Use of Commercial Rigid Polyurethane Foam for Decontamination and Decommissioning

Prepared for the
U.S. Department of Energy
Office of Environmental Management

BECHTEL JACOBS COMPANY LLC
managing the
Environmental Management Activities at the
East Tennessee Technology Park
Oak Ridge Y-12 Plant Oak Ridge National Laboratory
under contract DE-AC05-98OR22700
for the
U.S. DEPARTMENT OF ENERGY

Facility: East Tennessee Technology Park (K-25 Site), K-25/K-27 D&D Project, Bechtel Jacobs Company LLC

Title: Use of Commercial Rigid Polyurethane Foam for Decontamination and Decommissioning

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Description

A use of Commercial Rigid Polyurethane Foam (PU) was developed and implemented to stabilize fissile and non-fissile residual radioactive materials present in contaminated equipment and process pipes at the U.S. Department of Energy's (DOE's) K-25 and K-27 facilities at the East Tennessee Technology Park (ETTP) located in Oak Ridge, Tennessee.

A feasibility study was conducted and custom formulation of rigid polyurethane foam was developed for use at K-25/K-27. Also, a comprehensive performance testing program was conducted for Bechtel Jacobs LLC (BJC) by the Argonne National Laboratory (ANL) to determine the aging behavior of PU for Infiltrating Contaminated Process Gas Equipment (PGE) and Piping. The study included aging effects due to mechanical stresses, heat, moisture, temperature cycling, biodegradation, and radiation exposure. The study and tests concluded that the foam integrity is maintained more than 1000 years under landfill conditions and is suitable for use as void filler. Results of this study and properties of PU are summarized in Argonne National Laboratory Report ANL-06/32 "Study on Degradation of a Commercial Rigid Polyurethane Foam Used for Filling Process Gas Equipment (PGE) and Pipes and Corrosion Behavior of Pipes at K25/K27" (August 2006).

Benefits

Use of PU allows building demolition to occur with most of the process equipment and piping in place; therefore, improving personnel safety by eliminating most of the time workers will spend in the rapidly deteriorating structure removing process gas equipment and piping systems. With the use of this foam, only a small portion of the process equipment and piping, which contains more than allowable residual materials for transportation and/or disposal, must be removed prior to demolition. This is a significant improvement in safety cost savings compared to removal of all contaminated equipment and piping prior to demolition. Use of PU also reduces radiation exposure by minimizing the potential spread of contamination during demolition and loading of demolition debris. In addition, criticality safety is enhanced by encapsulating residual fissile material in place (Fig. 1), thereby preventing its movement and eliminating the potential for infiltration of water during demolition and disposal.

Fig. 1. Polyurethane Foam encapsulates surrogate materials.

PU also provides an excellent visual barrier to classified materials and technology and eliminates easy access to classified/fissile materials (Fig. 1), which meets the project's stringent security requirements. By qualifying as a void filler material, PU avoids the use of substantially heavier void filler materials (e.g., grout) to reduce subsidence. In addition, application of PU is less labor-consuming than grout. Table 1 provides qualitative comparison of benefits of PU versus grout.

Table 1. Benefit comparison

Attributes	PU	Grout, etc
Personal Safety	X	
Security	X	X
Contamination Control	X	
Strength/#	X	
Cost/#		X
Ease of Application	X	
Initial Capital Cost		X
Remote Demolition	X	
Void Filler	X[1]	X

1. Approval of PU as void filler for K25/K27 Project only

Since it is applied as liquid, it flows like water, then rises as it reacts, flowing over and encapsulating residual contaminants and filling virtually all void spaces (Fig. 1), including the small holes and crevices prevalent in the very complex and large-geometry process equipment (Fig. 2). Due to its light weight and flowability, it can be applied easily while components and pipes are in place, thereby allowing remote demolition of buildings (Fig. 3 and 4).

Fig. 2. Application of Polyurethane Foam into complex large-geometry equipment.

