MOBILE ROBOTICS APPLICATION IN THE NUCLEAR INDUSTRY

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ABSTRACT

Mobile robots have been developed to perform hazardous operations in place of human workers. Applications include nuclear plant inspection/maintenance, decontamination and decommissioning, police/military explosive ordnance disposal (EOD), hostage/terrorist negotiations and fire fighting. Nuclear facilities have proven that robotic applications can be cost-effective solutions to reducing personnel exposure and plant downtime.

The first applications of mobile robots in the nuclear industry began in the early 1980's, with the first vehicles being one of a kind machines or adaptations of commercial EOD robots. These activities included efforts by numerous commercial companies, the U.S. Nuclear Regulatory Commission, EPRI, and several national laboratories. Some of these efforts were driven by the recovery and cleanup activities at TMI which demonstrated the potential and need for a remote means of performing surveillance and maintenance tasks in nuclear plants. The use of these machines is now becoming commonplace in nuclear facilities throughout the world. The hardware maturity and the confidence of the users has progressed to the point where the applications of mobile robots is no longer considered a novelty.

These machines are being used in applications where the result is to help achieve more agressive goals for personnel radiation exposure and plant availability, perform tasks more efficiently, and allow plant operators to retrieve information from areas previously considered inaccessible. Typical examples include surveillance in high radiation areas (during operation and outage activities), radiation surveys, waste handling, and decontamination evolutions.

This paper will discuss this evolution including specific applications experiences, examples of currently available technology, and the benefits derived from the use of mobile robotic vehicles in commercial nuclear power facilities.

BACKGROUND

The first significant efforts to introduce mobile robotics to the U.S. commercial nuclear industry began in the early 1980's. One of the earliest efforts was to develop a surveillance and sampling vehicle to work in the accident affected areas at Three Mile Island. The radiological conditions in these areas necessitated that an unmanned method be investigated. This work demonstrated that a remote system could be utilized in a commercial nuclear facility to access areas where personnel entry was undesirable or impossible.[1] It was also recognized that there were much broader benefits to be recognized in routine applications of these machines.

Programs sponsored by the Nuclear Regulatory Commission (NRC), the Electric Power Research Institute (EPRI), and the Department of Energy (DOE) along with private efforts led to the development of several systems which are currently used in nuclear facilities to lower exposure to plant workers. The initial programs were focused primarily on surveillance machines such as the SURVEYOR,[2] developed by ARD, Inc. under EPRI sponsorship (Figure 1) and SURBOT®,[3] developed by REMOTEC, Inc. and sponsored by the NRC (Figure 2). Development has continued on vehicles of this type with dozens of these machines now in use with current applications encompassing video and audio surveillance, radiation and contamination measurements, decontamination tasks, pipe inspection, and waste handling. The following paragraphs will give specific examples of some of these tasks and their benefits.

