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PROCEEDINGS OF THE CONCRETE DECONTAMINATION WORKSHOP

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Workshop Chairmen

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PREFACE

The 1980 Concrete Decontamination Workshop brought together representative of industrial firms providing decontamination equipment, techniques, and expertise, as well as organizations formerly or currently involved in facility decontamination. The two-day meeting provided a forum for exchanging ideas and experiences concerning concrete decontamination. The presentations and ensuing discussions emphasized techniques and equipment, performance rates, contamination control procedures, and project costs.

The workshop was sponsored by the U.S. Department of Energy (DOE), Richland Operations Office - Surplus Facilities Management Program Office (RL-SFMPO). The Pacific Northwest Laboratory (PNL) organized the meeting as part of the DOE-sponsored project, D&D of Hanford Facilities Technology, managed by Bud Arrowsmith and Richard Allen of PNL.

This Proceedings includes 14 papers submitted by workshop attendees. The papers describe concrete surface removal methods and equipment, as well as experiences in decontaminating and removing both power and experimental nuclear reactors.

We wish to extend our appreciation for the guidance and support provided by Jerry Landon, DOE-RL-SFMPO. We are grateful for the able assistance of Andrea Currie in developing the paper preparation guidelines and coordinating the Proceedings production. We also wish to thank Sue Porter, workshop secretary, and Roy Lundgren for help in making meeting arrangements and coordinating activities in Seattle.

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CONCRETE DECONTAMINATION AND DEMOLITION METHODS

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The U.S. Department of Energy (DOE), Division of Environmental Control Technology, requested Nuclear Energy Services to prepare a handbook for the decontamination and decommissioning (D&D) of DOE-owned and commercially-owned radioactive facilities. The objective of the handbook is to provide the nuclear industry with guidance on the state-of-the-art methods and equipment available for decommissioning and to provide the means to estimate decommissioning costs and environmental impact.

This paper will summarize the methods available for concrete decontamination and demolition to provide an overview of some of the state-of-the-art techniques to be discussed at this workshop. The pertinent information on each method will include the selection factors such as the rate of performance in terms of concrete removal per unit time (cubic yards per day), manpower required by craft, unit cost (dollars per cubic yard) and the advantages and disadvantages.

The methods included in this overview are those that have been routinely used in nuclear and non-nuclear applications or demonstrated in field tests. These methods include controlled blasting, wrecking ball or slab, backhoe mounted ram, flame torch, thermic lance, rock splitter, demolition compound, sawing, core stitch drilling, explosive cutting, paving breaker and power chisel, drill and spall, scarifying, water cannon and grinding.

1. INTRODUCTION

Concrete is universally used in all nuclear facilities such that nearly every decommissioning program must address itself to either the demolition or surface decontamination of concrete structures. Certain structures become radioactive during the operating period of a nuclear facility either through direct activation or surface contamination. Activated concrete represents the most difficult concrete removal activity due to the relatively high radiation dose and potential for release of radioactive particulates during demolition. Radioactive fluid leaks may contaminate floor or wall surfaces of a facility which, because of the porosity of concrete, prove to be resistant to nondestructive cleaning methods. Although non-radioactive concrete structures do not represent any unique demolition difficulty, the volume of such concrete coupled with significant reinforcement represents a formidable dismantling task.

Concretes typically encountered include biological shields which may be 2 to 10 ft thick standard (140-150 lb/ft^3) or high density concrete (magnetite or metal aggregate, 250-325 lb/ft^3). Reactor basemats or facility footings can be as much as 25 ft thick.

Contamination on floors and walls can be removed without demolishing the structures. This may be advantageous if the facility is to be converted to other uses.

This paper provides an overview of concrete demolition and scarifying processes for various concrete types and thicknesses. The following sections present a tabulation of available processes and detailed information important to the selection of a method.

2. PROCESS SELECTION

The selection of a specific process should be based on the experience learned from the conventional demolition industry, and applicable experience from actual decommissioning programs. Table 1 presents a tabulation of processes that may be used for all concrete types and thicknesses. The detailed information on each process provided in the following sections will aid in selection of the optimum process.

3. DETAILED DESCRIPTION OF PROCESSES

3.1 CONTROLLED BLASTING

3.1.1 Description of Process

Controlled blasting is ideally suited for demolition of massive or heavily-reinforced, thick concrete sections. The process consists of drilling holes in the concrete, loading them with explosives and detonating using a delayed firing technique. The delayed firing increases fragmentation, and controls the direction of material movement. Each borehole fractures radially during the detonation. The radial fractures in adjacent boreholes form a fracture plane. The detonation wave separates the fractured surfaces and moves the material towards the structure's free face. Figure 1 illustrates a typical "blasting round" for massive concrete demolition, and explains the terminology used in designing a blast; for example, the burden is the distance from the free face.

Blasthole design is based on a range of geometric relationships from which the blast design can be developed using an incremental powder loading per borehole. Pages 19-28 of Reference 1 provide guidance on standard blasting ratios. Under no circumstances should the user embark on a blasting demolition program without the services of a certified blasting technician.

Drilling methods for blast hole preparation include percussion air-operated drills, electric, pneumatic or diesel driven rotary drills or diamond-core abrasive drills. Percussion drills are the most versatile and can economically drill 1¼ in. to 2 in. diameter holes over a wide range of hardness or abrasiveness. Typical percussion drilling equipment is capable of drilling a 6 foot deep hole in 3½ minutes. Rotary drills are much larger indiameter (6 in. to 9

TABLE 1. Concrete Removal Methods: Summary of Applications and Relative Costs

Process	Concrete Thickness Application	Feasibility	Relative Equipment Cost
Controlled Blasting	≥ 2 ft	Excellent	High
Wrecking Ball	≤ 3 ft	Excellent	Low
Air and Hydraulic Rams	≤ 2 ft	Good	Low
Flame Cutting	≤ 5 ft	Fair	Low
Thermic Lance	≤ 3 ft	Poor	Low
Rock Splitter	≤ 12 ft	Good	Low
Bristar Demolition	≤ 1 ft	Fair	Low
Compound Wall & Floor Sawing	≤ 3ft	Good	Low
Core Stitch Drilling	≤ 2 ft	Poor	High
Explosive Cutting	> 2 ft	Good	High
Paving Breaker	≤ 1 ft	Poor	Low
Chipping Hammer & Chisel	≤ 3 in.	Poor	Low
Drill & Spall	≤ 2 in.	Excellent	Low
Scarifier	≤ 1 in.	Excellent	Low
Water Cannon	≤ 2 in.	Fair	High
Grinding	≤ 0.25 in.	Poor	Low

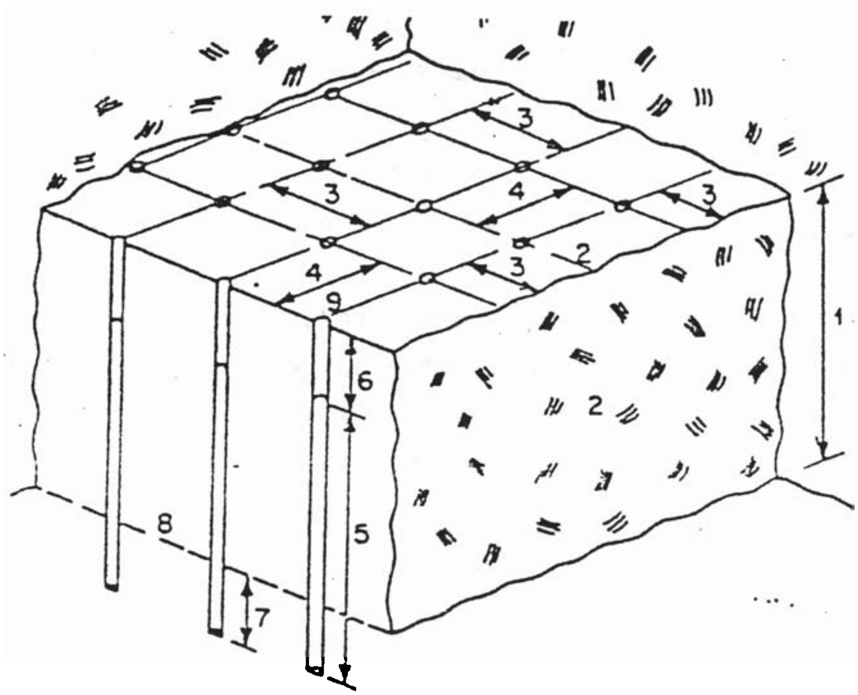

FIGURE 1. Blasting Round

in.) and are best suited for light concrete without reinforcing rods. Diamond-core abrasive bits are more expensive than percussion drills but bit life is longer. When cutting through reinforcing rod, abrasive drilling is slower and diamond loss is common.

Various types of explosives are available for use in demolition applications. The selection of the best type of explosive requires an evaluation of the properties of the explosive and of the concrete itself. A blasting expert is qualified to select the best explosive for the purpose. The major types of explosives include PETN 85% high velocity gelatin dynamite, cast TNT, liquid explosives, water gel explosives and high strength ammonia dynamite (Ref. 1, 2).

When blasting massive concrete sections with multiple charges, delayed detonation is used to direct the muckpile (rubble) and improve fragmentation. The first row of charges directs the burden perpendicular to the borehole plane. Subsequent burden plane charges would direct movement towards the vertical unless delayed sufficiently to allow forward movement of preceding burdens. A delay period of approximately one millisecond-per-foot of burden provides sufficient time for free face movement, and allows subsequent burdens to fragment perpendicular to the boreholes.

3.1.2 Applications

Controlled blasting is the concrete demolition method recommended for all concrete greater than 2 feet in thickness provided noise and shock in adjacent occupied areas are not limiting. The process is well suited to heavily-reinforced concrete demolition because with proper selection of the blast parameters a high degree of fragmentation may be achieved. The exposed reinforcing bar may then be cut with an oxyacetylene torch or bolt cutter.

The Elk River Reactor dismantling program used controlled blasting to demolish the 8 foot thick steel-reinforced radioactive biological shield. A blasting mat (composed of automobile tire sidewalls tied together) was placed over the blast area. Continuous fog sprays of water were used before, during and after the blast to hold down dust. Alternatively, a spray mixture of water and 5%-by-weight sodium silicate (water glass) may be used for dust control.

3.1.3 Performance and Cost Factors

Typical concrete removal rates and approximate costs in 1979 dollars are shown in Table 2. The removal rates include drilling, loading, shooting, rebar cutting and loading the muckpile into hauling equipment. The unit cost includes crew cost, materials (explosives and dust control measures) and subcontractor overhead and profit. Shipping and disposal are not included. A typical blasting crew consists of the blasting expert, six laborers, one iron worker and one equipment operator.

TABLE 2. Concrete Removal Rates and Costs Using Controlled Blasting

	Concrete Type	Removal Rate yd^3/day	Removal Cost, \$/yd^3
1.	Massive Reinforced Standard Concrete (Non-Radioactive)	100-400	100
2.	Massive Non-reinforced Standard Concrete (Non-radioactive)	250	13
3.	Massive Reinforced Standard Concrete (Radioactive)	4-6 * 100 **	400
4.	Lightly Reinforced Standard Concrete (Non-radioactive)	200	35
5.	Non-reinforced High Density Concrete (Radioactive)	6-8*	35
6.	Lightly Reinforced Standard Concrete (Radioactive)	6-8*	200
	References	3,4,5	3,5

* Actual removal rates including inefficiency due to personnel and area contamination control and radiation work area control.

** Higher removal rate possible if adequate space is available to use large capacity loading and hauling equipment.

3.2 WRECKING BALL OR WRECKING SLAB

3.2.1 Description of Process

The wrecking ball is typically used for demolition of non-reinforced or lightly reinforced concrete structures less than 3 feet in thickness. The equipment consists of a 2-to-5 ton ball or flat slab suspended from a crane boom. The ball may be used in either of two techniques to demolish structures. The preferred method is to drop the ball from a height of 10-to-20 feet above the structure. The maximum height of structure is limited to about 100 feet. A 5-ton ball would require a 200 ton crane for the maximum height (Ref. 6). This method develops good fragmentation of the structure with maximum control of the ball after impact. The second method is to swing the ball into the structure using a suck line for recovery after impact. The structure height is limited to about 50 feet because of the crane instability during the swing and after impact. The latter method is not recommended because the target area is more difficult to hit and the ball may ricochet off the target and damage adjacent structures while putting side loads on the crane boom. The flat slab may only be used in the vertical drop mode, but offers the advantage of being able to shear through steel reinforcing rods as well as concrete.

3.2.2 Applications

The wrecking ball or slab is recommended for non-radioactive concrete structures less than 3 feet in thickness. It would be virtually impossible to control the release of radioactive dust during demolition due to the access needed for the crane to drop or swing the ball. For non-radioactive structures, the wrecking ball is an effective method and provides good fragmentation to expose reinforcing rods.

A wrecking ball was used in dismantling the Elk River Reactor containment building cylinder and dome after the outer insulation and steel shell were removed, and after all radioactive material had been removed from within the structure.

3.2.2 Performance and Cost Factors

Typical concrete removal rates with a wrecking ball are shown in Table 3, exclusive of loading or disposal. The unit cost includes crew cost, equipment rental and subcontractor overhead and profit. The range in costs reflect the accessibility to move large equipment to the muckpile for loading and hauling. Shipping and disposal are not included in these costs. A typical wrecking ball crew consists of the crane operator, one crane oiler, two laborers and a fore-

TABLE 3. Concrete Removal Rates and Costs Using a Wrecking Ball

Concrete Type	Removal Rate yd^3/day	Removal Cost, $/Yd
Lightly Reinforced Standard Concrete	40	18-34
Non-reinforced Standard Concrete	50	12-25
Concrete Block Structures	60	10
Heavily Reinforced Standard Concrete	Not Recommended	100
References	6	4,7

3.3 BACKHOE MOUNTED RAMS

3.3.1 Description of Process

Backhoe mounted rams are used for concrete structures less than 2 feet thick with light reinforcement. The method is ideally suited for low noise, low vibration demolition and for interior demolition in confined areas. The equipment consists of an air- or hydraulic-operated impact ram with a moil or chisel point mounted on a backhoe arm. The ram starts impacting as soon as there is resistance to the point and stops when breakthrough occurs or when the ram head is lifted. With the ram head mounted on a backhoe, the operator has approximately a 20 to 25 foot reach, and the ability to position the ram in limited access structures.

3.3.2 Applications

The ram is recommended for applications with limited access for heavy equipment such as a wrecking ball, and where blasting is not permitted. The air rams need to be modified to direct air exhaust away from the work area to prevent the spread of dust (nuisance and radioactive dust). The hydraulic ram recycles the hydraulic fluid, so no modification is necessary. Dust and contamination control is maintained with water fog sprays before and during breaking activities.

The air ram was successfully used for light concrete demolition at the Sodium Reactor Experiment (SRE) in Santa Suzanna, California (Ref. 8). However, at Elk River a hydraulic ram proved to be too slow in demonstration tests for use on the massive, heavily reinforced biological shield. The ram was replaced with the more favorable controlled explosive demolition.

3.3.3 Performance and Cost Factors

The backhoe-mounted ram can remove approximately 20 yd^3/day of non-reinforced concrete. The approximate unit cost in 1979 dollars for ram breaking of concrete is $40/$yd^3$ (Ref. 8). The unit cost includes crew cost, equipment rental and subcontractor overhead and profit. Shipping and disposal are not included in the costs. A typical crew consists of the ramhoe operator, one laborer and a foreman.

3.4 FLAME CUTTING

3.4.1 Description of Process

Flame cutting of concrete consists of a thermite reaction process whereby a powdered mixture of iron and aluminum oxidizes in a pure oxygen jet. The temperatures in the jet are approximately 16,000°F, which causes rapid decomposition of the concrete in contact with the jet. The mass flow rate through the flame cutting nozzle clears away the decomposed concrete, leaving a clean kerf. Reinforcing rods in the concrete add iron to the reaction to sustain the flame and assist the reaction.

The nozzle is mounted on a metal frame which straddles the area to be cut. The nozzle, with associated hoses, is tracked on the metal frame at a steady rate. The rate is dependent upon the concrete depth. A starting hole is cut through the concrete to prevent blowback of material and consequent torch damage. Once started, the torch is advanced along the workface by a variable speed electric motor controlled by the operator.

Heat and smoke may be removed with a 5 to 7 horsepower squirrel-cage blower, and directed through a flexible duct which houses a water fogger to hold down smoke particulate. The high gas temperatures preclude the use of HEPA filters for contamination control, making the flame cutting technique unsuitable for use on radioactive concrete without pre-cooling the effluent gas.

3.4.2 Applications

Flame cutting of concrete is used when vibration to the surrounding area is intolerable, and when the thickness of the concrete to be cut exceeds the capabilities of mechanical cutters such as diamond saws. Flame cutters are capable of cutting through a maximum depth of 60 inches with or without reinforcing rod (Ref. 9).

3.4.3 Performance and Cost Factors

The flame cutting speed is approximately 1 hour/ft^2 of cut area. The torch consumes approximately 800 ft^3 of oxygen, 14 lbs of iron powder and 6 lbs of aluminum powder per square foot of cut area. The approximate unit cost in 1979 dollars for flame cutting is $175 per square foot of cut area. The unit cost includes crew cost, equipment and subcontractor overhead and profit. Shipping and disposal are not included. A typical flame cutting crew consists of the torch operator and one laborer full time during cutting.

3.5 THERMIC LANCE

3.5.1 Description of Process

The thermic lance consists of an iron pipe packed with a combination of steel, aluminum, and magnesium wires through which a flow of oxygen gas is maintained. The thermic lance cuts utilizing a thermite reaction at the tip of the iron pipe, in which the constituents are completely consumed. Temperatures at the tip range from 4000 to 10,000^{o}F, depending upon ambient conditions. The lance is ignited using an oxyacetylene torch, thermal igniter or electric arc. Typical lances are 10-1/2 ft in length and 1/4 in. to 3/8 in. in diameter. Two lances may be connected in tandem to increase burn time and to permit complete consumption of each lance.

A thermic lance set-up will consist of the lance, an oxygen supply (generally two or more cylinders connected in tandem), associated regulator equipment to maintain oxygen pressure at 70-125 psi, 3/8 inch diameter hose, and protective clothing and faceshield for the operator.

A thermic lance generates a large quantity of smoke and hot gases, the actual amount depending upon the material being cut. For this reason, a control envelope is necessary for radioactive concrete cutting to contain the vaporized material in order to prevent the contamination of the surrounding area.

3.5.2 Applications

The thermic lance will cut any material that is likely to be encountered in a nuclear facility. The reinforcing rods in the concrete speed the burning by adding more metal to the thermite process. Material further than 1 inch from the hole is not affected. The thermic lance can be used to cut holes, slits or openings in a wide variety of materials.

3.5.3 Performance and Cost Factors

The 10½ foot thermic lance will burn for at least 6 minutes, and can burn a 2 inch diameter hole through reinforced concrete to a depth of 1½ to 3½ feet. The lance holder costs approximately \$50.00, and the 10½ foot lance is \$7.00 each. Oxygen supply cost about \$6.00 per 100 ft^3 at STP.

3.6 ROCK SPLITTER

3.6.1 Description of Process

The rock splitter is a method for fracturing concrete by hydraulically expanding a wedge into a pre-drilled hole until tensile stresses are large enough to cause fracture. The tool consists of a hydraulic cylinder which drives a wedge-shaped plug between two expandable guides (called feathers) inserted in the pre-drilled hole. Figure 2 shows a schematic of the splitter operating principle.

The unit is powered by a hydraulic supply system, and operates at 7100 psi pressure. When the plug is extended and fracture occurs, an automatic pressure relief valve lowers the pressure to 900 psi. With the unit in neutral position the pressure drops to 50 psi.

Units are available to develop splitting forces approaching 350 tons. The maximum lateral expansion of the feathers is approximately 0.75 inches. Concrete may be separated at the fracture line using a backhoe mounted air ram or similar equipment. The reinforcing rod in reinforced concrete must be cut before separation is possible. For heavily reinforced concrete, additional holes and fractures will be necessary to expose the reinforcing rod.

3.6.2 Applications

The splitter is ideally suited for fracturing concrete in limited access areas where large air rams cannot operate. The process is silent (except for hole drilling) and is used extensively for demolition near hospitals and other densely populated areas. Hole sizes range from 1-3/16 to 1-3/4 inch, and depth of 12 to 26 inches, depending on the size of the unit selected. For massive concrete sections, holes are drilled from 1 to 3 feet apart to establish a fracture line.

Reinforced concrete sections up to 8 feet thick may be cut with a single large unit. Reinforced concrete sections of 10 foot thickness will require two or more large units operated simultaneously.

3.6.3 Performance and Cost Factors

For reinforced non-radioactive concrete, removal rates of 250 yd^3/day have been demonstrated. Drilling and splitting time requires approximately 5 to 10 minutes per hole. The approximate cost of the rock splitter and power unit range from $6500 to $8000 from the smallest to largest cylinder available. Cost per unit of output are dependent on the geometry and working conditions of the application.

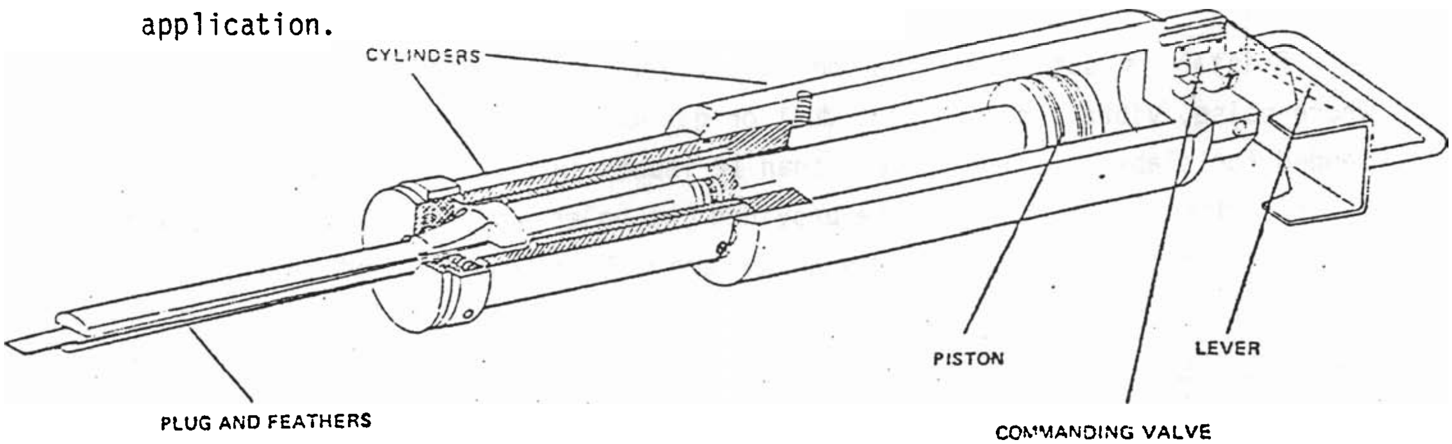

FIGURE 2. Schematic of Rock Splitter

3.7 BRISTAR* DEMOLITION COMPOUND

3.7.1 Description of Process

Bristar concrete demolition compound is a chemically expanding compound which is poured into pre-drilled holes and causes tensile fractures in the concrete upon hardening. Bristar is a proprietary compound of limestone, siliceous material, gypsum and slag. The powdered compound is mixed with water and kneaded to a fluid paste. The paste is filled into holes drilled in a fracture line of predetermined burden, spacing and depth. Within 10-20 hours, Bristar pressure will develop to over 4300 psi. Concrete tensile strength ranges from 200 psi to approximately 425 psi, such that low grade concretes are likely to fracture

* Registered trade name of Onoda Cement Co., Ltd., Tokyo, Japan (Ref. 10).

easily. Cracks will form and propagate along the fracture line. The crack width will range between 1/4 inch after 10 hours to almost 2 inches after 15 hours. The fractured burden may then be removed with a paving breaker, backhoe or bucket loader. If reinforcing rod is encountered, it must be cut separately. The compound is not classified as a hazardous substance and can be readily stored and handled. There is no noise or vibration (except for drilling holes), or flyrock, dust or gas release. Contamination control is only required during drilling and removal.

3.7.2 Applications

Bristar is suited for use on massive non-reinforced concrete structures where noise, vibration, flyrock, dust or gas must be avoided. It is not recommended for slabs of concrete less than 12 inches in thickness. The compound can be used with reinforced concrete provided the holes are located along the plane of reinforcing rod so the fractured surface will expose the rods.

3.7.3 Performance and Cost Factors

The rate of removal of massive non-reinforced concrete is dependent on the crack formation time (10-20 hours) and the quantity of concrete to be removed. For small jobs the removal rate will be slow because of the time to fracture. For large jobs, drilling may be continuous with mucking out following hole loading by about 20 hours. In this manner the removal rate may approach that of controlled blasting for the same material.

The quantity of Bristar required for a 2 inch diameter hole per foot of hole depth is 2½ lb/ft. The approximate cost for Bristar is about $80.00 for a 44 pound container.

3.8 WALL AND FLOOR SAWING

3.8.1 Description of Process

Wall and floor sawing is generally used when disturbance of the surrounding material must be kept to a minimum. A diamond or carbide wheel is used to abrasively cut a kerf through the concrete. The blades can cut through rein forcing rods although the rods tend to break off the blade diamonds. The blade is rotated by an air or hydraulic motor. For most applications the saw will be mounted on a guide which also supports the saw's weight. The operator manually advances the blade into the work. The dust produced by the abrasive cutting is controlled using a water spray. The abrasive blade produces no vibration, shock, smoke, sparks, or slag and is relatively quiet.

3.8.2 Applications

Thicknesses up to 3 feet have been cut with concrete saws. The maximum thickness of cut is approximately equal to one-third of the blade diameter.

3.8.3 Performance and Cost Factors

The saw cuts approximately 150 in^2 per minute of cut surface, regardless of thickness. Cutting can be done either manually or remotely.

The approximate cost of floor sawing concrete is $\$8.00/ft^2$ of cutting surface for non-radioactive, non-reinforced concrete. Reinforced concrete cutting costs are higher because of the additional replacement diamond saw blades necessary, and the increased time to cut through heavy rebar. The approximate cost of wall sawing is $\$22.00/ft^2$ of cutting surface for reinforced concrete up to a 7/8 inch-diameter reinforcing rod. The saw is operated by one operator with no helper.

3.9 CORE STITCH DRILLING

3.9.1 Description of Process

Core stitch drilling consists of close-pitched drilling of holes in concrete using a diamond or carbide-tipped drill bit in an electric or fluid-driven rotary drill. The center lines of the holes are located to correspond to the desired breaking plane in the concrete. The hole pitch is such that there is very little concrete left between adjoining holes (less than ½ the radius of the holes). When a line of holes has been drilled along the breaking plane, the remaining concrete between the holes may be sheared by a hydraulic wedge, or by dropping a wrecking ball onto the piece to be removed.

3.9.2 Applications

Core stitch drilling produces no gases or smoke, thereby facilitating contamination control. The dust produced by the drilling is controlled by a water spray, which is also used to cool the drill bit. Core stitch drilling is used where surrounding material must not be disturbed, or where accessibility is limited. However, the slab to be removed must be accessible to the method of shearing the concrete (bar, slab or wrecking ball). The method is not recommended for reinforced concrete because the remaining reinforcing rod inhibits shearing.

3.9.3 Performance and Cost Factors

Concrete drills can cut a 4 inch diameter hole through 4 feet of concrete in 60 minutes. The pitch between holes is recommended to be no greater than ½ inch for 4 inch diameter drills. Accordingly, this process is very slow and costly for large volumes of massive concrete removal.

The core drilling costs range from $17.00/ft for 1½ inch diameter holes, to $550.00/ft for 24 inch diameter holes. Drilling depths greater than 3 ft can increase these costs by a factor of 3 (Ref. 11). These costs include labor, drill bits, and drill motor costs.

3.10 EXPLOSIVE CUTTING

3.10.1 Description of Process

An explosive cutter consists of an explosive core such as RDX or PETN, surrounded by a casing of lead, aluminum, copper or silver. Cutting is accomplished by a high explosive jet of detonation products of combustion and deformed casing metal. The jet forms a directed shock wave which severs the target material. The cutter is approximately 1 inch wide and chevron-shaped with the apex pointing away from the material to be cut. When detonated, the explosive core generates a shock wave which fractures the casing inside the chevron and propels the casing into the material to be cut.

The target material is cut, not fractured or snapped. In concrete, there would be some local fracturing and pulverizing of the surrounding area. In reinforced concrete, some of the deeper reinforcing rods will not be cut. In this case, either a reinforcing rod cutter or oxyacetylene torch can be used.

Other explosive types are available such as HNS, DIPAM, HMX, CH-6, HNAB, DATB, TATB, KHND and NONA, to accommodate higher temperature (up to 600^{o}F) applications. Lead casings are most frequently used for the smaller sizes and core loadings, and aluminum, copper or silver used for larger sizes.

3.10.2 Applications

Explosive cutting is normally used either when the geometry of the object being cut is too complex to employ other methods, or when several cuts must be made simultaneously (e.g. removal of a large prestressed beam where it is impractical to shore up the ends for temporary support).

Explosive cutters are used for precision cutting rather than massive heaving or demolishing. Cutters have been used on concrete for removing buildings, salvaging bridges, and felling smokestacks.

3.10.3 Performance and Cost Factors

Typical prices of lead sheathed RDX explosive cutters range from $14.00/ft for 300 grains/ft to $64.00/ft for 2200 grains/ft (Ref. 12). These prices may be used as input for cost estimating purposes, but actual demolition should be estimated and directed by a demolition expert.

3.11 PAVING BREAKERS AND CHIPPING HAMMERS

3.11.1 Description of Process

Paving breakers and chipping hammers remove concrete (and asphalt) by mechanically fracturing localized sections of the surface. Fracturing is caused by the impact of a hardened tool steel bit of either a chisel or moil point shape. The bit is driven in a reciprocating motion by either a compressed air or hydraulic fluid pressure source.

Paving breakers (also called "jackhammer" and "pneumatic drill") weigh approximately 35 to 100 pounds and are intended for use on floors. The chipping hammer is similar in concept to the paving breaker but is light enough (15-35 lbs.) to be hand-held for use on walls or ceilings.

3.11.2 Applications

Paving breakers are recommended for use on floors to remove small areas that are inaccessible for heavy equipment. They may also be used to expose reinforcing rods after controlled blasting to permit cutting of the rods. The chisel point may be used to scarify surface areas of concrete floors where contamination may have penetrated several inches deep in localized areas. Contamination control may be accomplished using water or fog sprays. Chipping hammers are recommended for use on walls to scarify small areas where contamination may have penetrated several inches deep over localized areas. However, the limited removal capacity and significant weight (up to 35 pounds) make it impractical for use on large areas. Other techniques are better suited for this purpose.

3.11.3 Performance and Cost Factors

Concrete removal using paving breakers or chipping hammers is labor-intensive. The cost for removal of non-reinforced concrete by paving breakers is $\$32.00/yd^3$. The crew consists of one light equipment operator and two laborers. The crew has an output of 20 yd^3/day.

For reinforced concrete, the crew consists of one light equipment operator, two laborers and one ironworker. The crew output is 12 yd^3/day at a cost of \$62.00/yd^3.

Chipping hammer costs are essentially those of the hammer operator's hourly rate since the consumption of materials and power requirements is insignificant.

3.12 DRILL AND SPALL

3.12.1 Description of Process

The drill and spall technique was developed for the removal of contaminated surfaces of concrete without demolishing the entire structure. The technique consists of drilling 1 to 1½ inch diameter holes approximately 3 inches deep into which is inserted a hydraulically operated spalling tool. The spalling tool is similar in to the rack splitter, but uses shorter feathers. The holes are drilled on approximately 12 inch centers such that the spalled area from each hole overlaps the next.

3.12.2 Applications

The drill and spall technique is recommended for removing surface contamination that penetrates one to two inches into the surface. Removal of the surface radioactivity in this manner eliminates the need to dispose of large quantities of non-radioactive concrete as with other volume removal techniques. Contamination control while drilling is accomplished with a filtered vacuum system. Fog sprays may be used to wet the surface and reduce contamination and dust levels.

3.12.3 Performance and Cost Factors

The average removal rate is approximately 7.5 yd^2/hr for standard concrete. No detailed cost information is available yet on removal costs since the tool is still in the developmental stage. The equipment cost, exclusive of the positioning equipment, is estimated to be about $10,000. A typical drill and spall crew would probably consist of one operator, one platform positioner operator, two laborers and a front-end loader operator.

3.13 SCARIFIER

3.13.1 Description of Process

The scarifier technique is best suited for the removal of thin layers (up to one inch in thickness) of contaminated concrete. The tool, marketed under the trade name of "Scabbler" by the MacDonald Air Tool Company, New Jersey, U.S.A., consists of pneumatically operated piston heads which strike the surface to chip off the concrete. The piston heads are available in either 5-point or 9-point tungsten carbide bit sizes depending on the degree of surface roughness allowable. The 5-point bit has 1/4 inch high points and the 9-point bit has 1/8 inch high points.

The pistons are mounted in a wheeled-floor chasis which is available in 5, 7 and 9 piston sizes. The chasis is pushed along the floor to remove the surface layer. The chasis can be modified to include a HEPA filtered vacuum exhaust system to capture contaminated dust. Other tool models include a 3-piston wall scabbler which may be spring counter-balanced to relieve the tool weight. Smaller hand-held units are available but are not intended for large surface area removal.

3.13.2 Applications

The scabbler tool is recommended for applications where the concrete surface is to be reused after decontamination. The scarified surface is generally level with coarse finish (¼ to ½ inch peak-to-valley height) resulting from the 9-point bit. The coarse surface is suitable for bonding to a concrete finish cap, and the smoother surface suitable for epoxy, polymer and similar finishes.

A 7-piston floor model scabbler was used at the SRE decommissioning program to scarify slightly contaminated floors. An HEPA filtered vacuum exhaust system was fitted to the floor scabbler to control the release of contaminated dust.

3.13.3 Performance and Cost Factors

The concrete surface removal rate is 5 square yards per hour per bit (Ref. 13) for the floor scabbler, which represents 35 square yards per hour for a 7-piston unit. The three-piston wall scabbler will remove 8-12 square yards of surface per hour.

The approximate unit cost in 1979 dollars for floor and wall scarifying is $1.40/yd^2$ for the 7-piston floor model, and $6.25/ft^2$ for the 3-piston wall model. The unit cost includes operator cost, air consumption cost, dust and chip removal, subcontractor overhead, and profit. A typical crew consists of the tool operator and one laborer for chip removal.

3.14 WATER CANNON

3.14.1 Description of Process

Two types of high-pressure jet spalling devices have been developed under the common name of water cannon (Ref. 14): Type (1), the Glycerine Gun, fires solidified glycerine capsules in a modified 458 magnum rifle through a nozzle. Type (2), the Water Cannon, uses compressed gas to drive a piston which forces water through a small diameter nozzle.

(1) Glycerine Gun: The glycerine gun uses a 458 magnum rifle with a short smooth bore barrel. A nozzle is threaded onto the end of the barrel to reduce the diameter from 0.45 inches to 0.17 inches. A 9-inch diameter funnel-shaped shield is placed around the nozzle to protect the operator and collect chips and dust through a vacuum exhaust system. Rubble pieces are 0.5 inches to 0.75 inches in diameter, and are covered with glycerine which contains the dust. The shield extends one inch beyond the nozzle to provide the necessary standoff from the workspace. Figure 3 shows the glycerine gun.