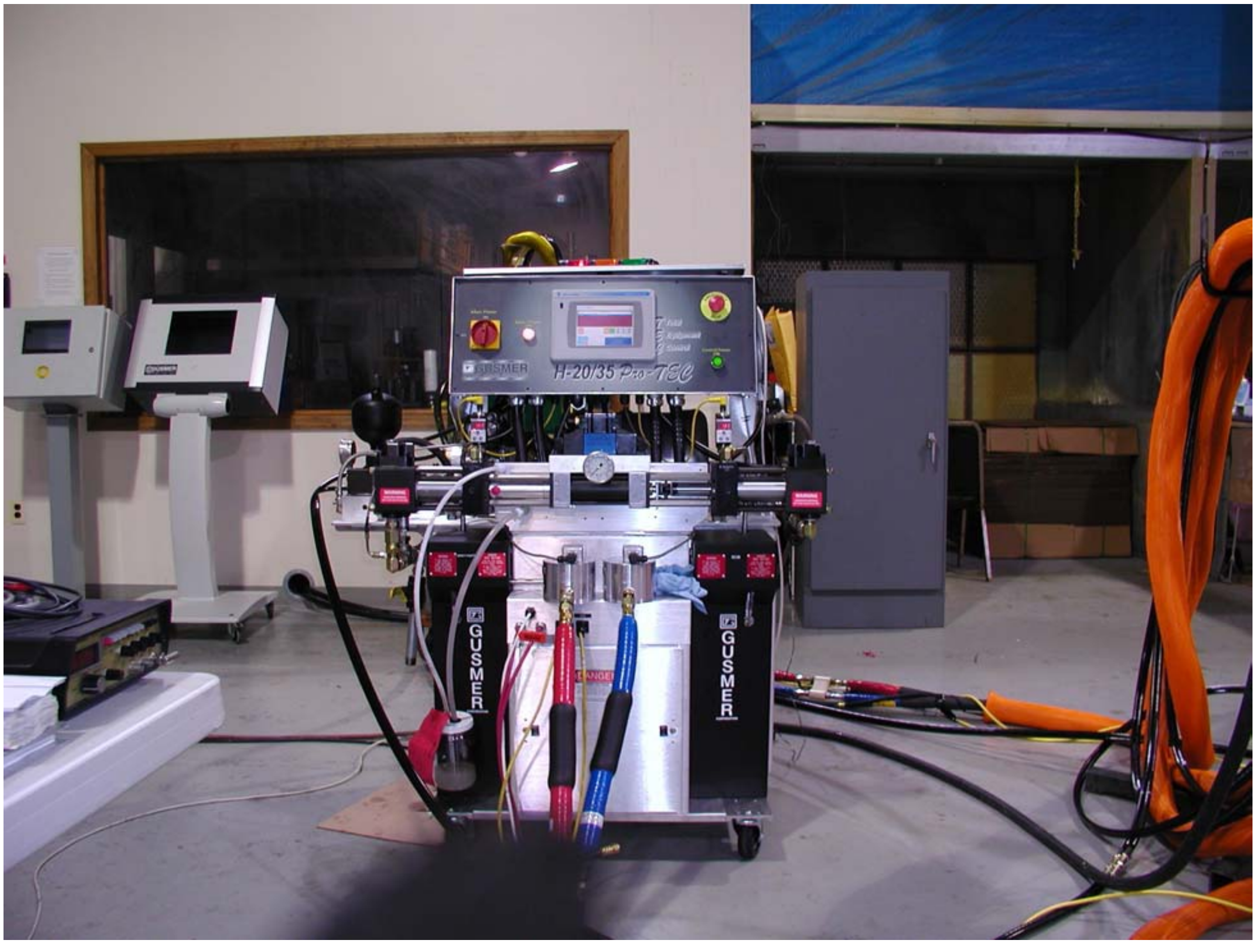

Fig. 3. Foam application machine.