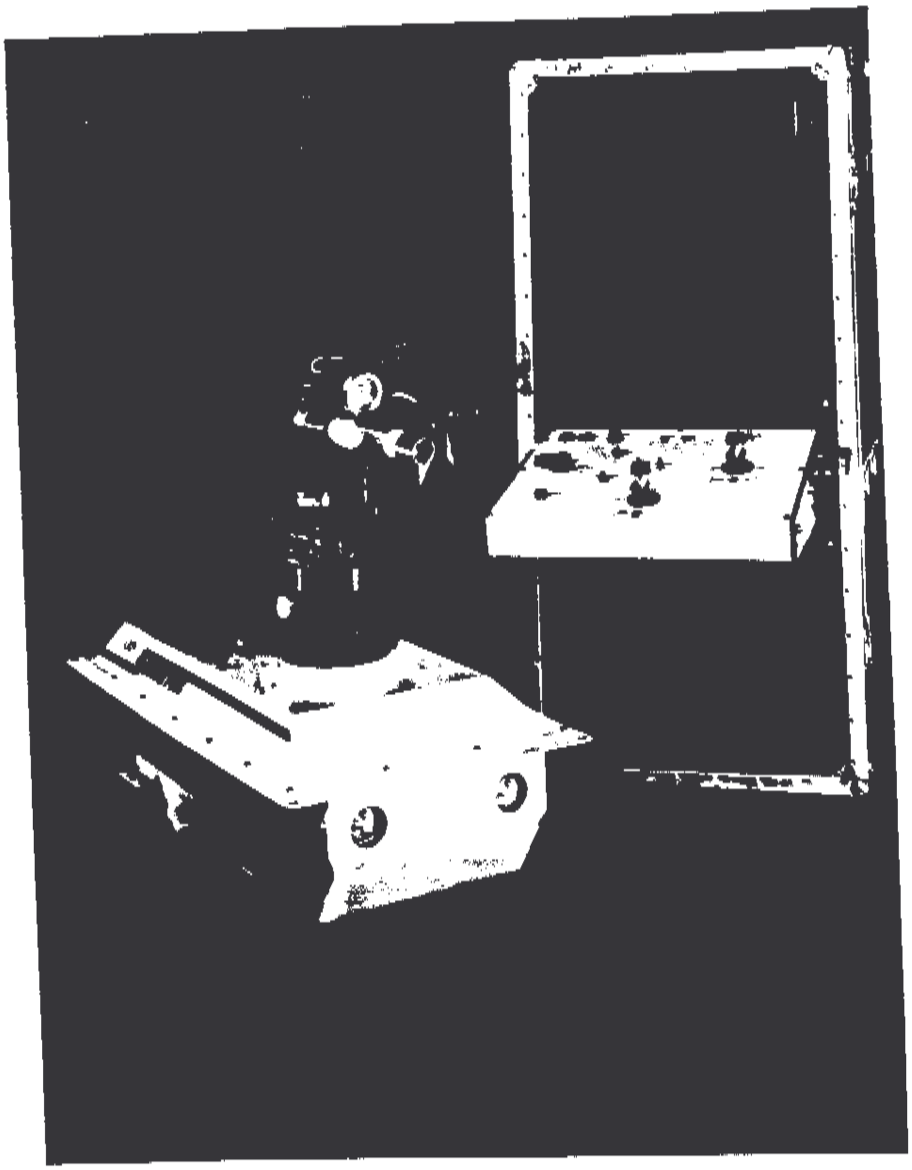

Figure 1. Surveyor.

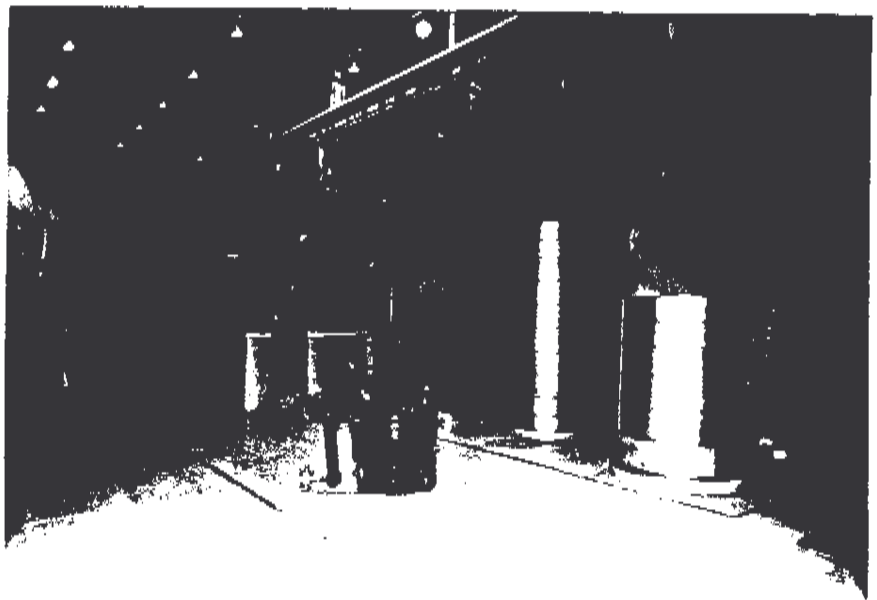

Figure 2. SURBOT® Performs an Inspection During Testing at Brown's Ferry.

