BNL 68088

DECOMMISSIONING THE BROOKHAVEN NATIONAL LABORATORY BUILDING 830 GAMMA IRRADIATION FACILITY

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Under Contract No. DE-AC02-98CH10886 with the

UNITED STATES DEPARTMENT OF ENERGY

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ABSTRACT

The Building 830 Gamma Irradiation Facility (GIF) at Brookhaven National Laboratory (BNL) was decommissioned because its design was not in compliance with current hazardous tank standards and because its cobalt-60 sources were approaching the end of their useful life. The facility contained 354 stainless steel encapsulated cobalt-60 sources in a pool, which provided shielding. Total cobalt-60 inventory amounted to 24,000 Curies (when the sources were shipped for disposal). The decommissioning project included packaging, transport and disposal of the sources and dismantling and disposing of all other equipment associated with the facility. Worker exposure was a major concern in planning for the packaging and disposal of the sources. These activities were planned carefully according to ALARA (As Low As Reasonably Achievable) principles. As a result, the actual doses experienced during the work were lower than anticipated. Because the sources were sealed, most of the remaining equipment was not contaminated; therefore disposal was straightforward, as scrap metal and construction debris. However, disposal of the pool water involved addressing environmental concerns, since the planned method was to discharge the slightly contaminated water to the BNL sewage treatment plant.

INTRODUCTION

The Building 830 Gamma Irradiation Facility (GIF) at Brookhaven National Laboratory was identified in 1997 as having an underground tank that had to be modified to meet requirements of Article 12 of the Suffolk County Department of Health Code. Because the facility had no U.S. Department of Energy (DOE) program support and had been under-utilized for some years, BNL management decided to decommission it instead.

The GIF consisted of a pool, 8 ft. by 10 ft. by 13 ft. deep, with sealed cobalt-60 gamma sources located at the bottom of the pool. The water depth provided shielding. Access to the sources for irradiation studies was through stainless steel air tubes 16 ft. x 4 in. OD x 16 gauge wall thickness. One-inch lead jackets around the air tubes above the water level counter weighed the tube buoyancy and provided shielding to personnel. Pool water was circulated through a chiller/filter system, maintaining pool temperature at 7EC to prevent algae growth.

The 354 sources in the GIF, all fabricated from cobalt-60, contained about 32,000 Curies at the time of the decision. The sources consisted of flat pieces of activated cobalt encapsulated in stainless steel sleeves that were flat or cylindrical. The sources were held in arrays in stainless steel racks at the bottom of the pool in an upright, cylindrical orientation so that air tubes could be inserted into the array. Most of the source arrays were inside open-topped lead casks, whose purpose was to provide shielding and minimize radiation scatter from other sources, to control irradiation testing. Thus, dose rates at one source array had minimal contributions from other source arrays. There were 23 source arrays containing the 354 sources. The weakest array contained less than 50 Curies, the strongest had about 2,000 Curies. Dose rates for the sources (at the bottom of the air tubes) ranged from Greys (Gy) per hour to 100 kGy/hr. Figure 1 shows the sources distributed in racks at the pool bottom after the air tubes had been removed.

The decommissioning project, initiated in February 1999 and completed in November 2000, involved three phases:

1) Preparation of the facility for source removal and planning removal,
2) Packaging and shipment of the sources for disposal, and
3) Disposal/discharge of the pool water and final decommissioning.

PLANNING SOURCE REMOVAL AND FACILITY PREPARATION

Phase 1 included planning and preparation activities. Any work with the cobalt-60 sources would be performed while the source remained in the pool, so that occupational exposures remained negligible. Two steel transport/disposal containers were designed and fabricated. Design considerations included sizing to contain the 354 sources and to fit the transport cask (a "Type B" CNSI 1-13G) payload limit of 5,000 lbs. The room and pool were prepared for introducing the disposal containers that would hold the sources. This involved removing all the air tubes from the pool and dismantling a wall that blocked forklift access. The source count was verified visually at this stage, since records of the source inventory were questionable. Phase 1 activities also included arranging acceptance of the sources at the DOE disposal facility. A waste profile for a single shipment was prepared and submitted to Hanford.