The glycerine gun fires solidified glycerine capsules 2 inches long by a 0.45 inch diameter. The capsules are propelled by gun powder loaded into conventional cartridge cases. The glycerine is accelerated by the propellant, and is extruded through the nozzle at very high velocity. Wax is placed in the cartridge case to hold in the powder, and to create a moving seal around the glycerine to prevent combustion gases from bypassing the glycerine.

(2) Water Cannon: The water cannon uses compressed gas to drive a piston and force a small quantity of water through a nozzle. Figure 4 shows a schematic of the water cannon components. A funnel-shaped shield is placed over the nozzle to protect the operators and collect debris through a vacuum system. The gas which propels the piston is compressed by a hydraulic impactor. Firing rates of up to 5 shots per second are possible. Water is injected into the chamber in front of the piston after each shot.

The unit is usually mounted on a back hoe or excavator and may be articulated to spall concrete walls, floors or ceilings.

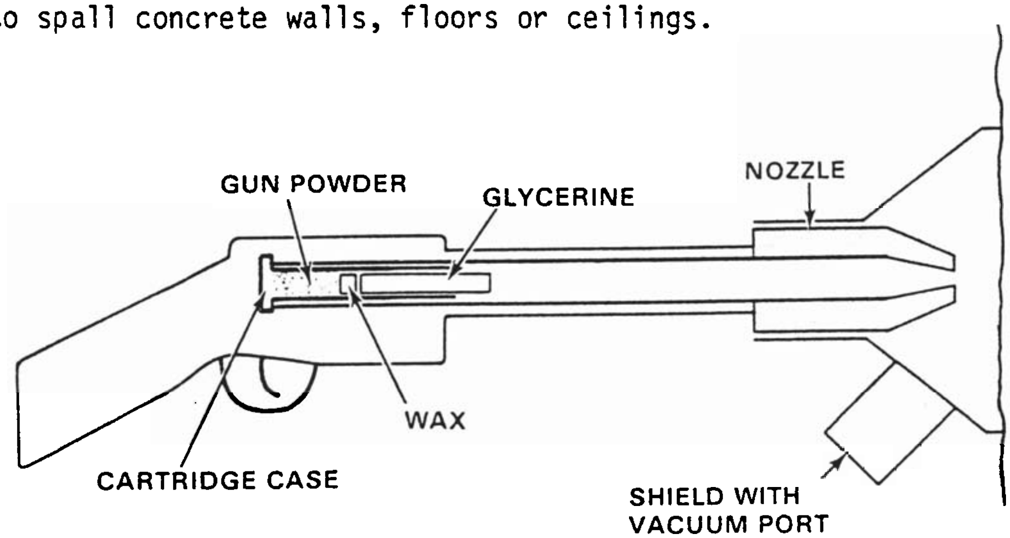

FIGURE 3. 458 Magnum Water Cannon

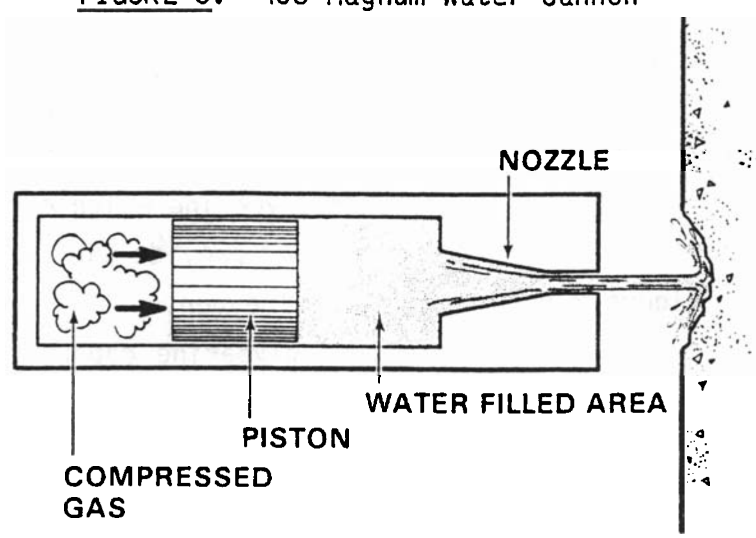

FIGURE 4. Schematic of a Water Cannon Basic Components

3.14.2 Applications

The glycerine gun has been extensively tested, and has been shown to create spall craters 3 to 4 inches in diameter and 0.75 inches deep. The shots are fired about 3 inches apart in a triangular pattern. The glycerine gun is most effective when fired around and behind embedded aggregate. Shots at hard, round river gravel will result in small spalls.

3.14.3 Performance and Cost Factors

Tests in high-strength concrete required 24 shots to remove 1 ft^2 of surface and took 5 to 6 minutes (approximately 10 ft^2/hr). The glycerine gun can be positioned and held by hand, and can be fired as fast as the operator can reload and position the gun.

The water cannon generally exhibits slower rates of removal than the glycerine gun. Typical rates of 1 ft^2 in 15 minutes (4 ft^2/hr) have been demonstrated. The water jet serves to coat the rubble particles and thus helps to reduce the spread of contamination.

No detailed cost information is available yet on removal costs since these tools are still in the developmental stages at Battelle Pacific Northwest Laboratory. A typical crew would consist of the gun operator and one laborer.

3.15 GRINDING

3.15.1 Description of Process

The grinding process includes a large number of similar tools for the removal of thin layers of surface contamination from concrete. In many cases the contamination is limited to the paint coating or concrete sealer finish. The technique consists of abrading the surface using coarse-grained abrasives in the form of water-cooled diamond grinding wheels or multiple tungsten-carbide surfacing discs. Machines to power these abrasives are of the circular floor grinding type where the grinding head rotates parallel to the floor. Water required for cooling is injected into the center of the grinding head eliminating any possibility of dust. Supplementary contamination control can be accomplished through the use of HEPA filtered vacuum systems attached to or held near the machine. The surface may be moistened before and during grinding to hold down dust levels.

3.15.2 Applications

Grinding is recommended primarily for thin layers of contamination because of the rapid disintegration of the abrasives when in contact with concrete.

Floor and hand-held grinding machines have been successfully used at the San Onofre Unit 1 Nuclear Plant to remove surface contamination.

3.15.3 Performance and Cost Factors

Typical diamond grinding removal rates with disc type rotary floor grinders are capable of removing several thousand square feet (per day) of surface approximately ½ inch deep, and lesser areas to as much as 1 inch deep. The machine may be operated by one operator.

The approximate unit cost in 1979 dollars for concrete floor grinding is $36.00/yd^2 (Ref. 11). The approximate unit cost includes operator cost, grinding wheels and discs, electricity, dust removal and packaging, and subcontractor overhead and profit.

A typical crew consists of the machine operator and one laborer for dust removal and packaging.

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EQUIPMENT FOR REMOVAL OF CONTAMINATED CONCRETE SURFACES

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The Pacific Northwest Laboratory is investigating and developing equipment that will rapidly and economically remove contaminated concrete surfaces while producing a minimal amount of contaminated rubble. Evaluation of various methods for removing concrete surfaces shows that many of the techniques presently used for decontamination require excessive manpower, time, or energy, or they remove more material than is necessary to clean the surface. Excess material removal increases the quantity of waste that must be handled under controlled conditions. Three unique decontamination methods are presented here: the water cannon, the concrete spaller, and the high-pressure water jet. The water cannon fires a small, high-velocity jet of fluid to spall the concrete surface. The concrete spaller chips away the concrete by exerting radial pressure against the sides of a shallow cylindrical hole drilled into the concrete surface. The high-pressure water jet is a 50,000-psi spray that blasts away the concrete surface. Each method includes means for containing airborne contamination. Results of tests show that these techniques can rapidly and economically remove surfaces, leaving minimal rubble for controlled disposal. Also presented are cost comparisons between the water cannon and the concrete spaller.

INTRODUCTION

Accidental spills, vapor releases, and fine particles of various substances have contaminated concrete surfaces, necessitating development of methods to remove these surfaces. Ideally, these methods should:

- reduce the contaminated waste volume that has to be placed into controlled storage,
- provide a convenient method for cleaning surfaces (such as those contaminated by a small spill), and
- remove surfaces quickly.

This discussion compares various techniques that have been used to clean concrete surfaces by removing the surface. Three techniques which have been investigated by the Pacific Northwest Laboratory (PNL) for removing surfaces are also described: the water cannon, the concrete spaller, and the high-pressure water jet.

The equipment was developed with the assumption that removal of the top 1/8 to 1/4 in. of surface would remove most of the contamination. If the contamination has gone into cracks or deep voids in the surface, the removal processes can be repeated until the surface is acceptable.

Preliminary findings on equipment evaluations and development are described by Halter and Sullivan.[1,2]

COMPARISON OF VARIOUS TECHNIQUES

A comparison of these various surface removal techniques can be found in Table 1. Sand blasting is a technique that is used to remove some surface contamination. It is effective only if the contamination is right on the surface, and it is a slow technique. The sand blasting medium becomes contaminated and so adds to the material needing to be placed in controlled storage. A blasting technique using dry ice pellets has been evaluated, but this is even slower than sand blasting.

TABLE 1. Comparison of Various Concrete Surface Removal Techniques[a]

Technique	Limitation	Estimated Relative Speed at which a Unit of Surface Area Can Be Removed
Sand Blasting	Grit Adds to the Contamination	Slow
Dry Ice Blasting	Very Slow Penetration	Slow
Flame Spalling	Heat May Cause Undesirable Chemical Reactions	Slow
Explosives	Generates Moderate Quantities of Dust which Must be Controlled	Fast
Jack Hammer	Awkward to Use on Walls	Medium Fast
Impactor Powered by Air or Hydraulics	Limited to Large Accessible Facilities	Fast
Scrubber or Scabbler	Awkward to Use on Walls	Slow
Water Cannon		
Hand-held Modified 458 Magnum Rifle	Gun Powder Combustion Products are Produced	Slow (5-6 min/ft^2)
Rapid-Fire Model	Limited to Large Accessible Facilities	Slow (3-4 min/ft^2)
Concrete Spaller with 38-Pound Air Drill to Make Holes		
Hand-held		Medium Fast (50-60 sec/ft^2)
Semi-Automated on Platform		Medium Fast (35-40 sec/ft^2)
High-Pressure Water (40,000 to 60,000 psi)	Produces Contaminated Water	Fast (10-15 sec/ft^2)

(a) Source: Halter and Sullivan [2]

Flame spalling has not been tried because handling the by-products of combustion, which may be contaminated, would be more difficult.

Explosives have been used to remove surfaces. Although the technique is fast, the structures need to be sturdy, the surfaces must be large, and experts are needed.

Jackhammers are fairly effective but are awkward to use on walls and ceilings and in tight, constrained areas. An impacter, a large jackhammer-like device which must be mounted on a backhoe, is limited to large, accessible areas. Operators can easily remove complete walls but find it difficult to remove only a 1/4- to 1/2-in. surface layer.

The scrubber, or scabbler, works well on floors but is slow by comparison to other techniques. In its present configuration the scrubber would be difficult to use on walls and ceilings.

Two types of water cannons have been evaluated. One is a 458 magnum gun which is fairly slow, requiring 5 to 6 min to remove 1 ft^2 of concrete surface. The second technique is a rapid-fire model. It will fire 4 to 5 shots per second, but it must be picked up and repositioned after each shot. Besides the disadvantage of having to reposition every time, the spall made is only 1 to 2 in. in diameter, which means the rapid-fire model is only slightly faster than the manual water cannon.

The concrete spaller has proven to be a fast, effective technique. When the drill and spaller are hand held, about 1 ft^2 of surface per minute can be removed. When the drill is mounted on a platform, the speed can be increased to 1-2/3 ft^2 per minute.

A technique using very high pressure water was fast, removing 4 to 6 ft^2 per minute, but the water used must be treated afterwards to remove the contamination.

WATER CANNON

The water cannon, which is shown in schematic form in Figure 1, is a modified 458 magnum rifle with a nozzle on the end. Cartridge cases are primed and filled with gun powder, and a wax plug is added to contain the powder. Solidified glycerine sticks (2 in. long x 0.45 in. in diameter) are fitted into the loaded cases. The altered cartridge is then chambered and shot. The glycerine is formed by the nozzle into a high-velocity stream which then spalls the concrete surface on contact. Each cartridge casing can be reused approximately ten times. A shield to which a vacuum system can be attached was placed around the nozzle to collect the by-products of combustion and the rubble. One cubic foot of rubble is generated for every 24 ft^2 of surface removed.

The water cannon makes about a 2- to 3-in.-diameter spall, as shown in Figure 2. The spall is about 3/4 in. deep at the center. Figure 3 shows a 1-ft^2 sample wall which was spalled in about 6 min with 24 shots. Figure 4

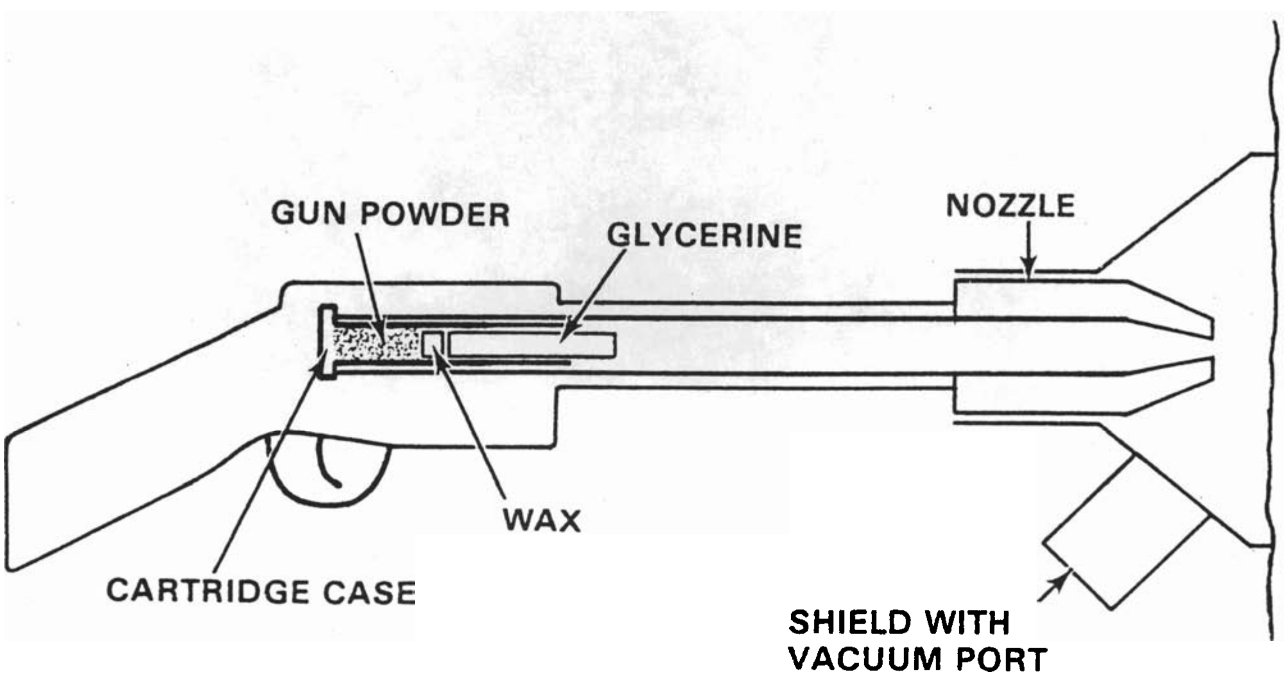

FIGURE 1. 458 Magnum Water Cannon Schematic

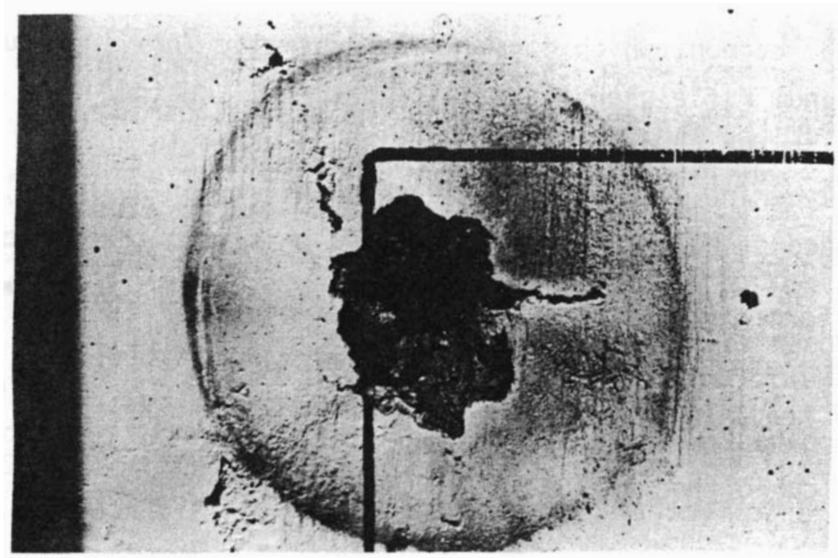

FIGURE 2. A Typical Water Cannon Spall

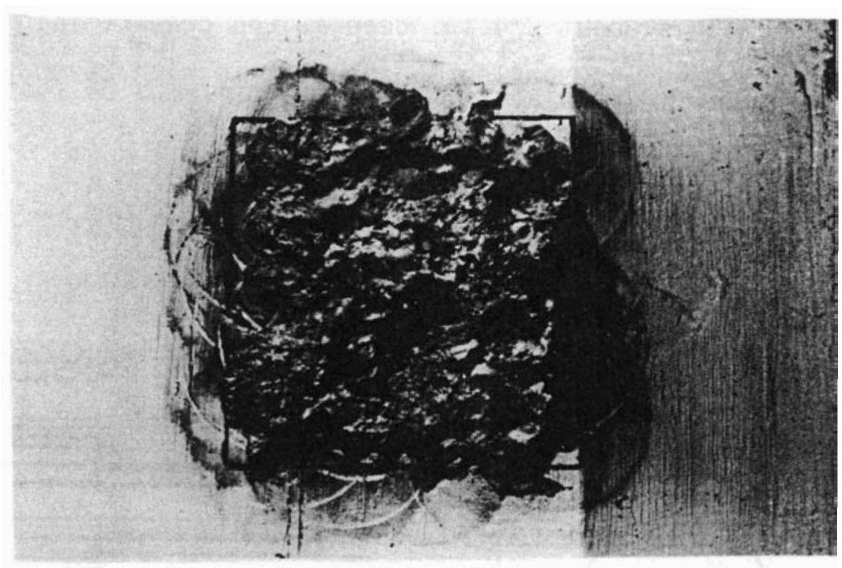

FIGURE 3. One Square Foot of Surface Removed by the Water Cannon

FIGURE 4. Water Cannon Being Operated Without a Vacuum

is a picture of the gun being operated without the vacuum cleaner attached. The glycerine tends to capture or encapsulate all the dust; therefore there is no airborne dust contamination. Because of the compactness of the unit and the vacuum system, the water cannon would be most useful on small areas of contamination in confined areas.

The water cannon is capable of removing approximately 58 ft^2 of surface over an 8-hour shift. This is based on 25 cannon shots to remove 1 ft^2 of concrete surface, four shots per minute, and a working team of two men actually using the water cannon for 6 hours of each 8-hour shift. One man loads the cases with the glycerine charges and passes the cartridges while the other man fires the cannon.

The material costs shown in Table 2 are based on \$0.58 per shot. This includes gun powder, primers, glycerine, cases (reused 10 times), labor to load the cases and mold the glycerine, and the cost of the water cannon and the vacuum system amortized over their useful lives. With labor costs of \$560 per day, the cost to remove 1 ft^2 of surface is approximately \$24.25.

TABLE 2. Cost Comparison of Water Cannon and the Two Concrete Spaller Systems for One 8-hour Shift

Technique	Surface Removed (ft^2)	Labor Cost (2 men @ $35/hour)	Equipment Cost	Equipment Rental Cost Per Day	Removal Cost ($\$/ft^2$)
Water Cannon	58	$560	$ 835	--	$24.25
Concrete Spaller					
Hand Held	300	$560	$ 450	$50	$ 3.55
Platform	600	$560	$1030	$210	$ 3.00

CONCRETE SPALLER

The concrete spaller is a device developed by PNL specifically for removing concrete surfaces.[a] The concrete spaller consists of three basic parts: a hydraulic cylinder, a push rod, and a bit with expanding wedges. The schematic is shown in Figure 5. The bit is made of steel tubing, which is tapered at one end. The tapered end is machined into a circular wedge which is split into four equally spaced segments parallel to its central axis. A push rod with a tapered end to match the tapered tubing is inserted into the bit. The spaller is inserted into a predrilled hole, approximately 2 in. deep and 1 in. in diameter. The hydraulic cylinder is then activated, causing the wedges of the bit to be embedded into the wall. As the tip of the push rod pushes against the bottom of the hole, it forces the wedges away from the bottom, causing an average 8-in.-diameter spall. The holes are drilled 8 in. apart in a triangular pattern. A dust shield placed around the drill and used in conjunction with a vacuum cleaner collects the drilling chips.

A spall produced by the concrete spaller is shown in Figure 6. The spaller and a spalled panel are shown in Figure 7. Ocassionally small areas of surface were left intact. These areas were then redrilled and spalled again. Note that the rubble produced by spalling is conveniently sized so that handling is easy and much of the surface layer remains intact. A water

(a) The concept for the concrete spaller was patented by C. H. Allen.[3]

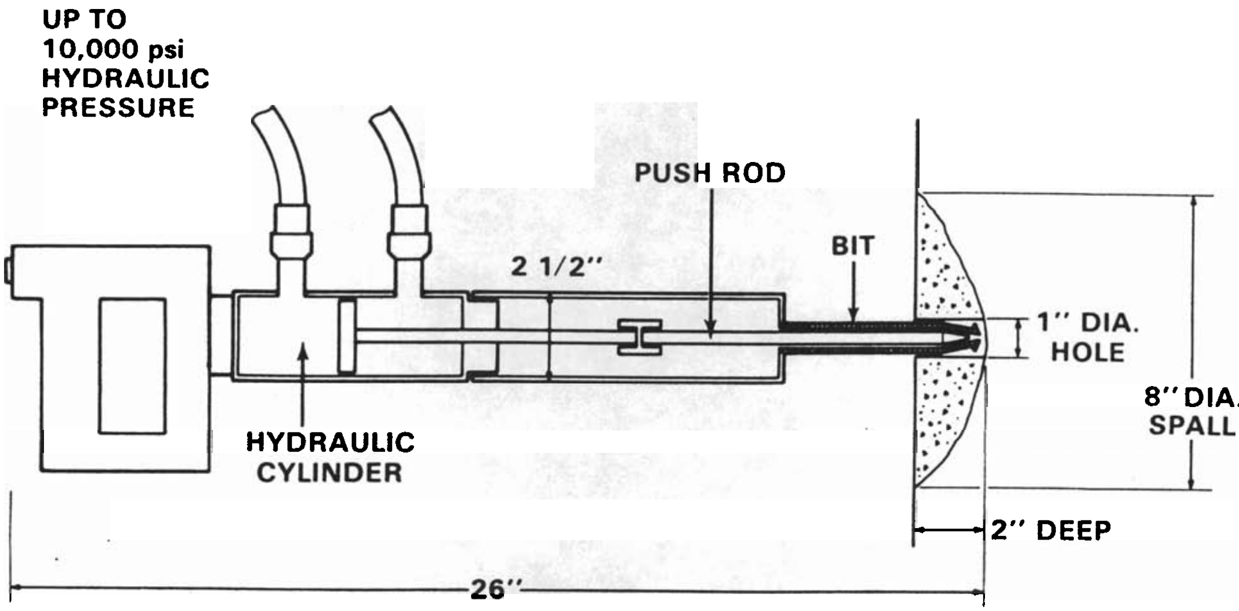

FIGURE 5. Concrete Spaller Schematic

mist could be sprayed over the rubble to contain any dust generated by the spalls. The rubble can then be scooped into boxes for disposal. The thickness of the surface removed is nominally 1 in. If at that depth contamination is still found, the spalled surface can be redrilled and spalled as many times as necessary. Approximately one cubic foot of rubble is generated for each 10 ft^2 of surface removed.

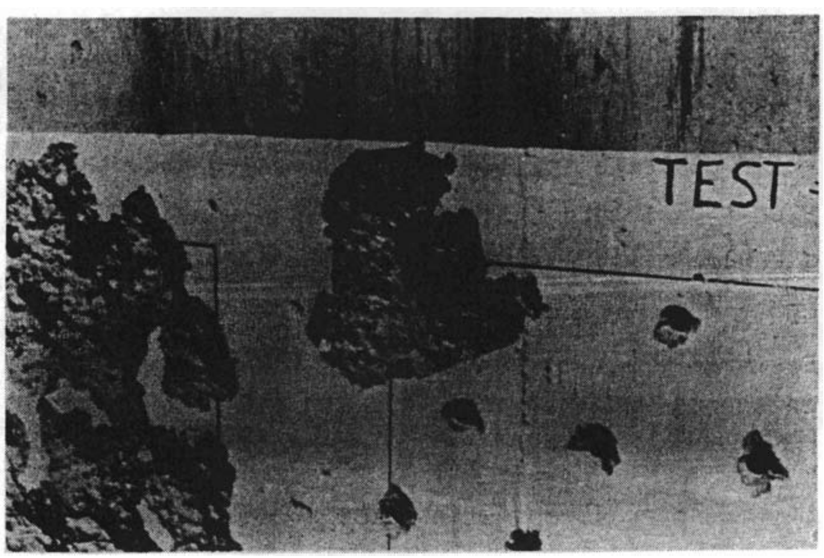

FIGURE 6. Spall Made by Concrete Spaller

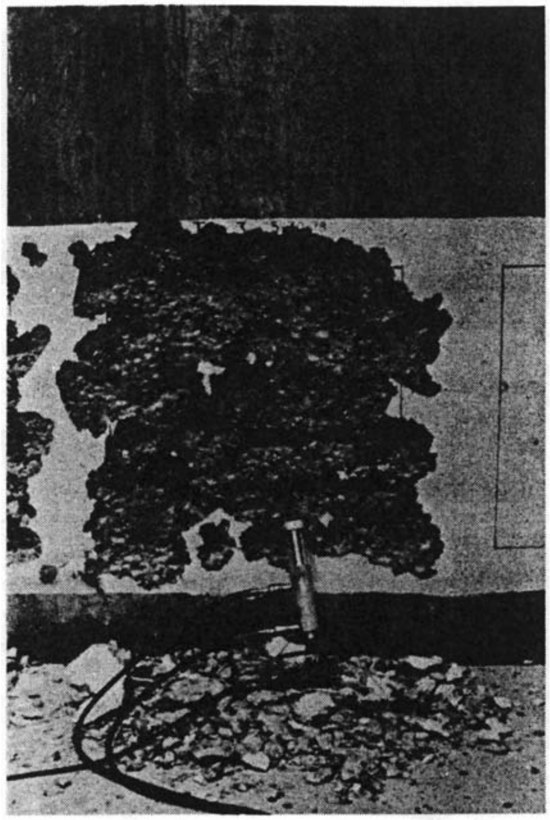

FIGURE 7. Concrete Spaller Next to Spalled Test Panel

The concrete spaller can successfully be used to remove the surface of concrete made with reinforcing steel (rebar). The outer layers of concrete can be removed down to the rebar. If contamination is still deeper, spalling can be done around the rebar so that the rebar can be removed also.

The hand-held concrete spaller was used during decontamination of the 303-C facility on the Hanford Reservation during July 1979. Approximately 30 ft^2 of painted concrete floor with smearable contamination were reduced from 30,000 desintegrations per minute to background radiation level with one pass of the spaller. Previously tried detergent, strippable, and solvent-based decontamination agents were not able to bring the floor area to a nonsmearable condition.

To simplify the overall operation, the spaller is suspended on a cord attached to a pivoting overhead arm beside the operator. From insertion of the spaller into the hole to insertion in the next hole, the spalling operation is only five seconds. Drilling the holes is the time-consuming part of the operation. To increase the hole drilling rate, the drill was mounted on a track or a platform. The time of 25 seconds per hole required by the hand-held drill method was decreased to 10 to 15 seconds by the use of the track-mounted drill on the platform. The drill was positioned horizontally and moved in and out for operation. Later, motors and a control system were added to the drilling unit in an effort to further increase the drilling rate. The width of the track was also increased so that an 8-ft-wide strip could be covered each time the platform was positioned. Figure 8 shows the drill in operation. Figure 9 shows the wall being spalled. Motorizing the drill added some problems, the most important being that the drill has to be backed up and repositioned manually when it hits rebar. Because of the need to reposition the drill manually, the plan to use automation on the drill and let it work its way across the wall while the operator was spalling had to be abandoned. Normally rebar is 3 in. deep, which would pose no problem for the first pass of the spaller.

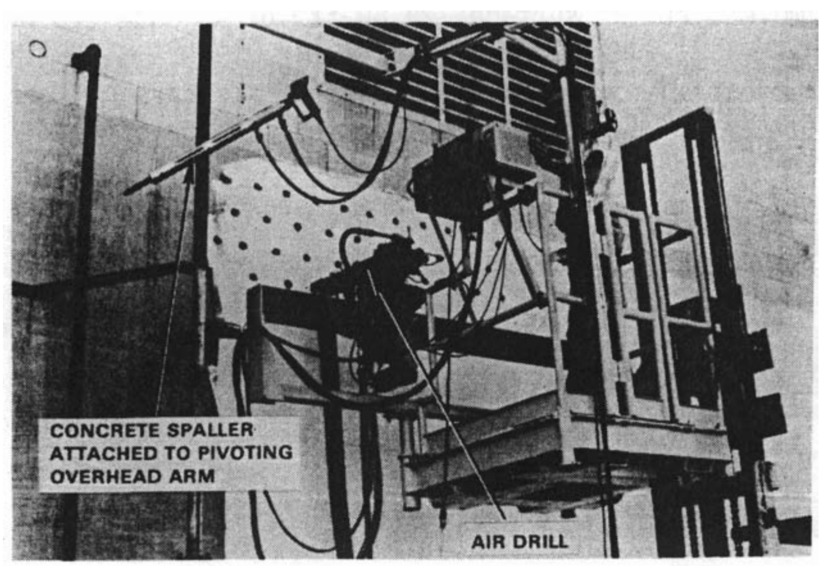

FIGURE 8. Automated Air Drill in Operation

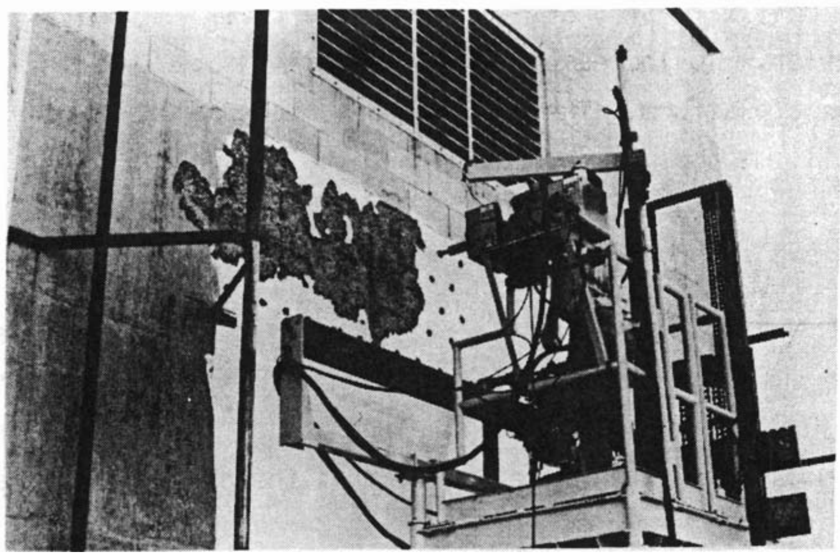

FIGURE 9. Concrete Spaller in Operation

The hand-held concrete spaller is capable of removing approximately 300 ft^2 of surface per shift. It is assumed that 1) 3-1/3 holes and spalls are required to remove 1 ft^2 of surface, 2) 60 ft^2 of surface can be removed in an hour, and 3) the equipment is used by two men for five hours each shift (the reduced man output per shift is because of the physical effort required to use the air drill).

The material costs shown in Table 2 are based upon $0.45 per spalled hole. The costs include the amortized costs for drill bits, the drill, spaller bits, the hydraulic pump, cylinder, hoses and handle, and vacuum cleaner with absolute filters. Rental costs are included for an air compressor to power the drill and vacuum cleaner. The cost to remove 1 ft^2 of surface is $3.55.

Because of the faster drilling rate, the platform-mounted concrete spaller is capable of removing approximately 600 ft^2 per shift. About 100 ft^2 of surface can be removed each hour by two men working 6 hours over an 8-hour shift.

The material costs increase to $0.49 per spalled hole with the addition of the platform, and the rental costs increase because a forklift is used. However, with the more rapid removal rate, the cost to remove 1 ft^2 of surface is $3.00.

HIGH-PRESSURE WATER

The high-pressure water technique for surface removal was developed by Flow Industries Inc. of Kent, Washington. The system consists of two pressure intensifiers powered by hydraulics. They generate a water pressure of 50,000 psi, which is transmitted by a small-diameter pipe to three nozzles in the hooded unit shown in Figure 10. These nozzles move back and forth across the surface being removed, eliminating 1/8 to 1/4 in. of the surface. Figure 11 shows two of the nozzles and a slab of concrete with part of the surface removed.

The system can remove approximately 6 ft^2 of surface per minute. It is also very powerful: it not only blasted the grout from between the aggregate but it removed the tops of the aggregate as well. The technique produces a lot of mist and small-size rubble which shoots out everywhere.

Although untried, it is expected that the water and rubble can be picked up by a high-flow vacuum system. The water and rubble could be separated, the rubble contained, and the water filtered and used again.

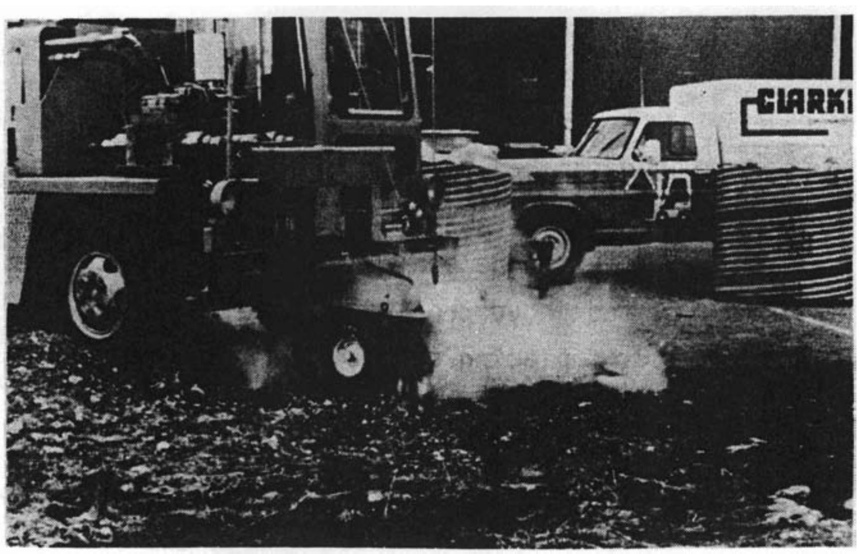

FIGURE 10. High-Pressure Water Surface Removal Equipment in Operation

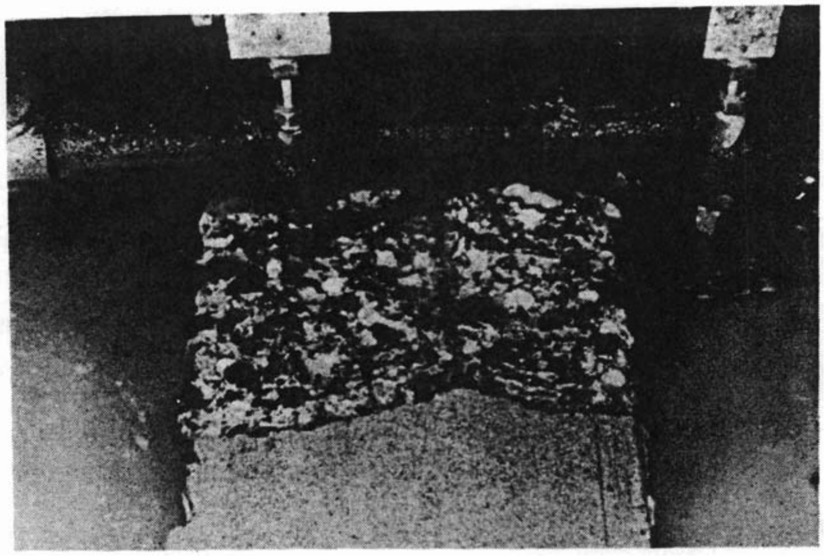

FIGURE 11. High-Pressure Water Nozzles and a Slab of Concrete with Part of the Surface Removed

The high-pressure water system might lend itself to being developed for use on walls and ceilings.

