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THE ART OF IMPLOSIONS HAS IMPACTED THE SUCCESS OF THREE  
DECONTAMINATION AND DECOMMISSIONING PROJECTS AT FERNALD

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## **THE ART OF IMPLOSIONS HAS IMPACTED THE SUCCESS OF THREE DECONTAMINATION AND DECOMMISSIONING PROJECTS AT FERNALD**

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### **ABSTRACT**

The Department of Energy (DOE) at the Fernald Environmental Management Project (FEMP), near Cincinnati, Ohio, has successfully impacted the safety, cost and schedule goals of the Decontamination and Dismantling (D&D) Program by using the art of implosions. An implosion is the act of bringing a structure down in a well planned and directed manner using explosive materials. Three major structures in three separate projects were imploded using this well known commercial technology.

Safety is, and will always be, the major consideration with each of the projects. As each project succeeded another, the work process used new and improved methods to lower the risk to the environment, provide a safer workplace by reducing the exposure of high risk work and reducing the spread of lead, asbestos and radioactive materials. The time frame for dismantlement of the steel structures was greatly improved, thus reducing the total project cost. The lessons learned were incorporated from one project to another, to continually improve the work process.

A number of alternatives were considered for the removal of the structures, seven, four and three stories in height. The subcontractor and its demolition sub-tier contractor worked in a fixed price lump sum contract environment. While skeptical at first, the subcontractor realized the benefits of the technology, a win-win situation for all participants.

The overall planning of each of the events was tied to the needs of the client (DOE), the stakeholders and the community surrounding the site, and the continuing progress at the Fernald site. The recording and application of several key lessons learned in the sequence of implosions, will be the key issues of interest in this paper.

Each project offered interesting opportunities for contingency planning, coordination, safety culture adjustments, and high regard for the protection of surrounding structures. The technology has afforded the subcontractors a means to reduce the overall duration of the D&D portion of the project and met the need to prepare the structure for final disposition as a waste stream.

The paper will describe the key issues discussed above in order to raise the level of knowledge of those considering the attributes of the innovative technology on an environmental cleanup project.

### **NOMENCLATURE**

ASCII - American Standard Code for Information Interchange  
ATF - Bureau of Alcohol Tobacco and Firearms  
CFR - United States Code of Federal Regulations  
D&D - Decontamination and Dismantlement  
DOE - United States Department of Energy  
DOT - United States Department of Transportation  
FEMP - Fernald Environmental Management Project  
IFB - Invitation to Bid  
NFPA - National Fire Protection Association  
OSHA - Occupational Safety and Health Administration

### **INTRODUCTION**

Mention the word implosion and people immediately conjure up images of destruction, explosions, smoke, fire, dust and debris. On the contrary, just the opposite is true when explosives are utilized in a controlled, engineered fashion to dismantle a contaminated structure. At The Fernald Environmental Management Project (FEMP), it was proven that implosions were the safest, and most cost effective way to

accomplish the final dismantlement of three large structures. In fact, on steel frame structures three stories and taller, implosions should always be considered as an alternative means of dismantlement (one to two story structures can be dismantled via other means).

## HEALTH AND SAFETY

The first and foremost concern of accomplishing implosions at the FEMP is safety. No matter the size or scope of the project, everyone is encouraged to seek out safer methods of working. It is this continuous investigation for safer methods which eventually led to the suggestion that implosions be used at the FEMP. The innovative method of structural dismantlement employing implosions was used at the FEMP, and established to be safer than conventional means of dismantling contaminated structures.

Building height, lead paint, asbestos, and radiological contamination in three structures (Plant 7, Plant 4, and Plant 1) imposed unique challenges to minimize health, safety, and environmental risks in their safe dismantlement. All three buildings were constructed in the 1950's and shared similar structural similarities i.e., steel frame, and steel decking seam welded to structural members. The safest alternative to the removal of these structures must consider:

- Exposure of workers to extensive high altitude work;
- Exposure to lead fumes from the torch cutting of steel and;
- Exposure to fugitive asbestos fibers and radiological contaminates.