RADWASTE TANK FLOW EDUCTOR CLEANOUT

At Pennsylvania Power and Light's Susquehanna Nuclear Plant, a mobile vehicle is used to cleanout plugged flow mixing eductors inside radwaste processing tanks.[4] These tanks include Reactor Water Cleanup (RWCU) resin phase separator and waste sludge phase separator tanks. The vehicle manipulates a flexible hydroblasting nozzle into the nozzle openings thus eliminating the need for human entry. Previous task completion had required human entry into the tank with the accompanying hazards of radiation exposure, confined space entry, and high-pressure fluid use. The completion of the task remotely resulted in significant radiation exposure savings.

The Susquehanna radwaste processing system includes two RWCU phase separator and one waste sludge phase separator tanks. A typical tank configuration is shown in Figure 3. A system of eductor nozzles and associated piping is used to provide mixing in the tanks. The mixture pumped through the nozzles is a dense resin/water slurry and the venturi section of the nozzles tend to plug during processing.

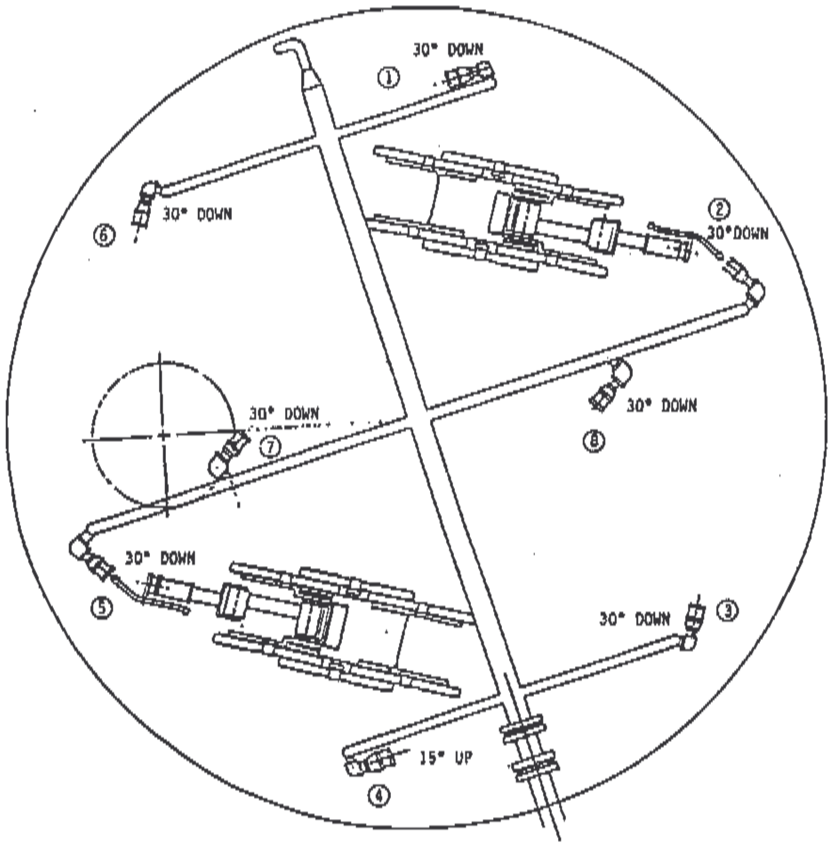

Figure 3. Typical Tank Configuration.