Not enough research has been done with this technique to estimate the cost of operation.

CONCLUSIONS

The three techniques described in this paper are felt to meet the criteria for decontaminating concrete surfaces. Although some noncontaminated surface material is removed with the contaminated material, the amount of rubble which has to be placed in controlled storage is reduced drastically over the often used method of placing the whole wall or floor into storage.

The physical size and type of the equipment will depend upon the size of facility to be cleaned. While hand-held equipment will be used in confined areas, a large platform with several automated drills and spallers could be used in large containment vessels and canyon buildings.

ACKNOWLEDGMENT

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APPLICATION OF DIAMOND TOOLS WHEN DECONTAMINATING CONCRETE

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The utilization of diamond concrete cutting tools offers new potential approaches to the recurring problems of removing contaminated concrete. Innovative techniques can provide exacting removal within a dust-free environment. Present day technology allows remote control operated equipment to perform tasks heretofore considered impossible. Experience gained from years of removing concrete within the construction industry hopefully can contribute new and improved methods to D&D projects.

INTRODUCTION

Gentlemen, it is both an honor and privelege to appear here before this distinquished group. My name is Barry Woods, I am President of Concrete Coring Company, Incorporated and my associate here today is Roger Gossett. Keeping in mind that this is a workshop with the aim of an informal exchange of information, our paper has been submitted accordingly. We hope to generate some new thoughts toward techniques of concrete decontamination. To provide you with a brief background of what Concrete Coring Company is and as a visual aid for you to refer to in a few minutes, each of you should have received a brochure of our companys' operations. I would like to explain that we are a company specializing in total and partial concrete removal by the most modern methods and tools available. Our company is a network of franchises reaching from Florida to the West Coast with some foreign branches. Each franchise is independently owned and operated and performs autonomous of the others. For example, our Vancouver, Washington office just completed a project in New York last month. Some franchises are large and some relatively small. Joint ventures are common occurrences between franchisees. We maintain our own central fulltime engineering facility which is located in California. This facility concentrates on research and development of new tools, manufacturing proprietary equipment presently in daily use, plus production of specialized equipment for special jobs. I understand that many in attendance today are unfamiliar with diamond concrete cutting tools; therefore, at this time we would like to show a portion of a motion picture. The purpose in showing this film is to help acquaint you with the size and speed of this equipment and what some of the capabilities are. We ask your indulgence in overlooking the commercial overtures. The film itself is twenty minutes long; however, we will only show seven minutes today. Anyone wishing to see the film in its entirety may do so by contacting us afterward. This film is also available to you in cassette form with projector at no charge. The equipment that you have just seen being operated in this film represents some of the basic diamond concrete cutting tools used within our industry today. These tools, when combined with demolition tools and used by experienced operators in conjunction with jackhammers, chipping guns, hyrams, hoerams, and flame-cutters, can literally remove any concrete structure or portion thereof economically within exacting standards and restrictions.

TECHNIQUES AND EQUIPMENT USED FOR CONCRETE DECONTAMINATION

It is generally accepted there are relatively few ways to decontaminate a building surface. Each has its limitations as well as advantages. They are: seal the radioactivity on the surface if the activity level allows, swabbing with water or decontamination agents, steam ejection, flame spalling, pressure blasting with abrasives or other agents, and mechanical removal of the surface. It is to this latter method, mechanical removal, that we address ourselves. We wish to consider only instances wherein the radioactivity has penetrated the concrete to a degree that dictates removal of the contaminated concrete or the removal of the surface layer only.

In the past, the most commonly used methods for achieving the above, has been by utilization of explosives, sand or shot blasting techniques, air and hydraulic powered hammers operated either manually or mounted on power equipment such as backhoes or bobcats, plus various brushes, sanders, grinders, and rock splitters. The employment of these tools usually generates large amounts of dust resulting in substantial airborne contaminates with the threat of recontamination of clean surfaces. Additional adverse side effects such as structural damage to remaining areas, excessive noises and vibrations are also frequently associated with these tools.

We are most familiar with the previously described impact or demolition tools as we own many of these items at the present time and use them in our daily course of business. We concur that in many instances these are the proper tools to be utilized on concrete decontamination projects. However, we have serious reservations, doubts, and fears that in many cases the advantages offered by diamond cutting tools remains mostly unknown and untried. The techniques we employ are the result of years of successful trial and error experiences.

ADVANTAGES AND DISADVANTAGES OF DIAMOND CUTTING TOOLS

The advantages diamond tools offer are, economy, speed of cut, total control of the size and surrounding surfaces to be removed, no; dust, vibrations, excessive noises or other adverse side effects.

The only disadvantage usually associated with diamond tools is the water used for cooling. This reputation comes from within the construction industry where the water must be vacuumed up or a mess may result. When we are speaking of controlling the water on D & D projects or risk further contamination spread, obviously a more serious approach is required and we have several alternatives at our disposal. We can presently control the water in most cases to any extent necessary with special notice and equipment. We can reduce the large spray of water now being used to a fine mist and sacrifice some diamond life thereby preventing airborne contamination with little or no excessive amounts of water resulting. We can substitute carbide instead of diamonds or some combination thereof. We can alter our bond formulas when manufacturing diamond tools and seek tools which utilize far less water. We can seek cooling fluids other than water, and finally, we can cut dry if necessary as we have before on several occasions due to unusual circumstances.

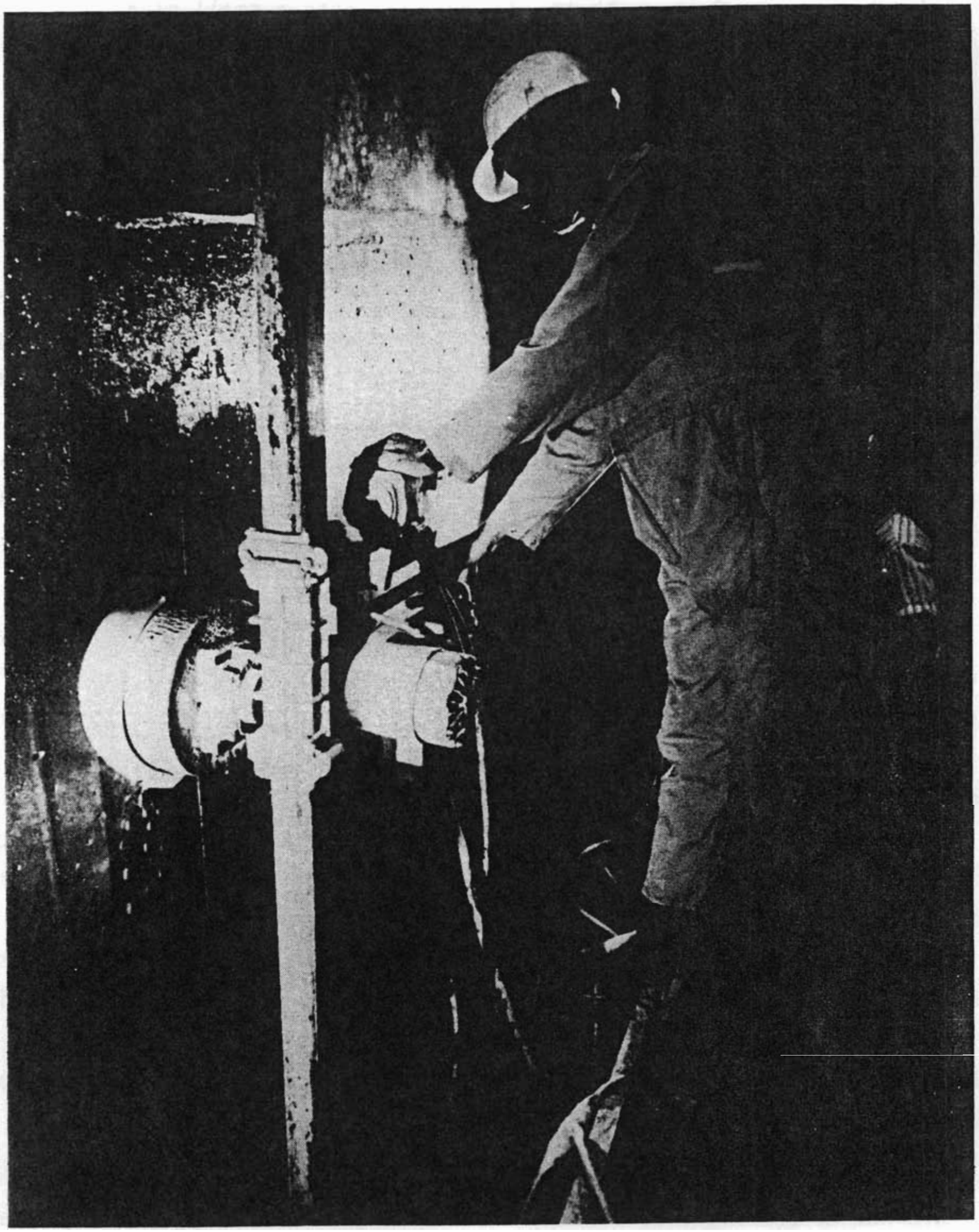
We would ask for your opinions, suggestions, and imagination as to the adaptability of some job site projects depicted in our brochures being applied towards D & D tasks.

If you would be kind enough to open the core drilling brochure and turn to the upper left hand corner of page eight (8) you will see a remote control core drilling application. Present day technology makes this economically possible. Remote control removal is feasible if the need exists. Core drilling is used in a variety of ways, for example, please refer to page six (6), the top portion illustrates a large block of concrete that has been "line" or "stitch" drilled free, also note the bottom portion of page nine (9) wherein a long core is being extracted. Virtually any size, depth, or shape of concrete can be removed dust free. If the contamination level were such that removal to a solid waste center in containers were required, the concrete could be precut to match the container size.

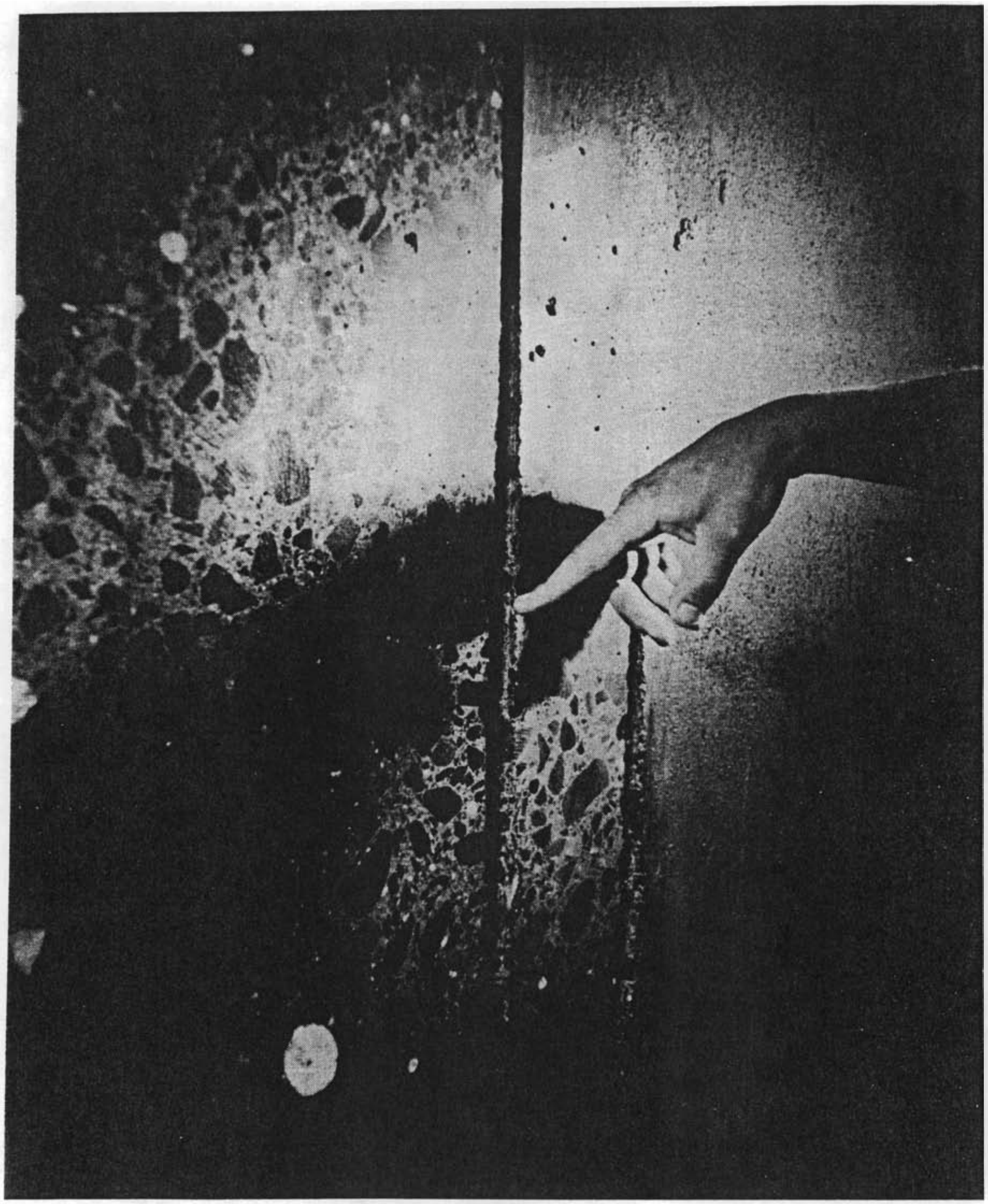
With respect to removing concrete slab areas, please refer to the flat sawing brochure. On page three (3) you will note a small slab area being cut free by a small electric powered saw, by comparison, if you would next refer to the wall sawing brochure, page six (6), bottom left hand corner, you will see a large section of slab being removed. Also depicted on other pages are unusual applications of this equipment. We should mention at this point that wall saws depicted in this brochure are predated, the more current models do not require the operator to hand crank or be next to the saw while the actual cutting operation is taking place. The modern state of the art provides models which are self feeding and operate from a remote control box much as depicted by the illustration on page two (2). Cutting depths up to 24 inches are possible from one side with this saw. This equipment is also convertible to a track mounted slab or wall grinder as depicted in photographs number one (1) and number two (2). Photograph number two (2) indicates depths of removal. This particular feature would be extremely efficient in rapidly removing one (1) to two (2) inches of vertical surface concrete.

With respect to grinding and grooving or partial removal of slab areas, we refer you to our grinding and grooving brochure. You will see that this equipment comes in all sizes from hand held, on page five (5), to 20 foot long self propelled machines, page seven (7). On page six (6) is an enlargement of a grooving head, consisting of a series of blades mounted on a spindle. If, for example, the top three (3) inches of concrete were required to be removed from a slab we would simply use a combination of the proper diameter blades; thence, saw cut approximately three and one-half (3½) inches deep and the concrete wafers remaining between the individual blade slots would simply break and chip off dust free with ease. This method is much more efficient than attempting to grind off three (3) inches of concrete or the use of jackhammers or chipping guns to accomplish same. Reference to the photographs numbered three (3), four (4), and five (5) may assist you visually.

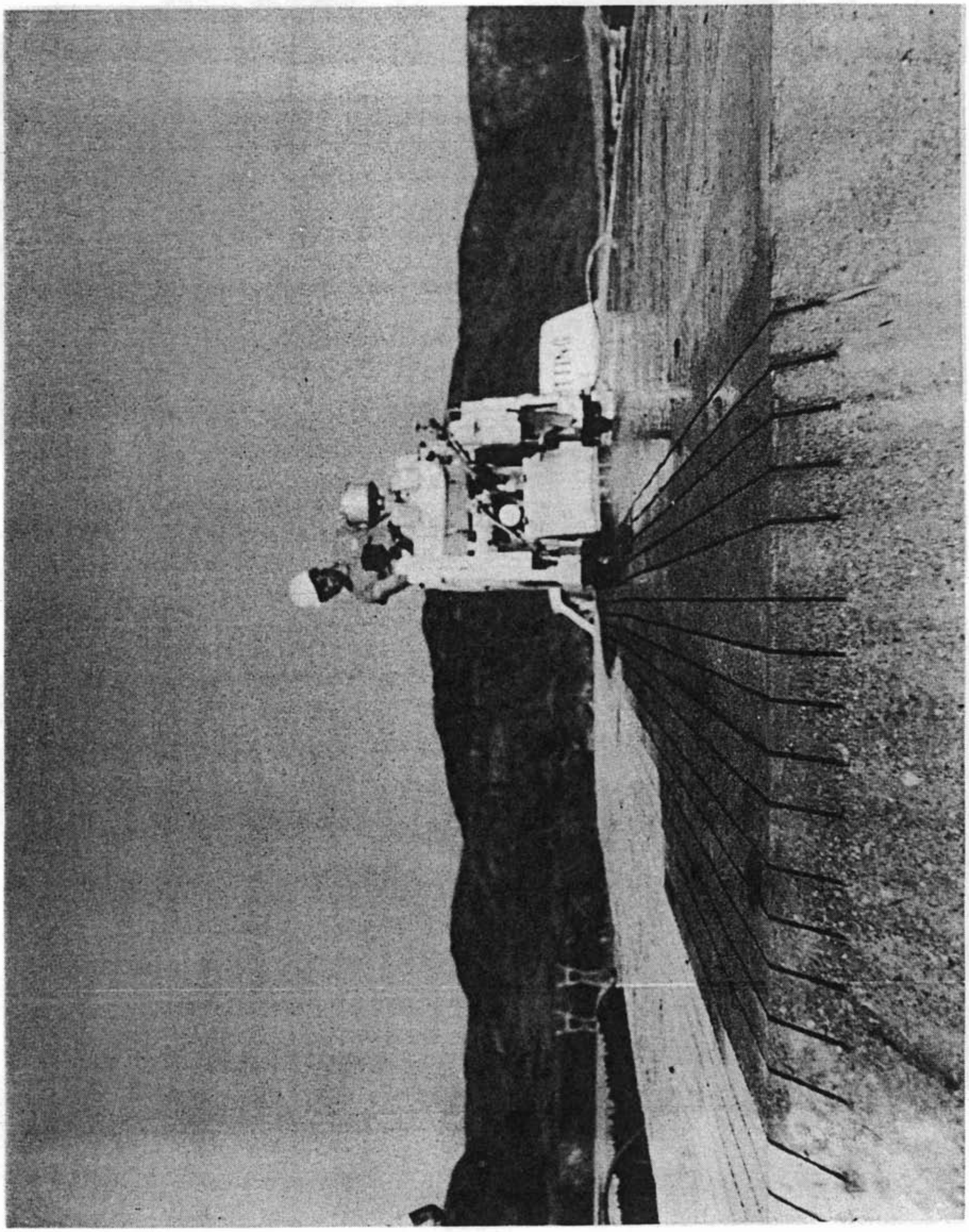
Considering our time allotment has expired I would simply like to emphasize in closing that perhaps the remote control capability alone may provide capabilities to complete tasks that heretofore were considered impossible.



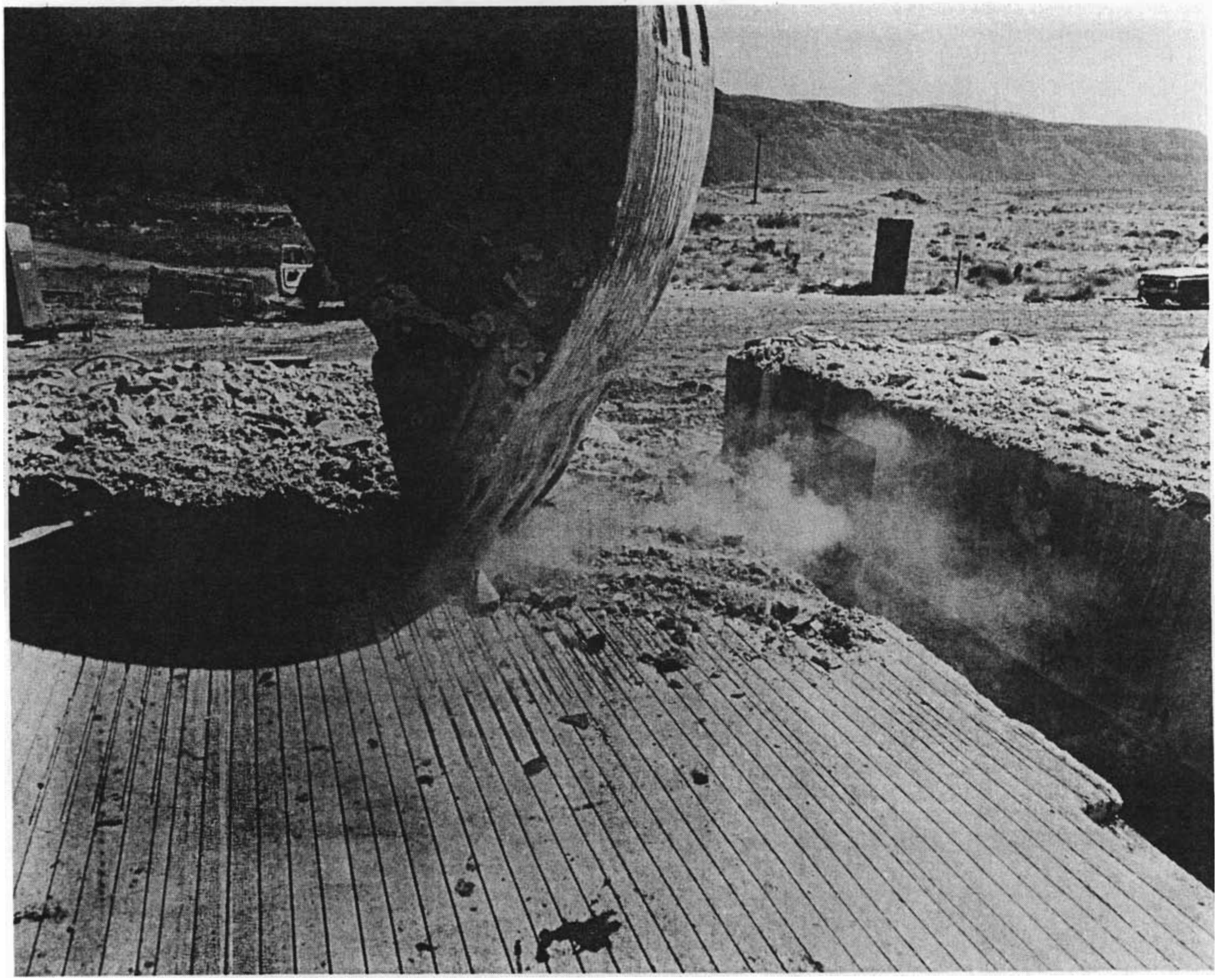
PHOTOGRAPH 1.



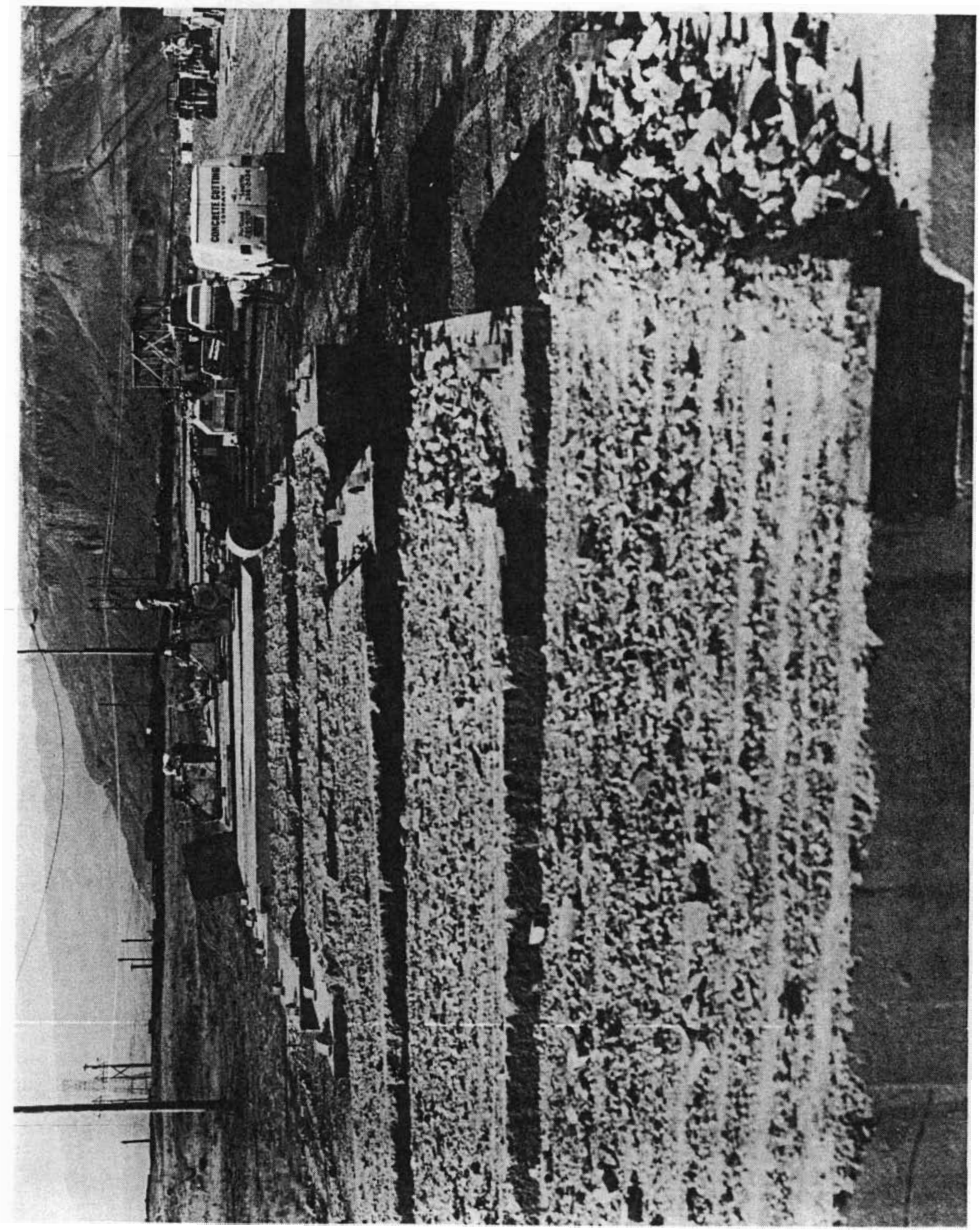
PHOTOGRAPH 2.



PHOTOGRAPH 3.



PHOTOGRAPH 4



PHOTOGRAPH 5

The following is a list of nuclear plants that Concrete Coring Company has performed work on either during construction phases or plant maintenance.

Dresden Nuclear Power Station Unit I, Unit II, Unit III (Illinois)

Yankee Nuclear Power Station (Massachusetts)

Enrico Fermi Atomic Power Plant Unit I and Unit II (Michigan)

San Onofre Nuclear Generating Station Unit I, Unit II, Unit III (California)

Browns Ferry Nuclear Power Plant Unit I and Unit II (Alabama)

Diablo Canyon Nuclear Power Plant Unit I and Unit II (California)

Zion Station Unit I and Unit II (Illinois)

Cooper Nuclear Station (Nebraska)

Rancho Seco Nuclear Generating Station Unit I (California)

Trojan Nuclear Power Plant Unit I (Washington)

Hanford Nuclear Plant Unit I and Unit II (Washington)

LaSalle County Nuclear Station Unit I and Unit II (Illinois)

Bryon Station Unit I and Unit II (Illinois)

Grand Gulf Nuclear Station Unit I and Unit II (Mississippi)

Seabrook Nuclear Station Unit I and Unit II (New Hampshire)

Palo Verde Nuclear Generating Station Unit I and Unit II (Arizona)

Quad Cities Station Unit II (Illinois)

Donald C. Cook Plant I and II (Michigan)

DIAMOND BLADE GRINDING AS A MEANS FOR REMOVING SURFACE CONTAMINATION FROM CONCRETE

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The use of a highway grinding unit for the decontamination of a 5,000 square foot surface is described. The type of equipment presently in use is described. Performance characteristics, waste collection and water usage are commented on. Variables in blade design are discussed. Feasibility of the grinding technique for water soluble contaminants and vertical surfaces is referred to.

INTRODUCTION

In the process of decontaminating a depleted uranium manufacturing facility, a considerable area of blacktop was found to have a contaminated surface layer. The blacktop, approximately 5,000 square feet, adjoined a building in which depleted uranium was the stock used in a manufacturing process. As a result of a decision to relocate and expand the manufacturing operation, the facility had to be inspected for agency compliance. The inspection revealed widespread contamination throughout the main manufacturing building as well as the surrounding blacktop area. With respect to the blacktop area, the problem was viewed as finding a suitable method for the removal of a surface layer of approximately 1/8" thickness in order to render the area suitable for unconditional release. The level of contamination was low (approximately 10,000 - 20,000 DPM per 100 square centimeters) but above acceptable levels.

A description of the project emphasizing the blacktop problem was presented to the Penhall Company. Penhall, with over 20 years experience in the sawing, breaking, and grinding of concrete, was requested, to study the problem and recommend a solution. The recommendation was to apply a diamond blade grinding procedure to the blacktop. This process was identical to the grinding process which Penhall had perfected in the removal of approximately 9,000,000 square feet of highway and freeway surfaces.

In the subject case the surface was successfully removed by the grinding operation. The generated swarf was picked up by a vacuum system attached to the unit and pumped to a water tank truck. The moist swarf was removed from the tank truck, allowed to dry and transferred to 55 gallon drums for shipment to a burial site.

Subsequent radioactivity surveys demonstrated that the remaining blacktop was within acceptable levels for unconditional release.

BACKGROUND

The removal of vast amounts of concrete pavement using diamond saw blades dates back to the early 1960's when the process of highway grooving proved to be highly effective in reducing the number of wet pavement accidents on California freeways. In the years since, hundreds of miles of freeway pavement have been grooved in the Los Angeles area alone. Although the initial costs for blades are high, grooving with diamond saw blades is the only known method by which this process can be done economically.

By the mid 1970's, the process known as highway "grinding" became an economically feasible method for rehabilitating old, bumpy sections of highway, which process might be described as grooving with diamond blades spaced very closely together.

The working "head" of a grinding machine is a spindle on which as many as 250 diamond blades are mounted, and the blade assembly may be up to 4 feet wide. The amount of concrete removed from the surface of a highway, of course, depends on the degree of roughness. Often it is necessary to grind away the surface to depths of over one inch, and this normally requires two or more passes with the diamond head. A single head of blades will remove from 30,000 to 100,000 square yards of highway surface, depending on the hardness and abrasiveness of the concrete mixture and one machine will typically resurface about 3,000 square yards per 8-hour shift (about 1/2 mile of a 12-foot wide lane).

The grinding unit used on the subject project weighed 16,000 lbs. and was powered by a 225 h.p. turbo-charged diesel engine. It was hauled on a three axle truck equipped with a tilting and rollback bed for ease in loading and unloading. A 38" wide cutting head was used.

Technical Discussion

Highway grinding machines are built for rigidity - the ability to deliver maximum horsepower and torque to the heavy blade spindle so as to produce an even profile on the highway surface. The tractor engines used (usually diesel) will generate up to 300 horsepower at about 2,000 rpm. The blade spindle rpm is varied with interchangeable pulleys, and is most often rotated in the direction counter to direction of forward motion to produce a condition known as "up-cutting". The thrust of up-cutting tends to drive the blades down into the pavement thus making it easier to maintain level cutting.

The critical elements in a grinding process includes diamond blade selection, collection system and water control.

The diamond blades (12 to 14 inch diameter) are essentially alloy steel disks on which are mounted diamond-bearing composite "segments" carefully formulated from mixtures of industrial diamond particles and metal powders. The diamond/metal powder mixtures are molded under heat and pressure to produce dense composite "segments" subsequently silver brazed onto the steel disks. Each blade will contain from 16 to 20 segments. The diamond particles may be either natural "mined" diamond or they may be synthesized, the latter of which are generally stronger due to the lesser amounts of defects in the crystals. In both cases, the particle sizes used range from 20 down to 60 U.S. Mesh.

The proprietary metal alloys used to hold the diamonds in place are known as "bonds" and these can be tailored to the properties of the concrete being ground - a bond suitable for grinding high strength concrete containing very hard aggregates would not necessarily be suitable for low strength concrete containing soft aggregate and vice versa. For this reason, it is highly desirable to know as much as possible about the properties of the concrete in advance of the job. Some of the more important properties to be sought out in advance are:

1. Hardness, size, and soundness of the aggregate.
2. Composition, size, and shape of the sand particles used in the mix.

3. Compressive strength of the concrete mix in the present state of cure. (Compressive strength tests can be performed non-destructively on the job site.)

From these data, the blades can be formulated so as to optimize the grinding process in terms of blade wear and cutting rates and, hence, give the lowest overall costs.

The cooling and waste collection systems are of particular concern for contemplated uses in decontamination. The entire grinding head is enclosed in a vacuum hood which fits closely over the blades. Rubber seals fitted around the hood are in contact with the pavement surface at all times.

An 8,000 gallon capacity water tanker truck supplies cooling water for the blades. The water is pumped from the tanker by means of a centrifugal pump and the blades are wetted through a spray bar at a rate of approximately 50 gpm.

During the grinding operation, an impeller vacuum pump which is mounted on the grinding unit pulls the swarf and returning cooling water into a collection box which is also mounted on the unit. Within this collection tank, the difference in density between the air and water is utilized to separate the two. The air is exhausted to ambient while the water and solids are drawn out of the bottom of the collection tank. A centrifugal pump then transfers the swarf and water back to the tanker truck which is equipped with baffled and filtered compartments. The solids settle out in the forward tanks and the clean water is recirculated back to the grinding unit. The efficiency of the entire vacuum system is such that the pavement surface after grinding has the appearance of being damp-mopped. Within a few minutes, the pavement surface is completely dry.