FEMP project management initially considered three dismantlement alternatives. The three alternatives were:

1. Mechanical tripping. Mechanical tripping of the building consists of selected removal of key members, (i.e., certain bays, X-bracing, & floor plates), cutting of columns and floor plates, and then pulling the building over with heavy equipment.
2. Modular dismantlement. Modular dismantlement consists of removal of entire floors on several bays as a unit with a heavy lift crane. This method involves cutting adjacent steel members and lifting the section to ground level.
3. Implosion. Implosion uses shaped charges to remove columns and splice plates on various floors so the building will fall in on itself. The shaped charges act as a cutting tool by directing millions of pounds of cutting force in the form of hot, expanding gases on the steel members (Albertin, et al, 1996).

After thoroughly examining all three options, FEMP project management and a demolition sub-contractor determined that the implosion method would be the safest and most cost effective option. To prove this, a study was conducted on Plant 7 comparing dismantlement via implosion vs. manual methods. It was determined

that using an implosion would significantly reduce worker exposure to the major health and safety risks identified. Table 1 below highlights the comparisons of exposure to risk elements in the implosion vs. manual dismantlement method.

**Table 1 - Plant 7 Comparison of Implosion vs. Manual Dismantlement Methods**

Disassembly Item	Implosion Method	Manual Method
Sum of torch cuts on columns	90 linear feet of flange cuts	420 linear feet of cuts
Sum of torch cuts on decking	0	3000 linear feet
Full cuts on columns	No	Yes
Possible exposure to rad & lead fumes	90 linear feet of torch cutting	3420 linear feet of torch cutting
Potential lead fume exposure	25 man hours	640 man hours
Possible rad exposure	2 weeks	8 weeks
High altitude work	No	Yes
Perform work around open floors	No	Yes
Number of Heavy lifts	0	80
Duration	2 weeks	8 weeks

(Albertin, et al, 1996)

## FACILITY HISTORY

The FEMP is a Department of Energy (DOE) facility located near Cincinnati, Ohio. Between 1953 and 1989, the FEMP, then called the "Feed Materials Production Center" produced mainly high purity uranium metal products for the nation's defense programs (DOE, 1995). The facility also produced some thorium metal products, which were intended for an experimental fuel cycle. The uranium products produced at the FEMP were used at other DOE facilities to make plutonium and tritium (DOE, 1995). In July 1989, uranium metal production ceased at the facility, and resources were redirected to focus on environmental restoration.

## DECONTAMINATION & DISMANTLEMENT

All structures at the FEMP are scheduled to undergo an extensive and exhaustive process of Decontamination and Dismantlement (D&D)

designed to properly dispose of contaminated materials and restore the site for beneficial use. The D&D process involves:

- Characterization of materials and contamination;
- Removal of all drums and loose materials;
- Building safe shutdown;
- Gross decontamination;
- Equipment, piping, and asbestos removal;
- Release clean of interior structure;
- Removal of interior and exterior siding;
- Structural steel removal using implosion method;
- Waste recycling and disposition (Albertin, 1996).

### STEEL STRUCTURE CHARACTERIZATION

While the three structures imploded at the FEMP shared similar structural characteristics, their function, size, and level of contamination were dissimilar. The following points illustrate the size, function, and degree of contamination of the three structures imploded.

- Plant 7 was the tallest, most visible structure at the FEMP, measuring 80 feet wide x 60 feet tall x 110 feet high (seven stories) (DOE, 1993). Plant 7 was used as a pilot plant for the reduction of uranium hexafluoride ( $UF_6$ ) to uranium tetrafluoride ( $UF_4$ ), and later served as a storage warehouse for drums of  $UF_4$ . Radiological surveys of Plant 7 indicated that it was lightly contaminated (DOE, 1993). Plant 7 was imploded on September 9, 1994.
- Plant 4 was approximately 2.5 times the footprint of Plant 7, but only 2/3 the height (122' x 170' x 92' feet high). Plant 4, also known as the green salt plant, housed the hydrofluorination process at the FEMP, and was used from start up until 1988. In Plant 4, Uranium trioxide ( $UO_3$ , orange oxide) was converted to uranium tetrafluoride ( $UF_4$ , green salt). Radiological surveys of Plant 4 indicated that it was heavily contaminated (DOE, 1993). Plant 4 was imploded on August 24, 1996.
- Plant 1 was a four story structure measuring 82' x 202' x 50' high. Plant 1 was the receiving point for all enriched materials to be processed at the FEMP. Ore concentrates and recycled uranium metals were weighed, sampled, and milled in this plant for distribution to other processes at the FEMP. Radiological surveys of Plant 1 indicated that it was moderately contaminated (DOE, 1993). Plant 1 was imploded on February 22, 1997.