Located in shielded rooms within the plant, the typical radiation levels inside the tanks are 30-50 mSv/hr (3-5 R/hr) with accompanying high contamination levels. Previously, the method for clearing of the nozzles had been for a worker to enter the tank via a manway and manually insert a hydrolaser into each nozzle, one at a time. Water pressure would then be applied to clear the obstruction. Due to high radiation levels in the tank, the worker was limited to only a few minutes of stay time in the tank. This typically resulted in several entries being needed to complete the work. The significant radiation exposure and concern for worker safety in the tank led the utility to investigate alternate means for completing this task. A mobile robot was developed and used to clear the clogged nozzles. This task has been repeated on several occasions and the exposure savings alone have justified the equipment acquisitions and personnel safety has been enhanced by eliminating the confined space entry. An average of 30 mSv (3 Rem) exposure was received during manual cleaning of the tanks. This has been reduced to 4 mSv (400 mrem) on average. Additionally, the robotic vehicle is also used for other operations in high radiation areas of the plant.

ROUTINE SURVEILLANCE IN BWR STEAM CYCLE

The steam cycle operating areas of BWR's have high gamma dose rates due to the presence of N-16. These areas occasionally require entry for tasks such as equipment surveillance, corrective maintenance, and other essential tasks. In addition to exposure concerns, many of these areas typically have elevated temperature and humidity levels further restricting personnel entry.

Several stations, including Brown's Ferry, Hope Creek, LaSalle, Perry, and Pilgrim are utilizing mobile vehicles to perform entries into these areas.[5] Figure 4 shows a machine being used at Hope Creek to perform a typical surveillance task. The typical machine can perform visual and audio surveillance, radiation and contamination measurements, monitor temperature and humidity, and record the information on videotape for record keeping. Additionally, as the operator is located outside the affected area, the tasks can be performed without the time constraints caused by the environmental conditions which can contribute to a more thorough completion of the task. The savings vary according to the plant conditions and the application, with average savings exceeding 100 mSv (10 Rem) annually.[6]

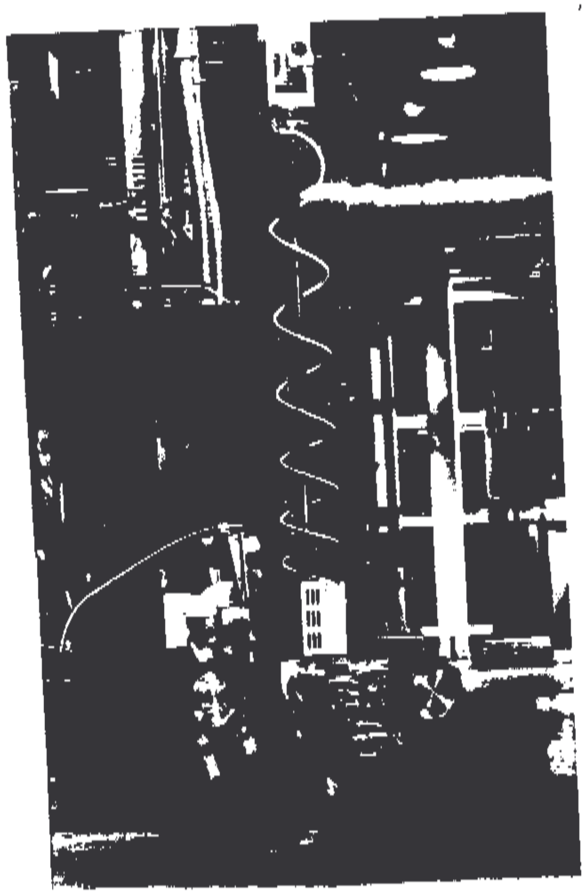

Figure 4. A Mobile Vehicle in Use at Hope Creek.

CONTAINMENT ENTRY AND SURVEILLANCE IN OPERATING PWR'S

This design of a PWR typically utilizes a large concrete structure called the containment building to house the reactor and supporting components such as the steam generators, reactor coolant pumps, and coolant piping. Inside the containment, these components are further segregated inside concrete rooms or partitions. This allows personnel to access the containment building when the reactor is operating, but access into most of the rooms is limited or not allowed due to high radiation levels.

