THE SUCCESSFUL DECONTAMINATION AND DECOMMISSIONING OF THREE GASEOUS DIFFUSION PLANTS

J. Stevens
British Nuclear Fuels Limited Incorporated

ABSTRACT

This paper describes the challenges and lessons learned involved with decontaminating and decommissioning the first three gaseous diffusion facilities in the United States.

BNFL BACKGROUND

BNFL Inc. is an American environmental services company whose expertise is providing technical solutions to clean up nuclear waste. The focus is on providing innovative solutions for the nation's most difficult environmental and nuclear challenges. An industry leader in safe operations, BNFL offers a full array of decontamination and decommissioning management and

Fig. 1. BNFL-ETTP gaseous diffusion facilities.

operations services within the United States and internationally. In addition to 10 years experience in the United States, the BNFL-ETTP (East Tennessee Technology Park) team—senior management, project managers, supervisors—have extensive experience in the nuclear utility, waste management, project safety, and construction industries.

BNFL History

In August 1997, the Department of Energy awarded BNFL Inc. a fixed-price contract. The purpose of the project included the decontamination and decommissioning of three gaseous diffusion plants (GDP)—K-33, K-31 and K-29—at the ETTP, formerly known as the K-25 site, located in Oak Ridge, Tennessee. This project included the removal and dismantlement of over 1,500 converters—some over 32,000 pounds—decontamination of over 5 million square feet of facilities, and the disposition of 328 million pounds of contaminated materials. The massive size of the facilities, in addition to the cost of the project, made this one of the largest nuclear decommissioning projects in the world. The only project that comes close in size is the DOE Rocky Flats site. All 400 facilities located at Rocky Flats would fit into these three gaseous diffusion buildings—K-33, K-31 and K-29.

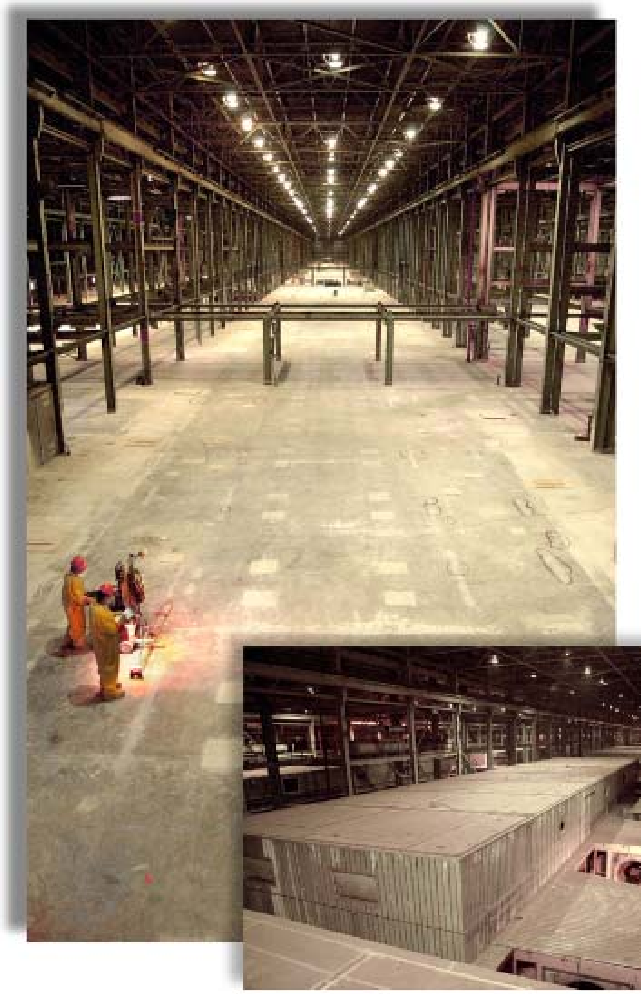


Fig. 2. Before and after pictures of gaseous diffusion building.