### EXPLORING A BETTER IDEA

When the FEMP's project management and stakeholders were initially approached about the possibility of using implosions for steel structure dismantlement, the initial reaction was skepticism. This skepticism was fueled in part because FEMP project management and stakeholders had no technical expertise with the use of explosives and had a policy in which no explosives were allowed on site. At the FEMP, confidence

and expertise in building dismantlement resided in more traditional methods. Furthermore, it was believed that the use of explosives on a contaminated structure would be opposed by the public.

In order to achieve an agreement on using implosions to dismantle structures at the FEMP, one of the oldest and most respected implosion firms in the business was invited to the site. The implosion firm's experience and expertise (they have successfully imploded thousands of different structures), was used to educate (see Table 1) FEMP project management and stakeholders about implosions and reinstate that they are the safest and most cost effective method to remove the large steel frame structures.

### EXECUTION OF IMPLOSION WORK

Planning for each of the implosions started prior to the issuance of a request for bid. All potential D&D subcontractors were pre-qualified for prior experience in DOE work, demolition work, asbestos abatement, work in a radiological setting, heavy rigging, and a good safety record. The execution of the D&D work involved the preparation of detailed work plans on each key decontamination and dismantlement phase of the project. The work plans were written by the subcontractors and reviewed and approved by FEMP project management, checking the plan for compliance with all applicable rules, regulations, and specifications required in the subcontract. The structural steel dismantlement work plans for each of the plants were started at least three months prior to the beginning of work. As the evolution of the implosions proceeded, the amount of detail in the work plans increased dramatically between the first and third implosion. The work plan for Plant 7 was eight pages, while the final work plan for Plant 1 consisted of 25 pages. This increase was the result of more planning and details being shared with the project team over time. The primary objectives of an implosion work plan are listed below:

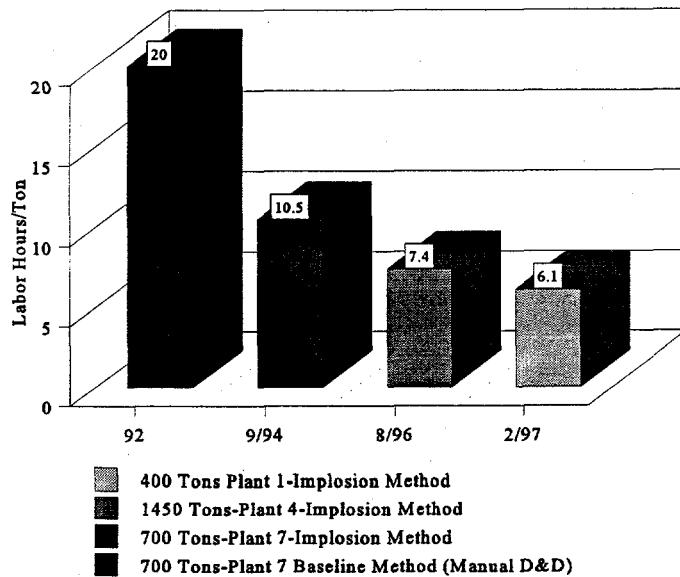
- State the scope of work;
- Schedule for completion of work;
- State the pre-requisites of the work;
- State the technical approach;
- The sequence in which the work is to be completed;
- Necessary construction equipment and materials required;
- Methods of contamination control;
- List the implosion contractors credentials;
- Contingency plans for detonation failure;
- Methods for the protection of adjacent structures and buildings;
- Plans for seismic monitoring;
- Crew sizes;
- Health and safety training requirements;
- Personal protective clothing requirements;
- Prepare a comprehensive hazard assessment;
- State explosives storage requirements;
- State explosives on-site transportation requirements;
- Drawings showing locations and types of charges;
- Steel structure pre-cutting details;
- Listings of charge configurations and;
- Fragmentation protection details.