A final aspect of Phase 1 involved careful planning of the source transfer from the pool to the shipping cask by remote handling for ALARA purposes. The two 5-inch thick steel containers, or liners, would each contain half of the total source inventory. Loading and closure of the liners with the sources was to be accomplished while the sources were in the pool, resulting in minimal occupational exposures. However, transfer of the containers from the pool to the shipping cask involved potentially high radiation exposures to workers because the containers would have contact dose rates as high as 800 Gy/hour, according to calculations based on the July 1999 inventory of approximately 26,700 Curies. Calculated and measured dose rates are discussed further under Phase 2 activities.

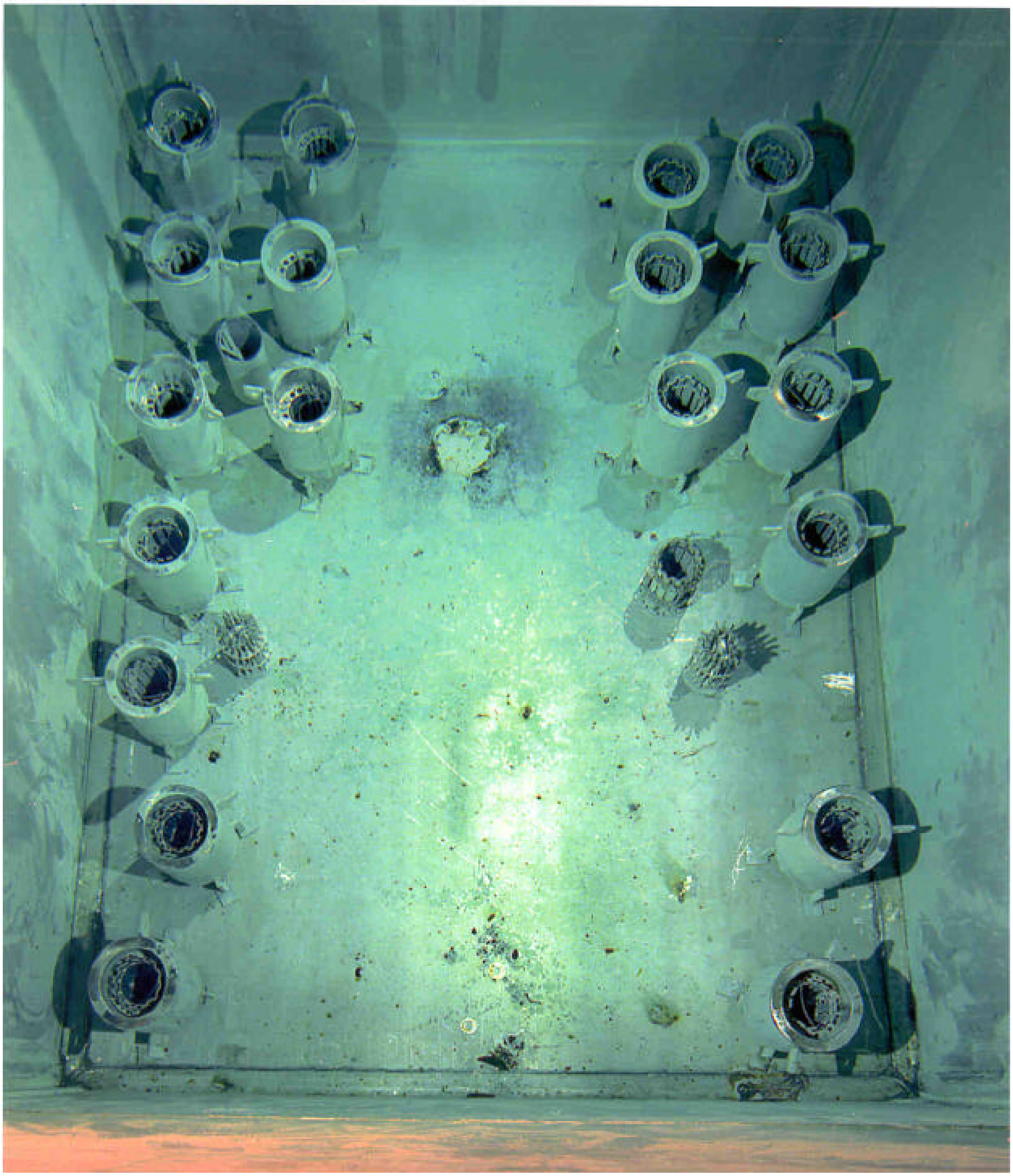

Figure 1. View of sources in racks after air tube removal.