This large D&D project employed over 1,400 workers—at its peak—to perform the heavy construction, dismantlement, removal, and disposal of process equipment, support materials, and waste. To accomplish this project, BNFL Inc. established and operated one of the most sophisticated D&D workshops in the nuclear industry and the largest nuclear Supercompactor in the world.

All three facilities were built during the beginning of the Cold War era and were used primarily for uranium enrichment processes. Production of enriched uranium ended in 1985, and the gaseous diffusion facilities were permanently shut down in 1987. Contaminates that were found in the three buildings consisted of polychloride biphenyls (PCBs), friable and nonfriable asbestos, chlorofluorocarbons (CFCs), chromates, lubricant oils, miscellaneous materials regulated under the Resource Conservation and Recovery Act, uranium, and other radionuclides.

Largest Single Nuclear Decommissioning Project in History

Building K-29 was built in 1951 and encompassed almost 600,000 square feet of space. Building K-31 was built in 1952 and covered 1.5 million square feet of space, and building K-33—built in 1954—covered over 2.8 million square feet. The area in K-33 covered 64 acres, or 64 football fields. All three facilities had similar construction consisting of steel frame structures with reinforced, non-combustible concrete floors with the first levels supported by concrete/steel columns sustaining concrete beams. The roof support structures, consisting of exposed steel beams, girders, and trusses, was connected to exposed structural steel columns extending from the second floor. The roof was constructed of a steel deck assembly and the walls were constructed of concrete block or Transite.

The K-29, K-31 and K-33 process buildings were originally designed and built to house the low enrichment (<20% U-235 by weight) part of the Oak Ridge Gaseous Diffusion Plant cascade. The plant enriched uranium in the U-235 isotope by the gaseous diffusion process that utilized uranium hexafluoride (UF^6) as the process gas. During the operation to support highly enriched uranium (HEU) production, peak enrichment level in the cascade was 12.65% for K-29, 6.2% for K-31 and 2.5% for K-33. With the termination of HEU production in the K-25 and K-27 process buildings, the K-29, K-31 and K33 process buildings continued to produce low enriched uranium (LEU) with an average enrichment of 3.2% (peak enrichment of 4.9% for K-29, 2.9% for K-31 and 1.7% for K-33).

All three GDPs operated in a similar manner. The UF^6 gasses were introduced into the piping systems at a high temperature. The gasses then traveled into the diffusion equipment stages. One stage contained a motor, a compressor and a converter. The UF^6 gasses would flow from the compressor into the converter through the barrier material in the converter where small amounts of U-235 diffuse through the barrier material. This splits the gasses into two streams—one with slightly enriched uranium and one with slightly depleted uranium. The two streams of gasses produced would then be sent through multiple stages thousands of times so that certain enrichment levels could be met.

Lessons Learned

Decommissioning Gaseous Diffusion Plant's entailed a number of considerable challenges. The plants were all Category 2 nuclear facilities, contained significant quantities of fissile material, encompassed significant hazards from industrial safety, and contained numerous unknowns. Because of these challenges, creativity and foresight were required to continually address the challenges on this type of project. A few of these challenges are discussed below.

Waste Movements

One of the major obstacles was dispositioning over 300,000,000 lbs. of contaminated material. Since the material was handled several times before it was shipped (removed, processed, packaged), this would equate to the handling of over 1 billion lbs. of contaminated material while working under restrictions/requirements from criticality safety, Authorization Basis/license, radiological safety, industrial hygiene, and hazardous materials safety. The project routinely shipped over 2,000,000 pounds of contaminated material off site each week. To say that this activity was difficult would be an understatement.

To quickly move this much material on a consistent basis, it was necessary to integrate the characterization of the waste into the packaging and transportation activities. This allowed BNFL to reach its target of shipping the waste within five days of its generation.

To achieve this integration, a program was developed to enable the material to be characterized “in place.” The material was sampled/measured on an area-by-area basis in sufficient detail so the characterization data could be used to ship the waste. This allowed the characterization to be done with only the weight and identity of where the material came from and the amount of U-235 estimated in the field by the technicians. This was all tracked through procedural requirements.