Parallel to the preparation of the implosion work plans, FEMP project management prepared detailed implosion coordination plans. The purpose of these plans were to identify:

- Comprehensive procedures for coordination of all FEMP, subcontractor and client personnel within the controlled access area;
- FEMP access requirements during the implosion period;
- Identification and location of all personnel within the complex and exclusion zones;
- Identification of observation posts and personnel at the time of the implosion;
- Photography requirements;
- Implosion countdown procedure;
- Chain of command roles and responsibilities;
- Post implosion survey procedure to inspect for proper detonation of charges;
- Post survey procedure to check for radiological contamination levels;
- Supervision plans for media personnel and,
- An independent safety assessment of the work plan.

This entire process of executing implosions became more efficient and thorough as the evolution of the implosions proceeded from Plant 7 to Plant 1. Chart 1 below highlights this efficiency increase exhibited in the succession of implosions using the labor hours needed to dismantle a ton of steel.

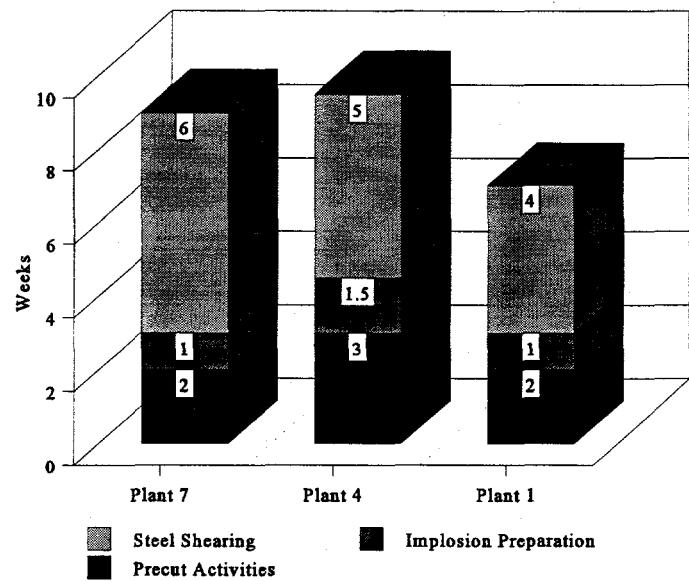
**CHART 1 - FEMP D&D STRUCTURAL DEMOLITION UNIT RATE**



### Cost and Schedule

In addition to offering significant health, safety, and environmental benefits, it was proven that implosions had a major cost and schedule advantage over the manual method. Implosions have an inherent advantage over manual dismantlement in the fact that significantly fewer man-hours are needed to dismantle the structure. In an implosion, most of the time (two weeks) is consumed by pre-cutting the structure, with only several days needed to actually attach the charges and perform the implosion. Whereas in manually dismantling a structure, months and months are required by a large workforce to remove it piece by piece. One can quickly grasp the cost and schedule benefits that an implosion offers. For example, it was calculated that imploding Plant 7 saved \$5 million and seven months from the manual method of dismantlement. Chart 2 below, illustrates the time it took to perform the major tasks of an implosion for each of the plants. The calculated schedule for manually dismantling these plants was approximately ten months.

**CHART 2-STRUCTURAL STEEL DISMANTLEMENT-MAJOR TASK ELEMENT DURATIONS**



*Precut includes cutting building column webs*

*Implosion includes attachment of charges*

*Steel shearing includes shearing of steel to meet size criteria*

### **LESSONS LEARNED**

To improve on future efforts, the FEMP has an extensive documentation program in place to record what aspects of a project were successful and those that need improvement. The following topics represent the key "lessons learned" from the implosions conducted at the FEMP. Each topic will be depicted in the context of the implosion where it was most successful, with an explanation of how applying lessons learned from previous efforts made it successful.

