DECOMMISSIONING ALARA PROGRAMS CINTICHEM DECOMMISSIONING EXPERIENCE

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ABSTRACT

The Cintichem facility, originally the Union Carbide Nuclear Company (UCNC) Research Center, consisted primarily of a 5MW pool type reactor linked via a four-foot-wide by twelve-foot-deep water-filled canal to a bank of five adjacent hot cells.

Shortly after going into operations in the early 1960s, the facility's operations expanded to provide various reactor-based products and services to a multitude of research, production, medical, and education groups.

From 1968 through 1972, the facility developed a process of separating isotopes from mixed fission products generated by irradiating enriched Uranium target capsules. By the late 1970s, 20 to 30 capsules were being processed weekly, with about 200,000 curies being produced per week. Several isotopes such as Mo^{99}, I^{131}, and XE^{133} were being extracted for medical use.

As an expected consequence of this production, the hot cells became contaminated with mixed fission products. In addition to activation products formed in the reactor core structure and biological shield, mixed fission products were also generated in the reactor primary cooling system due to cross contamination from the hot cells and tramp Uranium in the coolant system.

Early in 1990, a decision was made to decommission the facility for unrestricted release after various underground radioactive leaks were discovered in the reactor hold-up tank, transfer canal, and hot cell exhaust system.

Cintichem has been actively decontaminating and dismantling the facility since early 1992, after 1½ years of preparatory work. As of November 1993, about 75% of the physical decommissioning work had been completed, with over 99.9% of the radioactivity (about 4,200 curies) removed. This has been accomplished with about 190,000 person-hours of hands-on management labor, and 138 person-Rem of radiation exposure. At completion of the decommissioning project it is expected that 140,000 cubic feet of radioactive waste will have been generated.

Approximately 50% of the incurred exposure can be attributed to five of the thirty-eight major decommissioning tasks, (i.e., preliminary decontamination of the hot cells and underground exhaust removal) (72 person-Rem), and reactor core structure dismantling and bioshield decontamination activated concrete removal (7 person-Rem). At the onset of this work, radiation dose rates in excess of 1,500 Rem/hr (gamma) and 10,000 Rad/hr (beta) were encountered in the hot cells along with surface contamination levels in excess of 2E9 DPM/100 cm^2 of aged mixed fission products. During the reactor core structure/activated bioshield work, exposure rates up to 1000R/hr were encountered.

Significant dose reductions were accomplished with a new ALARA management program that was set-up for the decommissioning project. ALARA techniques included remote robotic demolition of activated concrete, remote high-pressure washing of the hot cells, and extensive use of shielding in the work areas.

INTRODUCTION

Cintichem received approval to commence full-scale decommissioning of its reactor and hot laboratory facilities in February 1992. Since that time, the nuclear fuel, reactor core structure, activated bioshield concrete, and a majority of piping and components have been dismantled and removed from the reactor facility. In the hot laboratory facilities, the interior of the 5 hot cells have been decontaminated to less than 1 mRem/hour and demolished, the hot cell underground exhaust duct filtration system removed, and most of the transfer canal structure has been removed as well as most of the surrounding contaminated soil. Currently, over 93% of the radioactivity has been removed from the facility, with about 80% of the overall physical decommissioning work completed. Due to the aggressive nature of the Radiation Protection and ALARA programs, the occupational radiation exposure to date has only been 38% of the original estimate in the Decommissioning Plan, while the physical decommissioning workscope has expanded an additional 60%.

PROJECT BACKGROUND

Description of Cintichem Reactor and Hot Laboratory Facility

The Cintichem, Inc., nuclear reactor facility is located within the Town of Tuxedo, in Orange County, New York. The plant site consists of 100 acres of land, owned by Cintichem. It is in an industrial park area known as Sterling Forest, and is about 3-1/4 miles northwest of the village of Tuxedo Park.

There are six principal buildings at the plant site, with only the Reactor Building, the Hot Laboratory Building and the Class A Low Level Radioactive Waste Storage Building included in this decommissioning.

Reactor Building

The reactor building is a 70 x 92 x 57-ft-high reinforced-concrete structure set into an excavation in the side of the adjacent rock mountain. The exposed portions of the walls and roof are reinforced concrete with a minimum thickness of 12 in. and 8 in., respectively. The volume of the reactor building is about 285,000 ft^3.