A method was developed to manually scan items to determine the U-235 content. The process was controlled and validated through measurement of the U-235 content in the Uranium Waste Monitor (UWAM). The UWAM is a large passive neutron counter that was able to count containers as small as a B-25 box or as large as an inter-modal container. This system was able to measure quantities as low as 5 grams of U-235 and was also used to catch anomalies with any of the waste profiles.

The characterization process was also used with the projects Supercompactor. (The Supercompactor will be addressed later in the paper.) With the characterization process, the team was able to “standardize” the process into a database. This meant that when the box left the compactor, it had characterization data with it. The shippers merely “downloaded” the data into the correct shipping papers and then shipped the material.

Final Survey Issues

BNFL began the decontamination and final status survey activities in building K-33 in late 2002. BNFL's scope of work included the development and implementation of a survey process that resulted in the unconditional release of the buildings and allowed the buildings to be used by future occupants for industrial use. In addition to K33, BNFL was responsible for the unconditional release of building K-31. Both buildings consisted of over 22,000,000 square feet of surface area. The process included performing housekeeping of the buildings, which consisted of physically wiping and/or vacuuming all accessible surfaces in the building. Once the cleaning was complete, BNFL performed both removal and fixed radiological surveys. Surveys were conducted based on process knowledge, historical data, and sampling and analysis data. The data was then analyzed for decontamination and further characterization planning. The data that exceeded the contract end point criteria required BNFL to evaluate the extent of contamination, bound the affected area, and perform a reasonable decontamination effort. Additional surveys were conducted to verify the success of the decontamination effort. This was especially critical with the physical conditions of the buildings which had a ceiling height of ~54 feet. In order to access the overheads, survey techs were required to use high-reach manlifts. This effort was compounded by physical problems such as heat stress, insects, and psychological problems due to working at extreme heights.

Some of the challenges were a result of the contract language regarding the existing conditions of the buildings which indicated the building had minimal amounts of contamination (<2%) and only "trace" amounts of transuranics and Tc-99. BNFL discovered, however, that Tc-99 was the predominate isotope of concern in the overheads. This characterization indicated that >20% of the overhead surfaces were affected and exceeded the contract end-point criteria. Transuranics were discovered and posed a significant problem in K-31 which required imposition of transuranic controls over ~10% of the floor areas. While having a minimal impact on the decontamination, the presence of transuranics required a much more rigorous survey protocol, more time consuming, and more costly.

During the performance of final status survey in building K-33, BNFL encountered higher than expected levels of radioactivity. It was determined that a request for new end-point criteria could be justified using a dose-based approach. This effort began in November 2003. Multiple draft proposals were submitted to the DOE to obtain authorization for different release guidelines. All of the drafts received comments and direction for change. In late April of 2004, BNFL determined that the quickest path of relief from the current guidelines was a request for supplemental limit for Tc-99 that would be applied only in the overhead area of the buildings. BNFL used RESRAD-BUILD software to calculate the dose to a warehouse worker, which is the projected building occupant.

To tackle this problem, BNFL submitted two reports for the DOE review and approval. The first document was titled "Method for Calculation of Surface Activity Limits for Dose-Based Release Criteria at Buildings K-31 and K-33." This was a technical description of the dose model. This was submitted first to assure that all questions and concerns of the DOE technical consultants had been addressed and that results from the model were technically acceptable. The routine exposure scenario that was agreed upon for this model was the continual occupancy by a warehouse worker for 25 years. The worst case scenario was a building renovation worker for one year. These parameters were discussed, reviewed, and accepted by the DOE technical consultants. Upon acceptance by the involved parties, this model provided the technical basis for calculating the dose per disintegration for the radionuclides of concern to the Three-Building Project. This information was used to propose an alternate Surface Activity Guideline (SAG).