In routine highway grinding operations approximately 4,000 gallons of water is utilized in the recirculation process. By the end of an 8-hour work shift, there are typically 11 tons of swarf in the tanker. The amount of swarf generated is, of course, variable due to the composition of the material removed. The swarf is dumped through six inch lines located under the water tank and is cleaned with high pressure water jet.

Concrete Decontamination

The highway grinding equipment in its present form may be used for the removal of low-level insoluble contaminants. In this case, the water usage would be minimized. The use of flocculents settles the swarf quickly and facilitates drying. The damp swarf can be removed from the holding tanks without the use of a flushing stream. The greatest part of the swarf empties itself through the six inch lines and the little remaining may be cleaned out with some sort of squeegee. Holding tanks or plastic lined pits may be used for drying. The disposition of higher level insoluble wastes would necessitate considerable technical innovation based on the same general principles.

In cases where the use of cooling water is prohibited, dry grinding may be feasible. For example, diamond drills were developed for dry use in sodium-cooled reactors. It is conceivable that the principles applied there could be utilized in the development of a diamond grinding process without water cooling. The design of blades for maximum heat transfer using high conductivity metal bonds, high conductivity disks, and high speed rotating seals would have application in this area. It is, of course, to be expected that surface removal rates would have to be considerably slower so as to minimize the rates of heat build-up in the diamond tools.

Excessive heat generated in a diamond tool affects the integrity of the diamond particles through thermal shock and through graphitization. Excessive heat also affects the rotational stability of the blade itself due to uneven thermal expansion, and this effect shows up quickly via sudden heavy vibrations in the rotating system. However, there are cases where diamond sawing without the use of liquid coolants have been successful, such as the sawing of porous, abrasive brakelining materials. In these cases, the adverse effects of thermal expansion were avoided by simply splitting the blades into two semicircular sections and reassembling the sections on a specially designed spindle. When this was done, thermal expansion became uniform and did not distort the blades.

To date, we have not developed equipment that will perform the diamond blade grinding operation on vertical surfaces. However, the problem has been conceptually examined by our equipment division.

It is considered that a reasonable approach would be based on technology already developed for concrete wall sawing. In this technique, small diameter holes are drilled on the wall surfaces and concrete anchors set in place. Metal track is bolted to the anchors, and the saw traverses the track either man-operated or automatically by servo motors. Waste collection and water control would present a more severe problem here than on horizontal surfaces.

Another approach to vertical surfaces which would have the advantage of increased working distances from higher level radiation fields would involve the use of a backhoe or similar device. In this case, the articulated arms would press the track against the wall and the rest of the grinding operation would be controlled by the backhoe operator.

In cases where access or working space is limited, there are lawn mower size grinding units available. So far, we have not equipped these units with vacuum waste collection systems. However, this would not appear to present any fundamental problems.

In summary, diamond blade grinding has present application in contaminated concrete removal under certain circumstances. The scope of its application could be extended considerably with further development.

INNOVATIVE TECHNIQUES FOR REMOVING CONCRETE SURFACES

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This report centers on the use of heat to decompose contaminated concrete to facilitate its removal. It discusses the use of electrical resistance heating and induction heating to cause differential expansion between the reinforcing steel and the concrete in order to spall the concrete. It introduces the concept of using induction heating to both decompose and spall steel impregnated concrete, acknowledging the work of Charles H. Henager in this field.

The techniques are offered as theoretical and untested possibilities. Their practical application depends upon the effectiveness of alternatives and upon further development of these concepts.

INTRODUCTION

The decontamination techniques considered here stem from an earlier investigation of the effects of heat on concrete as a demolition device.(1)

These techniques are untried and each has what appear to be practical limitations. They appear to have theoretical validity. Depending upon the alternatives, they could be of practical value for specific situations.

These techniques include the use of:

- space heating to decompose concrete surfaces
- electrical resistance heating of steel reinforcing bar to spall concrete from the steel
- electrical induction heat to spall concrete from steel reinforcing bar
- electrical induction heat to decompose and spall steel-impregnated concrete (Wirand®).

The use of heat to decompose concrete calls for a brief review of the nature of concrete and its responses to heat. Concrete is composed of calcium carbonate ($CaCO_3$) cement (20% to 30%) and rock and sand aggregate (70% to 80%). The cement glues the aggregate together. Concrete has some 5% to 6% water by weight, even when dry. Eighty percent of this water is free water and 20% is chemically bound.

When the temperature of concrete is raised to 212°F, the free water is driven off as steam; an explosive spalling of the concrete occurs if the temperature is raised faster than the water vapor can escape through the pores of the concrete. At about 400°F to 500°F the chemically bound water is driven off. This dehydration causes the cement paste to shrink and lose some of its adhesion. There is a strength loss at this point on the order of 10% to 25%.

When the temperature is raised to 1063°F, there is a change in the crystalline structure of quartz (from quartz alpha to quartz beta), which results

® Wirand is a registered trademark of the Battelle Development Corporation, Columbus, Ohio.

in swelling and internal cracking. Concrete with quartzitic aggregate will have lost 50% to 75% of its strength at this approximate temperature.

Between 1200°F and 1600°F, Portland cement ($CaCO_3$) converts to $CaO + CO_2$, with the CO_2 leaving as a gas. After exposure to the atmosphere, as the concrete cools, the CaO absorbs moisture from the atmosphere and converts to $CaOH_2$. $CaOH_2$ is considerably weaker than CaO and will spontaneously disintegrate, with the rocks and sand falling loosely. The scale of strength loss due to heating is taken from Abrams.[2, Figure 15]

The specific heat of reinforced concrete is a nominal 0.20 Btu/lb. It takes about one-fifth as much heat to raise a pound of concrete 1°F as it takes to raise the same weight of water 1 F. The specific heat of steel is a nominal 0.10.

Thermal conductivity is the rate at which heat is passed through a substance. It is expressed in Btu/ft^2/degree F temperature difference/ft. The thermal conductivity of concrete is 0.54, and the thermal conductivity of steel is 26.2.[3] Heat goes through steel some 48 times as fast as it goes through concrete.

In the progression of heat through a concrete wall or slab, the surface exposed to heat is heated much higher than the concrete behind it initially because of the low thermal conductivity of concrete. Over a period of time, however, the heat distribution approaches a straight line steady state from the high inner temperature to the lower temperature of the outside edge of the wall or structure.

A simplified heat progression rate is that each 3/4 in. of depth of concrete raised to 1600°F requires 4 hr.[2, p. 35, Figure 25]

SPACE HEATING TO DECOMPOSE CONCRETE SURFACES

Space heating to decompose concrete surfaces requires an enclosed space and a noncombustion heat source such as electrical heating units. Electric space heating is limited by the size of the units available. The largest located are 100 kW, which at 3412 Btu/kW equals 341,200 Btu/unit (cost 1980, $3,000 each). It is possible to hook up a large number of units. They can operate at 1700°F to 2100°F temperatures.

As an example, an enclosed space 24 ft^3, such as a pit, would have 5 sides and a lid of 576 ft^2 each, 2,880 ft^2 plus lid. To raise 2,880 ft^3 of concrete 1,600°F would require 2,800 ft^3 x 140 lb/ft^3 x 1600° x 0.20 specific heat = 129,000,000 Btu. Two thousand eight hundred eighty ft^2 of concrete would transmit by thermal conduction 0.54 x 2,800 ft^2 x 1,750° x 2,700,000 Btu/hr. The hourly input of 2.7 million Btu would require 48 hr to deliver the required 129 million Btu.

Eight 100-kW heating units would produce 2,700,000 Btu/hr (8 x 340.000). To compensate for heat losses from the lid and possible unit failures, 12 units should provide that factor.

To compensate for heat passing beyond the first foot of depth, a doubling of the time could be required. A reasonable heat input would appear to be 12 heating units operating for 96 hr. Checking this against the simplified heat progression rate of 3/4 in./4 hr, 96 hr = 18 in., a reasonable correlation.

The action of the concrete should follow these steps:

1. exhalation through the pores of the concrete of free water in the form of vapor - This could involve some explosive spalling. The volume of this vapor, which would be highly radioactive, could be generally computed as 0.80 x 0.06 x the volume of the concrete heated to 212°F x 1600 (expansion of water to steam).
2. exhalation of chemically bound water, also highly radioactive, computed as 0.20 x 0.06 x the volume of the concrete heated to 400°F x 1600
3. progressive strength loss of the concrete as it approaches 1600°F
4. Minor contamination of previously uncontaminated concrete could occur as that portion cools below 212°F and draws moisture from the atmosphere through the contaminated portion.

The heat progression through the mass would not initially be in a straight line. At the point of initial 1600°F heat penetrating to the 12-in. depth, the mass heated ahead would show a dropoff to some 200°F within a further 12 in. By doubling the 12-in. depth volume, we should be able to make a rough computation of the volume of free and chemically bound water escaping to the pit in the form of steam vapor. In the example used of a 24-ft^3 space, the 2,880 ft^2 of concrete surface x 2 ft depth = 5,760 ft^3 of concrete. Six percent moisture content x 5,760 = 35 ft^3 water, some 2,800 gal. Three hundred fifty ft^3 x the expansion of steam = 560,000 ft^3 of steam to be handled.

In addition, there would be further penetration of heat into the concrete mass after the heat source was removed as the heat sought a steady-state distribution. This would result in a continued exhalation of vapor for a time as the mass cooled. This reduced vapor flow would pass through radioactive material and could pick up radioactivity. It would have to be contained and treated until the steady state is reached and the temperature begins to recede at the innermost penetration.

The feasibility of decontamination by space heating depends upon the vulnerability of the heating units to spalling concrete and upon the ability to confine, draw off, and treat the radioactive vapors released.

ELECTRICAL RESISTANCE HEATING OF STEEL REINFORCING BAR

Decontamination by electrical resistance heating consists of passing an electric current through the reinforcing bar causing the reinforcing steel to expand, break its bond with the concrete and spall the concrete.

This differential expansion can be readily accomplished when the reinforcing bar is continuous, not grounded to other objects, and accessible for attachment of electrical leads. The passing of electrical current through it in sufficient quantity will cause the rebar to heat internally. As it expands from the heat, its deformation will be resisted by the concrete. A 300°F difference in temperature is generally sufficient to break the concrete. This is confirmed by J. P. Vidosic, who states:

> When the deformation arising from change of temperature is prevented, temperature stresses arise that are proportional to the amount of deformation that is prevented . . . In the case of steel, a change of temperature of 12°F will cause in general a unit stress of 2,340 lb/in.^{3}(4, p. 5-17)

At 195 lb/in.^{3}/degree F, a change of 302°F would generate a stress of 58,890 lb/in.^{3} This generally exceeds the full bonding strength of concrete and could reasonably be expected to cause failure. The steel could be heated some 8 times the 300°F cited and generated deformation forces far beyond that required.

The procedure is not likely to be successful for the already constructed plants with which we are most concerned because: 1) the reinforcing steel is tied together in grids which can pass large amounts of current without heating, 2) the reinforcing rods are discontinuous, and 3) the ends are not readily accessible for attaching electrodes.

These problems could be overcome readily in new construction. Continuous separate bars with accessible ends could be built into areas of concrete expected to become heavily contaminated. Decontamination of these areas would become safe, fast, and inexpensive.

A process for accomplishing electrical resistance heating of reinforcing steel is described in French Patent #918,321, not available at time of writing.

The electrical resistance procedure could be carried out with a minimum amount of human exposure to radioactivity.

ELECTRICAL INDUCTION HEAT TO SPALL CONCRETE FROM STEEL REINFORCING BAR

Electrical induction heating can heat buried steel without heating the intervening concrete. Decontamination by induction heating of a shallowly buried rebar or wire mesh pattern would avoid the necessity of exposing the ends of the steel for attachment of electrodes and the necessity that the steel be a continuous conductor. Since it has a limited depth of penetration, induction heating should be designed for use in areas not expected to be deeply contaminated. It requires preplanning into new construction to be most effective.

It requires a relatively sophisticated device compared to resistance heating. It should be a safe and relatively economical method for decontamination. Induction heat creates a rapidly reversing magnetic field which penetrates through concrete to the buried steel. It induces an electrical current in the buried steel and, by reversing the direction of the current, causes the atoms to rapidly and continuously change their alignment, creating heat.

There are many induction heating devices on the market and they can be modified for particular application. The details of design and operation of one such device are contained in a Japanese patent.[5] It claims that when the reinforcement has been heated 150°C (302°F) above ambient, the reinforcement will break its bond and the concrete can then be readily removed. This is confirmed by Vidosic.[4]

The current must reverse fast enough to heat the molecules of the steel, but slow enough to permit penetration of the magnetic field through the concrete. Four hundred Hertz is the frequency range proposed by Itoh. Higher frequencies have a falling off of penetration and their reflections in the very high frequencies can be harmful to humans, causing cataracts and bone damage. The coil requires continuous cooling to prevent it from burning out. This can be accomplished by wrapping the coil with copper tubing through which water is passed, rather than with solid cooper wire. Itoh specifies the use of a capacitor to increase the effectiveness of the magnetic flux.

The effective use of induction heating requires the placement of reinforcing or wire mesh at the depth required to be removed.

Reduction of human exposure would call for a remote-controlled heating coil.

The procedure requires a fairly complex machine and has limitations of depth of penetration and heat capacity. It has the possibility of reducing human exposure to radioactivity.

INDUCTION HEAT WITH STEEL IMPREGNATED CONCRETE (WIRAND®)

A drawback of induction heating is that it generally requires preplanning and pre-building of the steel mesh or rebar at the optimum depth for decontamination. This drawback could be partly overcome by imbedding steel in the concrete itself. The heat would only have to penetrate to the depth that was to be removed and that depth could be varied according to how deeply the concrete was contaminated. The penetration could be set for 1 to 6 in. This mixture of steel and concrete could be used as a surface coating over new or existing uncontaminated surfaces to assure their future readiness for decontamination.

There is such a steel-impregnated concrete in existence called Wirand®. It has millions of steel wire strands mixed throughout the concrete. The steel amounts to some 2% of the mix. The expansion of a 2% steel content should be sufficient to fracture the concrete. I base this on the calculation that 2% of a cubic yard (46,656 $in.^3$) = 933 $in.^3$ of steel. This would amount to 390 lin ft of 1/2-in. rebar. That much rebar would rupture a cubic yard of concrete just on the face of it. By Vidosic's figures, 933 $in.^3$ of steel raised 300°F would generate a deformation stress of 58,890 lb x 933 = 54,944,370 lb. The temperature could easily be quadrupled. In addition, the concrete itself could be decomposed by these millions of internal heat sources if they were heated above the 300°F specified for spalling. Charles Henager, Sr., of Battelle, Pacific Northwest Laboratories, invented and developed Wirand® and is the authority on its composition and application.

Wirand® can be gunited onto surfaces expected to become contaminated without extraordinary expense. It is an established product which has been successfully gunited.

Study is needed to design the precise induction heating device to remove it. The theory is well established and there are many hardware examples to select from. The process can be remotely controlled to minimize human exposrure.

I believe that Battelle has a significant "in-house" solution in Wirand® to some of the problems of concrete decontamination.

SUMMARY

These techniques are offered as theoretical and untried possibilities. There appears to be theoretical justification for pursuing their development. In particuar, electrical resistance heating could find a practical application being built into reactor pit areas. Wirand® appears to have a wide potential application. Decomposition of concrete by space heating is an "iffy" alternative which could be valuable in heavily contaminated pit areas in existing installations.

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DECONTAMINATION OF LARGE HORIZONTAL CONCRETE SURFACES OUTDOORS*

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A study is being conducted of the resources and planning that would be required to clean up an extensive contamination of the outdoor environment. As part of this study, an assessment of the fleet of machines needed for decontaminating large outdoor surfaces of horizontal concrete will be attempted. The operations required will be described. The performance of applicable existing equipment will be analyzed in terms of area cleaned per unit time, and the comprehensive cost of decontamination per unit area will be derived.

Shielded equipment for measuring directional radiation and continuously monitoring decontamination work will be described.

Shielding of drivers' cabs and remote control vehicles will be addressed.

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INTRODUCTION

A study of the logistics and tasks for a large-scale decontamination of the environment is underway at ORNL as part of the Emergency Technology Program conducted for the Operational and Environmental Safety Division of the Department of Energy. The study is considering a situation in which contamination is initially deposited by aerosol on surfaces and has been rained on. In contrast to much decontamination and decommissioning experience, it is assumed that there has been relatively little traffic on the affected surfaces.

In such a situation, most of the area that would be affected would be unpaved. However, decontamination of the few percentage of paved area would have a high priority and a certain amount of time urgency in a large operation to provide access to the affected area and pathways for logistic support. It is also assumed that decontamination methods used must pick up the contamination rather than simply flush it down a storm drain or into the surrounding soil or drainage system. In concept, something like a large vacuum cleaner is required, operating in conjunction with a method of providing a controllable amount of abrasion or erosion of the surface. It is expected that the contamination will be tightly bonded to the surface or trapped in surface porosity or cracks, and would be largely unmoved by the usual street vacuum sweeper.

However, there is hard wire-brush-street-sweeping equipment which can remove a limited portion of the surface layer. For contamination trapped in deeper pores or cracks, road planers may be useful. These abrade the surface with hardened steel bits and may be adjusted to remove the surface to a depth ranging from a few millimeters to several centimeters.

With appropriate modifications, these machines should produce the least volume of waste and in a simple form--a freeflowing powder.

Use of high-pressure water jets for cutting rock and concrete is a proven technology. They would be advantageous for concrete surface removal in that there are no bits to replace. Unfortunately, there is no commercial waterjet equipment developed for continuous removal of broad surface areas. Existing equipment is single-nozzle, semiportable equipment for cutting small areas. Equipment could be developed for road surface decontamination, but it would require a major effort.

The addition of large amounts of water to the waste would complicate spoil removal. The water would make much more difficult the design and operation of the air filters required on equipment for continuous vacuuming of the cutting area.

WIRE-BRUSHING OF CONCRETE ROADS

The commercial equipment available is simply a street sweeper equipped with hard steel-wire brushes. These machines usually have two vertical-axis gutter brooms and one horizontal axis main broom, plus a conveyor that loads the fines into a box, the contents of which can be dumped into a truck. They are shown in Figures 1 and 2, one is manufactured by Athey Products in Wake Forest, North Carolina, and the other by FMC, Pomona, California.

By exerting sufficient pressure downwards on the brooms and letting them rotate at high speed, an abrasive action is exerted on the pavement. It changes color, and the hollows in the surface are swept clean.

Exactly how much surface layer thickness is removed is not known. Tests with chemicals identical to the fall-out should be performed to check to what measure they are removed.

Table 1 gives the costs for the two street sweepers considered. The cost per square meter is \$0.004--i.e., \$4,000/km^2 (\$11,000/mi^2). We have assumed 10 years lifetime and 1200 working hours per year as representative of this kind of equipment.

CUTTING OF CONCRETE ROADS WITH COLD PLANERS

The road construction industry provides machines to cut away concrete surface layers with hard bits.

We have taken from each of three major manufacturers (Dresser in Galion, Ohio, CMI in Oklahoma City, Barber-Greene in Aurora, Illinois) a light model,

FIGURE 1. Athey Mobilsweeper

FIGURE 2. FMC Mechanical Sweeper

TABLE 1. Performance and Cost of Wire Brushing Equipment

Manufacturer and Model	Sweeping Width (m)	Sweeping Speed (m/h)	Area Per Unit Time (m^2/h)	Crew Size	Purchase Price (k$)	Cost: Ownership ($/h)	Cost: Maintenance ($/h)	Cost: Labor ($/h)	Cost: Total ($/h)	Cost Per Unit Area ($/$m^2$)
Athey Mobilsweeper II	3.048	2475	7543	1	48	7.5	6	18	31.5	0.0042
FMC Mechanical Sweeper 12	3.25	2475	8044	1	60	9	6	18	33	0.0041

a middle model and a heavy model to compare them in terms of performance and cost. These models are shown in Figures 3 through 10.

As cutting depths we have taken 6 mm, 12 mm and 25 mm. It is estimated that all chemical contamination is contained in the first 6 mm. Irregularities of level in the road surface are usually less than 25 mm.

It is estimated by CMI that the cutting speed can be 15 meters per minute for a cut of 6 mm, 12 m/min for 12 mm, and 6 m/min for 25 mm in average concrete.

For the purpose of our calculations, it seems reasonable to assign the 6 mm cutting depth to the light model, the 12 mm to the middle one and the 25 mm to the heavier one.

The duty factor of such machines has been assumed to be 600 hrs/yr. There seems to be a consensus in the industry that this is a nationwide average, due to the working conditions, assignments, weather, etc. Cost calculations are generally made on such a basis.

Lifetimes of most road planers are given as 5 years (CMI, Barber-Greene). Dresser suggests 10 years for its Galion models.

Each manufacturer has its own way of making cost calculations. We have used the ownership costs, the operating costs, and the labor costs as given by each manufacturer without modification, in order to be able to make comparisons.

The maintenance costs usually do not include the replacement of the cutting bits because the wear of this item is so much dependent on the hardness of the concrete to be cut. We asked the various manufacturers to recommend methods of calculation for this cost item and got different answers.

Dresser indicated that its figures are based on the replacement of the bits every 8 hours.

CMI referred us to a manufacturer of bits (Kennametals in Bedford, Pennsylvania), who suggested 5000 to 6000 square meters as the area after which the whole set of bits has to be changed on the mandrel.

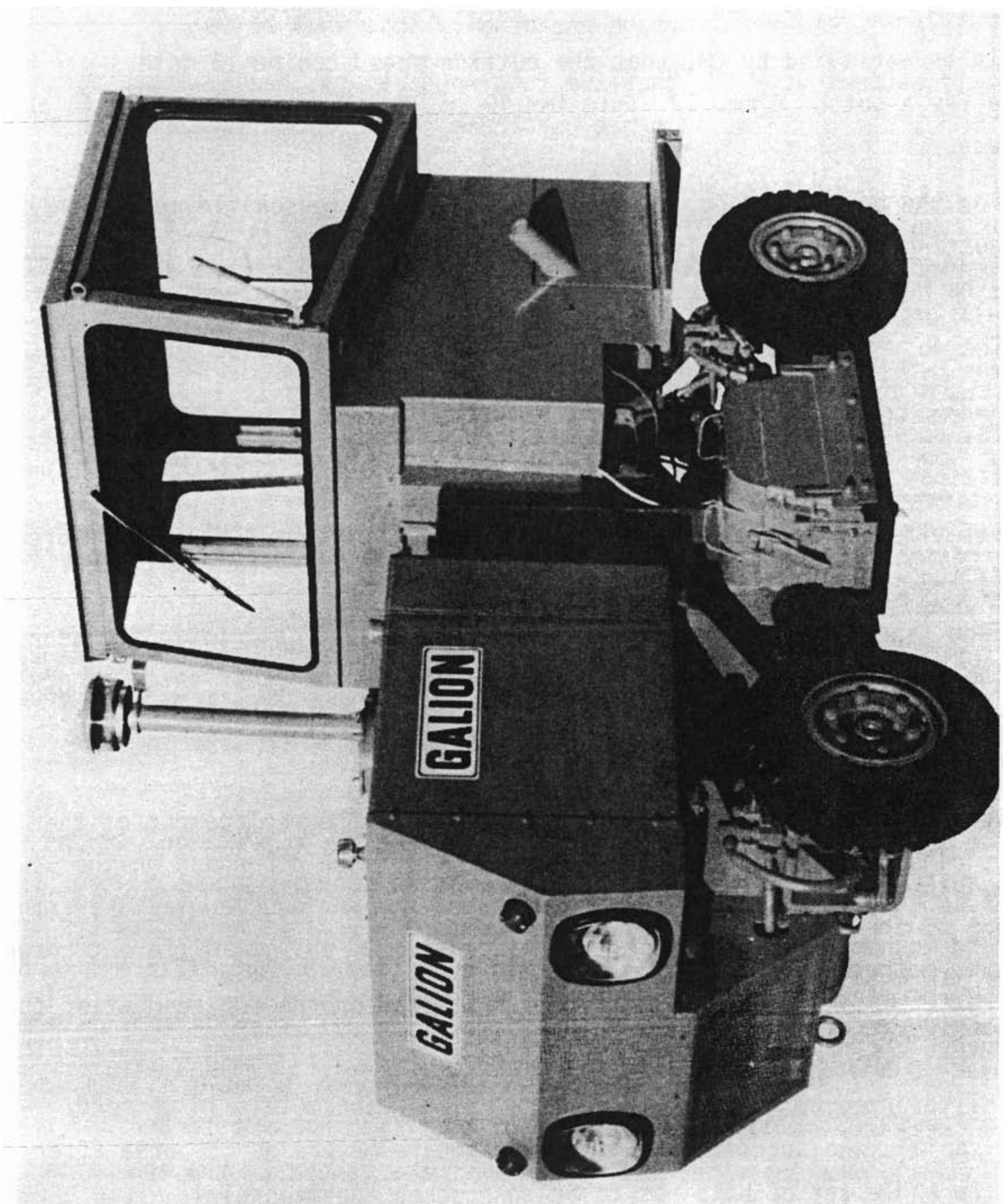

FIGURE 3. Dresser Galion Roadplaner RP 12

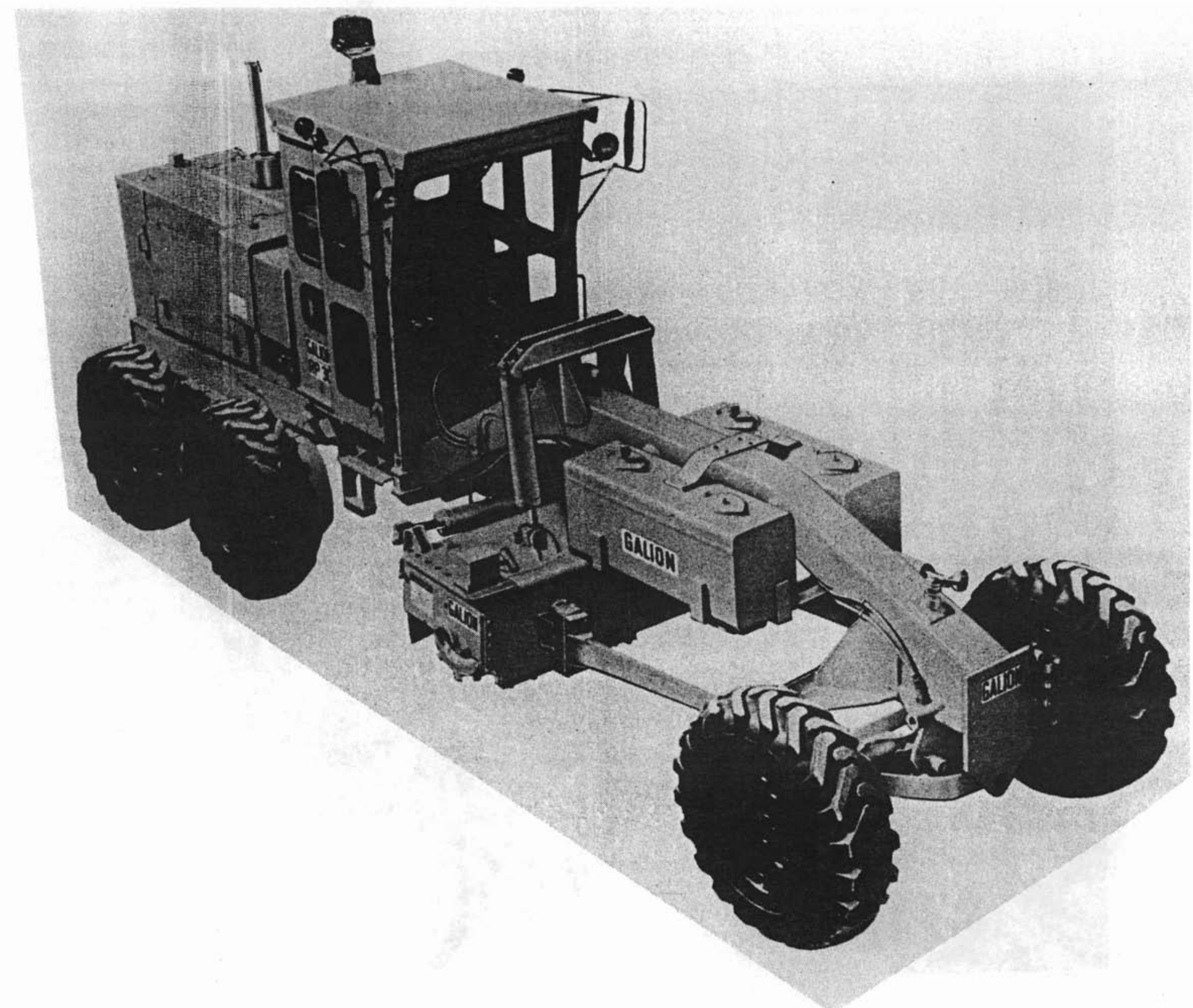

FIGURE 4. Dresser Galion Roadplaner RP 30/42

FIGURE 5. Dresser Galion Roadplaner RP-60

FIGURE 6. CMI Pavement Profiler PR-275-RT

FIGURE 7. CMI Pavement Profiler PR-525

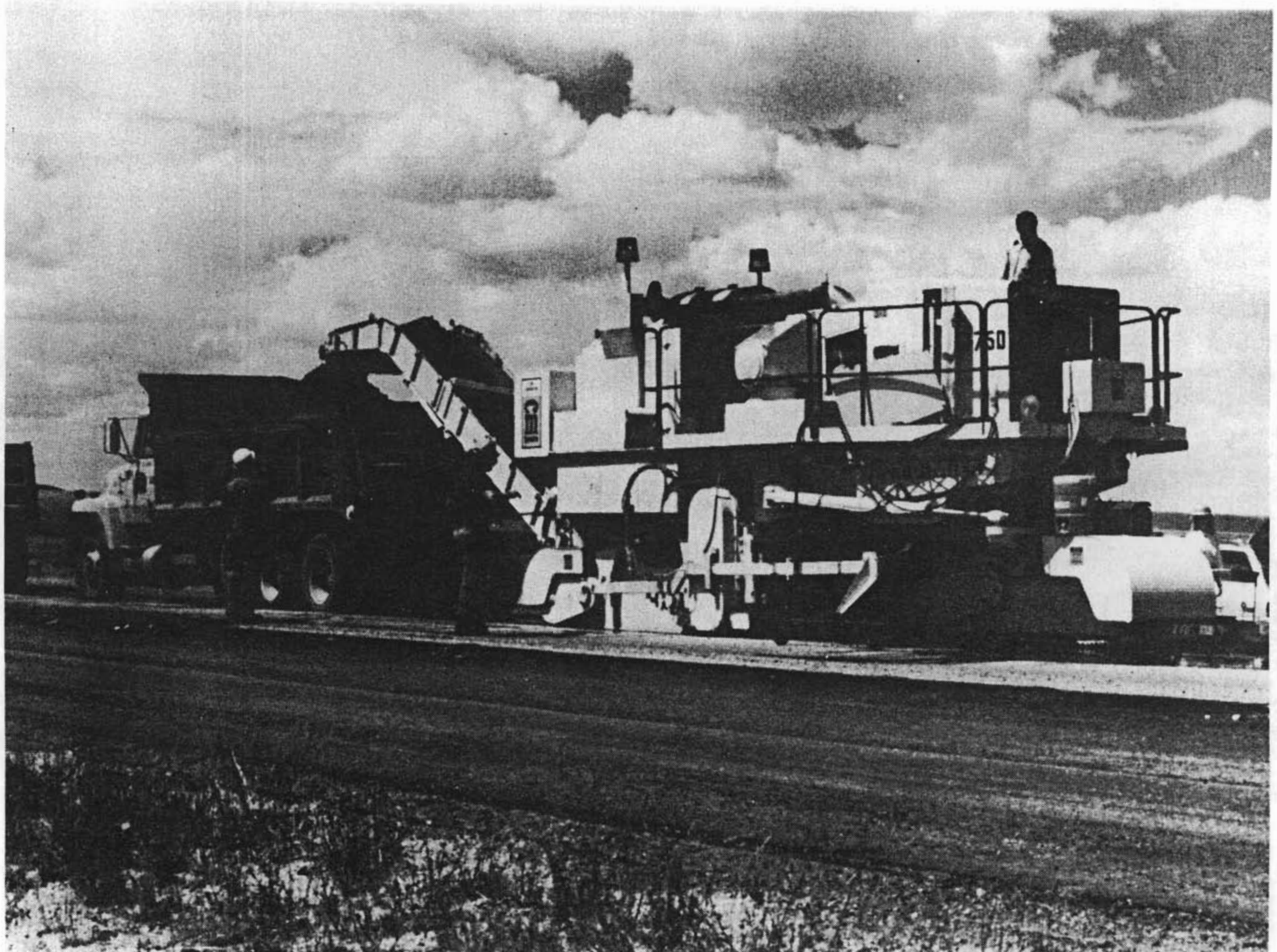

FIGURE 8. CMI Pavement Profiler PR-750

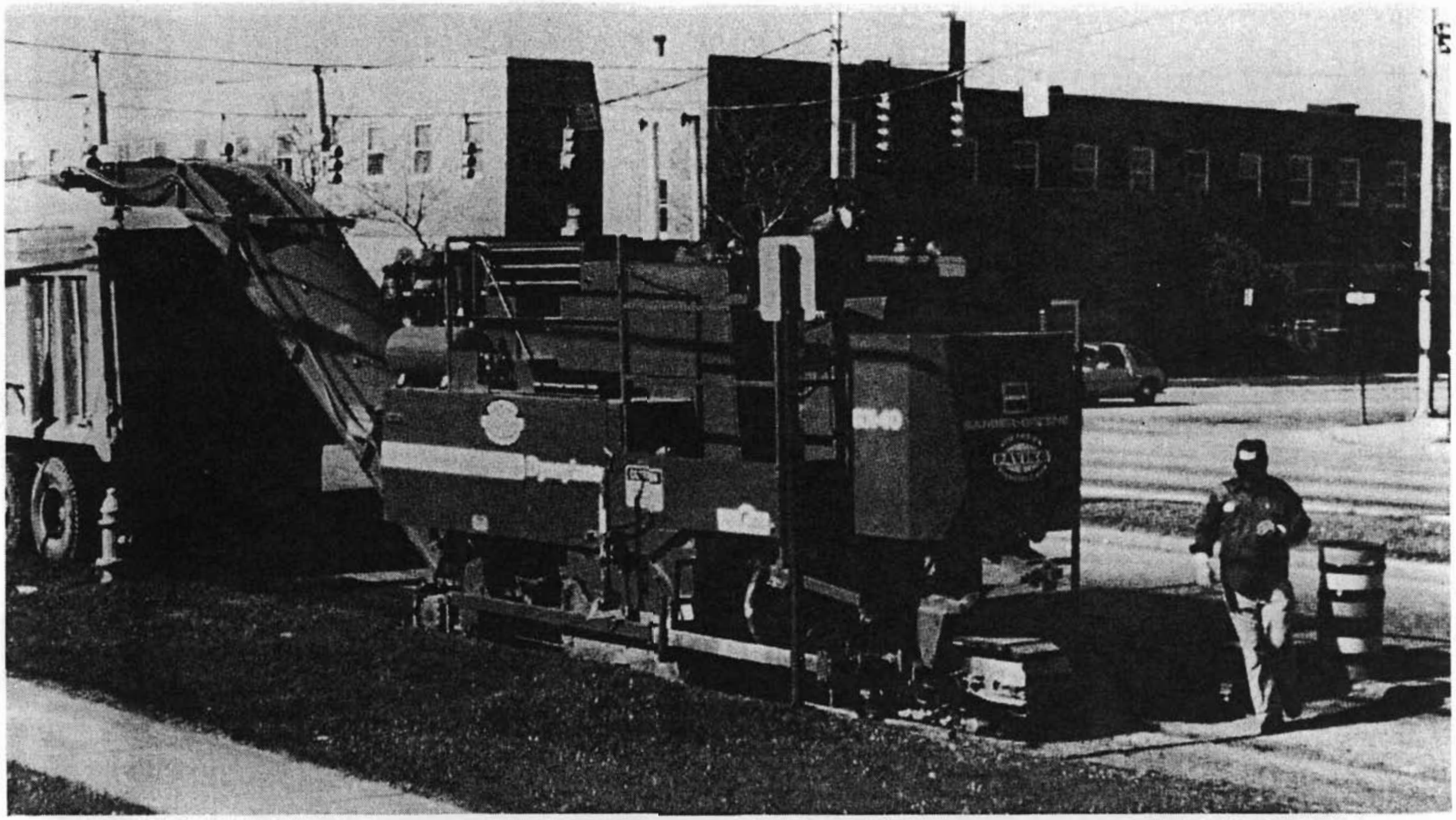

FIGURE 9. Barber-Greene Dynaplane RX-40

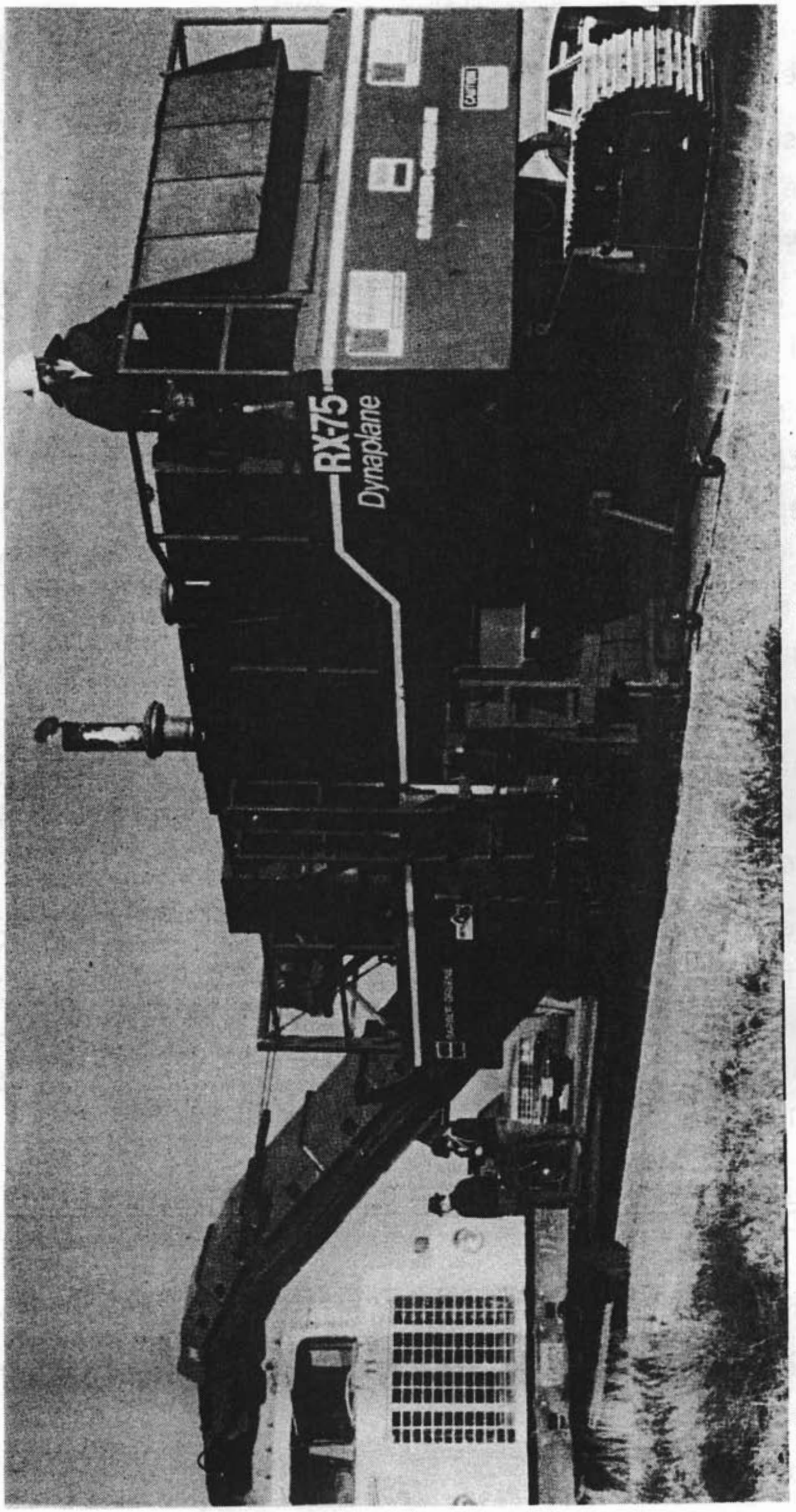

FIGURE 10. Barber-Greene Dynaplane RX-75

Barber-Greene suggested a figure of 0.5-1 ton of cut material per individual bit to be changed.