The nuclear reactor is a pool-type research reactor, and was licensed to operate at thermal power levels up to 5 MW. The reactor is a light-water-moderated, cooled, shielded, and reflected, solid-fuel reactor.

The reactor had a number of experimental facilities including six beam tubes, a thermal column and pneumatic rabbit tubes. The reactor core was suspended by an aluminum tower from a movable bridge, and was immersed in a 49 x 23 x 32-ft-high pool. The pool was divided into two sections, the narrower stall section contained the fixed experimental facilities and the open end of the pool provided storage space for irradiated fuel and experiments. A 4' wide x 12' deep x 108' long canal connected the open pool with the hot cells to permit the transfer of irradiated material between the two facilities.

A hold-up tank (HUT) (30 x 15 x 10 ft) was designed to provide a delay of the pool water in the primary system during normal operation to allow time for decay of short-lived radioisotopes in the coolant before the water entered the pump room. The HUT was an underground concrete enclosure adjacent to the pump room and buried under 30 feet of soil

Hot Laboratory Building

The Hot Laboratory is a concrete structure 225 feet long by 57 feet wide by 37 feet high. It contained five hot cells, each having 4-foot-thick walls of high-density concrete. The internal dimensions of cell 1 were 16 feet wide by 10 feet long by 15 feet in height. This cell was equipped with a Remote Handling Arm, one pair of heavy duty manipulators, and one pair of standard duty manipulators. Internally, cells 2, 3, and 4 were 6 feet wide by 10 feet long by 12.5 feet in height. Cell 5 is 6 feet wide by 10 feet long by 25 feet in height. Cells 2, 3, 4 and 5 were each equipped with a 4-foot thick lead glass shielding window and all cells are equipped with one pair of Master Slave Manipulators. Major access to all the cells was possible through rear doors (7 feet wide by 6 feet high by 4 feet thick). Access to all cells was also possible via roof openings containing removable plugs.

A canal containing water connected Cell 1 with the reactor pool. Radioactive samples, specimens, and isotopes, etc., were transferred through this canal and brought into Cell 1 via a motorized elevator. This canal also contained a wider area known as the gamma pit, with a large CO-60 source for gamma irradiation experiments.

The waste pit area is located at the north end of the hot laboratory building. It consists of 100 shielded individual radioactive waste storage cells. Each cell is 7-1/4 feet deep by 2-1/2 feet in diameter. The cells are arranged in a honeycomb fashion with additional shielding around the outer perimeter. Each cell has a removable shield plug and is internally vented to the hot cell exhaust ventilation filter system.

Radioactive Waste Storage Building

The Radioactive Waste Storage Building is a single-story concrete block building located 500 feet north of Building 2. It is approximately 24 feet x 60 feet and is utilized for storage of Class A waste, mostly 55-gallon drums.

Site History

The Cintichem facility, originally called the Union Carbide Nuclear Company (UCNC) Research Center, was originally designed and constructed to meet the joint needs of the Union Carbide Nuclear and Ore Companies. Planning and Construction of the Cintichem Sterling Forest facility began in 1957. The 5 MW reactor had its initial criticality in 1961.

Total megawatt hours of usage from initial startup to final shutdown on February 9, 1990 is approximately 906,000 MW hours.

During the operating history of the Cintichem reactor, the following operational occurrences took place which would have an impact on decommissioning safety from a radiological standpoint:

> From 1968 through 1972, the facility developed a process of separating isotopes from mixed fission products generated by irradiating 93% enriched Uranium target capsules. By the late 1970s, 20 to 30 capsules were being processed weekly and several isotopes such as Mo-99, I-131, and Xe-133 were being extracted for medical use. Approximately 200,000 curies of mixed fission products were being produced weekly.
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> In the mid 1970s, two events occurred which created a significant level of Ag-108/110m contamination throughout the reactor primary water system. During this period, the B_4C reactor control rods were replaced with AgInCd control rods to eliminate the potential for a stuck rod accident. Activated silver from these new rods began leaching into the pool system.
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> Late in 1989, an underground leak was discovered in the main hot cell bank underground ventilation system. Since this air contained contaminants from the hot cells, mixed fission products were discovered in the soil and ground water. Bedrock has also been affected in the vicinity of this underground duct work.