The liner transfer plan involved five steps. Because of the potential occupational exposures, the plan included maximum use of shielding and minimal exposure times. The first step consisted of lifting the container from the pool and into a 3-inch steel transfer box lined with 2-inch lead bricks. A 5-ton jib crane, installed next to the pool, was modified with longer control leads and a mechanical crank and cable system so that it could be operated and the jib swiveled remotely from behind a shield wall. The transfer shield box was mounted on a forklift already positioned in the room. The crane hook was fitted with a cable so that it could be detached from the container rigging remotely after the lift was completed. Miniature video cameras were installed around the room and on the crane so that the operator could observe the lift on a TV monitor behind the shield wall. Figure 2 presents a schematic plan view of the pool area, forklift, and crane.

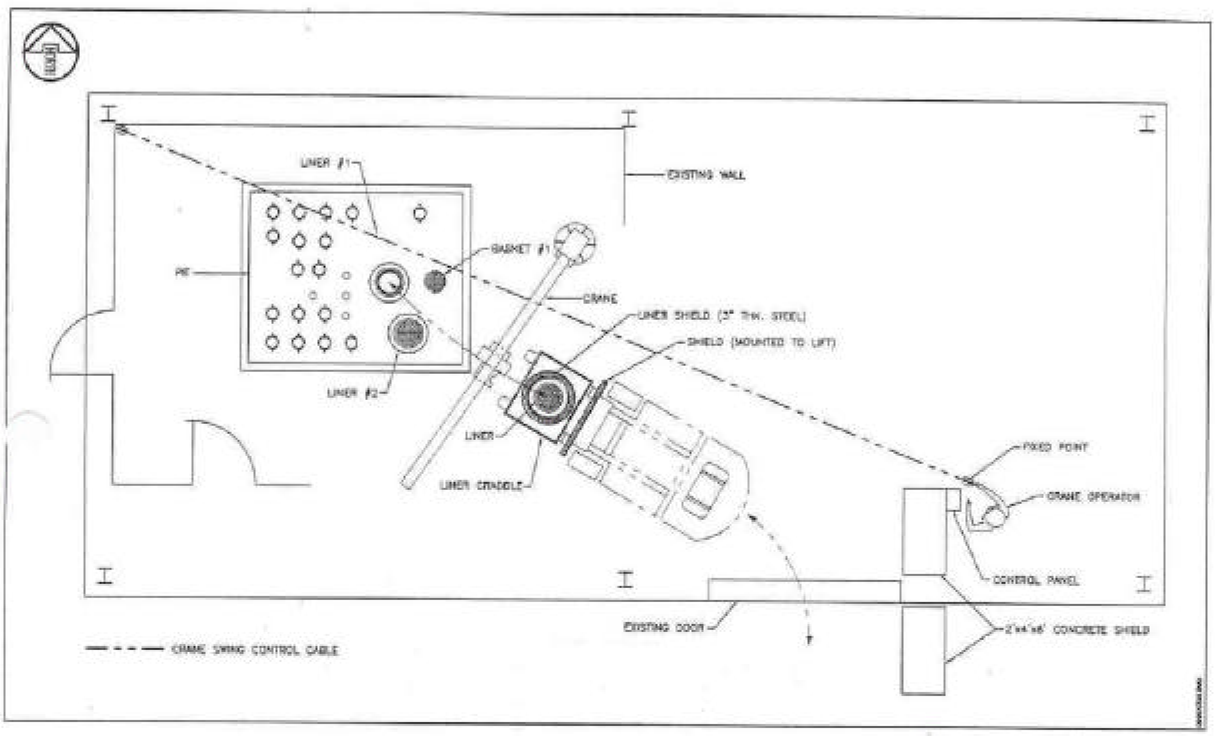

Figure 2. Plan view of GIF area ready for source liner transfer.