The second document was the proposal for alternative SAGs that would be used as the basis for the new end-point criteria for Final Status Survey. BNFL proposed alternate SAGs that would project an annual integrated dose to the warehouse worker of 5 mRem/yr from any combination of radionuclides. Due to the building construction and the isotopic distribution found in the building, calculations would be made for both the floor component and the overhead component separately. The sum of the fractions and the unity rule would be utilized to assure that the sum of these two components would not exceed 5 mRem/yr for the warehouse worker.

Based upon the isotopic mixture determined by the sampling campaign, a formula would be developed that would utilize the sum of the fractions approach to calculate an end-point criteria assuring compliance to the proposed alternative SAGs. Multiple current procedures would also have to be updated to assure that compliance is attained.

This approach was eventually approved for the overheads only. The floor limits remained at the current end-point criteria. This was subsequently modified to develop a consistent limit for the floor areas that were impacted by transuranic contamination. The program was implemented in several stages and proved to be successful in completing the final surveys.

The other contaminant that created problems during this phase of work were PCB's.

The K-33 Building, Operations and Cell Floor, PCB Remediation was initiated in July 2003. The east side of the K-33 building operations and cell floors (units 1 through 4) concrete floors were remediated (scabbled) while the west side (units 5 through 8) was not. As anticipated, the cell floor post-surface removal verification sample results showed no residual PCB contamination exceeding the limit of detection. The limit of detection was 0.5 mg/kg (0.5 ppm). However, the operations floor verification sample results demonstrated significant residual PCB contamination at concentrations greater than 1 ppm with significant data >10 ppm. Characterization results for the West side demonstrated some PCB contamination >50 ppm in the concrete slab. Therefore, BNFL needed to take another approach to dealing with PCB's.

40 CFR 761.61(a)(4)(i)(A) establishes the cleanup level for porous surfaces as ≤1 ppm for *high occupancy* without further conditions or restrictions. It also allows concentrations between 1 and 10 ppm to remain if the surface is capped and/or the site is fenced and deed restrictions are established. Options in 40 CFR 761.61(a)(4)(i)(B)(1) have a ≤25 ppm cleanup level for porous surfaces for *low occupancy* of the facility. The later two options **would not** meet the needs of the facility owner. While the first option **would** meet the needs of the facility owner, this stringent level for unrestricted use could include residential use, and the K-33 Building is an industrial facility that would be occupied by warehouse workers. Therefore, it is appropriate to evaluate the feasibility of a risk assessment to address the residual PCB contamination remaining in the K-33 Building concrete floors. In addition, the 1 ppm level was based on exposures to soil which can easily be disturbed by the wind and/or traffic resulting in particulate emissions. The residual contamination is fixed in the concrete matrix and it is not easily transferred or disbursed. Data is available for the K-33 Building documenting that PCB contamination is not readily transferred by walking over the concrete floor, and air sampling data collected during the concrete scabbing (a worst case bounding condition) established that the PCB concentration was below the detection limit for PCBs with only a few *estimated* PCB concentration detected. All air sampling data was well below the OSHA and TOSHA TWA PEL. A risk assessment would provide a scientific evaluation utilizing exposure models that will calculate the potential dose and risk to a future warehouse worker based on the residual PCB concentrations remaining in the K-33 Building. Since the K-33 Building is an industrial facility, a risk assessment for a warehouse worker and potential construction type activities to allow for renovation would be appropriate.

Risk Assessment Methodology

The risk assessment is a preliminary and conservative estimate of the lifetime added cancer risks from potential exposure to PCB's in K-33. The methodology used was a standard conservative EPA CERCLA (Superfund) screening equation and exposure factor. A conceptual model of the exposure scenario is presented in Figure 1.