The cost of one bit is $4. The number of bits per mandrel is given by the manufacturer for each model.

We have used the recommended methods in each case, using 5000 m^2 of cut area per change of bits for the CMI machines and 0.75 ton of cut material for the Barber-Greene machines.

The labor costs are also different--the size of the estimated crew varying as well as the assumed salaries and burden rates.

Table 2 shows the performance and hourly costs of the road planers. The final cost of the cutting operation lies in the range of $0.18 to $0.59/$m^2$ depending on depth of cut and type of machine. The deeper cuts are more expensive than the shallower ones, but not in proportion to their depths because larger machines are used. Usually one gains for a given depth in going to a larger machine. However, only the smaller machines can maneuver around sharp curves and man-holes.

The cost of the cutting operation per square kilometer would therefore lie in the range from $180,000 to $590,000, and per square mile in the range from $500,000 to $1,600,000.

The machines are compared for constant depth in Table 3. Not included are the costs of using trucks to carry away the rubble. The larger CMI and Barber-Greene machines are equipped with conveyors to pick up the rubble and load it into trucks. In the other cases force-feed loaders or vacuum pick-up equipment (for lighter rubble) have to be utilized as well.

MODIFICATION OF MACHINES FOR DECONTAMINATION OPERATION

Equipment for cleaning or removing surfaces will require varying modifications for decontamination operations, depending on the hazard of the material removed.

A system for picking up the removed material will be required in any case. Measures to prevent scattering of the contamination will generally be

TABLE 2. Performance and Cost of Road Cutting Equipment

Manufacturer and Model	Bits	Cutting Width (m)	Cutting Depth (cm)	Cutting Speed (m/h)	Area Per Unit Time (m^2/h)	Crew Size	Purchase Price (k$)	Cost					Cost Per Unit Area ($/$m^2$)
								Ownership ($/h)	Maintenance ($/h)	Bits ($/h)	Labor ($/h)	Total ($/h)	
Dresser Galion Road Planer													
RP 12	39	0.314	0.625	900	283	1	50	15	11	19	18	63	0.22
RP 30/42	128	1.066	1.25	720	768	1	112	36	16	47	18	117	0.15
RP 60	180	1.524	2.5	360	549	1	135	45	18	97	18	178	0.32
CMI Pavement Profiler													
PR-275-RT	136	2.032	0.625	900	1819	2	189	88	29	199	20	336	0.18
PR 525	176	2.642	1.25	720	1902	2	280	99	56	268	20	443	0.23
PR 750	247	3.78	2.5	360	1361	2	348	118	71	270	20	479	0.35
Barber-Greene Dynaplane													
RX-40	117	1.875	0.625	900	1688	4	221	90	90	129	75	397	0.24
RX-75	179	3.15	1.25	720	2268	4	358	146	105	348	75	709	0.31
RX-75	210	3.725	2.5	360	1341	4	363	149	115	452	75	790	0.59

TABLE 3. Comparison of Road Cutting Machines for Equal Cutting Depth (1.25 cm) and Speed (720 m/h)

Manufacturer and Model	Cutting Width (m)	Area Per Unit Time (m^2)	Costs: Ownership ($/h)	Costs: Maintenance ($/h)	Costs: Bits ($/h)	Costs: Labor ($/h)	Costs: Total ($/h)	Cost Per Unit Area ($/m)
Dresser Galion Road Planer								
RP 12	0.314	226	15	11	19	18	63	0.28
RP 30/42	1.066	768	36	16	47	18	117	0.15
RP 60	1.524	1097	45	18	97	18	178	0.16
CMI Pavement Profiler								
PR-275-RT	2.032	1463	88	29	159	20	296	0.20
PR 525	2.642	1902	99	56	268	20	443	0.23
PR 750	3.78	2722	118	71	540	20	749	0.28
Barber-Greene Dynaplane								
RX-40	1.875	1350	90	90	207	75	462	0.34
RX-75	3.15	2268	146	105	348	75	709	0.31
RX-75	3.725	2682	149	115	411	75	750	0.28

necessary. One approach is to enclose the cutting or brushing operation in a hood and connect it to powerful mobile vacuuming equipment. Figures 11, 12 and 13 lightly indicate location of the hood. Where the operation produces heavy cuttings, as in some road planing, the mechanical cutting removal system will have to be enclosed in the vacuum system (Figure 13).

CAB SHIELDING

For most applications, an enclosed cab with a filtered air supply will be required. For intermediate levels of fission product contamination, the cab will require shielding against beta radiation producing the high surface dose. A cab for one operator requires a surface of the order of 10 m^2, a cab for 2 operators, 16 m^2. With 3 g/cm^2 to get rid of the betas, one arrives at a weight of 300 kg. If one adds this to the radiation monitor (700 kg), one arrives at 1000 kg added weight to the vehicles. The street sweepers have a water-carrying capacity of that order that is not needed here. The road planers are heavier machines that can easily accommodate that type of surcharge.

Of major interest is the operator shielding that can be obtained for the weights that can reasonably be added to the machines with minor modifications but without redesign. Street sweepers are quoted as being able to carry 1 additional metric ton; whereas, more is possible with the lighter road planers and certainly 5 tons and more for the heavier models. To attenuate 2 MeV gammas by a factor 10 requires 2.3 attenuation lengths, or 57.6 g/cm^2 (5.1 cm or 2 in. of lead) giving 5.76 metric tons for a 1 man cab of 10 m^2. In fact, it is more like 7.5 metric tons because there is a build-up factor of the order of 2 at that energy in lead for an attenuation of 10. This weight is probably the limit for additional loading on the medium road planers. For reduction factors above 10 for gamma radiation, one will have to resort to remote control of the vehicles.

RADIATION MONITOR

A speculative development would be a collimated radiation monitor to scan the surface being removed for contamination level. It may be possible to provide feedback to the cutter to minimize the amount of material removed.

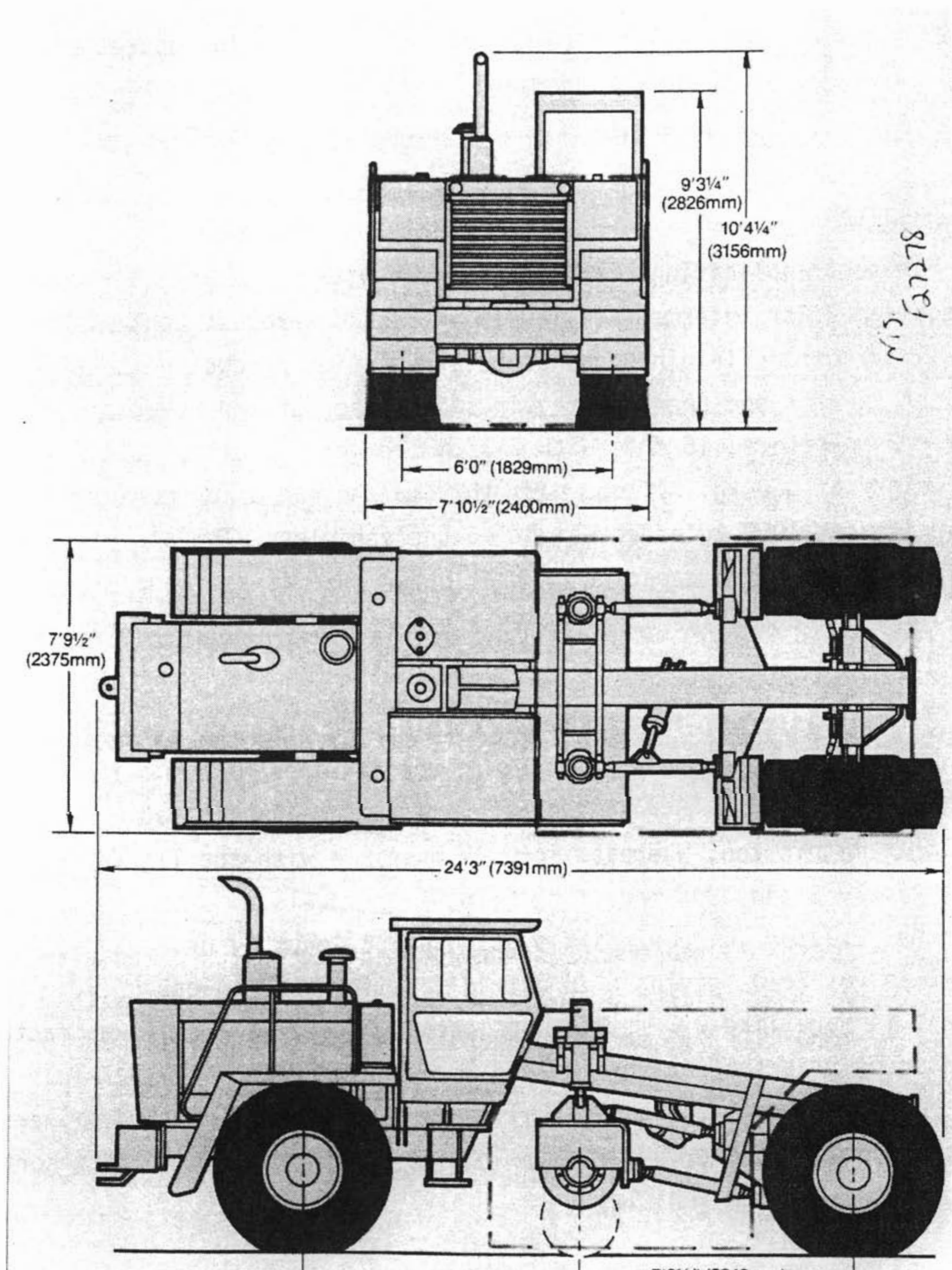

FIGURE 11. Schematic View of Dresser/Galion RP 60 Road Planer

FIGURE 12. Schematic View of Street Sweeper

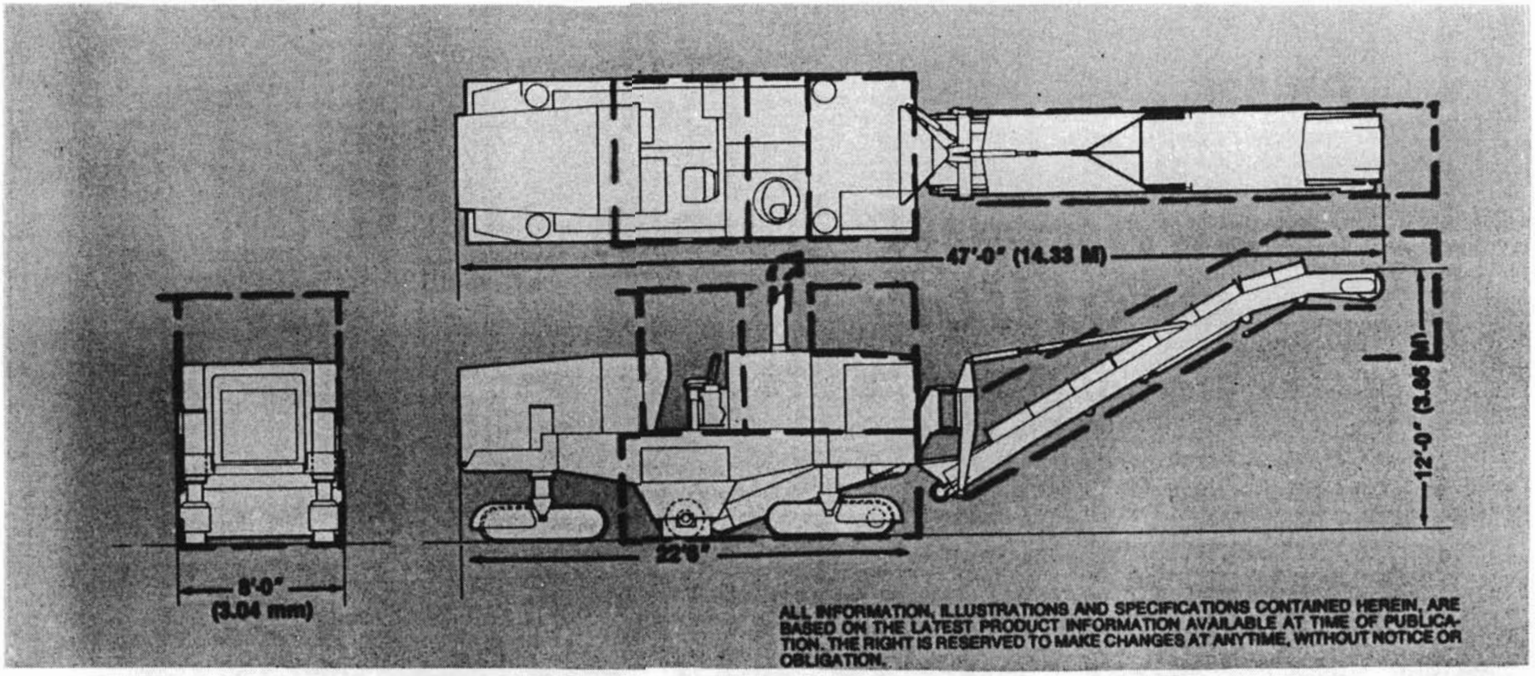

FIGURE 13. Schematic View of CMI PR 525 Pavement Profiler

A typical solid angle for the measurement could be that subtended by a circle of 30 cm radius at a distance of 150 cm. This represents 1/100 of the total spherical solid angle 12.56 steradian. A decontamination factor of 100:1 would be difficult to exceed in one pass. Therefore the counter should in principle be shielded for an attenuation of 10^4.

Radiation from fission products has two major components: betas and gammas, which carry roughly the same amount of energy. Their energy spectrum is also comparable and extends up to several MeV. However, the surface dose in soft tissue deposited by the betas is very much larger than that deposited by the gammas. As an example at 1 MeV energy, it takes 3×10^7 betas per square centimeter to produce 1 rad; whereas, it takes 2×10^9 gammas per square centimeter to do the same, i.e., a ratio of 70:1. The betas are easily stopped. At an energy of 6 MeV, which is about the limit to which the beta spectrum extends, the range of electrons in matter is about 3 g/cm^2, or 0.25 cm of lead. The gamma spectrum is rather constant to about 2 MeV and falls off thereafter.

Given the high energy of the radiation and the high attenuation required from the shield, one has an interest in taking the smallest possible detector to minimize shield size. Recently, cadmium telluride chips have been introduced. These chips have as high a sensitivity as sodium iodide per unit volume and can be made in very small sizes. As a result, one has practically a point-like detector, which is still able to measure accurately radiation levels of the order of 0.1 mrem/hr.

Taking the narrow-beam, mass attenuation coefficient of 0.04 cm^2 g^{-1} for 2 MeV gammas, leading to an attenuation length of 25 g/cm^2, and assuming that the beta/gamma sensitivity ratio of the detector is large enough to compensate for the gamma build-up factor in the shield, one ends up with a weight of 700 kg for the shield, resolved that one will measure the betas. More elaborate calculations will show if it is possible to reduce the shield weight below the figure given above, which is already not negligible for a vehicle.

A sketch of the shield is shown in Figure 14.

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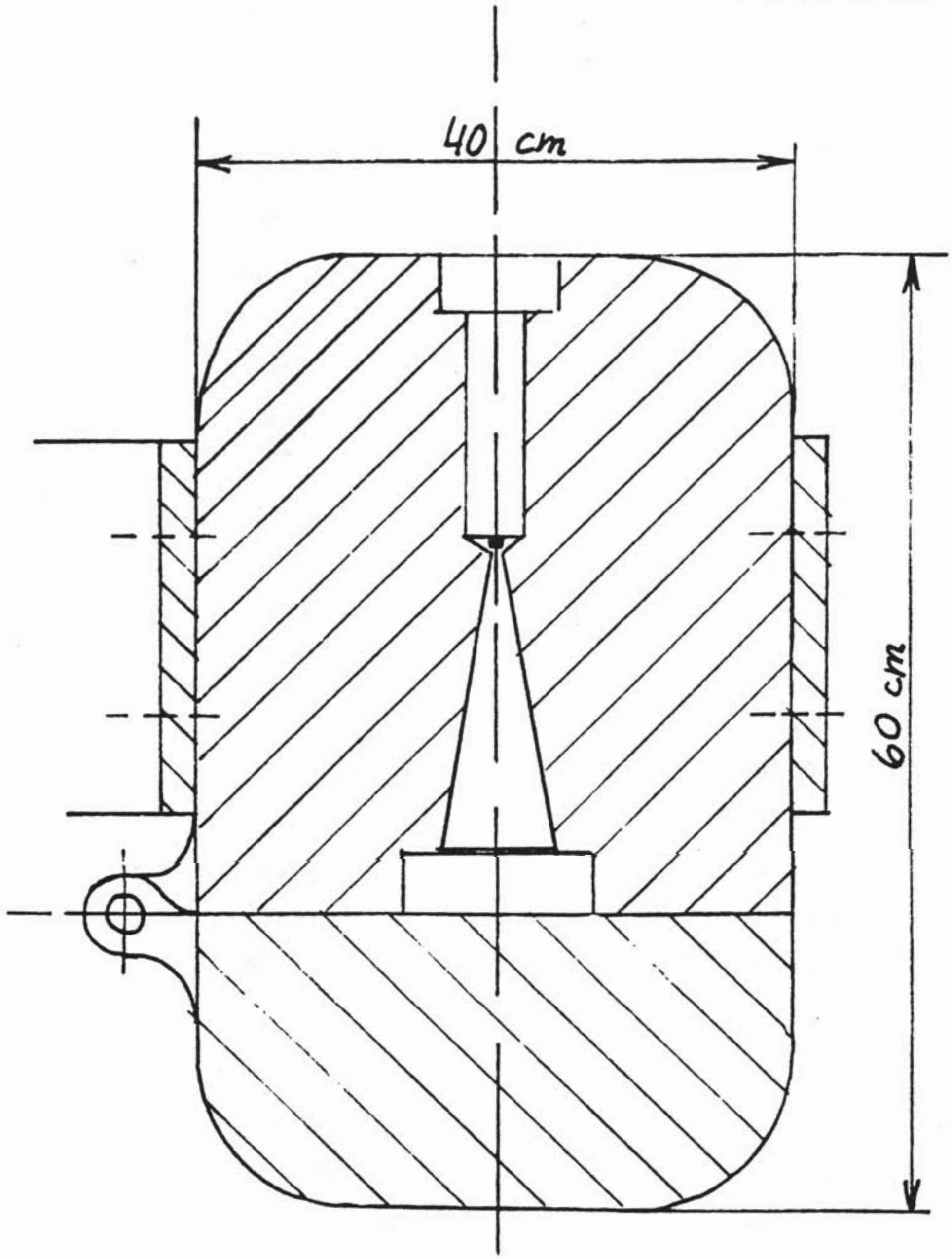

FIGURE 14. Section Through Decontamination Monitor

REMOTE OPERATION

For high-level contamination, remote operation would be considered. The technology is well developed.

Remotely operated vehicles have been designed and tested for road and airborne uses. They are equipped with head-aimed TV systems, video data links, telemetry, command data links, and vehicle control actuators. One industrial source, having developed remotely operated vehicle control, quotes figures of the order of $200,000 for a feasibility study including system assembly and preliminary tests (excluding the vehicle cost). For subsequent systems derived from the above, but procured in quantities of ten or more, adaptable to different types of vehicles, an estimate of $100,000 has been obtained.

MACHINE DECONTAMINATION

Depending on the machine and the intensity and type of contamination being removed, it may be desirable to modify the machine in order to facilitate its decontamination prior to maintenance work. This would, among other things, include covering complex portions and reentrant surfaces with a removable cover or coating. Wheels or tracks may be fitted with disposable covers.

CONCLUSIONS

There are a number of high-production commercial machines which should be adapable to removing tightly adhering contamination from large horizontal surfaces. These include street sweepers with hard wire brushes and road planers. Wire brushing can be accomplished in a non-toxic environment for about $\$0.004/m^2$. A single large machine can cover about 9 km^2 per year. Road planing, grinding off the surface 12 mm, can be carried out in a non-toxic environment for about $\$0.3/m^2$. Large machine productivity is about 1.5 km^2 per year.

These machines would require considerable modification for operation in a radioactive environment, including enclosure of the cutting tool, attachment of mobile vacuum pickup, possibly shielded cab, possibly remote control, and provisions to simplify decontamination of the machine prior to maintenance.

The great difference in cost between brushing and planing suggests that if brushing is at all effective, it should be attempted first. These methods, even with the cost increases from machine modification and contaminated operations, should remove contamination for substantially less cost than manual methods or pavement removal. The volume of contaminated waste should be significantly reduced.

Because the effectiveness of the decontamination operation will depend heavily on the nature of the contamination as well as the concrete surface, it must be verified experimentally for a given set of conditions.

The feasibility of developing high-production, large-area equipment for concrete decontamination using high pressure water jets should be examined.

EXPERIENCES IN REMOVING SURFACES WITH EXPLOSIVES

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The use of explosives in the demolition of radioactive concrete at both the Elk River and Industrial Reactor Laboratories facilities has demonstrated the safe application of this technology.

Some considerations in the use of explosives are blast produced dust, debris, toxic gas, vibration and air overpressures. These adverse blast effects can be minimized and controlled.

Explosives use is the most rapid method of removing large concrete sections. They have a wide range of application, are adaptable for removing irregular surfaces and lend themselves to a remote method of operation.

With careful planning, explosives can be a useful tool in the nuclear decontamination and dismantling process.

The use of explosives to safely remove radioactive and contaminated concrete without damage to the environment is a demonstrated technology.

Elk River, a 58 megawatt boiling water reactor dismantled during June of 1972 to July 1974, was the first use of explosives to demolish radioactive and contaminated concrete. We removed, shipped and buried some 1,550 cubic yards of concrete using 1,200 pounds of explosives. Most of this concrete was in the biological shield and fuel element storage well; however, we also had to remove several inches off the entire reactor building floor. The State of Minnesota required that we remove all "detectable reactor originated radioactivity" from the state.

A test program at ERR indicated that a maximum of 1 1/4 lbs. of explosive per delay period could be used without producing vibrations in excess of those normally seen during startup of the turbine generators in the adjacent U.P.A. power plant, and without damage to the structures. These tests also indicated that blast produced debris and dust could be controlled using blasting mats and a localized fog spray system. The maximum blast fired inside the reactor building was 1 1/4 lbs. per delay with 20 delay periods, or a total of 25 lbs.

All blasts were monitored using accelerometers mounted on the turbine generator pedestals in the power plant and a portable seismograph was used to monitor vibrations at various points around the site.

Removal of the biological shield produced approximately 12 rem of personnel exposure. We had high levels of airborne contamination in the biological shield cavity during the blasting operation. However detailed planning and the use of various types of respiratory protective equipment limited individual exposure to well below established criteria. We used a cover over the biological shield cavity and an air evacuation system with filters to separate it from the building environment.

Under the conditions, a considerable amount of concrete was removed using explosives without damage to the environment or the reactor building and adjacent power generating plant which was in operation during the project.

Of even greater significance, especially from a cost standpoint, was the decontamination and release of the Industrial Reactor Laboratory facility near Princeton, New Jersey.

IRL was a 5 megawatt "pool type" reactor which provided a source on neutrons, gamma rays and radioactive isotopes. The 30 foot deep pool had walls 1 1/2 to 5 feet thick, with six beam tube and other penetrations. The reactor was housed in an 87 foot high aluminum sheathed dome constructed of 12 in thick reinforced concrete. The pool walls in the upper portion were constructed of conventional concrete, while the lower portion contained some 422 yards of magnetite concrete. Adjacent to the reactor building was a 39,000 sq. foot laboratory building constructed with cement block walls. The final license holder was National Lead Co., their project manager for decontamination and release of the facility was Mr. David Leigh. The explosives portion of the project was accomplished during 1976. To date I have not written a paper describing the explosives work there.

On this project we selectively removed the radioactive portions of the pool walls, the beam tube liners, and a portion of the isotope garden with explosives. On the pool walls explosives were used to remove the concrete and reinforcing rods to a depth of 3 to 4 inches from the surfaces surrounding the area of maximum flux. Removal of the stainless steel beam tube liners required cutting them with linear shaped charges.

Blasting mats were used to restrain the blast produced debris and for most blasts a localized fog spray assisted in dust control. In addition, a movable, plastic covered, plywood environmental cover over the pool cavity was used. An air evacuation system with filters, operating through one of the beam tube openings, in conjunction with the cavity cover, effectively isolated the interior of the pool from the reactor building environment during the blasting. During most of the blasting no elevated airborne contamination was found. My blasting logs, which are the only reference I have, indicate the highest level detected was 2.7×10^{-9} microcuries per milliliter of ^{137}Cs and ^{60}Co. This work was accomplished in the sealed reactor building without breaking confinement.

Another project I should briefly mention was the removal of the Overhead Working Reservoir of the Materials Test Reactor at the Idaho National Laboratories in 1975. The reservoir was a water storage tank, 32 feet in diameter, 46 feet tall, supported on four 30 inch diameter legs with an overall height of 193 feet. The tank interior was contaminated with uranium, plutoniom, and miscellaneous fission products. Sources within the tank ranged from 3 R/hr to in excess of 500 R/hr. I used explosives in the form of linear shaped charges to cut off the supporting legs and drop the tank onto a prepared impact bed. In addition to the impact bed, the drop had to be made under some rather precise metero-logical conditions in the event of rupture of the tank. The tank was dropped without significant release of contamination, and at considerable cost savings over other methods of removal.

With regard to removal of radioactive or contaminated concrete explo-sives can offer advantages over other methods. They are faster than mechanical methods and lend themselves to a more remote method of operation, thus reducing the exposure of personnel to radiation. They are adaptable for removing irregular surfaces.

As with any other tool, explosives have their limitations. Drilling and blasting concrete is done regularly by the construction industry. Blasting inside of structures, however is rather highly specialized. The difference you gentlemen are interested in, is that the material is either radioactive or associated with radioactivity. This means greater control must be used over the blasting operation than is usual and state of the art blasting methods must be employed.

When a high explosive detonates, a shock wave is transmitted to the surrounding material. The magnitude and shape of this rapidly moving wave at various points depends on several factors: explosives type, type of material (concrete on our case), explosives column length or configuration, distance from the explosive, relationship of detonation velocity to wave propagation velocity of the material, etc. These waves move out very rapidly, in concrete something in the order of 15,000 feet per second. In most situations the majority of the fracturing produced is radial from the explosives charge and associated with these propagating stress waves. On their way out the stress waves place the material in compression, but when they arrive at a free surface they reflect back and the reflected compression waves become tension waves and produce spalling of the free surface. The radial fractures have been found to travel at velocities up to .4 the velocity of the stress waves. This means the cracks in concrete could be traveling at 6,000 feet per second. The initial fracturing takes place in a few milliseconds or less depending on the burden (distance between the explosives charge and the free face). Under the influence of the pressure of the gases from the explosives, the primary radial cracks expand, and the free surface yields and expland.

The fragmenting process takes place rather quickly compared to the moving out time of the broken material. It moves out about 50 to 100 feet per second, this plays a significant part in delay blasting. This 50 to 100 feet per second may not seem very fast, but a small excess charge in an unrestrained blast could produce considerable throw of the material. Material is ejected from the blast at much greater velocities if the burden on the explosives charges is too small.

The stress waves also produce vibration, or seismic energy. The subject of vibration resulting from a blast is too complex to discuss here in much detail. The damage potential of seismic waves is normally related to the peak particle velocity of the wave. Basically the peak particle velocity is the rate of change in the waves amplitude as a function of time, or in other words, how fast the ground is moving at a given spot. The peak particle velocity resulting from a blast is a function of the charge weight per delay providing the delay interval is 8 milliseconds or more rather than the total charge weight. With some degree of accuracy peak particle velocity can be predicted in advance; or at least a starting charge weight per delay for the circumstances at the site can be selected to avoid damage. The intensity of seismic motion than can be tolerated by various kinds of structures depends on their construction. Unless something is drastically wrong with preblast calculations, the first manifestation of damage would be expansion of existing cracks in the structure or cracking around points of stress such as the corners of door or window openings.

Blast produced vibrations are fairly well understood. However most of the studies conducted on this subject have involved the response of structures to blasts originiating outside of and some distance from the structure. For demolishing radioactive concrete most blasts are fired inside a structure, here you will have to rely on the experience and expertise of your explosives engineer a little more than usual.

Associated with any blast are air overpressures or air blast. Air blast is a compressional wave in air. It is produced either by the direct action of the explosion products from an unconfined explosion on the air, or by the indirect action of a confining material subjected to explosive loading. Noise is the portion of the spectrum of the air blast lying in the audible range from 20 to 20,000 Hz, while concussion is the portion lying below 20 Hz.

Air blast can be damaging. However as a practical matter I have not found it to be a serious problem. The potential is there, and in a sealed reactor building this subject must be considered. Some steps can be taken to control air blast, the most important being limiting the charge weight per delay and providing adequate cover over the charge.

All explosives when detonated produce compressed hot gases, which vary in volume, temperature and duration depending on the explosive. The products of combustion are mainly gases with some solid material. The nontoxic gases that are produced are steam, carbon dioxide and nitrogen. Toxic gases that may be produced are carbon monoxide and oxides of nitrogen. Depending on the reaction of the explosive on the material being blasted, their level may vary or others may be produced. Especially in a closed structure these gases may reach unacceptable concentrations. In the concentrations you will probably find them, they are not immediately life threatening and rather simple tests can be made to determine their presence and concentration. In the past I have found carbon monoxide to be the most copious of the toxic gases with lesser amounts of oxides of nitrogen present after a blast. This is especially true for explosives like PETN and RDX which have a negative oxygen balance so there is insufficient oxygen to prevent the formation of carbon monoxide.

Explosives placement can be external or internal. Obviously concrete can be broken by placing the explosives in direct, intimate external contact with it. However, charges of a magnitude necessary to completely breach concrete of much thickness or remove more than a very small amount of the surface would not be acceptable. An exception to this would be the use of shaped charges, this technology as with general explosives technology is expanding, and shaped charges that would be effective for this kind of work are available. I found however, both at ERR and at IRL that using linear shaped charges or direct application of thin strips of plastic sheet explosives, although effective, if any significant amount of work was to be done, controlling airblast and dust were very difficult.

When placing external explosives charges on radioactive or contaminated materials, an environmental envelope may be necessary over the blast area to prevent the spread of radioactive contamination, but the air blast associated with these charges tends to preclude close confinement and would require a rather substantial well constructed environmental envelope.