In the second step, an operator walked to the forklift, started it up, raised the load, drove outside to a marked position, lowered the load, turned it off, and walked behind a temporary shield wall. For the third step, another operator attached a hook for a mobile 150-ton Grove crane to the disposal container rigging. Although the weight capacity was well in excess of the load, the Grove was used because it had a 100-foot boom, giving the operator a safe working distance from the load. The fourth step was a lift from the shielded transfer box to the shipping cask mounted on a truck trailer. Finally, in the fifth step, the hook from the crane was removed from the rigging on the disposal container inside the shipping cask using a remote manipulator and a video camera.

Phase 1 activities took significantly longer than originally scheduled, primarily because of the unique nature of the shipment. The major delay involved acceptance at the disposal site. The waste profile documentation was approved after a thorough review and safety analysis of the shipping/disposal container design and consideration of the site's operational (as opposed to disposal) safety limits. The extent of the review and safety analysis, which was not anticipated when the schedule was first developed, added nearly six months to the original schedule. Adding to the delay was the need for the disposal site to prepare procedures specific for accepting and opening the CNSI 1-13G shipping cask. Finally, the disposal site had an operational safety limit requiring that the total source shipment inventory be less than 24,300 Curies. Decay calculations showed that this level would be reached in March 2000. The inventory limit thus led to an additional delay, waiting for the sources to decay to an appropriate level.

PACKAGING, TRANSFER AND SHIPMENT OF THE SOURCES

After the air tubes were removed from the pool, the sources were transferred from the 21 cylindrical rack arrays to the two steel disposal containers. It was known that the sources were of different strengths, and an attempt was made to divide the Curie inventory evenly between the two liners, based on the historical records of the individual source arrays. The transfer or packaging step, was accomplished using 20-foot poles equipped with pneumatic pliers at one end. Operators handled these manipulators from a scaffolding and railing placed over the pool to allow more convenient vertical access. Worker exposures were minimal and the process took about three days to complete.

This activity was carried out several weeks prior to the planned March 2000 shipping date in order to verify the Curie inventory. Records describing the setup and operation of the facility were incomplete, especially documentation of the fabrication of all the sources. Due to the incomplete documentation, the disposal site agreed that a dose-to-Curie content calculation was an acceptable verification of the inventory. Dose measurements were considered to be more accurate (and easier to model) if the sources were confined to one or two containers, rather than spread over 21 source racks in arrays ranging from 4 to 36 sources.

Dose measurements were made using an Eberline R07 dosimeter fitted with an underwater probe. Readings were taken at contact and at 6 inches from the container, at an elevation at which maximum readings were obtained. The elevation coincided with the midpoint of the height of the liners. Readings ranged from 5.5 to 10.5 Gy/hour, as shown in Table 1. Average dose rate values (7.5 Gy/hr) were used to calculate the Curie inventory using the Microshield computer code.

The Microshield code requires information about the source activity, configuration, and shielding or container geometry. The normal application of Microshield is to calculate dose rates for a known radioactive inventory to determine if additional shielding is necessary for personnel protection. Calculations of Curie inventory based on measured dose rate and known source geometry and shielding properties are therefore subject to some uncertainty. Additional uncertainty is introduced because the measured variations in dose rate cannot be introduced into the model. Based on an average dose rate of

7.5 Gy/hr, the total inventory was calculated to be a maximum of 12,000 Curies per liner, or a total shipment (both liners) of 24,000 Curies, as of the measurement date of February 12. This was consistent with the historical records, which indicated that the total inventory would reach 24,600 Curies as of February 12, 2000.

Table I. Summary of Dose Readings for Inventory Calculation

Liner #1*

Position**	1	2	3	4	Average	Top
@contact	7.5	5.5	6.6	10.5	7.53	8.5
@ 15 cm	3.3	2.7	2.5	4.5	3.25	
@ 30 cm	1.5	1.6	1.1	2.0		

Liner #2

Position*	1	2	3	4		Top
@contact	9.9	7.8	6.2	5.8	7.43	6.9
@ 15 cm	3.7	3.2	2.9	3.0	3.20	

* Readings in Gy/hr
** Position 1 was at a taped reference mark, with other positions in 90º clockwise increments around the liner.