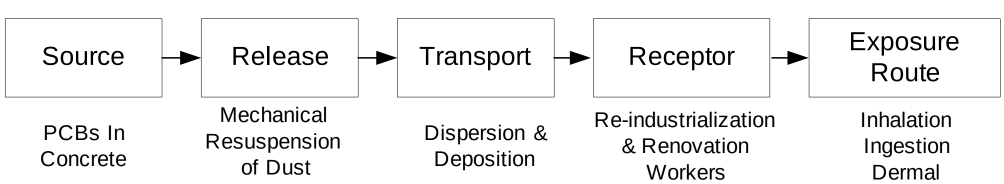


Fig. 1. Conceptual exposure model

The following two scenarios were evaluated:

- *A future use **warehouse worker** performing light industrial activities*. This individual works 250 days per year, 8 – 10 hours per day for 25 years. Conservative exposure factors as referenced by EPA Region 9 are used to estimate inhalation, incidental ingestion, and dermal contact exposures.

- *A future use **renovation worker** who performs intrusive construction-like activities*. This individual works 250 days per year, 10 – 12 hours per day for 1 year. Conservative exposure factors from EPA Region 9 are supplemented with recent EPA guidance for construction workers to estimate inhalation, incidental ingestion, and dermal contact exposures.

On the basis of is this conservative level screening assessment, it was apparent that PCB contamination in the concrete floors on the west side of the K-33 operations floor were far below the levels of regulatory concern. The contamination did not pose an unacceptable risk to those who may use the building in the future for occupational purposes. Additionally, post remediation data indicated that PCB concentrations on the east side of K-33 were generally less than 10 mg/kg. If the east side K-33 Ops floor data were factored into this assessment, the risks represented by this assessment would be lower.

The risk assessment demonstrated that, under conservatively estimated conditions, PCB's in the concrete in the K-33 west side Ops floor did not pose a significant risk in terms of the relevant regulatory guidelines. BNFL then implemented a sampling plan that would support a detailed assessment.

The changes in the radiological and PCB EPC were extremely helpful in completing this phase of the project. However, the efforts to develop and implement these new programs while the decontamination and final survey activities were already underway were extreme. Significant amounts of data had to be continually re-evaluated and new protocols had to be implemented in the field which required significant training and oversight.

Orphan Materials

During the dismantlement of these mammoth facilities, several materials encountered were difficult to disposition. One of these materials was the gaskets from the facility's ventilation systems. This material was contaminated with PCB's, chrome and radiological constituents, making it very difficult to disposition. BNFL was able to work with the EPA, State of Utah and the State of Tennessee to show that the gasket material was an integral part of the ductwork and that the Chromates were insignificant relative to the weight of the duct. BNFL was then able to compact the duct and dispose of the material in the mixed waste cell at Envirocare with the gasket in place.

Another material that was difficult to disposition was the deposit material that was found in the piping and other components. This was highly concentrated uranium hexaflouride compounds that contained differing amounts of enriched uranium. Because of the enriched uranium, it was difficult to obtain sample results because even a small sample size would exceed most laboratories' license for fissionable material. This material also contained hazardous constituents making it necessary to develop a blending process that would allow the material to meet waste acceptance criteria at any of the disposal facilities. It was also necessary for BNFL to develop a stabilization process so that the waste could meet the land disposal requirements.

The worst material encountered at the Three-building Project originated from the plants Cold Recovery Room system. This room contained a system that was used to remove the UF^6 material from the isolated components to allow maintenance to occur on those components. The system had a set of traps that was used to extract the UF^6 and store it until it was re-used. The system contained a lubricant that highly entrained the UF^6 gas. When it was opened, the lubricant would generate HF gas. Additionally, the pH of the resultant deposit material was so low that normal personal protective equipment was no longer protective (i.e. the gas dissolved the normally used rubber gloves). BNFL was required to engineer a system that could safely remove the piping, remove the deposit material and process the deposit material to allow for eventual disposal. BNFL engineers and operations personnel designed these systems and processes, and chemical resistive PPE was used to allow for extraction of the waste.

The Largest Supercompactor in the Country

In an effort to volume-reduce the amount of waste to be shipped off-site, the project constructed the largest Supercompactor in the nuclear industry. With over 330 million pounds of waste to remove from the site, volume reduction was necessary in keeping costs under control.