Early in 1990, it was discovered that primary water leaks existed in the pool systems' hold up tank, canal, and gamma pit facility. Leaks had been discovered and repaired a few years earlier in the hold up tank. As a result of these leaks, radioactive contamination was found to exist in the vicinity of the drainage system below the reactor building, areas immediately outside of the hold up tank, soil outside the hod up tank and pump room, soil outside of the canal and gamma pit structure, the hot lab building footings, and the north wall area of the reactor building.

Following the discovery of these leaks, operation of the facility was shut down and in May 1990 the decision to decommission the facility for unrestricted release was made. In June 1990, TLG Services, Inc. (TLG), a decommissioning services company, was contracted by Cintichem to co-manage the decommissioning project. At that time, Cintichem and TLG began a site-wide radiological characterization program which lasted approximately three months. Concurrently, conceptual planning, engineering, and cost estimates were prepared. In October 1990, the decommissioning plan was submitted to the USNRC and New York State Department of Labor (NYSDOL) requesting approval to start decommissioning. In November 1991 and January 1992, Cintichem received permission to start active decommissioning work from USNRC's NR and NMSS divisions, respectively.

DECOMMISSIONING PROJECT SYNOPSIS

The decommissioning option selected will require the removal of radioactive material to levels specified by the NRC and NYSDOL for free release. After removal of radioactivity, the buildings will be razed and the site backfilled. The currently projected cost for completion of the decommissioning is $72 million. As of February 1994, about 75,000 cubic feet of radioactive waste has been generated, with an estimated additional 52,000 cubic feet yet to be generated for project completion. The schedule for completion of the physical decommissioning work (i.e., to start final surveys) is January 1995.

Cintichem has been removing radioactivity within the reactor, hot lab building, Class A waste building associated contaminated systems exterior to these buildings, and areas immediately adjacent to them. The major decommissioning workscope to date has included the following:

Removal of activated core structure, associated components and activated portions of the biological shield;

Removal of contaminated equipment, components and fixtures;

Decontamination of building structural surfaces;

Removal of contaminated soil under and adjacent to the buildings; and

Removal of contaminated structures and equipment adjacent to and associated with the reactor and hot laboratory buildings.

RADIOLOGICAL CONDITIONS

A detailed site radiological characterization program, including activation analysis, was performed for the building and the immediately surrounding environs. The purpose of this characterization program centered on the need to obtain specific radiological data concerning areas of the plant that may have become internally or externally contaminated or activated during the reactor and hot lab operating history. This data was necessary for detailed decommissioning planning purposes, and determination of effective and appropriate decontamination and dismantling techniques. This data was also needed for planning radioactive material disposal, assessing potential hazards during decommissioning and determining ALARA controls. This characterization effort was started in June of 1990 and was completed in the fall of 1990.

Two principal sources of radioactive materials were present at the facility, activation products in the reactor building and fission products in the hot laboratory building, with a blend of these two sources found in the transfer canal area. At the time of radiological characterization in 1990, contamination was found to exist in one of two mixtures. In the hot lab the principle long-lived radionuclides consisted of Cs-137, Sr-90 and Ce-144. In the reactor facility the principle long-lived radionuclides consisted of Ag-110^m, Co-60, Eu-152/154/155, Cs-134 and Cs-137.

Based upon the initial radiological characterization data, and radiological surveys conducted during D&D work, items listed in Table 1 were found to be the major sources of radioactive material that would cause the majority of radiation exposure during the decommissioning process. This tables lists the principle contaminated structures - equipment, activated components, and subsurface contamination areas (soil, concrete fill and bedrock), and summarizes the radiological characteristics found.

Approximately 4,200 curies of radioactivity was determined to be present. The bulk of this radioactivity, about 3,640 curies, was found in the activated reactor core structure with the remaining 560 curies distributed within the hot cells, equipment, structural surfaces and soil.

EXPOSURE HISTORY EXPERIENCE

Initial Exposure Estimate

The initial radiation exposure estimate for performing the decommissioning was 366 person-Rem. This exposure was estimated to be incurred with 75,545 person-hours of exposure time. The bulk of the exposure (286 person-Rem, 78%) was expected to be due to 7 of the 38 D&D tasks (39% of the potential exposure hours). These tasks are more directly dealing with the hot cells and reactor core structures. Table 2 provides a breakdown of estimated exposure and exposure hours by major D&D task.