RADIATION SAFETY

Phase 2 activities included the installation of the shielding and remote handling equipment described earlier. After the crank and pulley system was installed, and the shielding blocks and video cameras were in place, practice runs were conducted with an empty liner to verify and minimize estimated times for the different work steps. This was important for determining that exposures to the forklift operator, rigger, and crane operator would be ALARA. During the practice runs, parking positions for the forklift were marked on the ground, so that all movements during each lift would be identical and reproducible. For the whole operation, a step-by-step procedure was developed, with hold/stop points identified to separate activities involving worker movements and liner lifts. At each hold point, status of radiological, mechanical, and staff conditions were to be verified; after this, the Operation Control Supervisor would order the next step to proceed. Staff within the radiation and high radiation areas (see below) would communicate by radio.

A high radiation area (> 1 mSv/hr) was expected when the liner was removed from the pool, extending 18.6 meters from the liner in all directions. The radiation area (> 0.05 mSv/hr) boundary around this extended to 100 m from the liner. It was decided to post the radiation area limits outside a perimeter at about 146 m, where calculated dose rates were at 0.02 mSv/hr. Figure 3 shows a schematic display of the buildings, roads, and projected radiation areas. Because the radiation area included other buildings, the transfer was scheduled for a Saturday, when no other workers would be present. BNL police and Radiation Control (RadCon) staff manned roadblocks with posted stanchions at all roads accessing the area, to prevent inadvertent intrusions. RadCon staff also traversed the areas between checkpoints to monitor radiation levels and observe for passersby.