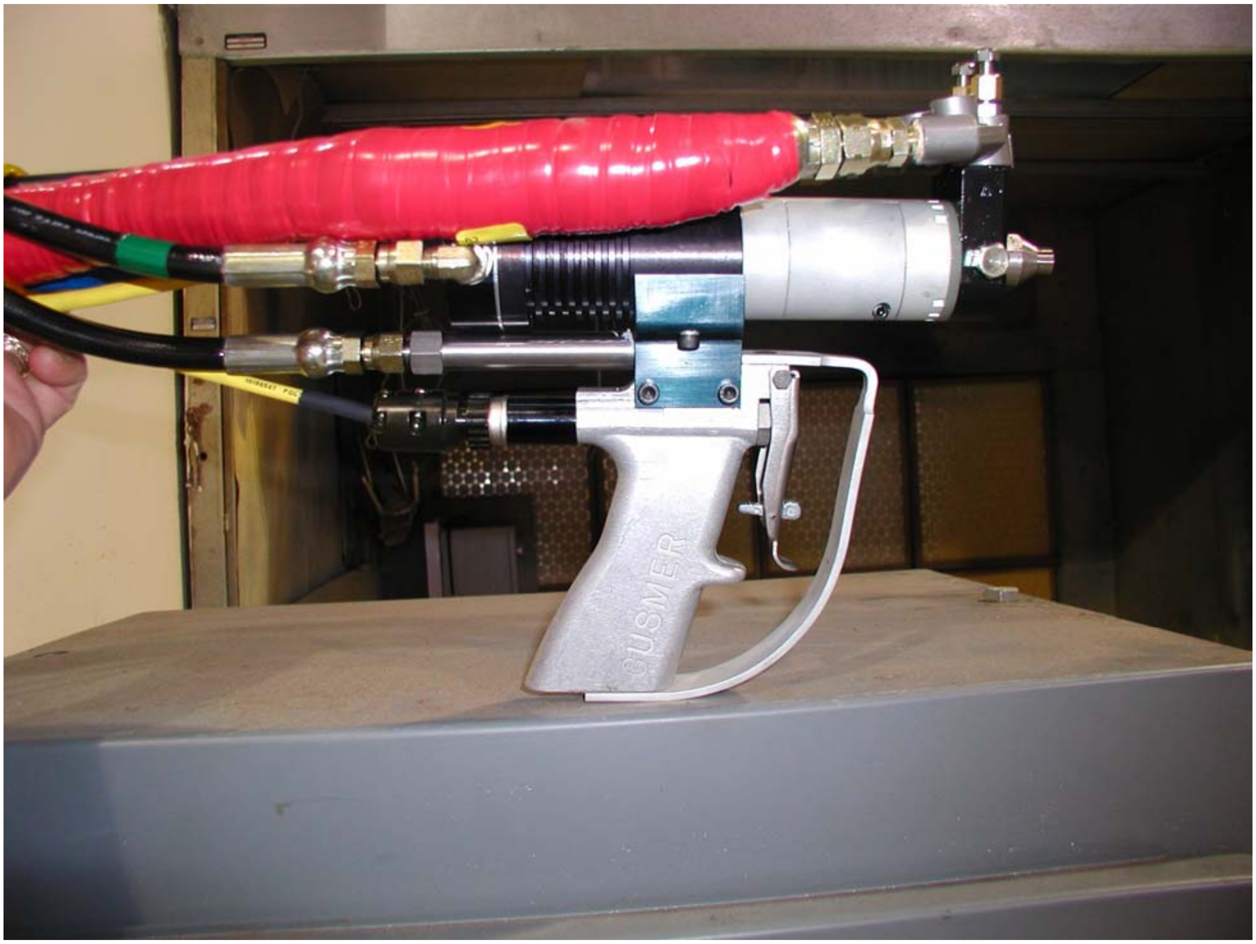

Fig. 4. Foam application mixing gun.