Actual Exposure

As of January 1, 1994, 138 Person-Rem have been incurred for the decommissioning project with 99.6% of the radioactivity being removed. This exposure was incurred with an expenditure of about 190,000 person-hours where radiation exposure was received. Future exposure needed to complete the project will be negligible (6 to 12 person-Rem for 1994) with 99.6% of the radioactivity already removed, the project will be completed with only 38% of exposure estimated to be received, but with 250% of the estimated exposure manpower. If one were to normalize the estimated and incurred radiation exposure by manpower actually incurred, then only 17% of the potential exposure was incurred. While this figure may or may not be entirely valid (because much of the overscope work tends to be performed at the tail end of a task where exposure rates have been reduced early on in the task), it does show that dramatic exposure reductions were realized on this project. This is especially significant in light of the fact that radiological conditions found when areas were "opened up" tended to be radiologically worse and much more extensive.

Table 3 presents a summary of the total decommissioning project as of January 1, 1994. As can be seen, the total project exposure is 137.8 person-Rem, with the "average worker" receiving 0.27 Rem per year. Worthy of note is the exposure for 1992, where 52% of the project exposures occurred in just one of the three projects first years, This is due to the fact that the NRC part 50 and 70 decommissioning orders were issued in late 1991 and early 1992, respectively. Prior to 1992, only preliminary work involving preparations for actual decommissioning

TABLE 1 - RADIOLOGICAL STATUS

STRUCTURES

Reactor Pool Surfaces - up to 620,000 dpm/100cm^2; up to 1 Rem/hr hot spots.

Transfer Canal Surfaces - up to 1,600,000 dpm/100cm^2 (hot spots); 2 mRem/yr.

Primary Water Hold Up Tank (HUT) - up to 500,000 dpm/100cm^2; up to 100 mRem/hr.

Interior Hot Cells - up to 2,000,000,000 dpm/100cm^2; up to 1,500 Rem/hr Gamma; up to 10,000 Rad/hr Beta.

Interior Hot Cell Filter Bank - up to 1,000,000 dpm/100 cm^2; up to 2 Rem/hr Gamma; up to 50 Rad/hr Beta.

Waste Water Tank Vault (T-1 Room) - up to 1,000,000 dpm/100cm^2; up to 1 Rem/hr.

SYSTEMS

Primary Reactor Cooling System - up to 810,000 dpm/100cm^2; up to 400 mRem/hr.

Waste Water Collection Tank Evaporator - up to 2 Rem/hr; 15 curies Cs-137/Sr-90 sludge.

Buried Hot cell Exhaust System (18"-36' dia. ceramic duct) - up to 10 Rem/hr Gamma; up to 100 Rem/hr Beta.

ACTIVATED COMPONENTS

Rector Core Grid Plate - 800 Rem/hr

Reactor Core Support Tower - 30 Rem/hr

Cooling Water Plenum - 34 Rem/hr

Core Outlet Assembly - 4 Rem/hr

Thermal Column Gamma Shield - 0.8 Rem/hr

Thermal Column Graphite - BKG to 2 Rem/hr

Beam Tubes - 7 Rem/hr (internal)

Activated Concrete Bioshield - up to 3 Rem/hr

TABLE 1 - RADIOLOGICAL STATUS
continued

SOIL/BEDROCK

Exterior soil to Reactor Holdup Tank and Pump Room - up to 10,000 pCi/gm; Co-60, Ag 110m, Eu 152/154/155.

Soil Surrounding Buried Hot Cell Exhaust Duct.

Filter Bank Room and T-1 Room - up to 500,000 pCi/gm; Cs-137, Sr-90, Ce-144.

Soil/Bedrock Under Hot Cells - up to 10,000 pCi/gm; Cs-137, Sr-90, Ce-144.

Soil/Bedrock Exterior to Canal/Gamma Pit - up to 1,000 pCi/gm; Cs-137, Co-60, Ag 110m.