I do not mean to imply that an external method of explosives placement should not be considered. In fact this method has application and I can imagine a number of situations where this may be preferred.

For the majority of work, the internal method of placement appears to be the most effective and preferred method. This involves drilling holes in the concrete. Two methods of bottoming the holes in the correct place may be employed: drilling through the radioactive concrete into the "clean" concrete, or drilling through the "clean" concrete to the desired place adjacent to the radioactive concrete. I have employed both of these methods with success, and have found drilling through concrete with low specific activity creates only minor problems.

The drilling equipment I have used is the basic rotary percussion drills, both air trac self propelled and hand held, used by the construction industry. For control of dust these drills can be equipped with water/soap injectors or a deflector in conjunction with a vacumn cleaner can be used to collect the dust and drill cuttings. In some cases a fine water spray directed at the collar of the hole is sufficient to control dust. A sharp drill bit and proper drill pressure will chip better than a dull bit.

Most concrete structures have reinforcing rods in them set very close to the surface, some 4 inches or so. If it is desirable to remove the concrete to this depth, then very light explosives charges placed behind the rods will very effectively push them out and they will displace the concrete. These charges can be placed by drilling into the face of the concrete to a point immediately behind the rods, or a long hole can be drilled parallel and immediately behind them; this long hole can then be lightly loaded. Spacings on the order of 5 to 6 feet can be used for the long holes.

At IRL we were very successful in removing approximately 3 inches from designated sections of the pool walls by drilling 1 1/2 inch diameter holes, 5 inches deep, on 18 to 20 inch centers through the radioactive concrete. These holes were loaded with 1 1/2 ounces of explosives each and initiated with electric blasting caps.

Some general observations I have made in the course of blasting radioactive concrete inside of reactor buildings:

A fog spray directed over the blast zone during and for a few minutes after a blast will help control blast produced dust.

Blasting mats should be used to restrain the broken material. I have even used chains to further restrain the mats as additional insurance that the material will not move out too far. These mats will also reduce air blast and since the material is not free to move about violently less dust will be produced.

A blast in high density concrete does not produce as much dust as one fired in regular concrete.

When blasting inside of a structure that contains radioactive material and contamination, good housekeeping is most important. The debris from each blast should be cleaned up prior to firing the next one.

As a rule the blast zone can be fairly well isolated from the building environment.

In summary: I believe that with careful planning, explosives can be a useful tool in the nuclear decontamination and dismantling process.

DECONTAMINATION OF CONCRETE SURFACES AT THE LOS ALAMOS SCIENTIFIC LABORATORY

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For the past two years the Los Alamos Scientific Laboratory has been engaged in decontaminating its former plutonium facility. The facility was in use for over 30 years for plutonium operations varying from dry metalurgical processes to wet (solution) recovery processes.

To date approximately 3400 square meters of floor surface have been decontaminated to permit re-use for nonplutonium work. Approximately 330 square meters of concrete surfaces required scarifying the contamination after all other attempts such as detergents and acid solutions had proven ineffective.

The uses of hand-held and floor type pneumatic scarifiers are described as well as an inexpensive but effective contamination containment chamber built at Los Alamos for use with the hand-held model.

Contamination control, waste handling, manpower requirements, and cost are documented for the techniques used at LASL.

INTRODUCTION

In early 1978 Los Alamos Scientific Laboratory (LASL) personnel were faced with the problem of decontaminating LASL's former plutonium facility, DP-West, to permit its re-use for nonplutonium work. Although the major early concerns were gloveboxes and process equipment, it was recognized that ultimately 5300 square meters of concrete slab floors would require decontamination.

Until the DP-West project began, concrete decontamination at LASL (beyond detergents and scrubbing machines) had been accomplished by scrubbing with acids, removal of contaminated paint with paint removers, and some limited scarifying with pneumatic chippers. These techniques had sufficed in the past, but DP-West presented larger areas than ever before, and quite possibly higher contamination levels than ever before. LASL decontamination personnel recognized the need for better techniques to prevent the decontamination of floors from becoming a bottleneck in meeting scheduled total building decontamination deadlines.

A review of the state-of-the-art revealed only one technique which might remove the contamination, yet salvage the floor. The technique involved the use of pneumatic scarifying tools known as scabblers, manufactured by McDonald Air Tool Corporation, South Hackensack, New Jersey. Wilbur D. Kittinger of Atomics International, Conoga Park, California, reported success with scabblers. Hand-held and floor type models were purchased, contamination containment auxiliary equipment was constructed, and experimentation began in some isolated areas.

The scabblers were found to be effective for decontaminating concrete that had several coats of paint, with contamination between the coats and sometimes in the concrete itself. Together with the established acid and paint remover operations, they have been used successfully in decontaminating approximately 3400 square meters of contaminated concrete slabs.

CONTAMINATION DETECTION TECHNIQUES

In a facility such as DP-West, with a long history of plutonium operations and known spills and releases of contaminants through the years, it is imperative that contamination both on the surface and under paint be measured.

Surface alpha contamination is measured with portable air proportional counters with a 50 cm^2 probe. The models used have been the Eberline PAC-7 and Ludlum 139, with lower detection limits of approximately 100 d/min/50 cm^2. Large areas are surveyed with wheel mounted instruments using 500 cm^2 probes such as the Eberline Model FM-30, with approximately the same detection limit.

The contamination under painted surfaces is measured by a LASL developed phoswich (phosphor sandwich) detector[1] which consists of a NaI crystal backed by a CsI crystal, and measures plutonium L X-Rays. The detector, electronics, and scaler are housed individually as shown in use in Figure 1. The electronics include an aural popper used when background noise levels permit.

The phoswich is very sensitive to scatter radiation, hence, plutonium process equipment and high contamination levels must be eliminated or reduced prior to its use. However, in the latter stages of a decontamination project, it is extremely useful as an indicator of how much contamination is under paint, in a wall, etc. Although confirmatory data are still being collected it appears that, in the field, the detector is capable of measuring 200 d/m/cm^2 through as many as five coats of paint.

SELECTION OF METHOD

The three basic techniques used at LASL are application of paint remover, acid solutions, and pneumatic scarifying. Each can be the most desirable method in one case, yet be the least desirable in another. The considerations and the pertinent questions involved in the proper selection are the following:

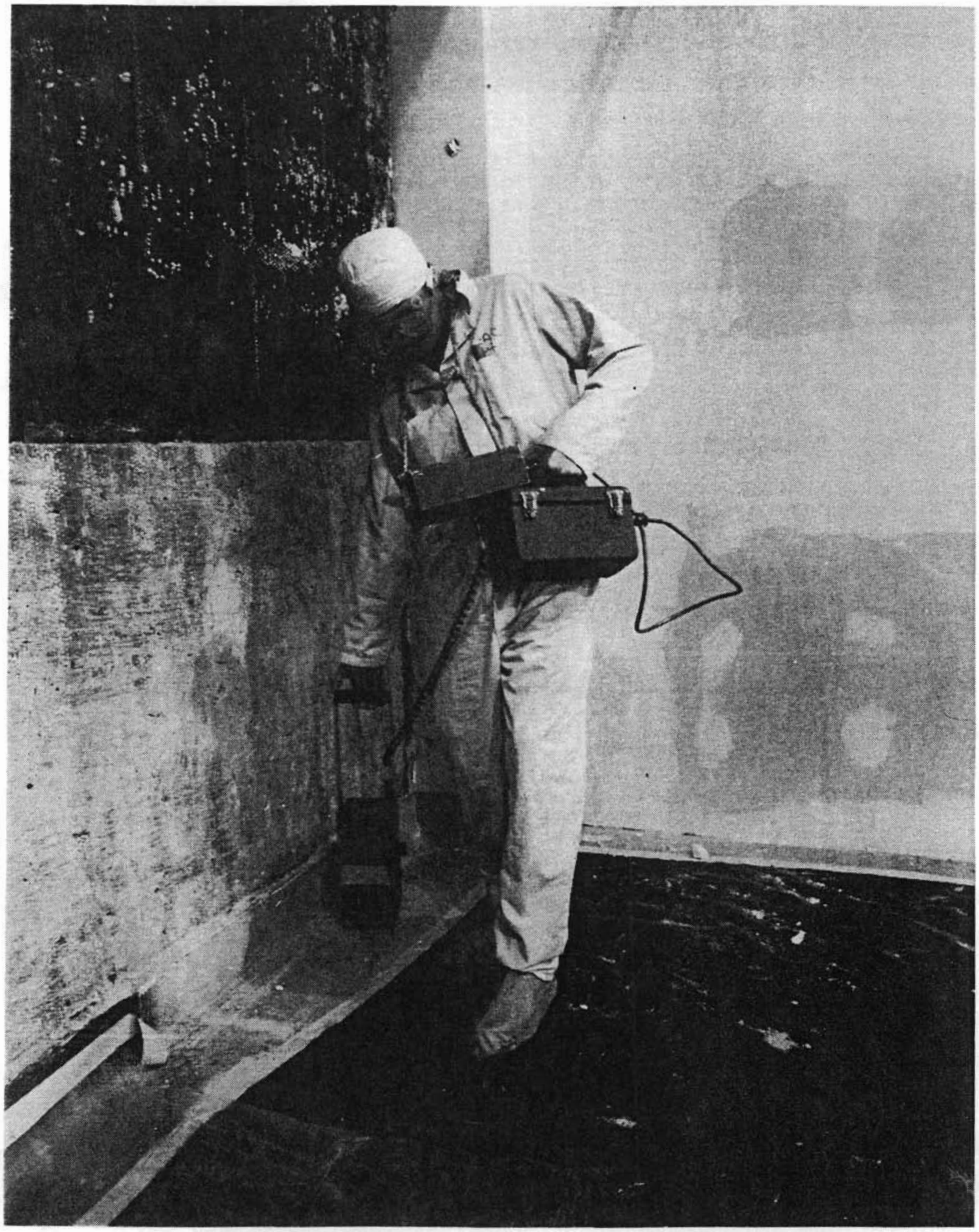

FIGURE 1. Phoswich Detector in Use

o GOALS	Is complete decontamination required, or merely decontamination to a level consistent with the surrounding surfaces? Is it important to minimize damage to the surface, because the surface must be restored?
o CONCRETE FINISH	Is the concrete painted? Was the floor painted prior to its first contamination? In short, will removal of the paint complete the job?
o SIZE OF AREA	Is the area large enough to justify the required preparation time? Can the job be done more quickly and effectively by a normally slower technique requiring less preparation time?
o CONTAMINATION	What are the contaminants? What is the contamination level? Is the contamination on the surface or under layers of paint?
o LOCATION	Is the area to be decontaminated near necessary utilities, i.e., power, water? Is the area congested, precluding the use of large equipment? What is going on in vicinity of operation, i.e., will noise or traffic control be problems?
o WASTES	Is a particular technique going to result in fewer waste handling problems?

The answers to the questions above, and the advantages and disadvantages of the techniques described in Table 1 are used in selecting the technique, or combination of techniques, to be used.

EQUIPMENT AND TECHNIQUES

PAINT REMOVAL

Equipment and Techniques

A commercially available paint remover, Turco Type 5351, is applied with a brush and allowed to set until a visible reaction takes place (about

15-20 minutes). The surface is then scraped with a hand held scraper or steel wool. Sometimes the surface is scratched to permit the remover to seep under paint. Two applications are usually required due to the roughness and porosity of the concrete surface. The applications are followed by a water and detergent scrubbing to remove the paint remover.

TABLE 1. Comparison of LASL's Concrete Decontamination Techniques

Technique	Advantages	Disadvantages
PAINT REMOVER:	Requires less equipment and people.	Slowest of the methods.
	Requires less preparation time.	If contamination is in concrete, other techniques are required.
	Does the least damage to floor surfaces; generates the least waste.	
ACIDS:	Improve detergent action when used with mechanical scrubbers.	Can carry contamination deeper into concrete.
	Very effective with loosely bound surface contamination.	Slow; may require several attempts.
	Cleans embedded metal items also.	Generates liquid wastes from rinsing operations.
		May require specialized ventilation systems.
SCARIFYING:	Fastest method for removing deeply embedded contamination.	Requires the most people, equipment, and utilities.
		Noisy and tiresome.
		Damages surfaces.
		Creates large volumes of water.

This method is useful for small areas (< 1 m^2) when the contamination is on the surface or between layers of paint but not in the concrete itself. Normal room ventilation is usually adequate; no special respirator equipment is required to handle the paint remover.

Preventing Spread of Contamination

The immediate surrounding area is covered with plastic to prevent spreading the contamination. Scrapings are damp and sticky, so airborne contamination is not a problem. The contaminants are controlled by packaging wastes and changing the brushes and scrapers frequently.

Waste Handling Methods

The volume of waste generated by paint removal operations (including contaminated applicators, scrapers, etc.), is less than .05 m^3 of waste per m^2 of surface. The wastes are placed in double plastic bags, sealed in cardboard boxes, and the plutonium content is measured to determine if the waste package is retrievable (> 10 nCi ^{239}Pu or 100 nCi ^{238}Pu per gram of waste). The measurement is obtained by a Multiple Energy Gamma Assay System (MEGAS)[2] that automatically measures the plutonium (transuranics) content, weighs the waste package, and computes transuranics concentration in nCi/g. Nonretrievable wastes are buried in shallow (≈ 10 m) trenches at the LASL Solid Waste Disposal/Storage Site. Retrievable wastes are stored in 20-year storage containers at the same site.[3]

Rate of Performance

Typically a small (< 1 m^2) contaminated area where two coats of paint must be removed can be decontaminated at a rate of 0.3 m^2/hour by two people. This includes changing clothes preparing the area, applying the paint remover, removing the paint remover, washing the area, and packaging the waste; but does not include time for transportation. Transportation time varies greatly at LASL because of the large geographical distances between facilities.

ACIDS

Acid solutions are used to remove contamination embedded near the surface of the paint or in concrete. Contaminated concrete is usually found in facilities where the concrete floor was not painted prior to using the facility.

Equipment and Techniques

The acids generally used are HNO_3 and HCℓ, in concentrations ranging from a 10-20% by volume used in scrubbing machines, to concentrated acids used to decontaminate small areas ($< 0.1\ m^2$).

The acid solutions are poured or sprayed on the contaminated area, allowed to set for a few minutes then wiped up with rags. The area is rinsed with water; the steps are repeated if necessary. A vacuum cleaner is used to collect the dilute solutions from the scrubbing machine and rinsing operations.

Preventing Spread of Contamination

The spread of contamination is prevented by isolating the area, packaging the waste frequently, and keeping the equipment as free of contamination as possible.

Waste Handling Methods

The use of acid solutions generates both liquid and solid wastes. Water is used in diluting the acids, washing the area and rinsing the rags. Liquid wastes are treated as part of the large volumes of low-level wastes handled at LASL's two liquid waste treatment facilities.[4] The wastes are transported to the treatment facilities by pipe line or by tank trailer. Solid wastes are disposed of at the on-site LASL solid Radioactive Waste Disposal/Storage Site.

Rate of Performance

The use of dilute acids in scrubbing operations increases the decontamination time required because of acid handling problems, the manual spreading of powdered detergents on the floor, and the additional rinse water required for the floor and the scrubbing machines.

A painted floor area that is relatively free of obstructions can be scrubbed at a rate of approximately 25 m^2/hr by two people. Unpainted surfaces may require two rinses when the concrete surface is rough.

The limited use of concentrated acids at LASL precludes good rate-of performance data. Two people are required for safety; the area may be nothing more than a few square centimeters, and it may be several miles from the technicians' work site. In general, the requirements for handling the wastes and the time required result in using this technique when there is no other option.

SCARIFYING

Equipment and Techniques

Pneumatic scarifying is used at LASL when the contamination is in the concrete. As mentioned in the introduction, most of the scarifying is done by a hand held or floor model scabbler shown in Figures 2 and 3. There are a few instances however, when different pneumatic chisels, hammers, or needle guns need to be used for a hard-to-reach spot.

The hand held model used at LASL is a McDonald Model HS single head unit. When it was first purchased and little was known about its operation, airborne contamination was a prime concern. Therefore, a confinement chamber was constructed from an old glovebox. The chamber, with its air and vacuum supply lines is shown in Figure 2. The scabbler is operated at 20 cfm of air at 80 psi pressure. It has been used to remove contamination at levels up to 2×10^8 d/min/50 cm^2. The chamber allows for interchanging to the less frequently used chippers, needle guns, etc.

The floor model used at LASL is the McDonald Model L-7. It utilizes seven heads similar to the one on the hand held unit and requires 100 cfm of air at a pressure of 100 psi. Its limitation is that it can only be used on very wet floors. Both units use replaceable tungsten carbide bits which have a working life of approximately 80 hours.

The use of the hand held scabbler requires two people, one doing the scabbling and one in a supporting role, i.e., surveying, monitoring the

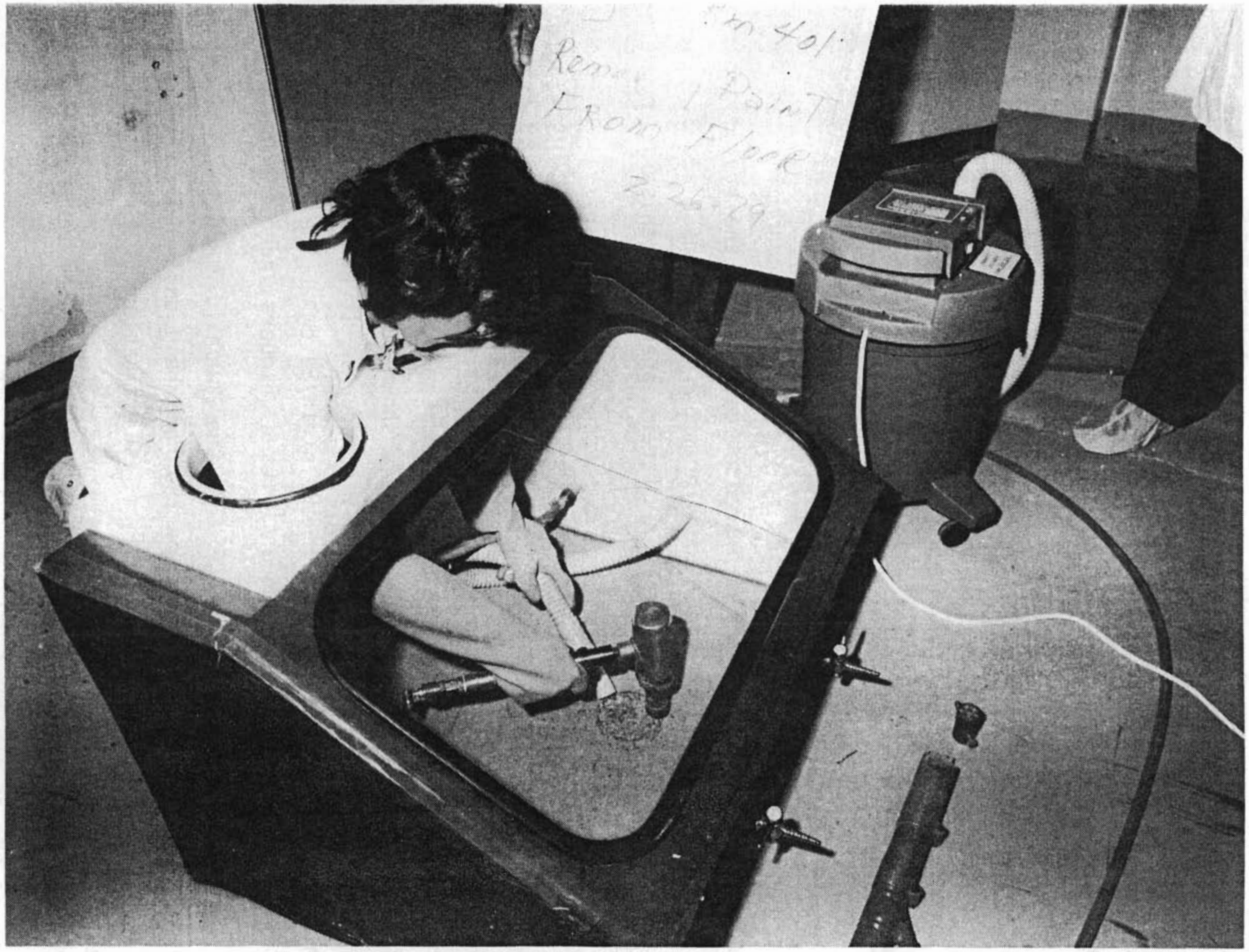

FIGURE 2. Use of Hand-Held Scabbler in a Confinement Chamber

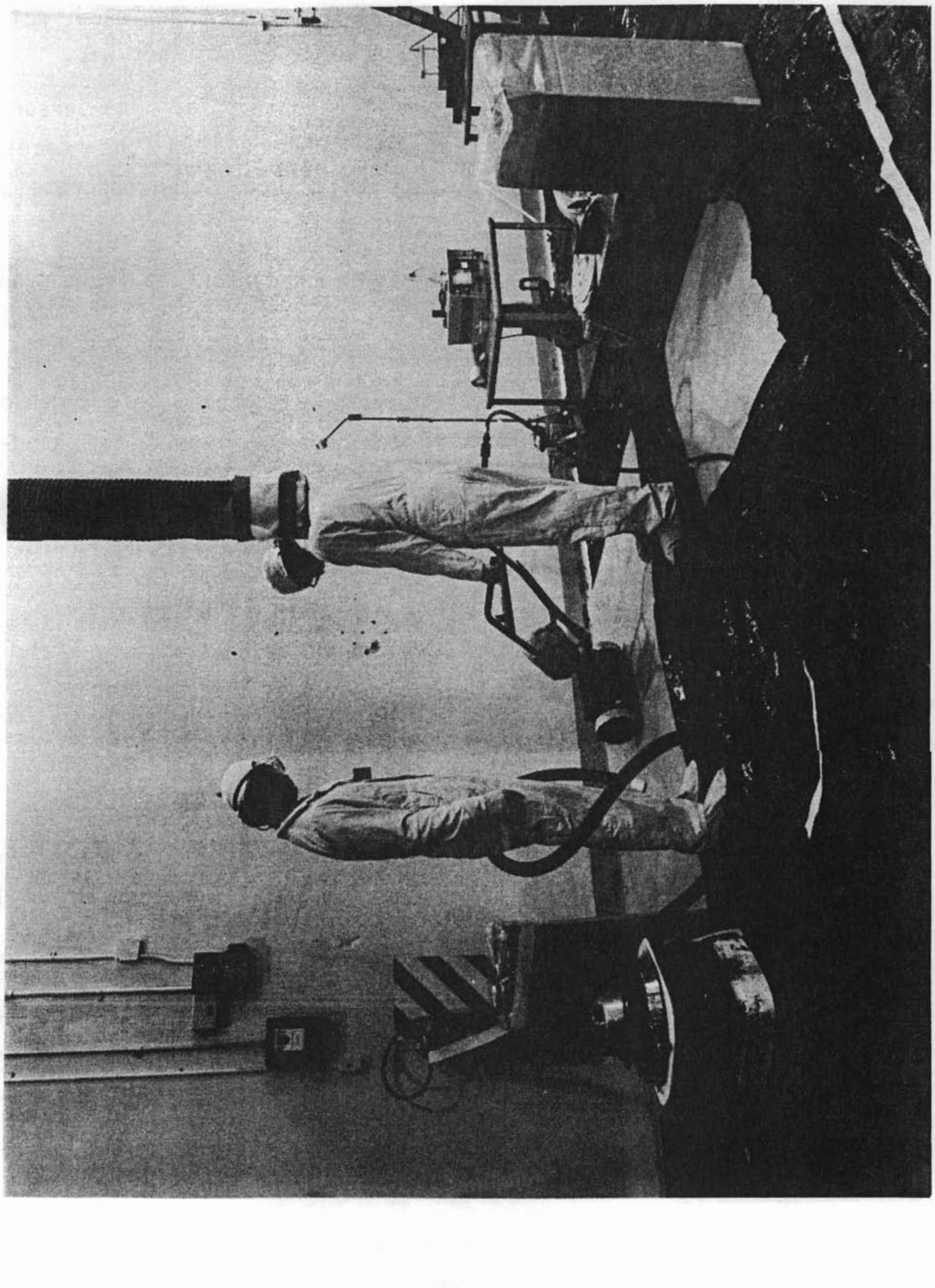

FIGURE 3. A Seven-Head Floor Scabbler, in Area Prepared for Decontamination

room air, assisting with the waste handling, etc. The two people need to alternate operating the scabbler to minimize fatigue. Experience indicates the confinement chamber is not necessary if surfaces are kept wet.

The floor model is used with a team of three people. One person runs the scabbler, one keeps the area wet and provides the necessary miscellaneous support, and one vacuums up the contaminated concrete as it is loosened.

With either scabbler, approximately 1/8 inch of surface is removed per pass. In general, unless contamination was embedded deeply as a result of a crack or opening in the concrete two or three passes complete the job. There are, however, cases where concrete must be scabbled to a depth of an inch or so. These cases have usually required the use of the hand-held model because the surface areas have been small.

Preventing Spread of Contamination

The spread of contamination is prevented by operating the scabbler under wet conditions, and by immediately vacuuming up water and concrete. Paint is sometimes employed prior to the operation to indicate where the scarifying needs to be done. The paint also assists in containing the contamination.

Waste Handling Methods

Of the three general techiques employed at LASL, the use of the scabbler produces the largest volume of waste. Experience at DP-West indicates wastes are generated at rates of 4 gallons of water and .04 pounds of cement/paint sludge per m^2 of concrete floor. Since the DP waste decontamination operation is only a few hundred meters from a waste treatment facility, waste handling has not been a problem. The liquid waste is transported in a tank-trailer; the cement sludge is transported in 200-liter drums.

Rate of Performance

The scabbling operations range in speed from 0.1 m^2/hr with the hand-held unit and a crew of two people, to 1 m^2/hr with the floor model scabbler and three people. Preparation takes longer compared to other methods because of equipment requirements.

PERSONNEL TRAINING

All three methods in use at LASL are performed by technicians versed in decontamination operations of all types. They are trained in the use of chemicals such as acids, bases, and solvents. They are knowledgeable in the use of the radiation monitoring instruments necessary to perform their jobs, and trained in the use of protective clothing and respiratory protection equipment. The step-by-step training is acquired through following established Standard Operating Procedures and by assisting experienced personnel. For safety reasons, no technician is allowed to work alone.

COSTS

In order to summarize LASL's experiences in the economics of decontaminating concrete surfaces, three hypothetical decontamination requirements are postulated. Areas of 1 m^2, 10 m^2, and 100 m^2 with different conditions and requirements are addressed in Table 2. The table shows the process selection considerations and LASL costs in time and dollars. The transportation time is omitted since LASL work areas are so widely dispersed. Including transportation time and costs would make cost comparisons with non-LASL operations very difficult. For a small job at LASL, the transportation costs may be as high as the cost of performing the decontamination. Table 3 lists equipment and services considered in the sample tasks. A rate of $22/hr, including overhead, is used to estimate project costs.

SUMMARY

The three simple decontamination techniques have been adequate for the DP-West project. The reasons have been:

- o the decontamination rate has been adequate to fit into the overall building decontamination schedule;
- o the spreading of contamination has been prevented;
- o with few exceptions, all contaminated concrete surfaces encountered have been floors;
- o the techniques have been effective, no contamination has been detected during refurbishing operations in decontaminated areas;
- o the wastes created are compatible to and easily managed by existing LASL waste treatment capabilities.

Although LASL's experiences are primarily with alpha contamination, the techniques can be expected to work with other contaminants as well.

TABLE 2. Decontamination cost comparisons for three different size areas under various conditions.

Contamination[a] Levels	Surface Condition	Method	Decon Man-Hours Area in m²			Total Man-Hours Area in m²			Total Cost $[b] Area in m²			Average Cost $/m² Area in m²		
			1	10	100	1	10	100	1	10	100	1	10	100
Low α; Low L X-Rays	Painted	Acid Scrubbing	1	2	8	4	6	15	90	135	330	90	13	3
	Unpainted	Acid Scrubbing	2	3	10	5	7	17	110	155	375	110	16	4
High L X-Rays; Low or High α	Painted	Paint Removal	4	16	160	7	24	176	150	530	3900	150	53	39
		Scabbling	10	30	300	16	54	336	350	1200	7400	350	120	74
	Unpainted	Scabbling	10	30	300	16	54	336	350	1200	7400	350	120	74
High α; Low L X-Rays	Painted	Paint Removal	4	16	160	7	24	176	150	530	3900	150	53	39
		Acid Scrubbing	2	3	8	6	8	17	130	175	375	130	18	4
	Unpainted	Acid Scrubbing	2	4	10	6	9	19	130	200	420	130	20	4

(a) α measurement used to measure surface contamination, L X-ray measurements used to measure contamination covered with paint (see text for instrumentation) levels, costs, etc.

(b) Costs are based on a $22/hr personnel cost which includes overhead.

TABLE 3. Equipment and Services Required for Decontamination of Concrete Surfaces.

EQUIPMENT:

McDonald scabblers, wall and floor models
Compressor, air line hoses and connectors
Vacuum cleaners, dry (filtered) and wet
Assorted vacuum hoses and attachments
Scrubbing machines, brushes
Tank trailer, pump and liquid hoses for waste disposal
Waste containers
Waste transport vehicle
Acids, paint remover, detergents, and paint
Cardboard boxes, plastic bags, plastic sheeting, scrapers
Rags, brushes pails, tape, and miscellaneous hand tools
Assortment of pneumatic hand tools
Protective clothing, respiratory, and ear protection equipment
Portable radiation detection instruments
Eyewash equipment

SERVICES:

Electrical power
Water
A crew of trained radiation workers

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RESTORATION OF AN IRRADIATED FUEL STORAGE FACILITY

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The irradiated fuel storage basin in the KW nuclear production reactor at the Hanford Site in Richland, Washington, was decontaminated and painted in preparation for converting the facility to storage of irradiated fuel from N Reactor. The storage basin is a concrete structure constructed with the top of the basin at ground level and extending 25 feet below ground level. The basin measures 84-feet wide and 126-feet long. When full of water, it holds 1.2 million gallons. During the 15 years that KW Reactor operated, the irradiated fuel was packaged and held in temporary storage pending shipment of the fuel for plutonium separation. The basin was also used to package other solid waste from the reactor. Corrosion product, activation product, and some fission product built up in the basin over the years and was present in a layer of sludge about 3-inches deep on the basin floor.

The solid waste was packaged in approved containers and buried in the 200 Area burial site on the Hanford Project. The concrete walls and pillars in the basin were decontaminated with a high-pressure aqua-blaster so there was no smearable contamination on the surfaces. Using a water jet, the sludge was flushed to a sump where it was picked up with a sludge pump and deposited in a crib which was formed in the basin area using a bulkhead to isolate the crib from the basin. After decanting the excess water from the sludge, it was pumped to a large tank designed to meet the burial and transport regulations. The tank containing the sludge was then transferred to the 200 Area burial site and placed in the burial trench.

The cement walls, floor, and columns were painted with an epoxy paint and released for conversion to storage of irradiated fuel from N Reactor.

This paper reviews the procedures and techniques used in cleaning the storage basin.

INTRODUCTION

The spent fuel storage facility in the 105-KW production reactor facility at Hanford was decontaminated and modified to provide interim storage for spent fuel from 100-N Reactor. Preparations for the conversion of the facility required that all contaminated water, storage containers and activation products be removed from the storage basin. Also, the storage basin walls and floor were decontaminated and a coating of Con/Chem - Fibercrete with appropriate primer were applied to retard deterioration in the concrete walls and to fix any contamination that may be lodged in deep pores or surface cracks in the concrete. Figure 1 shows the General inside area of the storage facility.

The work was completed with an average crew size of five people in seven months and at a cost of $115,000. There were no injuries to personnel, and there were no radiation incidents or spread of contamination.

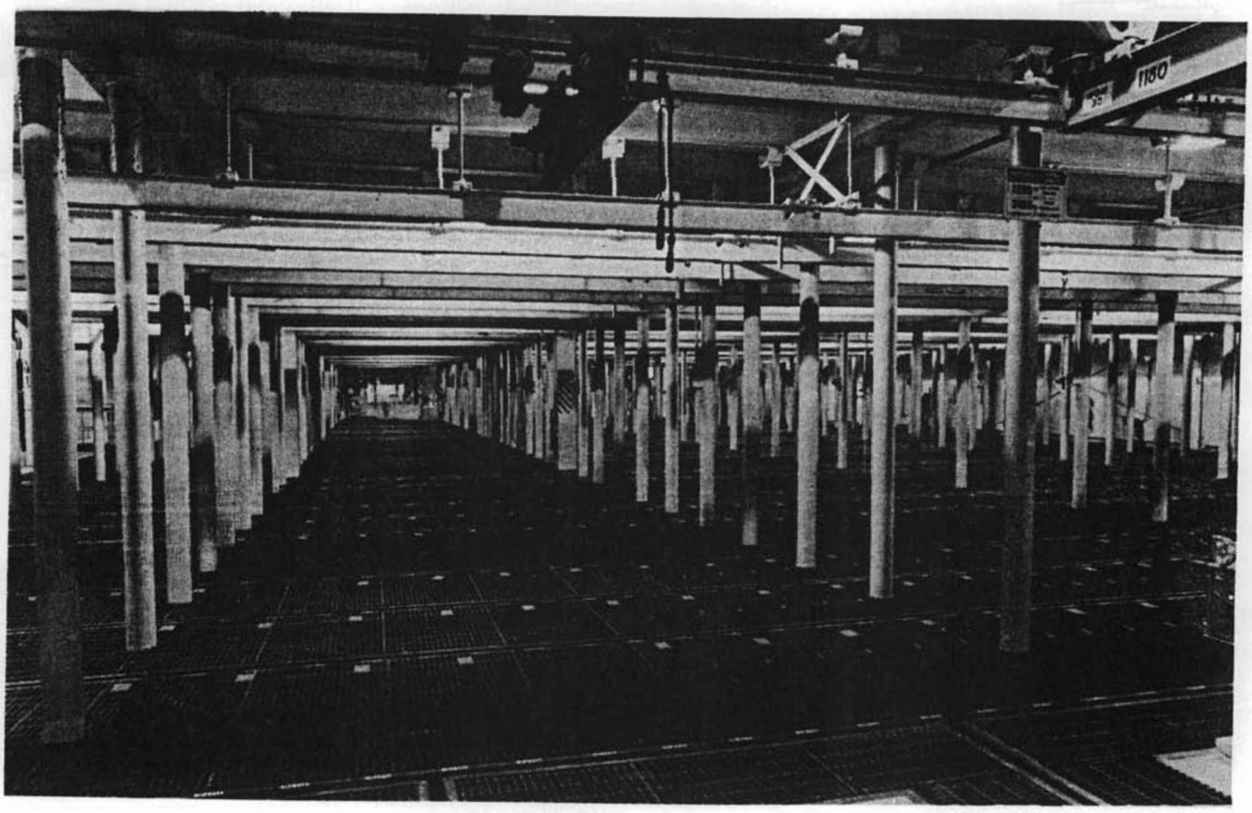

FIGURE 1. General Inside Area of Storage Facility.

SYSTEM DESCRIPTION

The fuel storage basin is 126-feet long, 84-feet wide, and 19.5 feet deep. (See Figures 2 and #). The basin can be isolated in three different sections by closing bulkhead gates at the ends of each division. This design facilitates repairs to the basin. The walls and floor of the basin are concrete. Under the floor of the basin is an asphalt membrane constructed in such a manner that leaks through the basin floor or wall will be directed to a collection header and then to an underground silo. The silo is equipped with a sump pump that returns the water to the basin through a filter. The storage basin was operated with 19 feet of water in the basin. The fuel stored in the basin was cooled by once-through cooling and the level was maintained by adjusting an overflow flume in the basin.