The Supercompactor was capable of processing 50 tons an hour, powered by 2,200 tons of hydraulic force. Seven 200-horsepower motors ran the Supercompactor and removed over 17 million pounds of stockpiled material. The Supercompactor was be utilized for those materials that could not be recycled practically or economically. The process of supercompaction applied intense pressures, in the order of tons/sq in (tens of MPa), to achieve substantial reductions in the volume of LLW (low-level waste) routed for disposal by landfill burial. Unlike conventional compactors, which are single-stage presses acting on materials in sacrificial containers, this facility accepted complete components such as coolers, compressor stators, valve bodies, and converter endcaps. The supercompaction facility consisted of 129,000 square feet of building area and had a dedicated truck and rail spur for receiving and dispatching material.

The fully open charging box was 26' long, 14' wide and 6' deep, so that materials could be loaded with the minimum amount of preliminary size reduction. Flippers closed down to 5' wide by 4' deep, until the partly compacted material was within the width of the 5' shear knife, and within the open height of the clamp. A feed cylinder then pushed the material incrementally under the compaction platen and then under the shear. Successive feed and compaction cycles produced a rectangular slab having excellent density, between 60% and 80% of full metal. To maximize machine utilization, a hopper was provided onto which the next charge of material could be loaded while the compaction cycle proceeded. The hopper tipped its load into the charging box within a few seconds after the feed cylinder had returned and the charging box had been fully opened. Typical throughput rates were in the range of 12 to 30 tons/hour, dependent on the feedstock.

Substantial savings were achieved both in burial disposal costs, and in the costs of size reduction, packaging, and subsequent transportation. Project safety was enhanced by reducing potentially hazardous processes. Supercompaction was clean and simple. The machine was industry-proven, and did not introduce any new hazards. Operations were carried out remotely, thus minimizing hazards and dose uptake to operators. Large components were compacted down to burial size criteria without interstage handling and labor intensive thermal cutting, thus minimizing hazards associated with these processes. The facility was provided with containment, ventilation, HEPA filtration and monitoring. The Supercompactor reduced waste volume by up to 75%, and provided safe disposal of the following:

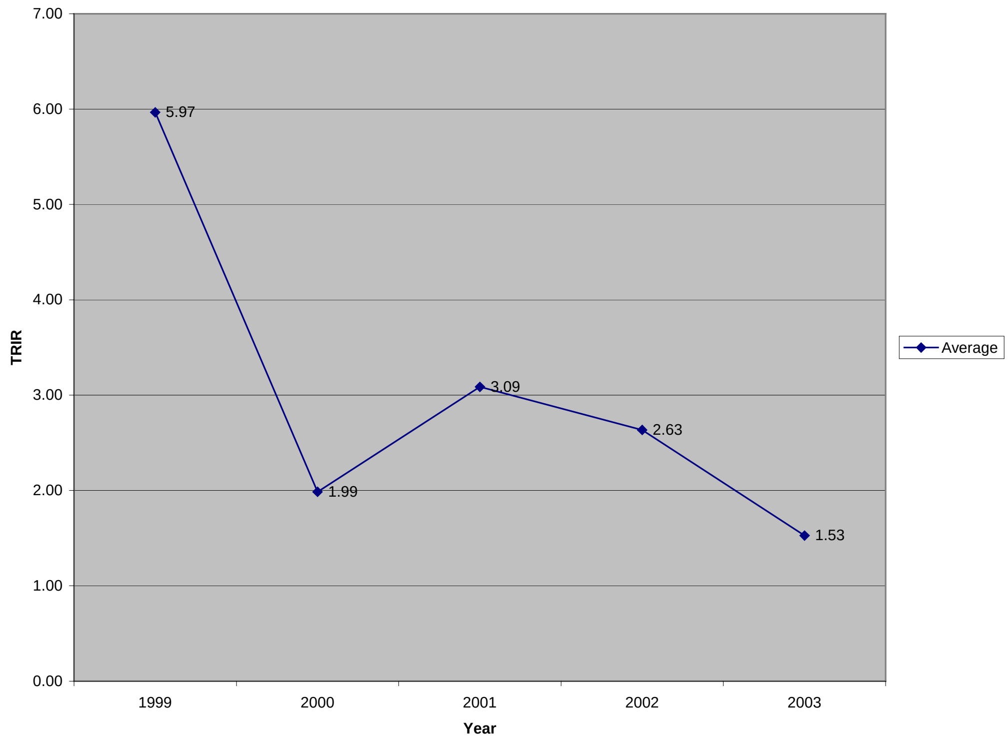
- 86,939 tons of low-level radioactive waste
- 13,117 tons of solid and mixed waste
- Approximately 122 tons of solid and RCRA waste
- 1,505 tons of solid and polychlorinated biphenyl waste
- 268 tons of universal waste stream
- 71 tons of asbestos
- 20,655 tons of recyclable material
- 350 tons of triple waste
- 40,000 total tons of non-hazardous solid waste.