TABLE 2

CINTICHEM DECOMMISSIONING PROJECT EXPOSURE ESTIMATE

TASK	PERSON-REM	EXPOSURE PERSON-HOURS
Remove Reactor Core Structure	32.0	6,400
Remove Activated Thermal Columns	111.0	802
Remove Rx Bldg. Piping and Systems	8.4	2,800
Remove Activated Concrete Bioshield	49.9	998
Remove Rx Beam Tubes	8.6	863
Remove Reactor Coolant Piping	8.5	2,833
Remove Activated Therm Col Liner	6.3	126
Remove Embedded Pipe Bioshield	3.2	650
Dismantle Rx Pump Room	3.6	1,790
Decontaminate Rx Pool	4.7	392
Remove Canal Structure	15.7	3,140
Decontaminate Hot Cells	22.3	11,150
Remove Underground H.C. Exhaust	34.1	3,410
Remove U.G. H.C. Exhaust Filter Rm	20.8	2,080
Other 24 Tasks	36.9	38,111
TOTALS	366	75,545

TABLE 3

PROJECT PERSON-REM SUMMARY

YEAR	PERSON REM	NUMBER OF EMPLOYEES	AVG REM/ PERSON-YEAR
1991	15.8	98	0.161
1992	72.2	178	0.406
1193	49.8	233	0.214
TOTAL	**137.8**	**509**	**0.270**

TABLE 4

PROJECT PERSON-REM BY WORK GROUP 1991-1993

WORK GROUP	TOTAL PERSON REM	AVG PERSONNEL	AVG REM/PERSON
D&D LABOR	88.60	67	1.320
WASTE MANAGEMENT	21.60	17	1.270
HEALTH PHYSICS/SAFETY	26.10	53	0.491
ENGINEERING/MANAGEMENT	0.95	8	0.118
MAINTENANCE	0.57	25	0..023
TOTAL	**137.80**	**170**	**0.810**

was performed. This work was limited to setup of new site services, equipment, etc., to support the upcoming D&D effort and non-destructive cleanup of the site. Therefore, exposures during 1991 were limited in nature. In 1992, actual decommissioning work started with the two highest level sources of radioactivity, removal of the reactor core structure and preliminary decontamination of the five hot cells. Both of these tasks involved handling radioactive materials with dose rates in excess of 1,000 Rem per hour, hence the higher average exposure decreased by about 31% from that of 1992 due to the decreasing inventory of radioactive material on-site. Average exposures in 1993 decreased by about 47% for the same reasons, and also due to a 31% increase in the number of employees.

Table 4 presents the distribution of exposures by work group for 1991 through the end of 1993. The D&D labor group had the highest total exposure and the highest average individual exposures with 88.6 person-Rem and 1.32 Rem per person over the three year period. This is understandable since this is the work group that actually is decontaminating and dismantling the facility. The next highest exposed work group, on an individual basis, is Waste Management at 1.27 Rem per person. This is the work group whose primary function is to treat, package and ship radioactive waste that is generated by the D&D labor group. The Health, Safety, Environmental Affairs (HSEA) department, of which it is primarily the health physics personnel that receive radiation exposure, had a total of 26.1 person-Rem, with an average exposure of 0.491 rem per person. However, the HSEA group personnel are diverse in function, ranging from work area crew coverage to environmental monitoring off-site. Therefore, the overall average for this group is misleading. Looking at the D&D HP sub-group, those technicians that cover D&D labor and waste management tasks, the average exposure rises to just slightly less than 1 Rem per person. Engineering, Management and Maintenance personnel had only incidental radiation exposures with a total of 1.52 person-Rem.

ALARA EXPERIENCE

Radiation exposures by D&D work task for the D&D labor group are presented in Table 5. As can be seen, many of the tasks were completed with much less exposure than anticipated, but with more exposure time on the task. A comparison of estimated exposures and exposure time is given in Table 6. The following presents some of notable experiences from the ALARA standpoint for these tasks.

Removal of Reactor Core Structure

Radiation exposures on this task were reduced to 13% of the initially estimated exposure. This was accomplished through increased use of remote underwater cutting techniques. A remote-operated hydraulically driven underwater circular saw was used to segment the activated core components underwater. This allowed workers to segment components that had exposure rates approaching 1,000 R/hr while incurring exposure rates of only a few millirem per hour due to the use of 15 feet of water shielding and distance. The crew assigned to this work practiced using the remote-operated saw and other remote tools (drills, taps, tongs, eyebolt holders) for about a month using a mocked-up "reactor core."