### **Partially Damaged Structure**

When engineering an implosion, it is critical that it is designed to completely fell the structure on the first attempt. A partially damaged structure resulting from a faulty implosion can present a plethora of challenges more difficult than the original structure presented. One of the most difficult challenges is determining the integrity and strength of the compromised structure. Strength and integrity have to be determined before personnel can work in or around the structure to safely plan a means of bringing the structure down. The initial implosion at the FEMP resulted in the dilemma mentioned above.

The implosions of Plants 1 and 4 were successes, the structures fell exactly where they were designed to fall on the first attempt. These successful implosions were the result of applying lessons learned from the implosion of Plant 7. The initial implosion of Plant 7 resulted in a partially fallen structure, for which the implosion contractor assumed full responsibility. An inquiry conducted by the implosion contractor and FEMP project management identified the key issues which contributed to the partially fallen structure. Those issues are identified below.

- **Independent Outside Review** - The first implosion plan at the FEMP did not receive an outside, independent review of the implosion plan to determine if it was sufficiently safe and adequate to bring the structure down. In the implosions of Plants 1 and 4, the implosion plan was reviewed and critiqued by an outside, independent consultant to ensure adequacy and safety. It is especially important to seek out this review when dealing with a sole source for technical expertise (implosions) which does not exist with project management or stakeholders.
- **Do Not Over-Relay on Gravity** - It was calculated that the structural strength of Plant 7 was four times stronger than ordinally estimated, consequently this over design of 1950's era structures was compensated for in the engineering of the following implosions. In Plants 1 and 4, key structural components such as column splice plates and bolts and web plates and bolts, and X-bracing were pre-cut on all floors. In Plant 7, pre-cutting was only conducted on selected floors. In addition, more and stronger charges were used on key structural members in Plants 1 and 4.
- **Media Influence** - The successful implosions of Plants 4 and 1 were well publicized after the fact. A valuable lesson was learned in the first implosion about not making the event a public spectacle. As the implosion date for Plant 7 drew near, increasing media presence and inquiry were transforming the implosion into a public spectacle. The anticipation of the implosion, created by extensive media coverage, fixed the schedule of the event. As a result, FEMP project management was diverting resources toward accommodating the media rather than focusing on achieving a successful implosion. Although the media's influence was only an ancillary factor, it was deemed important enough to

have removed event flexibility and influenced technical judgment.

### **Fragmentation/Adjacent Structure Damage**

In the implosion design, it is important to minimize the fragmentation which will occur from the detonation of the linear shaped charges used to cut the steel. The linear shaped charges are enclosed in copper cladding which will fragment upon detonation. Fragmentation mitigation is important from both a safety and property protection standpoint. FEMP project management achieved excellent fragmentation control in the implosions of Plants 7 and 1. In all of the implosions, the charges were wrapped with conveyor belting, and chain link fence to control fragmentation. In addition, some charges were enclosed by a plywood box for additional fragmentation control. However, after the Plant 4 implosion, pieces of the shaped charges were found up to 700 feet from the structure. This fragmentation was a result of more powerful charges used in the Plant 4 implosion. As a consequence, additional fragmentation control measures were taken before the Plant 1 implosion. The charges were wrapped with additional layers of belting and chain link fence, as well as adding two layers of geo-textile fabric to the outside of the assembly. To further protect adjacent structures from fragmentation, a geo-textile curtain was hung from the structure on two sides. These additional measures were successful in achieving fragmentation control. The points below indicate the proximity of nearby structures and the damage sustained, if any, from the implosions.

- Plant 7 - The nearest structure was 35 feet away and it received minor structural damage as a result of the implosion- several broken windows.
- Plant 4 - The nearest structures were 150 feet away and they received moderate structural damage-small holes were found in the siding of a building and sides of adjacent trailers.
- Plant 1 - The nearest structures were 40 feet away, and no damage was detected.