Occasionally during plant operations, access to these areas is needed to monitor plant components. Many times this has required that the plant reduce power or shutdown to lower radiation levels and allow entry. This results in a loss of plant availability to generate electricity and loss of revenue. A method to allow entry into these areas without power reduction will save personnel exposure, improve access to plant information, and improve efficiency. Remote vehicles are being used to perform these and other tasks at several PWR stations including Comanche Peak, Indian Point 2, Palo Verde, South Texas Project, and Vogtle.

DECONTAMINATION TASKS

Several utilities have also used their machines to perform decontamination tasks throughout the plants. The type of machines used vary from specialty underwater vacuuming robots to general purpose machines equipped with task specific end effectors. The typical tasks the machines are used for are not routine plant decontamination work, but are instead located in areas with high dose rates and contamination levels.

In PWR's, remote vehicles are routinely used to vacuum the reactor cavity areas during refueling operations. The machine operates submerged in conjunction with an underwater vacuum and filters to remove activity from the floor prior to draindown for reactor vessel reassembly. This allows for a more thorough cleaning of the floor and is much less labor intensive than manual methods.

Recently, some plants have begun to use these vehicles to enter and decontaminate areas where entries have not been made for several years due to very high dose rates and contamination levels. In one case, a utility used a mobile robot to enter a resin storage tank room where dose rates ranged up to 600 mSv/hr (60 R/hr) with spent resin up to 18 cm. (6 in.) deep on the floor. The machine was used to vacuum the material up to a collection device and perform all post decontamination radiological surveys of the room. The application of a strippable coating with the machine had been tested in mockup, but was deemed unnecessary after vacuuming resulted in acceptable levels of contamination. The machine also performed a complete visual surveillance of the room including the tops of the tanks.

SUMMARY

The use of mobile vehicles in nuclear power plants for exposure reduction and plant availability improvement is commonplace. As the operators gain experience, the applications and savings continue to grow and provide additional benefits to the users. This widespread use has enhanced the maturity of the technology and provided the economies of scale to assist the ALARA professional in the justification process. The growth of this industry outside the commercial nuclear environment also is providing technological advances and product improvements which will have a dramatic effect on the potential savings associated with this technology.

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Authors' Biographies

John R. White is the President and founder of REMOTEC, Inc., a world leader in remote technology and robotic vehicles. He has over 30 years of experience in remote operations in hot cells, fuel reprocessing, power reactors, and other hazardous environments. The holder of numerous patents and trademarks, Mr. White is recognized around the world as one of the leading experts in the field of robotics and remote systems.

Sammy L. Jones is presently Field Projects Manager for REMOTEC, Inc. of Oak Ridge, Tennessee. A former radiological engineer in a commercial nuclear station, Mr. Jones is responsible for the applications and design of remote systems to expand their use in nuclear and other hazardous areas. Mr. Jones's background includes positions in both commercial PWR and BWR facilities in a variety of areas including ALARA, outage planning, and field operations.

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DISCUSSION

Khan: At the time of Chernobyl, a lot of the robotics that went there got stuck in high-radiation areas. Their batteries ran out, etc. Have there been any significant developments since that period? Have robotics come a long way since then?

Jones: The primary problems they had at Chernobyl were terrain problems in reaching the accident scene and problems with the control systems of the machines which were microprocessor controlled, machines similar to ours. That is one of the reasons that DOE is sponsoring some radiation hardening research for mobile vehicles. This research is a big emphasis now, to rad harden the electronics. The machines are either electric or hydraulic, so these components are fairly rad tolerant, and the technology is very easily adaptable. There is a lot of work being performed in the microprocessor area. Some of it is a spinoff from work on space-based systems for NASA. JPL, Sandia, and Lawrence Livermore have done a lot of work in this area.