Removal of Activated Thermal Column Liner

The reactor end of the thermal column steel liner, and the one-inch-thick 5 ft by 5 ft "window" that sealed-off the dry interior of the column from the water filled pool presented a significant ALARA challenge. This work had to be performed with the pool water level below the bottom of the window, thereby removing the water shielding from the 80 R/hr window and nearby activated concrete bioshield. Many surprises were found in the design and construction of this structure that was not shown nor documented from the construction drawings. Additionally, this structure was modified without documentation during early facility start-up due to water leaks into the column. The aluminum window was found to have double the number of steel bolts (64 instead of 32) holding it onto the thermal column liner flange. The flange had also been modified to provide a better sealing

TABLE 5

ACTUAL D&D LABOR PROJECT EXPOSURES BY D&D TASK[a]

TASK	PERSON-REM	EXPOSURE-HOURS
REMOVE REACTOR CORE STRUCTURE	4.1	8,281
REMOVE ACTIVATED THERMAL COLUMN	1.2	590
REMOVE RX BLDG PIPING & SYSTEMS	2.3	1,219
REMOVE ACTIVATED CONCRETE BIOSHIELD	2.9	3,383
REMOVE RX BEAM TUBES	0.84	1,464
REMOVE REACTOR COOLANT PIPING[b]	0.14	466
REMOVE ACTIVATED THERM COL. LINER	0.83	1,768
REMOVE EMBEDDED PIPE BIOSHIELD	0.33	2,181
DISMANTLE RX PUMP ROOM	6.1	11,271
DECONTAMINATE RX POOL[b]	0.92	6,986
REMOVE CANAL STRUCTURE	7.7	12,526
DECONTAMINATE HOT CELLS	63.8	61,736
REMOVE UNDERGROUND H.C. EXHAUST	8.0	12,372
REMOVE V.G. H.C. EXHAUST FILTER RM[b]	2.6	5,428
OTHER D&D TASKS[b]	5.8	34,814
TOTAL	107.6	164,485

[a]excludes routine or non-task related activities
[b]still in progress as of 1/94

TABLE 6

COMPARISON OF D&D LABOR ESTIMATED AND ACTUAL EXPOSURES

TASK	% OF ESTIMATE PERSON REM	% OF ESTIMATE EXPOSURE HOURS
REMOVE REACTOR CORE STRUCTURE	13	130
REMOVE ACTIVATED THERMAL COLUMN	1	73
REMOVE RX BLDG PIPING & SYSTEMS	27	44
REMOVE ACTIVATED CONCRETE BIOSHIELD	6	340
REMOVE RX BEAM TUBES	10	169
REMOVE REACTOR COOLANT PIPING[b]	2	16
REMOVE ACTIVATED THERM COL. LINER	13	1,400
REMOVE EMBEDDED PIPE BIOSHIELD	10	335
DISMANTLE RX PUMP ROOM	169	630
DECONTAMINATE RX POOL[a]	20	18
REMOVE CANAL STRUCTURE	49	400
DECONTAMINATE HOT CELLS	286	554
REMOVE UNDERGROUND H.C. EXHAUST	23	363
REMOVE V.G. H.C. EXHAUST FILTER RM[a]	13	261
OTHER D&D TASKS[a]	16	91
OVERALL PROJECT	29	218

*still in progress as of 1/94

surface and increased rigidity for the windows. This modification added a stainless steel brace directly into the center of the neutron flux, causing radiation exposure rates to be much higher in the area than anticipated from the window and liner alone. As can be seen from Table 6, this caused the labor effort to increase by a factor of 14. However, exposures were still kept to just 13% of the initial exposure estimate.

To remove the window, a one-inch-thick steel plate slightly smaller than the window was suspended in front of the window such that only the bolts on one side of the window would be unshielded at any one time. After the shield was installed, the pool water level was lowered incrementally to limit the number of exposed bolts as they were removed. The bolts were removed using an electric impact gun with a socket on a 20-foot extension rod. This allowed workers to remove the bolts in a radiation field of 100 Rem/hr or less.