### **Contamination**

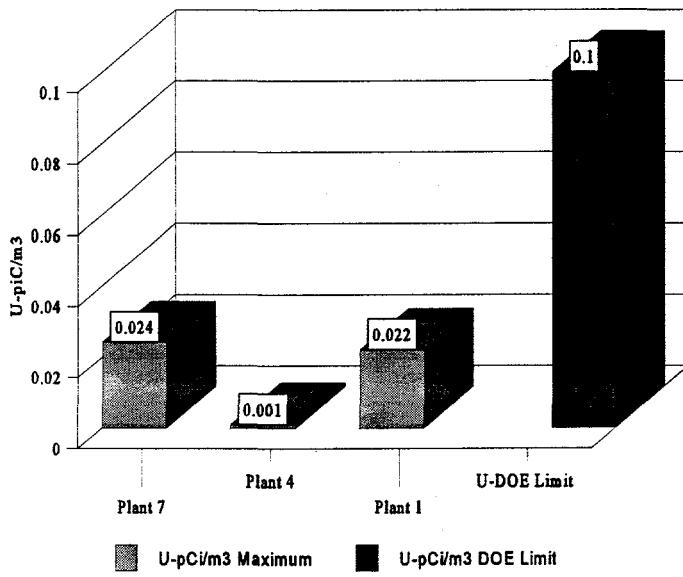
At a DOE site like the FEMP, there are a multitude of requirements and levels of oversight which exist to prevent any mishaps-mishaps which could easily lead to health & safety, property, and environmental detriment due to the nature of materials present. Therefore, contamination control during an implosion is an extremely important component of the event. In fact, the spread of contamination was a major concern when implosions were first suggested at the FEMP. However, contamination control was so successful in all of the implosions, that it turned out to be a non-issue. The following points list the controls employed.

- A geo-textile fabric was used to cover the structures' grade slabs and the footprint in which they were designed to fall.

- All of the structures were thoroughly decontaminated prior to the implosion using washing and vacuuming methods.
- A fixative was applied to the steel structure after the washing/vacuuming to lock down any fugitive fibers.
- Just Prior to the implosions, the structure and footprint were meticulously wetted with water to knock down any fugitive particles.

Chart 3 below illustrates just how successful the above measures were in the control of uranium dust during the three implosions. The *maximum* readings recorded, for each implosion, where chosen to depict how effective the controls were.

### CHART 3 - MAXIMUM AIRBORNE URANIUM CONCENTRATIONS RECORDED DURING IMPLOSIONS



( $U\text{-}pCi/m^3$  = picocuries per cubic meter) (Fernald, 94', 96' and 97')

#### Explosives Use, Transportation and Storage

A multitude of regulations and agencies exist, which set guidelines and oversee the use, transportation and storage of explosives. For example, the Department of Transportation (DOT), Department of Energy (DOE), Bureau of Alcohol Tobacco and Firearms (ATF), Code of Federal Regulations (CFR), and the National Fire Protection Association (NFPA) all played some role in the implosions at the FEMP. Prior to the initial implosion, FEMP project management and DOE personnel knew which regulations were applicable to the use of explosives, but did not completely perceive the nuances of each one. Consequently, the implosion contractor was the sole source of expertise in this area and was trusted to comply without substantial scrutiny. However, by the time Plant 1 was ready to be imploded, FEMP project

management and DOE had developed an intimate knowledge of the applicable rules and regulations. This competence allowed project management to provide oversight of the implosion contractor's use, storage, and transportation of explosives, adding another degree of safety. The points below list some of the principal regulatory issues which were addressed in the implosion work plans.

- Explosive materials and magazines to be delivered and transported on site in a properly placarded vehicle per DOT regulations.
- The shaped charges to be stored separately from the detonating devices per ATF regulations.
- The explosives storage area at the FEMP to meet the criteria of NFPA guidelines; including isolation and proper placarding.
- Provide 24 hour security of the explosive storage area, and restrict traffic, personnel access, and work activities while the implosion contractor is affixing charges to the structures.

For additional safety and security, the implosion contractor utilized a non-electric detonation system on all the implosions instead of an electric detonation system. Rather than initiating the detonators with electricity, the non-electric system utilized a signal tube containing reactive agents to initiate the detonators. This system is much safer than an electric system because there are no concerns that extraneous electricity or radio frequencies could initiate the detonators prematurely.