Safety – Last but not Least

Without an outstanding safety program, companies in the nuclear industry would not be allowed to conduct these projects. A number of unique programs were developed to address this issue. These programs allowed the project to reach one million man-hours without a lost time accident three times in three years and maintain a Total Recordable Incident Rate 80% to 90% less than the national average.

In order to maintain those numbers, employees and management relied on experience attained throughout the project, Lessons Learned, and the implementation of the Behavior Based Safety (BBS) program. Workers were involved in the full spectrum of project activities. Each employee was held accountable for safety from the first day of the project to the last. The attitude toward safety, quality, and continuous improvement was interwoven through every aspect of the project.

Table I. The Total Recordable Incident Rate from 1999 to 2003.



Behavioral Based Safety

The Behavioral Based Safety (BBS) program was implemented in an effort to better involve the employees with safety concerns. The program focused on employees observing the behaviors and work practices of fellow workers. When an employee observed a correct or incorrect action, discussions were instantaneous. Providing timely feedback allowed for immediate attention to a potential problem. Through behavioral learning, the expectation was that employees would also take safety practices home. Training was also provided through skits and videos, but the focus was commitment to safety.

The Tennessee Center for Labor-Management Relations awarded BNFL special recognition for its outstanding accomplishment in the design and implementation of the BBS program. Tennessee Center for Labor-Management Relations Dr. Barbara Haskew was very impressed with BNFL's accomplishments and is encouraging other companies to use BNFL's BBS program as a catalyst for their own safety issues.

In addition, BNFL implemented other ways to keep people focused as the project ended. "*Make Safety Personal*" was initiated by the BBS Committee. The team offered Popsicle's during the hot days of summer—Beat the Heat—and a lesson-learned flyer was distributed highlighting two DOE site fatalities. The flyer initiated one-on-one discussions on how fatalities occurred and what could have been done to prevent the accident. A safety poster contest was initiated in an attempt to get children/families involved. The object was to have children submit a drawing, along with a photo of themselves and the family, and use the photos on subsequent safety posters. The object was to bring home the theme, *Make Safety Personal*.

In an effort to keep the employees focused on safety at the end of the project, a safety bonus program was developed. For every week the project went without a recordable injury, a name was drawn for a $1,000 safety bonus. Upon completion of the project, we also gave away a truck and a boat.

CLOSING

Completing the single largest nuclear decommissioning project in the United States was challenging and exciting. Because of its massive size and uniqueness, BNFL had to be creative and inventive when solving numerous obstacles. Since there have been no other GDP decommissioning projects done within the DOE environment, there have been no previous programs or protocols from which to glean. Programs and procedures were developed specifically for this project, and equipment was designed from scratch. Experience and Lessons Learned allowed the ETTP team to overcome challenges and maintain one of the best safety records in the industry. Three times in three years BNFL surpassed one million man-hours without a lost time accident. There is no other project in this industry that can make that claim.