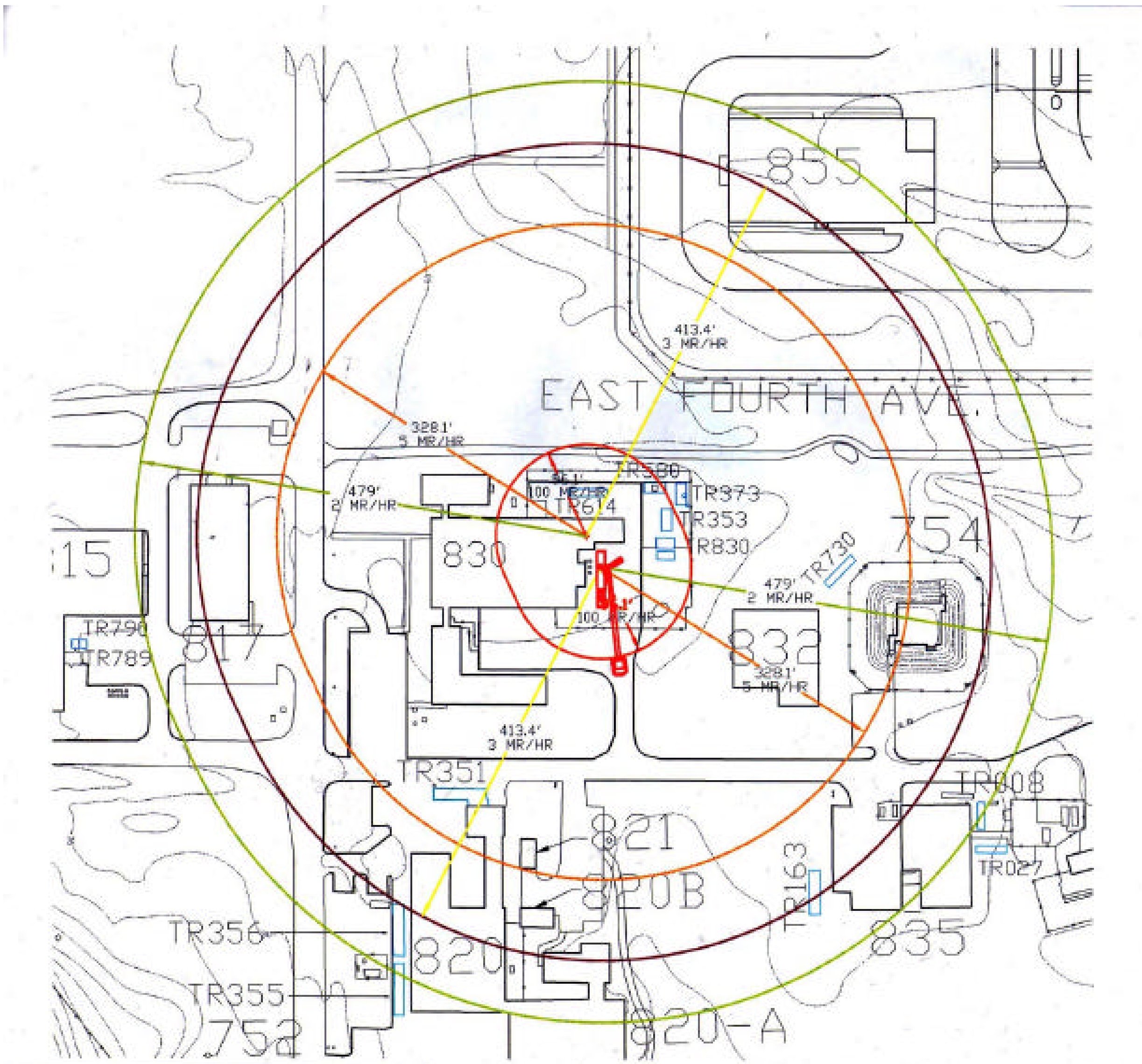

Figure 3. Radiation area layout.

On the day of the transfer, after the morning job briefing, all personnel reported to their positions and a radio test was initiated. Just prior to giving the signal to begin, the Operation Control Supervisor received an emergency page from BNL Police Headquarters. The job had to be delayed until Sunday due to a fire

at a radioactive waste storage area nearby, which required extensive RadCon support. However, on Sunday, loading of the disposal containers into the shipping cask proceeded without incident, and according to the plans previously described.
Dose rates measured during all activities were comparable to those calculated during the planning process, as listed in Table 2. In two instances, calculated doses were lower than those measured, and could have impacted total job exposure. These were at the GIF crane operator's position behind a shield wall inside the building, and the outside crane operator's cab. Inside the building, the higher dose rate was attributed to reflection from the interior wall. The outside crane cab dose rate was higher because the distance was shorter than the total boom length that was used in the calculation.

The total job exposure was estimated at 99 person-millirem during the work planning process. The Radiation Work Permit provided a conservative limit of 200 person millirem for the job, as summarized in Table 3. The highest single individual dose was lower than calculated.

After the shipping cask was reassembled and surveyed, the sources were transported to the disposal facility without incident. At the disposal facility, weather and a weekend contributed to an additional delay of four days and added (demurrage) costs. The liners containing the sources were finally disposed eight days after being removed from the GIF.

Table II. Comparison of Expected vs. Measured Dose Rates

Liner # 1			
Location	**Expected**	**Measured**	**Comments**
Behind Shield Wall	0.5 mR/hr	30 mR/hr	Possible reflection
13' from Liner	6.5 R/hr	7 R/hr	RMS-II
At Crane Operator Shield Wall	1.47 R/hr	100mR/hr	Liner shielded by transfer shield
Contact with Steel/Lead Transfer Box Shield	3.2 R/hr	1 R/hr	
Fork lift Driver Seat	75 mR/hr	35 mR/hr	
At Crane operator	132 mR/hr	260 mR/hr	Actual boom distance less than calculated
Contact with shipping cask	22 mR/hr	40 mR/hr	
Operation Control Point	>5 mR/hr <100 mR/hr	12 mR/hr	Distance was not known
Liner # 2			
Location	**Expected**	**Measured**	**Comments**
Behind Shield Wall	0.5 mR/hr	50-70 mR/hr	Possible reflection
13' from Liner	4.8 R/hr	5 R/hr	RMS-II
At Shield Wall	1.47 R/hr	1.4 R/hr	
Contact with Steel Shield	3.2 R/hr	10 R/hr	
Fork lift Driver Seat	75 mR/hr	30 mR/hr	

