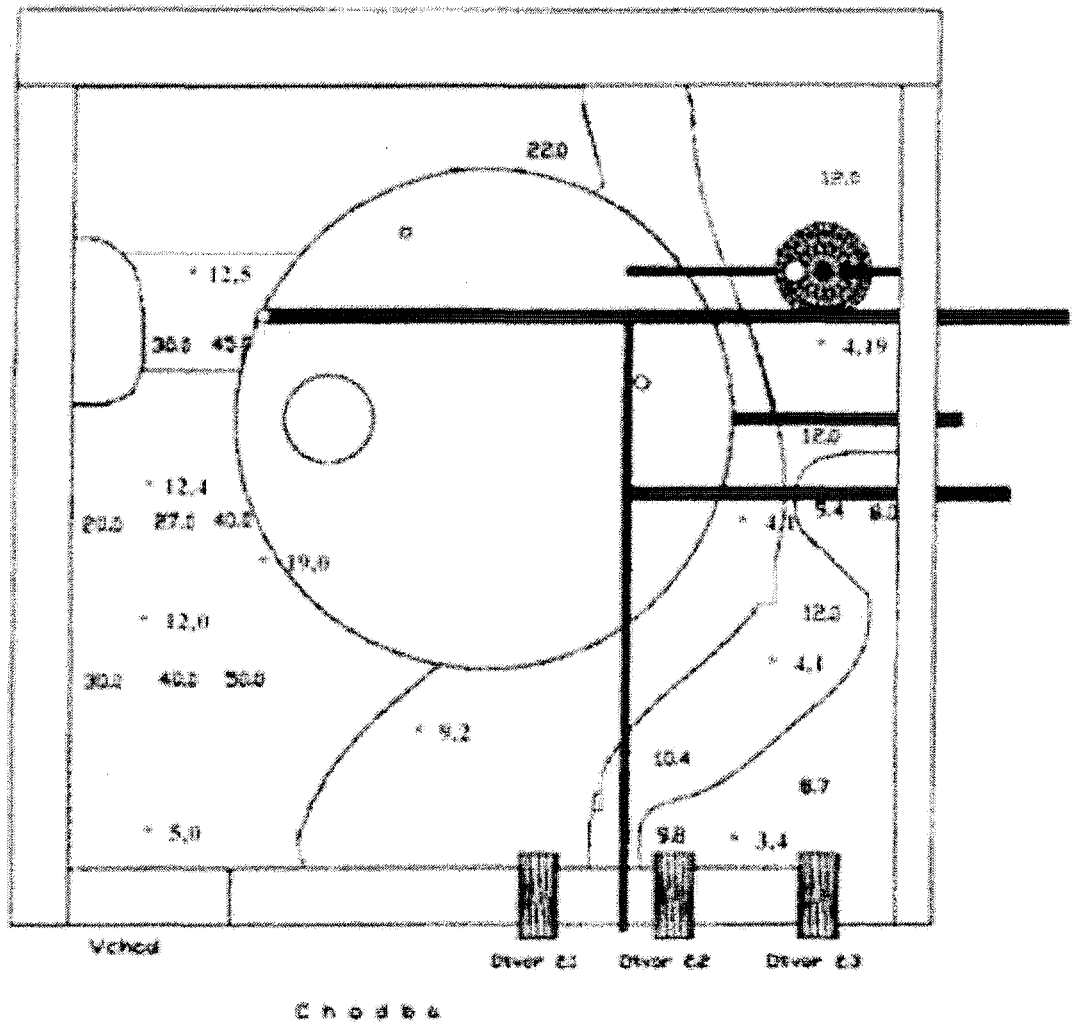

Fig. No. 8 Radiation situation in the room of neutralisation tank of AWPS

(room No. 7) before and after realised decontamination steps. Values represent the level of radiation in mGy/h (values marked by * represent obtained results after mentioned decontamination steps).

Up to the submission of this paper the containment and all the necessary equipment (automatic ventilation system, decontamination and fragmentation tools, radiation level measurement tools and manipulator DENAR-41) for decontamination of the underground storage tanks (tank No. 6/1) were installed. Things deposited like hoses, ledders, flasks and small sources of radiation were withdrawn from the inspection chambers of the tank. The surfaces of the inspection chambers were decontaminated by a high water jet. All unnecessary armatures of the tank were dismantled. After these steps the radiation situation in inspection chambers was much improved. The level of radiation decreased from 2mGy/h to 0.15 mGy/h. The mock-up tests of the manipulators DENAR-41 and MT-80 were performed in the beginning of 2001. It is planned that the manipulators will be used for cutting pipes inside the tanks, cutting the surface of tanks (thin surface of PESL - polyester glass reinforced laminate) and decontaminating their surfaces (by high water jet). It is supposed that by the end of 2002 several underground storage tanks with similar geometry and level of contamination (tanks No. 6/1, 6/2, 3/1, 3/2) would be decontaminated. According to the results of the decontamination it will be decided whether the tanks will be dismantled or will be reconstructed and reused.

CONCLUSION

The D&D of the nuclear installation is a challenging task from many points of view. One of them is the necessity of using advanced technologies. The remotely operated manipulators, software and hardware presented, should significantly contribute to the safe and low cost decontamination, dismantling and decommissioning of NPP A-1 Jaslovské Bohunice, as well as the other NPPs. A substantial reduction of occupational doses and environmental impact can be also expected. The most important revenue is the experience that the people involved in decontamination of AWPS have gained. The experience and data obtained from this pilot project will be utilized in the overall decommissioning project of A1-NPP as well as other NPPs in the future. The obtained results from the decontamination of the AWPS encourage us in using advanced CA technologies and remotely operated manipulators in D&D tasks. The acquisition of the 'as-built' state of the site and the simulation of decontamination and dismantling tasks by the computer tools described are recognized as being useful and effective. This procedure leads to a safer implementation of decontamination and dismantling tasks.

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