Once the activated aluminum window and steel bolts were removed, it was expected that the area exposure rate would decrease significantly. However, it did not, due to the presence of the unknown activated stainless steel brace. An exposure rate of up to 250 Rem/hr was encountered. A one-foot-thick, 5-foot-square, high-density concrete shield block was placed in front of the thermal column opening to shield the pool area from the steel brace. Half of the graphite blocks in the thermal column had previously been removed and the remaining half (4 foot thick) shielded the brace from the other side. The graphite blocks were then strategically removed and replaced with high density concrete blocks to allow torch cutting of the carbon steel thermal column liner to which the stainless steel brace was attached. After the liner was cut, the concrete shield block was removed from the pool opening and the cut liner-brace assembly was knocked into the pool with a battering-ram. The pool still had about three feet of water in it which provided some shielding. The brace and liner were then segmented using the same saw that was used to remotely segment the core components.

Remove Activated Concrete Bioshield

The "sphere" of activated concrete surrounding the reactor core area was removed incurring just 6% of the estimated exposure. This was done using a remotely operated demolition device known as a "Brokk," which is an electro-hydraulically operated machine similar to a small backhoe. It has a 4-wheeled base upon which is mounted a turrent with an articulated arm capable of operating a clamshell bucket, a digging bucket, a shear or a demolition hammer. This device was operated remotely at a distance up to 35 feet from the higher exposure rate area. This machine demolished the activated concrete, sheared the massive rebar and steel liner and then loaded the waste material into rad-waste containers. Being a complex device, a significant manpower penalty was incurred due to equipment breakdown time, as can be seen from the 340% manpower overrun.

Decontaminate Hot Cells

This work started in early 1991 and was completed in March of 1994. Decontamination of the hot cells proved to be a very difficult task, requiring over five times the initially estimated effort and almost three times the initially estimated exposure.

The initial decontamination steps were aimed at reducing radiation exposure rates inside the cells to allow removal of equipment and manned entry into the cells. This initial work consisted of using the existing manipulators to remove small objects from the cells and to then wipe down accessible surfaces. A high-pressure water spray was then used remotely with the manipulators to wash down the interior of the cells. This initial washing lowered the exposure rates at the cells' roof access plugs to tens of Rem/hr instead of the initial thousands of Rem/hr. This allowed workers to use long-handled tools to pick up and rig equipment to the overhead crane. Equipment was then lifted to just below the top of the cells where they could be decontaminated with high pressure water to allow disposal as Class A waste.

Once equipment was removed from the cells, the exposure rates at the top access plug areas was 1-2 Rem/hr, with exposure rates still in the range of hundreds of Rem/hr down inside the cells. The next step was to remotely remove as much contamination as possible from the interior cell surfaces. This again was done using

10,000 psi high pressure water with 20-foot-long water lances. This technique generally removed all the paint from the cells' interior surfaces. The high-pressure water decontamination continued until no longer effective, with exposure rate being lowered to 1 to 10 Rem per hour inside the cells.

At this point, manned entry into the cells was required for further decontamination work. The rear shield plugs were opened to allow access. Shielding consisting of 3/4-inch plywood sheets (for beta) and steel and lead sheets (for gamma) were installed over all surfaces. Only small work areas were left unshielded at any one time to keep exposure rates manageable. Workers then cut out installed fixtures and scarified concrete surfaces. Up to 4-5 inches of concrete surface was removed. This lowered exposure rates to below 10 mRem/hr.

At this point it became radiologically and environmentally feasible to core sample below the cells' floors to look for soil and/or bedrock contamination that could have originated from water leakage from the canal and gamma pit. After sampling, it became apparent that the cell structure could not be decontaminated to release levels due to cracks and fissures in the cells' foundation that became contaminated.

The hot cell structure was then demolished using the same remote-operated Brokks machine which was used to demolish the activated bioshield structure. These same "Brokks" are now being used to excavate contaminated soil and bedrock from beneath the hot lab building.

Authors' Biographies

Thomas S. LaGuardia is President of TLG Services, Inc., located in Bridgewater Connecticut. Mr. LaGuardia founded TLG in 1982 to specialize in decommissioning engineering and field services. He was previously with Nuclear Energy Services, Gulf Nuclear Fuels Corporation (formerly United Nuclear Corporation) and Combustion Engineering. Mr. LaGuardia has a Bachelor's degree in Mechanical Engineering from the Polytechnic Institute of Brooklyn and a Master's degree in Mechanical Engineering from the University of Connecticut. He is a registered Professional Engineer in Connecticut and New York.

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