Following the Plant 4 implosion, the implosion contractor determined that there were 16 shaped charges which were suspected of being only partially initiated or which did not initiate at all. The implosion contractor determined that the superstructure had begun to shift more quickly than some of the charges were detonated, thereby shearing the blasting cord leading to those charges prematurely. The partially and un-initiated charges were handled by the implosion contractor without incident. The lessons learned from this experience applied to the Plant 1 implosion were, the use of faster detonators and the development of a contingency plan to deal with partial and un-initiated charges.

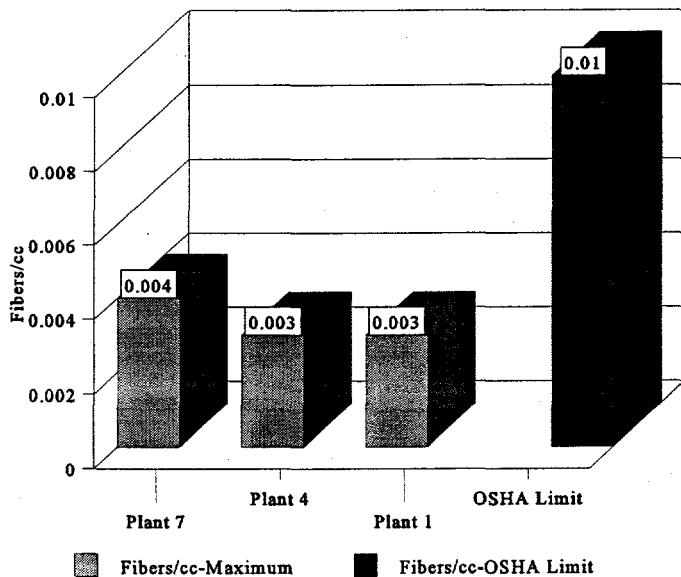
#### Construction Safety and Training

The mitigation of excessive work at heights and exposure to contaminants are two of the most persuasive points for using implosions in contaminated steel structure dismantlement. Despite the alleviation that an implosion offers to these risks, a modest amount of work in these conditions is needed to prepare the structure for an implosion. Therefore, it is important that everyone involved in the implosion work be trained in the hazards which exist, and in proper work practices which minimize risk and exposure to hazards. In addition to receiving training on safe work practices, the implosion contractor provided familiarization and instruction on the properties and characteristics of the linear shaped charges used in the implosions to FEMP project management, DOE, and stakeholders. In turn, the implosion contractor received the full suite of training required of contractors working at the FEMP. Not one injury or lost time accident was credited to the three

implosions, a fact which is attributable to the emphasis on, and culture of safety present at the FEMP. The points below summarize the progressive safety requirements for high altitude preparatory work on each of the plants.

- Plant 7 - 110 feet tall, with a preparatory work force of 17 men, of which 50 percent of the work required a tie-off.
- Plant 4 - 92 feet tall, with a preparatory work force of 28 men, of which 50 percent of the work required a tie-off.
- Plant 1 - 50 feet tall, with a preparatory work force of 20 men, of which 100 percent of the work required a tie-off.

#### CHART 4 - MAXIMUM AIRBORNE ASBESTOS CONCENTRATIONS RECORDED DURING IMPLOSIONS



(Fibers/cc = fibers per cubic centimeter) (Fernald, 94', 96' and 97')

#### Noise / Explosive Concussion Management

With the detonation of the linear shaped charges comes a corresponding, simultaneous, air, sound and seismic blast which radiates away from the source with decreasing intensity. For hearing conservation of those directing and observing the implosion, it is imperative that they be stationed a safe distance from the implosion and provided with hearing protection. Seismic forces generated from the implosion have the potential to impact underground utilities. To record these forces in the event of a potential impact resulting from the implosion, thorough monitoring was conducted during the events. For each of the implosions, the implosion contractor placed five

seismographs at pre-determined locations which recorded air and ground pressures created from the implosions. The seismographs recorded the data in an American Standard Code for Information Interchange (ASCII) format, for independent analysis should the need arise. Additionally, for historic, insurance and review purposes, extensive video coverage of the plants was captured before, during and after the implosions. The points below list the instant noise levels recorded for each of the implosions and the hearing protection required.