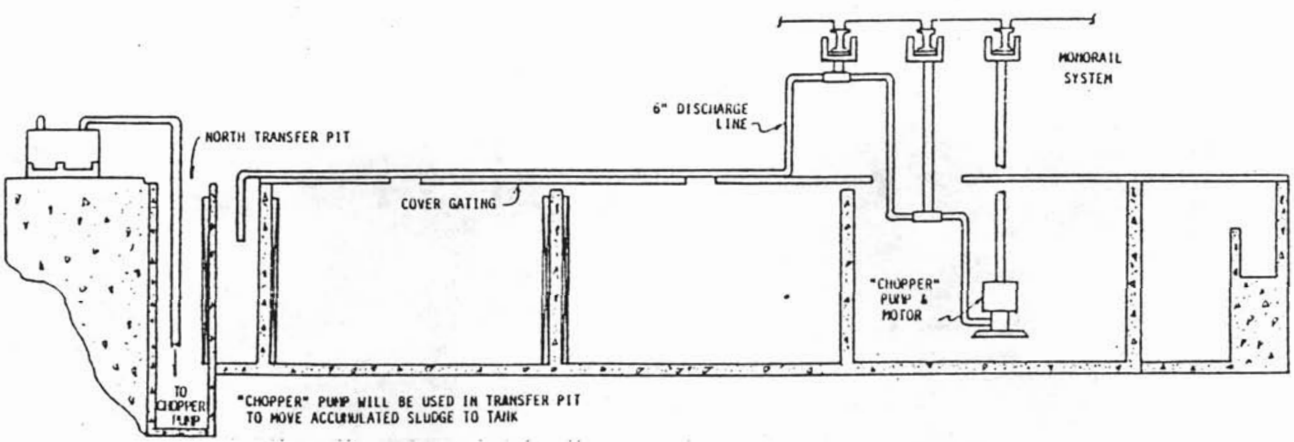

FIGURE 2. Elevation View K-West Fuel Storage Basin.

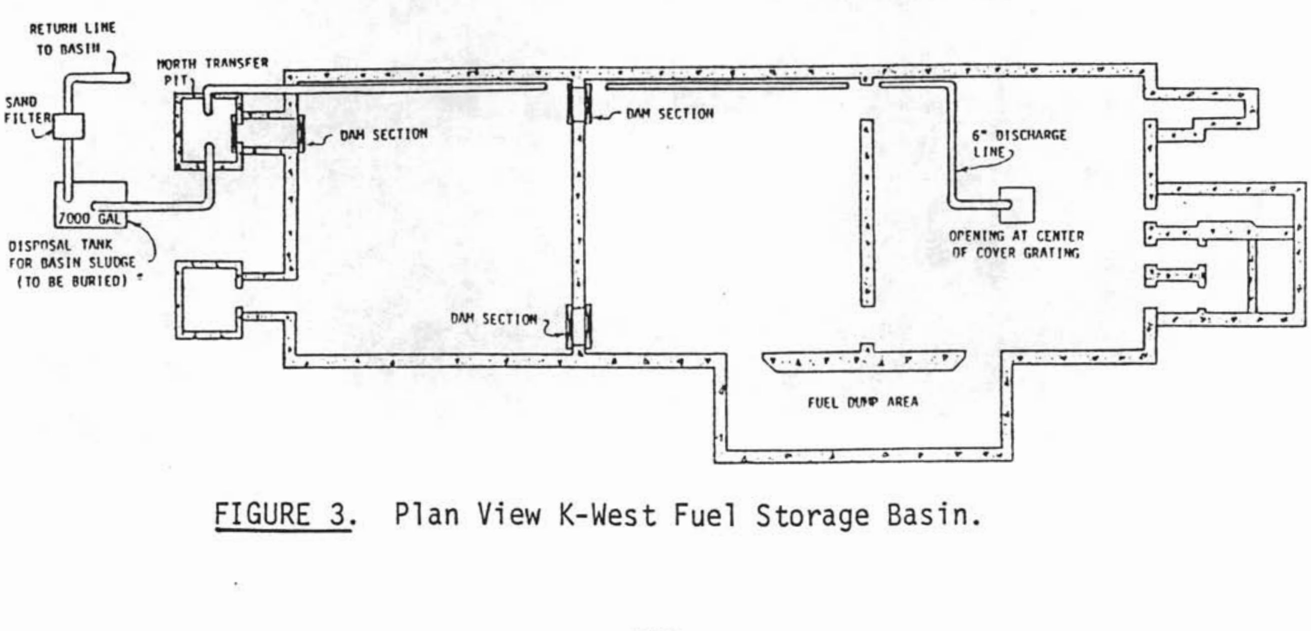

FIGURE 3. Plan View K-West Fuel Storage Basin.

DECONTAMINATION

Following the shutdown of the KW Reactor and the final discharge of irradiated fuel, the basin was emptied of all fuel by shipping the fuel in a special cask loaded in special railroad cars to the fuel separation operation in the 200 Area on the Hanford Site.

The fuel and spacers which centered the fuel in the reactor process tubes were stored in the basin in stainless steel and galvanized containers that were 18-inches long, 18-inches deep, and 18-inches wide. Several hundred empty storage containers were removed and decontaminated to controlled releasable limits using a mild solution of turco and clean water. The buckets were then placed in controlled storage. The spacers were packed in plastic bags and placed inside cardboard cartons and transported to the burial grounds in the 200 Areas.

During the 15 years of operation, there was an accumulation of corrosion product from the reactor piping and other components that built up in the form of sludge. Mixed in the sludge were fragments of Chromel-Alumel thermocouple wire which was used to measure the moderator temperature during operation. The thermocouple wire and other activation products in the sludge made it necessary to perform the sludge removal operation remotely.

The basin water was lowered to about three feet using a Flyte submersible pump with an inline sand filter to clean the particulates out of the water. The water was pumped from the basin to an earth crib used for disposal of low-level liquid waste during the operating period of the reactor.

Dams were then installed to sectionalize the basin in two sections. A transfer pit was isolated from the basin for the accumulation of the sludge. (See Figure 3.)

The sludge was analyzed to establish that the burden of transuranics in the sludge would be below a level of concern. It was found to contain <10 nanocuries per gram with a specific activity of 1.25E + 6 pCi/gm.

A sludge pump (Figure 4) was then installed in a sump in the west section of the basin. A Flyte submersible pump was installed in the east basin and was connected to a flexible flushing hose with an inline sand filter. The water from the east section was used to flush sludge from the floor to the sump pump where it was picked up by the sludge pump and pumped to the sludge accumulation pit. When the pit filled with water, the operation was shut down until the sludge settle in the pit. The water was then pumped from the pit to the east section of the basin for reused in flushing the sludge to the sludge pump. This cycle was repeated until all the sludge was moved from the basin floor to the accumulation pit.

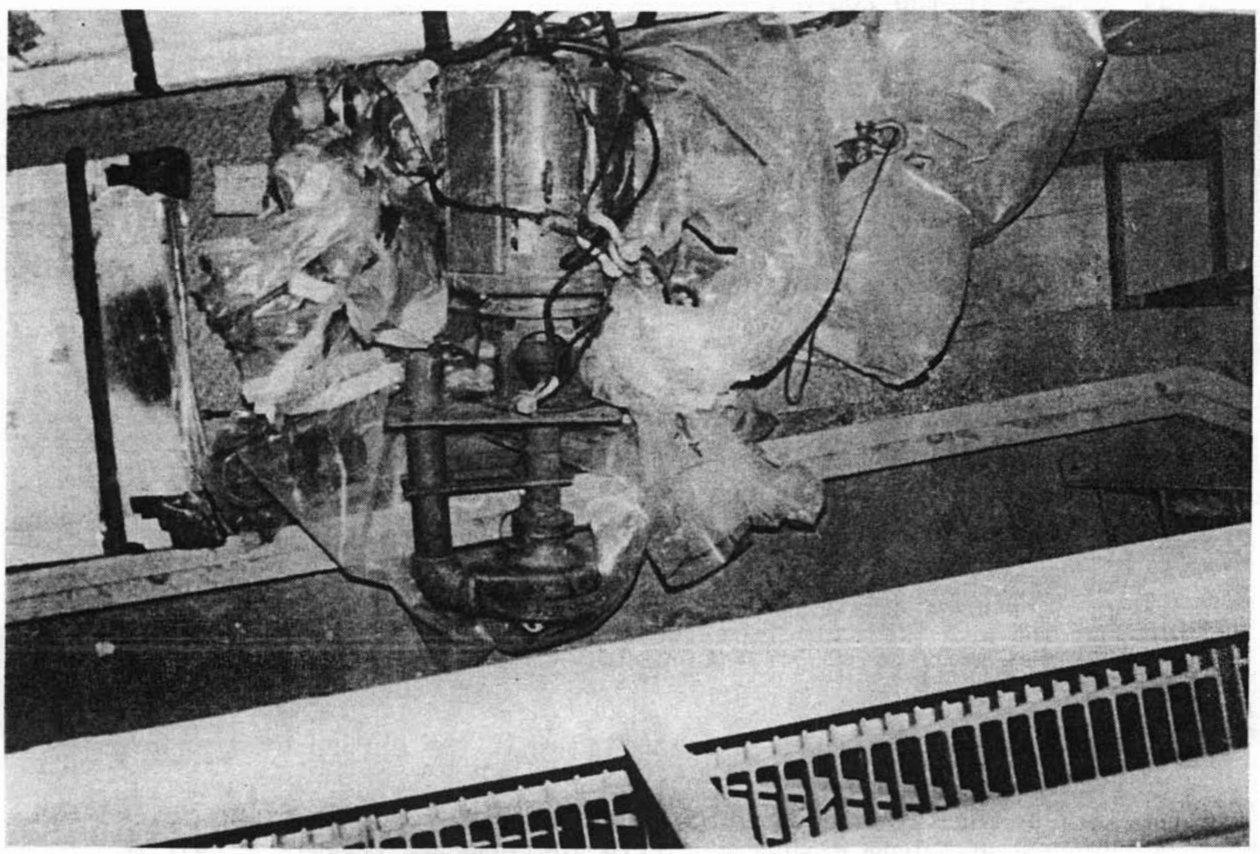

FIGURE 4. Sludge Pump

Following the transfer of the sludge to the accumulation pit, all the water was then pumped to one section of the basin. A portable ParTek Liqui-Blaster cleaner (Figure 5) was used to decontaminate the concrete walls and floor of the empty basin. After the basin was decontaminated with the Liquid-Blaster, the floor and walls were painted with Con/Chem - Fibercrete coating.

The sludge was pumped from the accumulation pit using the Vaughn sludge pump, to a 10,000 gallon reinforced steel tank (Figure 6). Several days were used to transfer the sludge. At the start of each day, the cap of water on top of the sludge in the tank was canted off and returned to the storage basin through a sand filter. The tank contained approximately 7,000 gallons of sludge when the pit was empty. The tank was filled with No. 4 industrial grade Vermiculite and transported to the burial grounds on a semi-trailer truck.

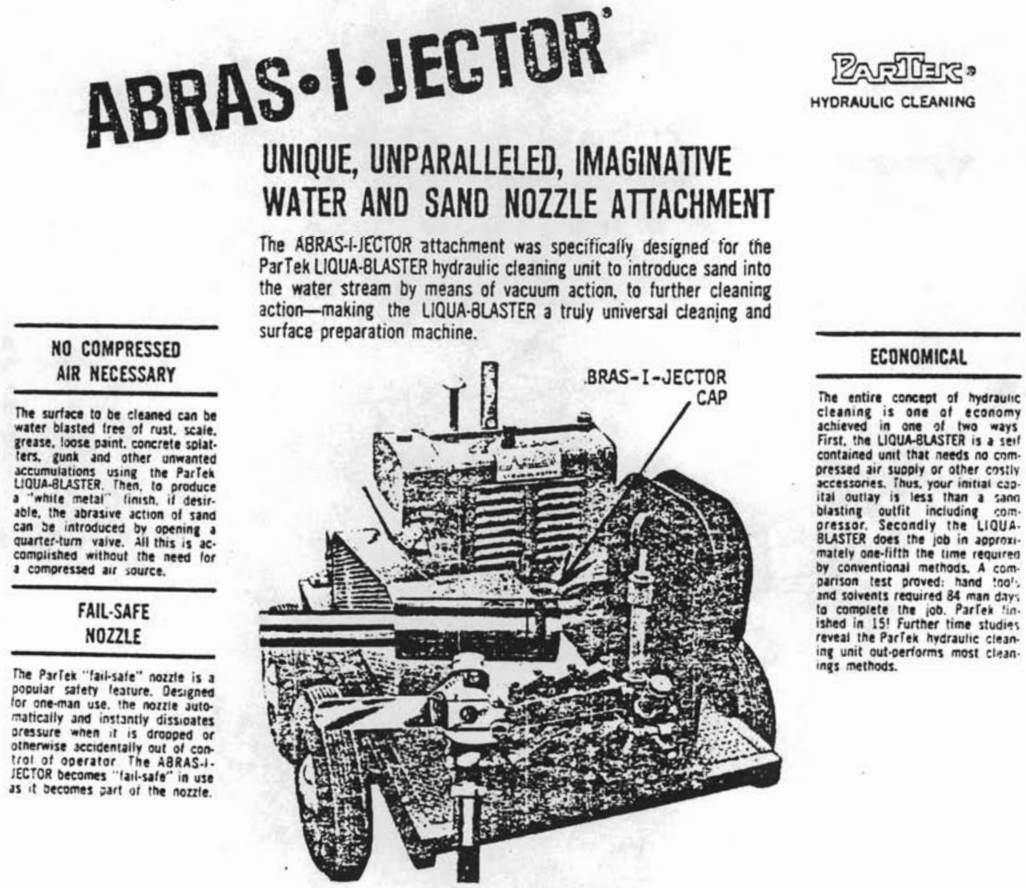

FIGURE 5. ParTek Liqua-Blaster

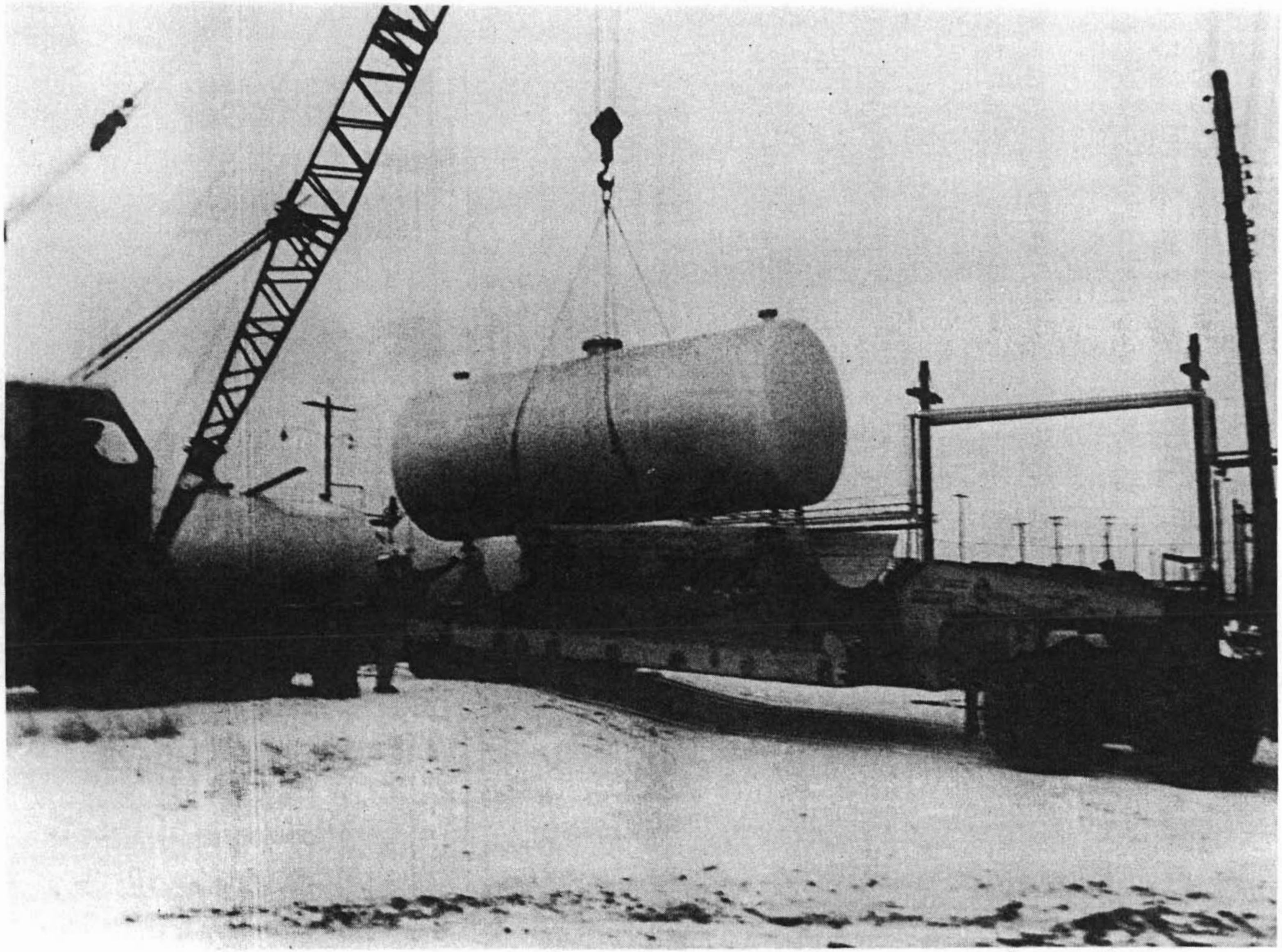

FIGURE 6. Steel Tank Used for Disposal of Sludge

RADIOLOGICAL EXPERIENCE

- The radiation level of material removed from the basin varied up to 35R per hour.
- Dose rates on the grating over the storage basin during sludge removal averaged 20 mR per hour.
- Dose rates inside the basin during sludge removal averaged 400 mR/hr.
- Following sludge removal maximum dose rates found inside the basin was 100 mR/hr.
- Following decontamination of the walls and floor of the basin, the dose rate inside the basin was less than 3 mR/hr and there was no smearable contamination.
- The sand filter used with the recirculating pump was an excellent filter for cleaning the particulate contamination out of the basin water. There was no detectable contamination in the water using an open window CP on an evaporated sample.
- The specific activity of the sludge was 1.25E + 6 pCi/gm. The activity is well within the requirements for a "low specific activity" category shipment.
- The sludge contained <10 nanocuries of transuranic elements per gram of sludge and, therefore, did not have to be packaged in a transuranic retrievable burial container.
- The calculated total activity of the sludge was 25 curies.
- The dose rates from the loaded container were:

Distance	Dose Rate (R/hr)
1 foot	1.1
3 feet	0.8
10 feet	0.4
20 feet	0.15

- Personnel exposure was not a controlling factor in crew size or in the time required to do the work. Employees used on this task were working on other jobs requiring radiation exposure, and as a result of a breakdown in record keeping, the total exposure used in completing the work is not know.

DETAILS ON EQUIPMENT USED

- A Vaughn, Model "Work Horse" 330, sludge pump, with a 100 HP, 404T Lincoln motor was used to pump the sludge from the basin. The pump performed well and no problems were encountered with the pump. (See Figure 4.)
- A Flyte submersible pump was used to recirculate the water and provide a flushing jet for moving the sludge on the basin floor. The pump has a capacity of 300 gpm at a discharge pressure of 50 psi. A piece of 3/4-inch pipe was used as a nozzle on the end of a 1-inch hose to flush the sludge to the sludge pump.
- The recirculating system was equipped with a Super Flow Permanent Media inline sand filter to remove the contamination from the basin water. (See Figure 7.) The filter, Moderl No. PF100 with a filter area of 4.9 square feet and 100 gpm flow, was a shelf item manufactured by Pacific Fabrication Inc. of El Monte, California. When the pressure drop across the filter built up to 50 psi, the filter was backwashed. The backwash water was discharged in the accumulation pit.
- A ParTek Liqua-Blaster, manufactured by the ParTek Corporation, Houston, Texas, was used to decontaminate the walls and the floor. The machine was equipped with Nozzle No. 1502-6065, and developed a nozzle pressure of 6,000 psi. (See Figure 5.)

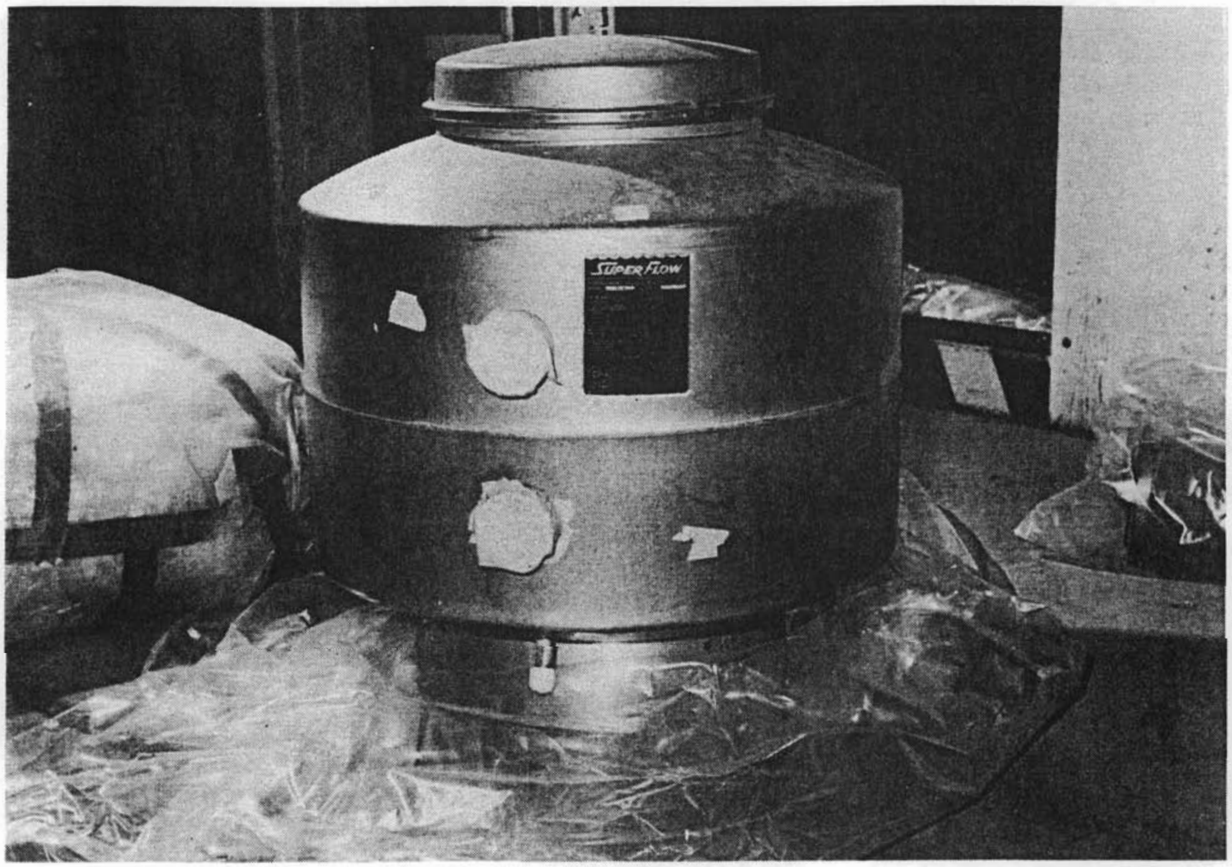

FIGURE 7. Super Flow Permanent Media Inline Sand Filter

EXPLOSIVE DEMOLITION OF ACTIVATED CONCRETE

D. L. Smith

EG&G Idaho Inc.
Idaho National Engineering Laboratory

This paper describes the removal of a radiologically contaminated concrete pad. This pad was removed during 1979 by operating personnel under the direction of the Waste Management Program of EG&G Idaho, Inc.

The concrete pad was the foundation for the Organic Moderated Reactor Experiment (OMRE) reactor vessel located at the Idaho National Engineering Laboratory (INEL). The pad consisted of a cylindrical concrete slab 15 ft in diameter, 2 ft thick, and reinforced with steel bar. It was poured directly onto basalt rocks approximately 20 ft below grade.

The entire pad contained induced radioactivity and was therefore demolished, boxed, and buried rather than being decontaminated. The pad was demolished by explosive blasting.

Work supported by the U.S. Department of Energy, Assistant Secretary for Nuclear Energy, under DOE Contract No. DE-AC07-76ID01570.

INTRODUCTION

This paper discusses the explosive demolition of a radiologically activated concrete pad.

The concrete pad was the foundation for the Organic Moderated Reactor Experiment (OMRE) reactor vessel located at the Idaho National Laboratory (INEL). The OMRE Facility before decontamination and decommissioning (D&D) is shown in Figure 1.

The OMRE was D&D'd during 1978 and 1979. The last phase in the D&D included removal of the vessel support pad. Successful removal of the activated pad allowed the pit to be backfilled and the area released for unrestricted use. Figure 2 shows the OMRE site after D&D.

DESCRIPTION OF PAD

The pad consisted of a cylindrical concrete slab 15 ft in diameter, $\sim$2 ft thick, and reinforced with steel bar. The slab was 20 ft below grade, and had been poured onto the prepared basalt. This made the concrete thickness nonuniform. The pad during construction is shown in Figure 3.

Because it was near the reactor core, the pad became activated and produced the radiation field shown in Figure 4. The curie content, isotopes present, and activation depth in the concrete pad are shown in Table 1. The nuclide content of the INEL surface soil is shown for comparison in Table 2.

REASONS FOR BLASTING

LESS EXPENSIVE

A pneumatic jackhammer and hydraulic splitter were used initially in an attempt to break the concrete. This method was extremely slow and

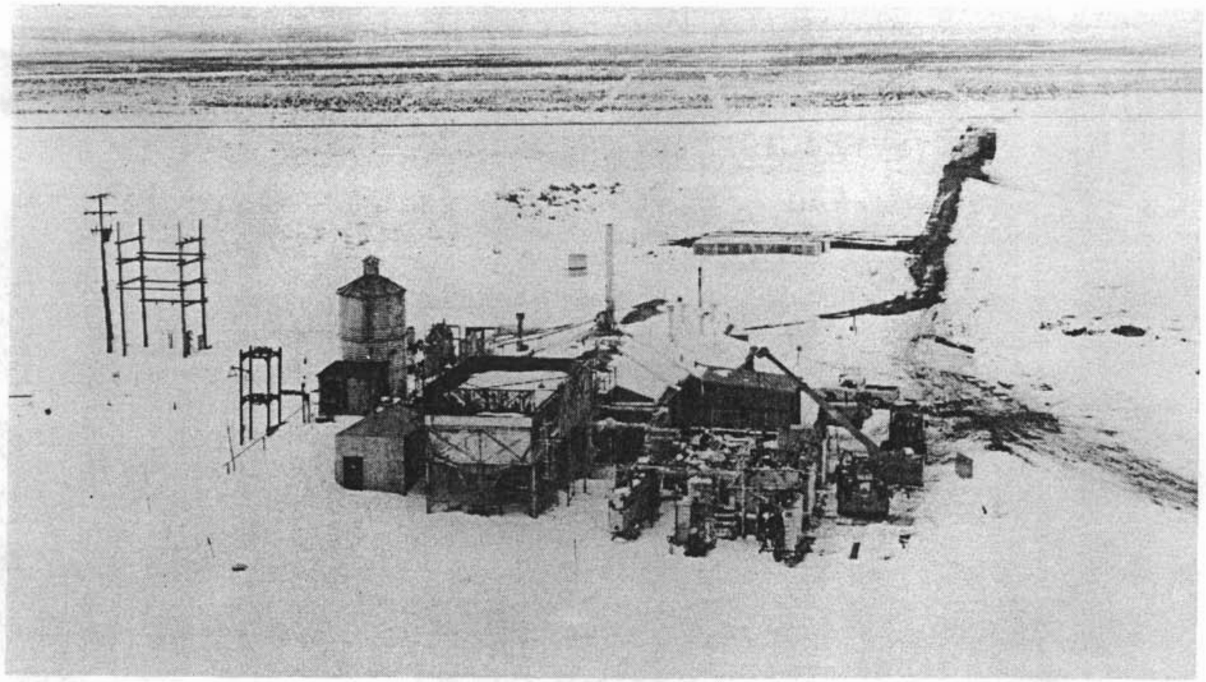

FIGURE 1. OMRE Facility Before D&D

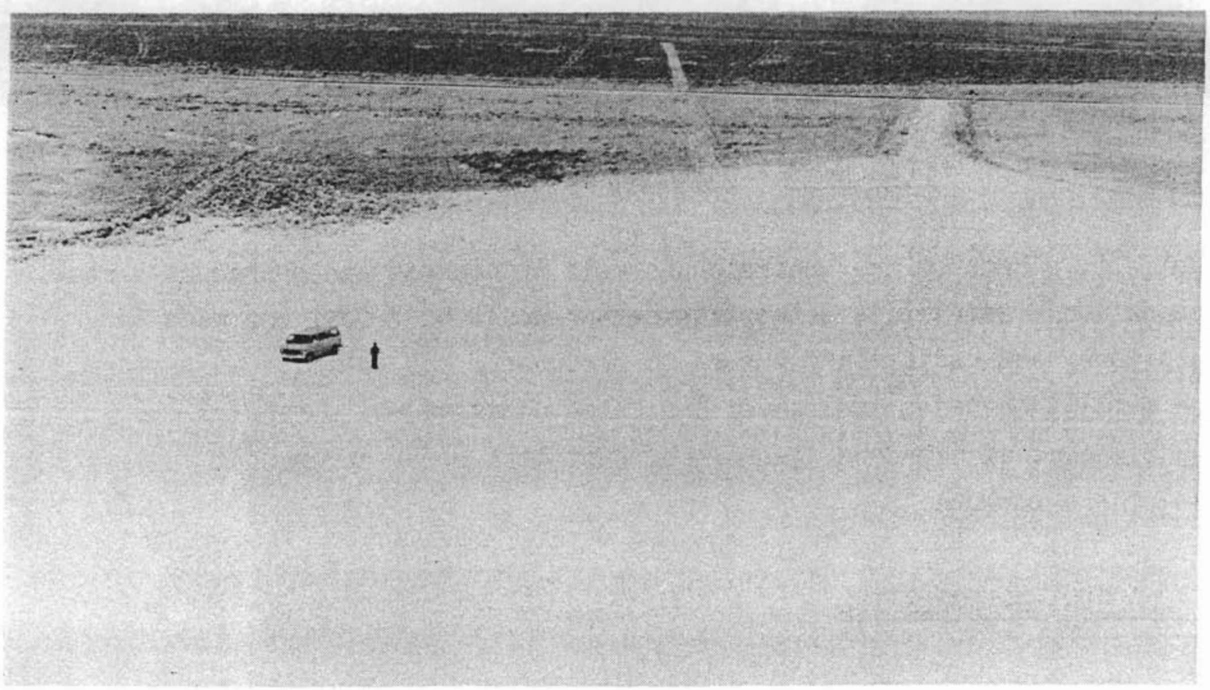

FIGURE 2. OMRE Facility After D&D

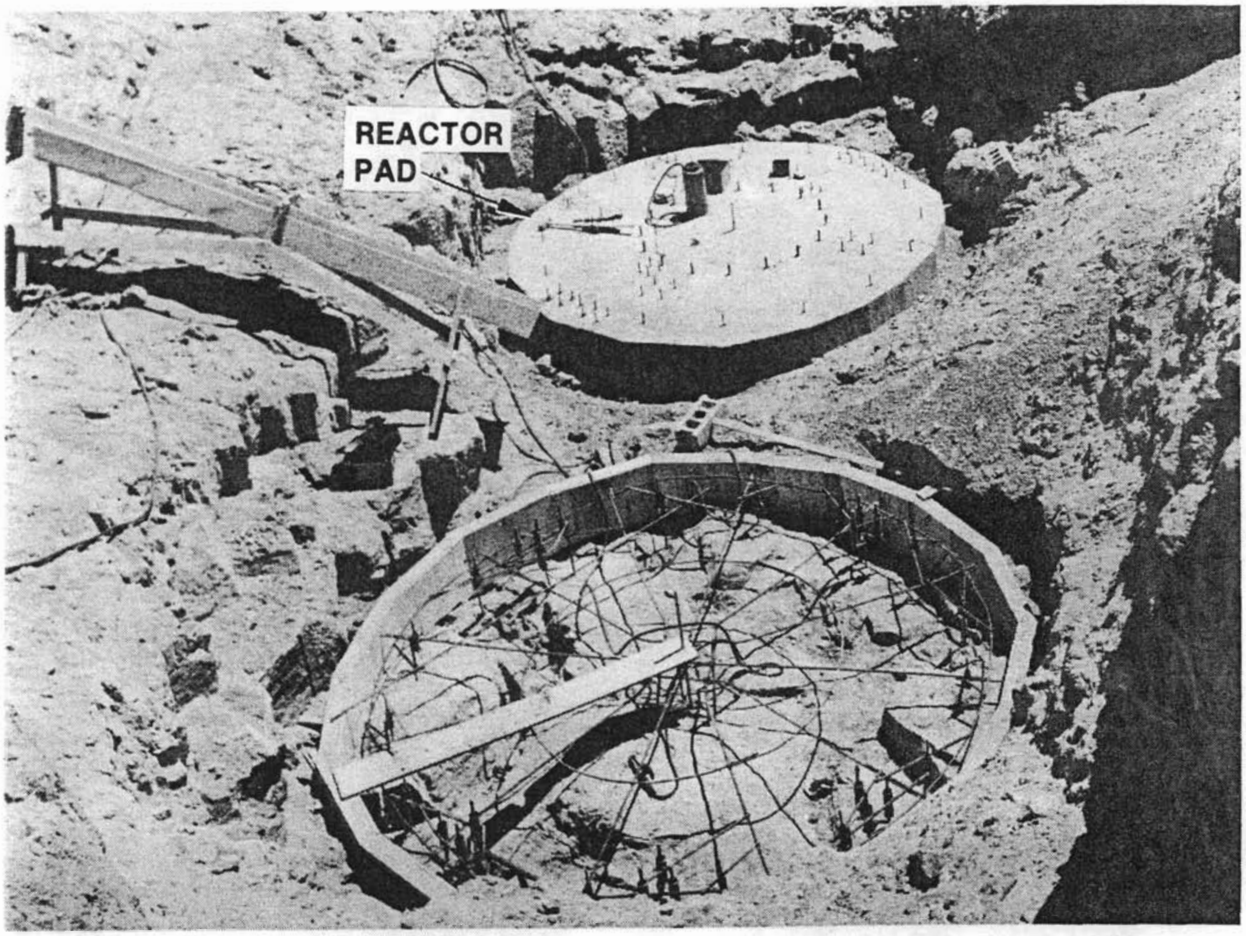

FIGURE 3. OMRE Pad During Construction

ineffective because the concrete was well reinforced and poured on a rock foundation. Demolition using this method would have cost too much in both money and radiation exposure to personnel. An estimate to perform the demolition using explosives indicated blasting would require the least amount of time and, therefore, cost less money and result in less radiation exposure.

DEVELOPMENT OF EXPERTISE

We wanted to gain expertise in explosive demolition of activated concrete because of its potential application to the INEL. A primary objective was to determine how to control contamination spread.