At Crane operator	132 mR/hr	250 mR/hr	Actual boom distance less than calculated
Contact with shipping cask	44 mR/hr	50 mR/hr	
Gamma Pool Control	>5 mR/hr <100 mR/hr	15 mR/hr	Distance was not known

Table III. Comparison of Estimated vs. Actual Dose

Totals for Project		
Dose Estimate Work Sheet	**RWP Allowance**	**Measured Dose**
99 mrem	200 mrem	140 mrem
Highest Individual Dose		
Dose Estimate Work Sheet	**RWP Allowance**	**Measured Dose**
36 mrem	100 mrem	30 mrem

DISPOSAL OF POOL WATER AND REMAINING EQUIPMENT

Phase 3 activities are scheduled to conclude in January 2001. Security and radiation alarms were removed immediately after the sources were shipped off-site. Miscellaneous equipment and plumbing were dismantled where possible. Water remaining in the pool contained low levels of cobalt-60 (<100 pCi/L), lead (~12 µg/L), and zinc (~110 µg/L). Residual zinc had to be reduced in order to be consistent with BNL's SPDES permits limiting discharges from the site sewage treatment plant. To achieve the discharge limit of 100 µg/L, the water was passed through a high-capacity (~400 L/min) diatomaceous earth pool filter. Reduced zinc concentrations were reached quickly because zeolite was mixed in with the diatomaceous earth, providing ion exchange as well as particulate filter capability. After this treatment, discharge was permissible because the water was not contaminated above the BNL sanitary discharge limits.

The discharge was delayed for six months because the established BNL procedure for evaluating discharges at BNL was revised shortly after the sources were shipped. While the GIF pool water was dischargeable under the revised procedure, the procedure itself was not formally approved. The six-month delay occurred because the BNL's Environmental Policy calls for the involvement of stakeholders, including regulators and community groups. Presentations describing the procedure to the Community Advisory Council and the Brookhaven Executive Roundtable were given after the procedure had been reviewed and approved by the BNL Operations Council, the BNL Integration Council, the DOE Area Office, and federal and state regulators. This extensive level of review is part of BNL's commitment to achieve site-wide ISO 14001 registration.

The stainless steel pool liner was surveyed and found to be releasable per DOE/BNL limits (<1,000 dpm/100 cm^2) after the pool water had been discharged to the sanitary sewer system. The tank was removed in December. Core samples of the pit bottom were taken to verify that no contamination had escaped. Following this, the pit was filled in and the floor was finished to match the rest of the room. The only remaining evidence that the GIF was in the room is the 5-ton jib crane.

LESSONS LEARNED

The Building 830 GIF decommissioning project has been a straightforward waste (source) packaging and disposal activity in the technical sense. Challenges arose when it came to coordinating the activities of the various parties involved and dealing with emergencies.

The unexpected fire emergency at a waste storage area at BNL caused a 24-hour delay and added to total costs, because the source liner transfer team involving police, RadCon, and riggers were mobilized twice before the operation was completed. Prior to this, delays in obtaining waste profile approval from the disposal site added to total costs, primarily in continuing project management and pool maintenance costs. Similar, but relatively lower additional costs, resulted from delays in obtaining permission to discharge the pool water. During this period, additional costs were lower because pool maintenance activities associated with storing kiloCurie amounts of cobalt-60 were eliminated, since the sources were no longer present.

Although these delays resulted in increased costs, neither safety in operations nor protection of the environment was compromised. The activities with the highest hazards, those involving work with the radioactive sources, were all planned carefully and with ALARA in mind. All other wastes and discharges were handled and disposed of in compliance with BNL, DOE, and federal and state requirements.

Increased costs are labeled as such for this project when compared to a baseline of activities and schedules developed in the early stages of the project. A significant lesson learned involves waste profile acceptance at the disposal facility. This proved to be a rather large schedule delay, which may have been much less if the profile had been initiated and contact made with the disposal site before the schedule was developed. With feedback from the disposal site about what information was needed and how much time was required for internal reviews for unique high activity shipments, a more realistic schedule and budget would have been developed initially.