- Plant 7 - At 700 feet, <80dB instant; no ear plugs required.
- Plant 4 - At 700 feet, <90dB instant, ear plugs required.
- Plant 1 - At 700 feet, <120dB instant, ear plugs required.

#### Accountability and Emergency Service Plans

From the initial implosion, FEMP project management developed and deployed precise accountability and emergency contingency plans. These plans were effective, efficient and used for all three implosions. To make accountability of site personnel easier, all three implosions were conducted on a Saturday when the site workforce was at a minimum. Beginning on the Friday afternoon before the implosions, access to the FEMP was only granted to those authorized on a written list prepared by project management. On the day of the implosions, access and exit logs were checked by project management and FEMP security to be sure that only those authorized by project management were in the restricted area. Furthermore, FEMP project management developed an explicit chain of command to direct pre and post implosion activities and to avoid any confusion as to who was in charge. Moreover, in the highly unlikely event of an injury or fire resulting from the implosions, medical and fire personnel were staged nearby.

#### RESULTS

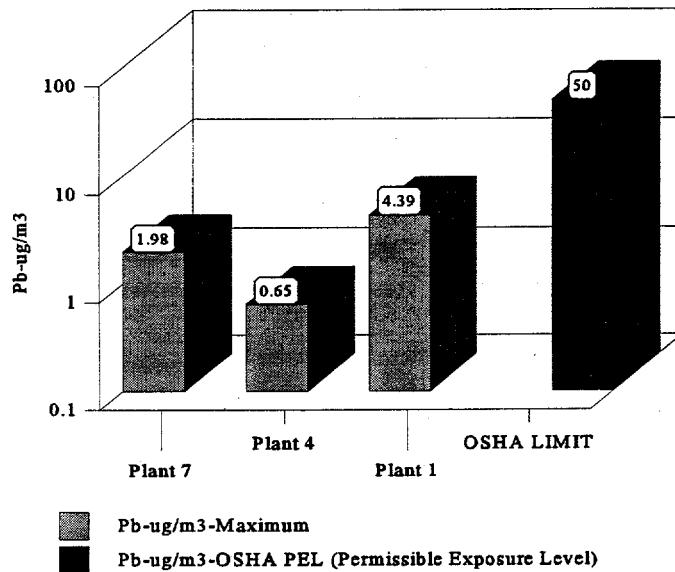
The implosions at the FEMP accomplished the tasks they were designed to perform. Most importantly, the buildings were removed from the site without injuries. Additionally, no lost time accidents or reportable's occurred in any of the three implosions. The implosions were also successful in removing the three structures on time and within budgets. And finally, the implosions were extremely successful in mitigating exposures of contaminants to the environment and human health. Chart 4 and Chart 5 depict the airborne concentrations of asbestos fibers and lead recorded during the implosions of the three plants. It is important to note, that the numbers shown in the charts represent the *maximum* values recorded to illustrate the actual levels compared to the regulatory limits. Chart 5 uses a semi-log scale to highlight the differences between the recorded values and the OSHA limit.

The numerous successes achieved with the implosions at the FEMP can be summarized by the key elements listed below.

- An absolute commitment to safety.
- The development of well detailed work plans.

- Training the work force to the work plans.
- The cultivation of an effective methodology for managing the D&D process.
- Recording and applying the lessons learned from the previous implosions.
- A belief and commitment to excellence on behalf of everyone involved.

**Chart 5 - MAXIMUM AIRBORNE LEAD CONCENTRATIONS  
RECORDED DURING IMPLOSIONS (SEMI-LOG SCALE)**



( $Pb\text{-ug/m}^3$  = lead/micrograms per cubic meter) (Fernald, 94', 96' and 97')

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#### Biographical Sketch

Mr. Borgman has over 23 years of engineering and management experience with Fluor Daniel, Inc. Mr. Borgman currently is a project manager who recently completed two D&D projects at the FEMP. Mr. Borgman joined the FEMP in 1992 and has completed a number of management assignments related to the D&D program. Mr. Borgman has also directed the engineering, construction and waste management aspects of D&D projects at the RCRA/CERCLA Fernald site.

Mr. Borgman has previously completed a number of management assignments in the nuclear power industry (project controls), the power cogeneration business and refinery business (civil manager).

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