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Issues

Since the foamed components and pipes are destined to be disposed at the Environmental Management Waste Disposal Facility (EMWMF) at the DOE's Oak Ridge Reservation, failure of Rigid PU in landfill conditions is expected to affect the subsidence and ultimate integrity of the final cap during the life of the landfill. A study was undertaken to evaluate long-term (> 1000 years) performance of the PU in the conservatively postulated landfill environment. The study evaluated for longevity of foam under degradation conditions such as mechanical stresses, heat, moisture, temperature cycling, biodegradation and radiation exposure. BJC contracted ANL with support from Illinois Institute of Technology (IIT), University of Illinois at Chicago (UIC), and Oak Ridge National Laboratory (ORNL) to perform the study.

Because PU is a man-made and not a natural material, it is not on an approved list of materials that can be used as filler to meet the landfill criteria of > 90% full. To be used as void filler, it required approval by DOE, the Environmental Protection Agency (EPA), and the Tennessee Department of Environment and Conservation (TDEC).

Measurement

Results of PU performance testing indicate longevity of the foam for more than 1000 years in landfill conditions and approval of use of foam as void filler by DOE, EPA (Region 4), and TDEC.

Results

Results of the longevity of the foam evaluated under degradation conditions such as mechanical stresses, heat, moisture, temperature cycling, biodegradation, and radiation exposure are as follows: As-fabricated, unconfined compressive strength of the urethane foam (density of 3.1 pcf) was found to be anisotropic[1]. The compressive strength of the urethane foam degraded with test temperature up to 90°C. Dry and wet aging of urethane did not degrade compressive strength for tests conducted at temperatures as high as 90°C and exposure times as long as 60 days. However, foam density decreased by 15% with such long-term exposure at elevated temperature. The density changes were mainly attributed to simple dimensional changes. Dry and wet freeze-thaw cycling also did not degrade the compressive strength for 30 cycles between -5°C and 50°C.

Consolidation properties of the foam were investigated using confined compressive strength tests to simulate stresses at burial depths of 90 feet of soil. Urethane foam with 3.1-pcf density showed that at 75 psi stress (corresponding to 90 ft or the maximum soil burial depth), strains were 50 to 60%. This % strain, which is the ratio of change length versus the original length, did not satisfy the Oak Ridge Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) EMWMF waste acceptance criteria (WAC) goal of < 10% physical consolidation requirement, as per the potential landfill overburden loads. Thus, higher density (7 pcf) foam was investigated. Confined compression tests on 7-pcf urethane foam showed consolidation of < 10% volumetric strain at stresses of 75 psi. In time-dependent, confined

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[1] Anisotropy means that a specific property (e.g., strength, density, etc.) is different in different direction.

compression testing at 75 psi, foam deformed < 8% in more than 1800 hours of testing. A biodegradation study showed the urethane foam to be non-biodegradable under anaerobic conditions. It is believed that the rigid foam was resistant to microbial attack, due to its chemical and physical structure. Irradiation of the urethane foam indicated no significant degradation of the foam and minimal gas generation during a gamma irradiation equivalent to a 1000-year alpha and gamma dose.

Based on the results of performance and longevity studies performed by ANL et al., and very positive experience with actual application of PU at K-25/K-27 decontamination and decommissioning (D&D) Project, BJC applied to DOE for an exemption for use of PU as a void filler, instead of grout. DOE, in turn, requested the regulators EPA and TDEC to approve PU as a void filler.

Current Situation

Based on the results of performance and longevity studies performed by ANL et al., and significant benefits derived from application of PU at K-25/K-27 D&D Project, both TDEC and EPA approved the use of PU as void filler for the K-25/K-27 Project.

BJC continues to use PU in all complex and large components and pipes, thereby enhancing safety and security, improving the schedule, and at the same time realizing cost savings. BJC recommends consideration of the use of PU across the DOE complex to improve contamination control and criticality safety related to residual materials in piping and equipment, and as a visual barrier for classified technology during D&D and disposal of components in landfills.