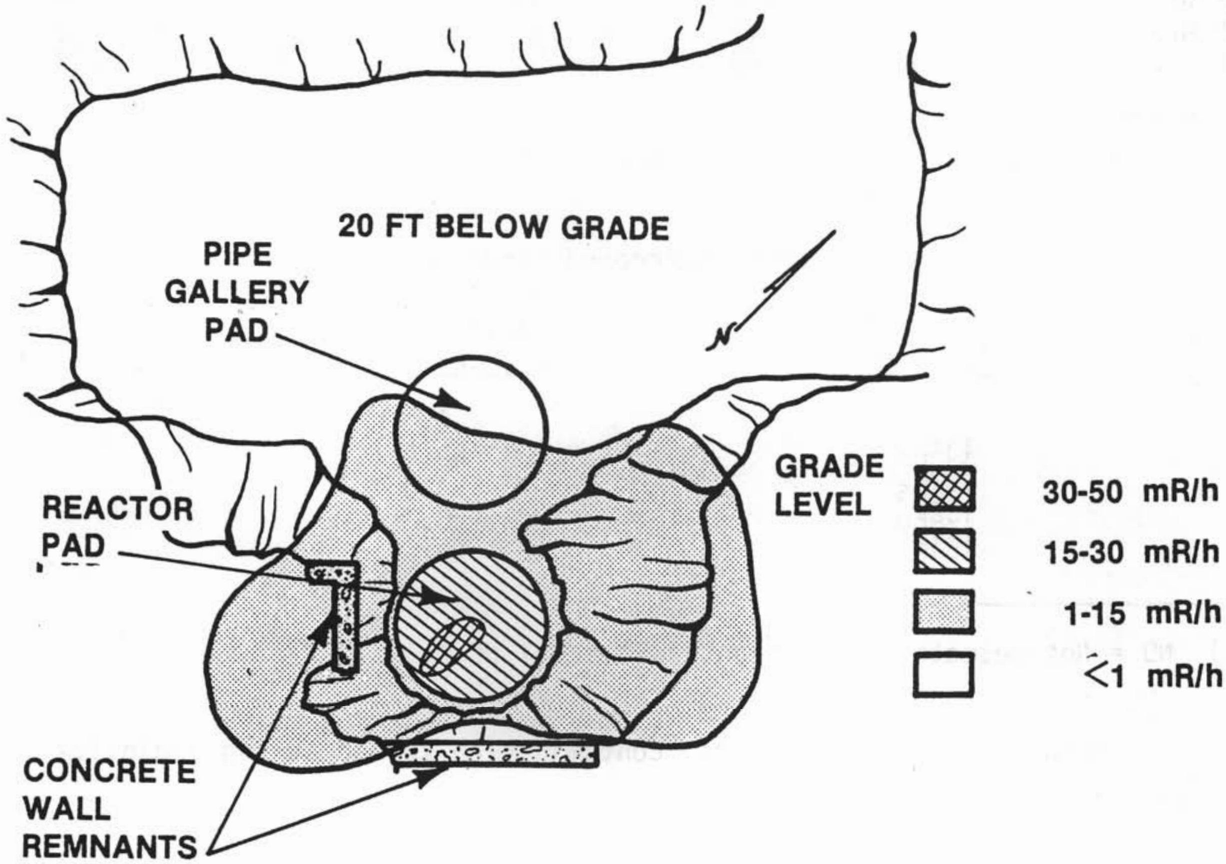

FIGURE 4. Top View of Pit Showing Radiation Fields

CONTAMINATION CONTROL

Although explosive demolition limits the time personnel are exposed to radiation, the possibility exists for contamination spread to be extreme if precautions are not taken.

TABLE 1. Nuclide Content in OMRE Reactor Pad (pCi/g)

Depth	^{154}Eu	^{60}Co	^{134}Cs	^{137}Cs	^{152}Eu
Surface	230	410	16	ND[(a)]	2400
6 in.	48	215	ND	ND	556
12 in.	20	78	ND	0.8	243
18 in.	12	45	ND	0.5	117

(a) ND = Not detected (detection limit = 0.1 pCi/g)

TABLE 2. INEL Background Nuclide Content

Isotope	Nuclide Content (pCi/g)
^{60}Co	0.1
^{134}Cs	ND[(a)]
^{137}Cs	1.0
^{152}Eu	0.1
^{154}Eu	ND

(a) ND = Not detected (detection limit = 0.1 pCi/g)

Two methods were used to limit contamination spread during explosive demolition.

1. The first method was to select the size of the explosive needed to break the concrete yet minimize rock throw and dust generation. This was attempted by using small charges initially and applying the experience and knowledge gained to subsequent detonations.

   This application was difficult, however, because the pad thickness was nonuniform and the pad had been altered through the use of the jackhammer and hydraulic splitter.

2. The second method was to use a blasting blanket over the area. This consisted of a covering of three layers (about 10 mils thick total) of Turco 5580-G over the concrete. This, in turn, was covered with layers of tarpaper and rubber-backed carpet to absorb the blast and limit rock throw. The pit walls and bottom were also covered with Hypolon to contain any escaping contamination. The Hypolon covering is shown in Figure 5.

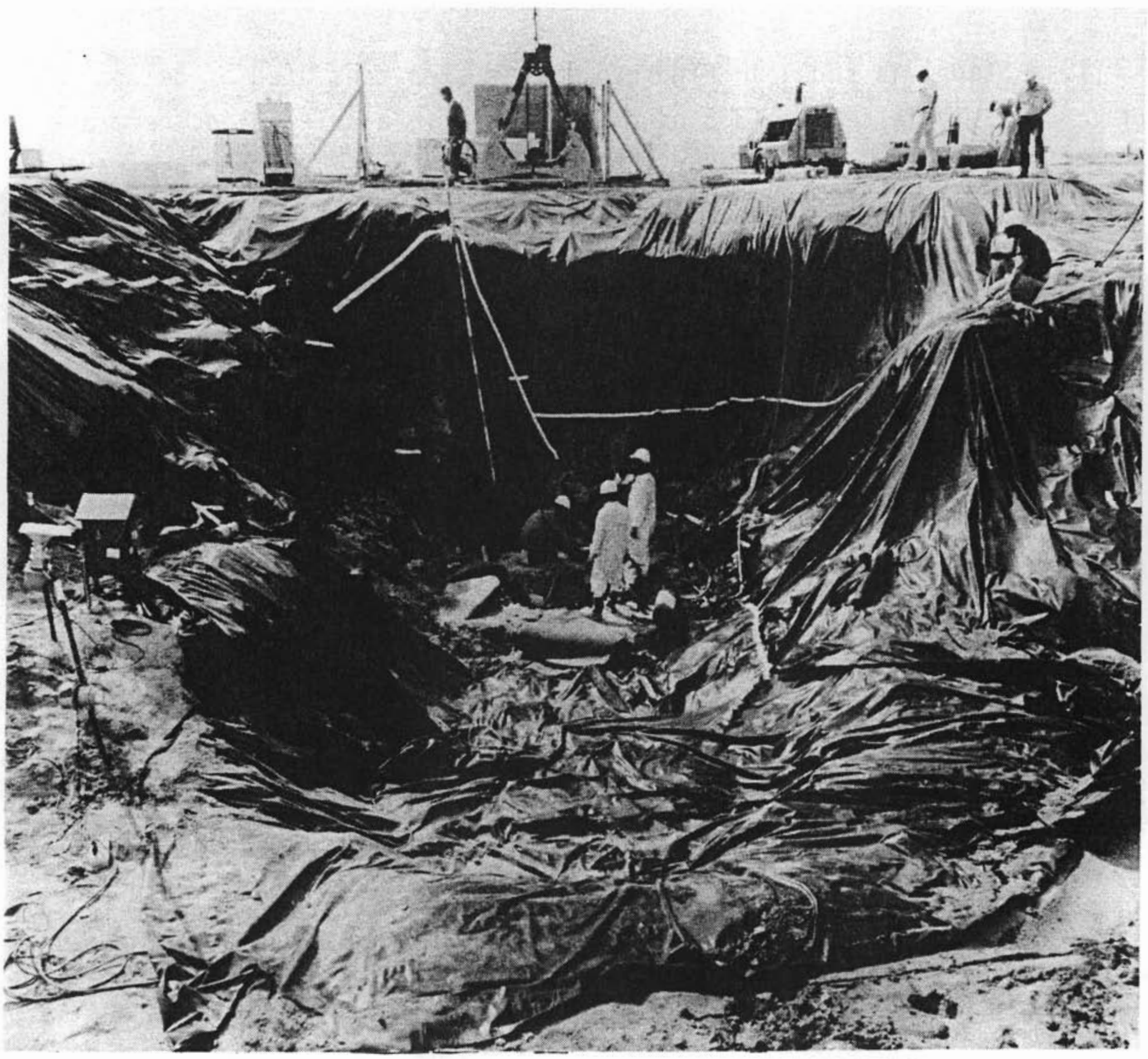

FIGURE 5. Hypolon Covering

DEMOLITION PROCEDURE

Demolition consisted of seven steps. The first step was performed on the unactivated concrete pad, and the other steps were all performed on the reactor pad.

Separate figures show each step in the demolition procedure. Each figure shows the location of the charge and a sketch representation of the results.

1. Step 1 is shown in Figure 6. This step consisted of detonating a single charge (3.5 oz of dynamite) in a hole 18 in. deep and 9 in. from the edge of the unactivated pad. The purpose of this shot was to gain knowledge and experience before beginning the test shots on the reactor pad.

2. Step 2 (Figure 7) consisted of detonating a single charge (3.5 oz of dynamite) in a hole 30 in. deep and 9 in. from the edge of the reactor pad. The depth of the hole was 30 in. instead of 18 in. to get deeper breakout of the concrete. No concrete breaking was obtained by this shot. Apparently the charge was detonated too deep, causing the energy to vent to the basalt.

3. In step 3 (Figure 8) a charge (3.5 oz of dynamite) was placed and detonated in each of two holes bored 18 in. deep and 9 in. from the edge of the pad. The holes were 1 ft apart. Concrete breakout was obtained about three-fourths through pad depth. Cracks formed toward center due to the cavity made during jackhammering. Rock throw was minimal, and dust generation was very light.

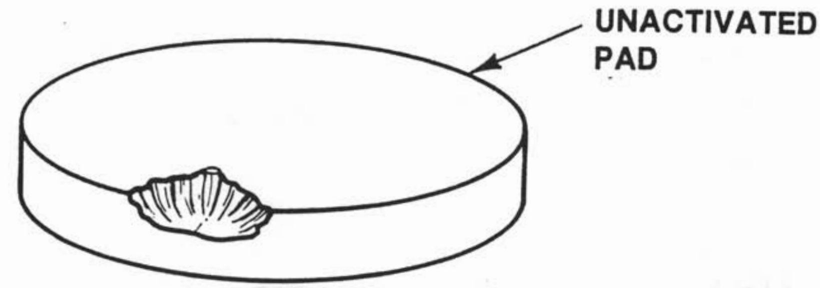

FIGURE 6. First Step in Explosive Demolition

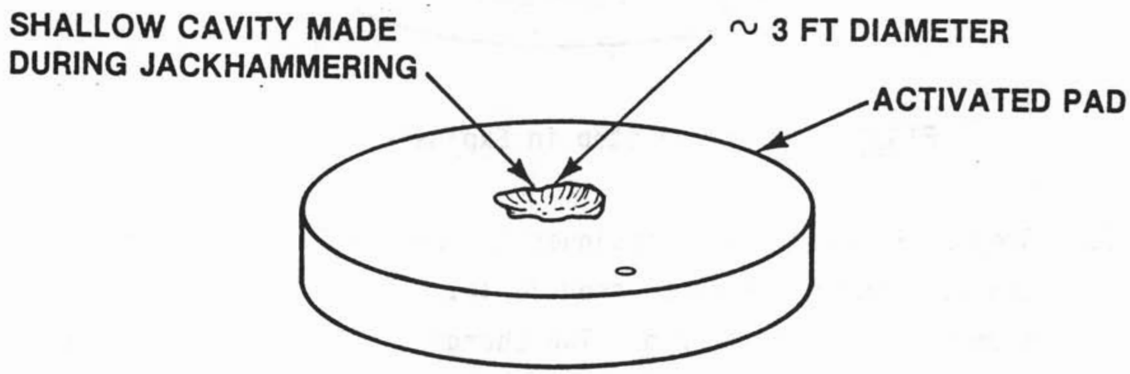

FIGURE 7. Second Step in Explosive Demolition

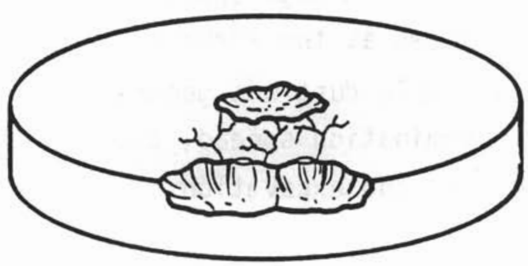

FIGURE 8. Third Step in Explosive Demolition

4. Step 4 (Figure 9) consisted of detonating two 3.5-oz charges in a single hole 32 in. deep and 9 in. from the edge of the pad. One charge was placed 32 in. deep and the other 18 in. deep.

Radial cracking was very good, concrete breakout went through the entire pad thickness, and rock throw and dust generation were minimal.

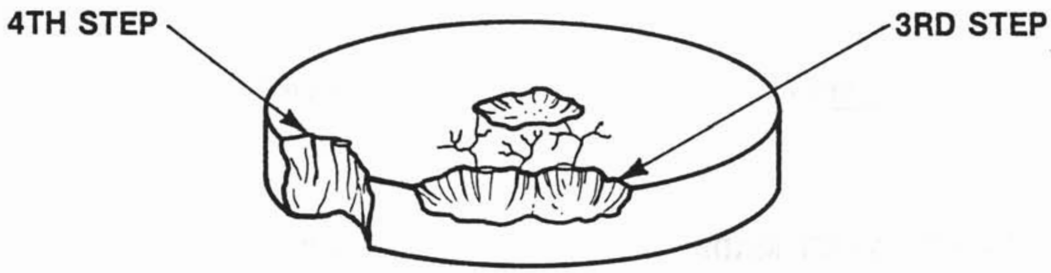

FIGURE 9. Fourth Step in Explosive Demolition

5. Step 5 (Figure 10) was designed to break a larger section of concrete. Four holes were bored 30 in. deep, 1 ft apart, and 1 ft from the edge of the pad. Two charges, consisting of 5.3 oz of dynamite plus 1.8 oz of nitrogenated fuel oil, were detonated in the bottom of each hole. Unexpectedly, the concrete broke inward instead of outward. This was probably caused by the cavity in the center of the pad. A high speed film of this detonation was made and will be shown at the workshop. The rock throw was about 50 ft, and considerable dust was generated. There was, however, no detectable contamination spread, and essentially all debris was contained within the excavation.

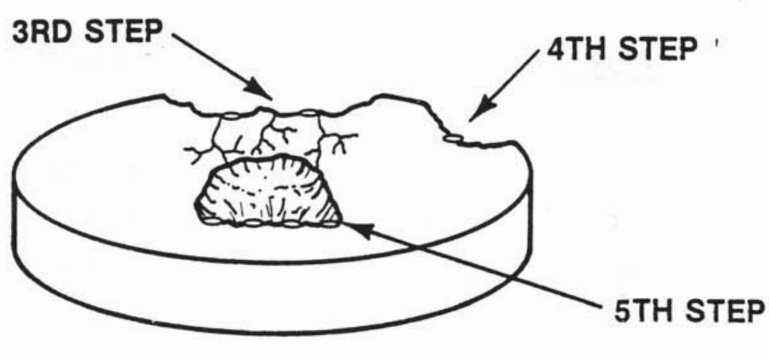

FIGURE 10. Fifth Step in Explosive Demolition

6. Step 6 (Figure 11) consisted of detonating a larger charge (7.1 oz of dynamite) in each of two holes. The holes were 28 in. deep, 1 ft apart, and 1 ft from the edge of the pad. Good concrete breakout was obtained with satisfactory control of rock throw and dust generation.

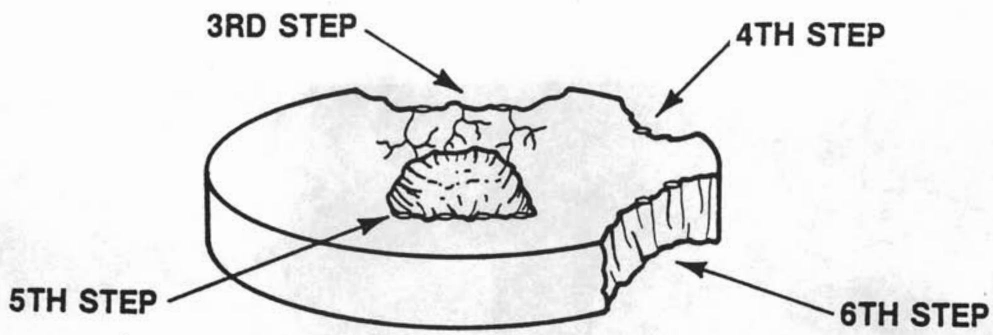

FIGURE 11. Sixth Step in Explosive Demolition

7. Step 7, the final step (Figure 12), consisted of detonating 7.1 oz of dynamite in each of 10 holes. The holes were bored in a circular pattern about 3 ft from the edge of the pad and approximately evenly spaced. The holes were bored to a depth of 28 in. Rock throw and dust generation were severe, but the debris was well contained within the covered pit area.

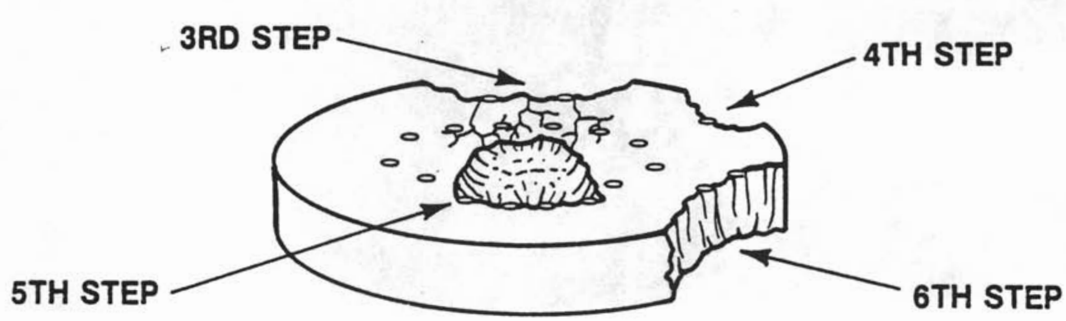

FIGURE 12. Seventh and Final Step in Explosive Demolition

A radiological survey following the final detonation showed no detectable contamination outside the pit area.

The largest piece of concrete remaining after the blast was a circular piece ($\sim$7 ft in diameter) from the pad center (Figure 13). This piece was loose from the basalt and was easily removed using a clam shell shovel.

FIGURE 13. Largest Concrete Piece Remaining After Blasting

CONCLUSIONS

It is possible to explosively demolish activated concrete without significantly spreading radioactive contamination. The demolition was adequate to allow safe removal of the activated concrete.

More effort should be devoted to the analytical and experimental determination of explosive charge size and placement to accomplish incipient breaking of the concrete.

Additionally, other materials to cover the concrete should be tried to better control rock throw and dust generation.

THE DECONTAMINATION OF CONCRETE SURFACES IN BUILDING 3019, OAK RIDGE NATIONAL LABORATORY

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Building 3019 at Oak Ridge National Laboratory was the first radiochemical processing pilot plant constructed in the United States. This facility has been used to demonstrate essentially all radiochemical separations processes being used today. The seven heavily shielded, remotely operated cells have been decommissioned and refitted many times. This has resulted in numerous programs involving decontamination of the concrete interiors of the cells. The entire building was contaminated with plutonium to transferable alpha levels varying from 50 to 10^8 dis/min/100 cm^2 after a non-nuclear chemical explosion in 1959. This paper will describe the efforts that took place over an 18-month period to return the facility to operation.

INTRODUCTION

I have chosen to confine my remarks to experiences in decontaminating concrete surfaces in one facility — Building 3019 — at the Oak Ridge National Laboratory. This facility was constructed in 1943 to serve as a pilot plant for the separation of a variety of isotopes from irradiated fuels and has operated almost continuously through 21 different programs. I have spent the past 28 years in the facility and have been closely involved in its operations.

HISTORY OF BUILDING 3019

Table 1 gives a historical review of the programs and accomplishments of the facility. The various programs completed between 1943 and the present are listed. It is interesting to note that, during the period 1943 to 1958, the plant was developing most of the processing schemes that are still employed today, and that kilogram quantities of plutonium, ^{235}U, and ^{233}U were being recovered. A list of materials processed between 1958 and 1960 is also shown. It was during this period that we experienced a chemical explosion which led to widespread plutonium contamination to the facility and the surroundings. The table shows some overlapping of time since we were using the cells for two completely different processes. Also included in Table 1 are (1) our most recent processing efforts, including development of the sol-gel process for preparing microspheres from ^{239}Pu and ^{238}Pu; (2) the preparation of over 1600 kg of ^{233}U as UO_2 for the Light Water Breeder Reactor Program; and (3) the preparation of 50 kg of ^{233}U as U_3O_8 and subsequent loading into 1700 packets for criticality studies in the Zero Power Reactor at Argonne, Idaho.

EXTENT OF PLUTONIUM CONTAMINATION

A view of the Pilot Plant is shown in Fig. 1. The heart of the building consists of seven heavily shielded (5 ft of concrete) cells in a row. The

TABLE 1. Oak Ridge National Laboratory Building 3019 History

Date	Program	Feed Material	Process Employed	Material Recovered (kg) Uranium	Material Recovered (kg) Plutonium	Irradiated Level (MWd/ton)	Cooling Time (Months)	Remarks and/or References
1943-1945	Weapons	X-10 uranium slugs	Biophosphate			Low		Plutonium recovery, separation, demonstration, and personnel training
1946-1948	Development	Enriched uranium	Redox			Low		Separation and recovery of enriched uranium
	Development	Enriched uranium	"25"			Low		Separation and recovery of enriched uranium
1950-1953	Purex	Uranium slugs	Purex	∿7500[(a)]	∿7	∿500	2-4	Demonstration of Purex Process, recovery of uranium and plutonium, train personnel, provide engineering data
1954-1958	Thorex	Thorium slugs	Thorex	60[(b)]		500-5000[(c)]	<1-30	Demonstration of three-cycle Thorex Process at high radiation levels and at short decay periods
	High-isotopic-purity ^{233}U	Thorex short-decay waste	Modified Interim-23	0.9[(b)]			12	Demonstrate recovery process and recover ^{233}U containing <0.5 ppm ^{232}U
1958-1960	SCRUP-2	NRX reactor fuel	Purex	5386	3.1	∿400	24	Recovery of high-quality plutonium
	SRPE	SRP fuel	Purex	1.4[(d)]	1.5	1000	∿12	Recovery of enriched uranium and plutonium
	BNL-1, -2	BNL reactor fuel	Purex	25,000[(e)]	18.3	∿500	∿12	Recovery of plutonium and uranium; 3019/3505 complex
	SNAP-A	SRP-uranium slugs	Purex	3071[(f)]	3.3	∿1000	∿6	Recovery of plutonium high in ^{240}Pu; provide wastes for fission product recovery in 3019/3505 complex

TABLE 1. contd

Date	Program	Feed Material	Process Employed	Material Recovered (kg)		Irradiated Level (MWd/ton)	Cooling Time (Months)	Remarks and/or References
				Uranium	Plutonium			
1958-1960	H-240	SRP-uranium slugs	Purex	5800[f]	7.7	~800	3	Recovery of plutonium high in ^{240}Pu in 3019/3503 complex
	S-240	SRP-uranium	Purex	5800[f]	13.7	~2200	3	Recovery of plutonium high in ^{240}Pu in 3019/3505 complex
	MTR-1	Plutonium-Aluminum Assemblies	Low TBP		0.5		>6	Recovery of plutonium high in ^{240}Pu in 3019/3505 complex
		CP-2 reactor fuel	Purex	4500			>12	
1958-1965	Volatility	Molten salt and fuel	Volatility	40.6[d]			48	Recovery of enriched uranium and demonstration of the Volatility Process
		Zirconium-Uranium fuel	Volatility	23[d]		~700	3-72	Demonstration of the process with zirconium-clad assemblies
		Aluminum-Uranium fuel	Volatility	2.3[d]			1-18	Demonstration of the process with aluminum-clad assemblies
1963	Kilorod	$^{233}UO_2$-$(NO_3)_2$ $Th(NO_3)_4$	Uranium solvent extraction, thorium steam denitration, sol-gel preparation, remote fuel-rod fabrication	37[b]		None	g	Fabricate 1100 stainless-steel-clad fuel rods charged with 3% $^{233}UO_2$-97% ThO_2
1966-1968	Plutonium sol-gel	Plutonium nitrate	Plutonium sol-gel development		0.4[h] 0.6[i]	None	g	Process development
	^{233}U purification	^{233}UNH	Modified Interim-23	280		None	g	To provide ^{233}U for experimentation

TABLE 1. contd

Date	Program	Feed Material	Process Employed	Material Recovered (kg) Uranium	Plutonium	Irradiated Level (MWd/ton)	Cooling Time (Months)	Remarks and/or References
1969-1979	LWBR	^{233}UNH, $^{233}UO_2$, and $^{233}UO_3$	Purification (SX, IX), oxide conversion	1675(b)		None	g	To provide ceramic-grade $^{233}UO_2$ of high quality for fabricating LWBR fuel
		$^{233}UO_2$-ThO_2 hard scrap	Thorex dissolution, SX, and IX	711(b)		None	g	To recover ^{233}U
1978-1979	ANL-ZPR	UNH	Purification (SX, IX) and oxide conversion	50		None	g	To provide 1700 packets of U_3O_8 for criticality studies

(a) Natural uranium.
(b) ^{233}U.
(c) g Mass ^{233}U/Ton Thorium.
(d) Enriched uranium.
(e) Natural uranium.
(f) Depleted uranium.
(g) Not applicable.
(h) ^{238}Pu.
(i) ^{239}Pu.

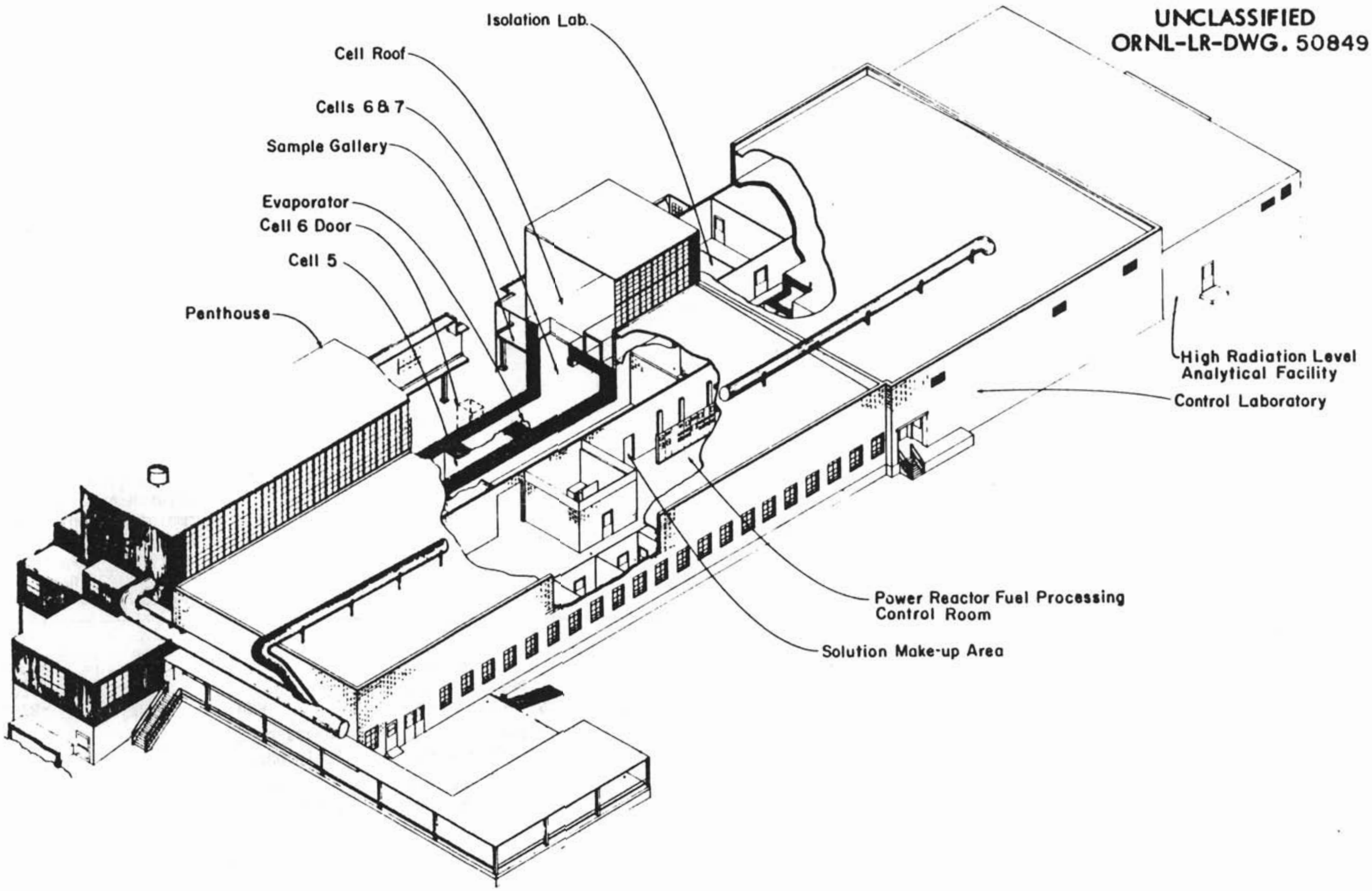

FIGURE 1. Radiochemical Processing Pilot Plant

chemical explosion occurred in the sixth cell from the east end of the facility in November 1959. A plan view of the facility is shown in Fig. 2. The majority of the internal cell area, all of the external cell area, and all floors in the facility, except the office area, were bare concrete when the incident occurred. The total area of concrete is 44,000 ft^2.

As a matter of interest, the extent of plutonium contamination outside the facility, released as a result of failure of a ground-level door which opened into the cell, is shown in Fig. 3.

The extent of internal contamination is shown in Fig. 4. The entire facility, including walls, ceilings, fixtures, etc., was contaminated to a transferable level of >50 dis/min/100 cm^2, with the in-cell areas contaminated to a level of 10^8 dis/min/100 cm^2. All contamination values in this paper refer to alpha measurements.

LIMITS FOR RESIDUAL CONTAMINATION

Now that I have described the problem, I will discuss the actions we took to return the building to its previous use. First, the required limits for residual contamination were established and are shown in Table 2. As expected, the only areas that could be cleaned to these limits were the office areas, primarily because the walls were composed of concrete tile with a smooth surface and the drop ceilings were easy to replace. Cleaning with detergent and sponges was effective in reducing the level to the specified values. The areas outside the offices were much more difficult to decontaminate to the desired limits, particularly the limits indicated by the direct-reading gas proportional meter. It is important to note that use of the gas-flow meter was in its infancy, and that extensive use of this instrument was not initiated until after the incident. Prior to this time, we had relied exclusively on the results obtained from counting smears and swipes. In any event, the decision was made that the specifications for residual contamination on surfaces would be increased by a factor of 10 provided the surfaces were coated with orange enamel followed by a light-color paint or concrete. This procedure was followed for all surfaces except the offices.

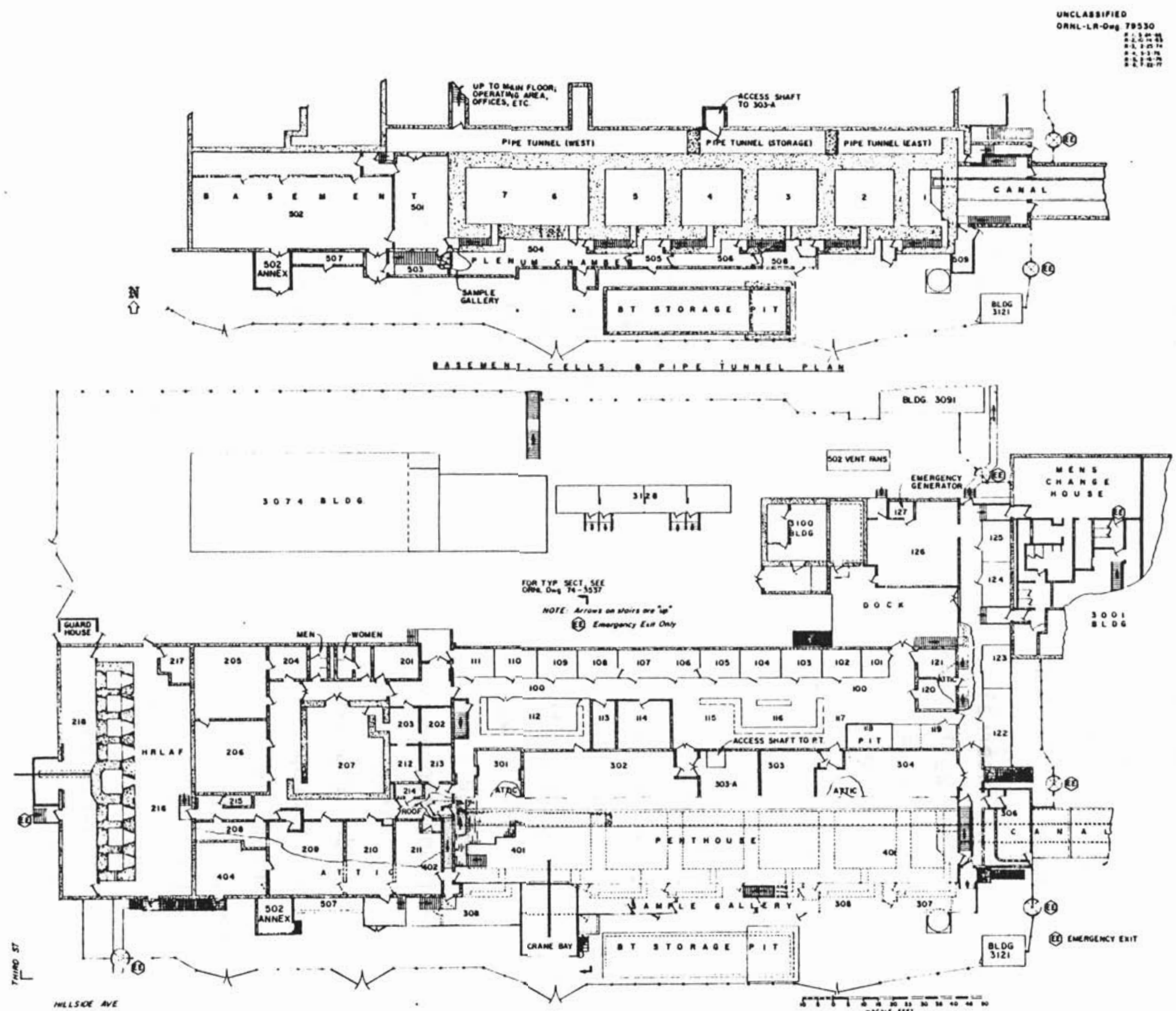

FIGURE 2. Plan of Radiochemical Processing Pilot Plant

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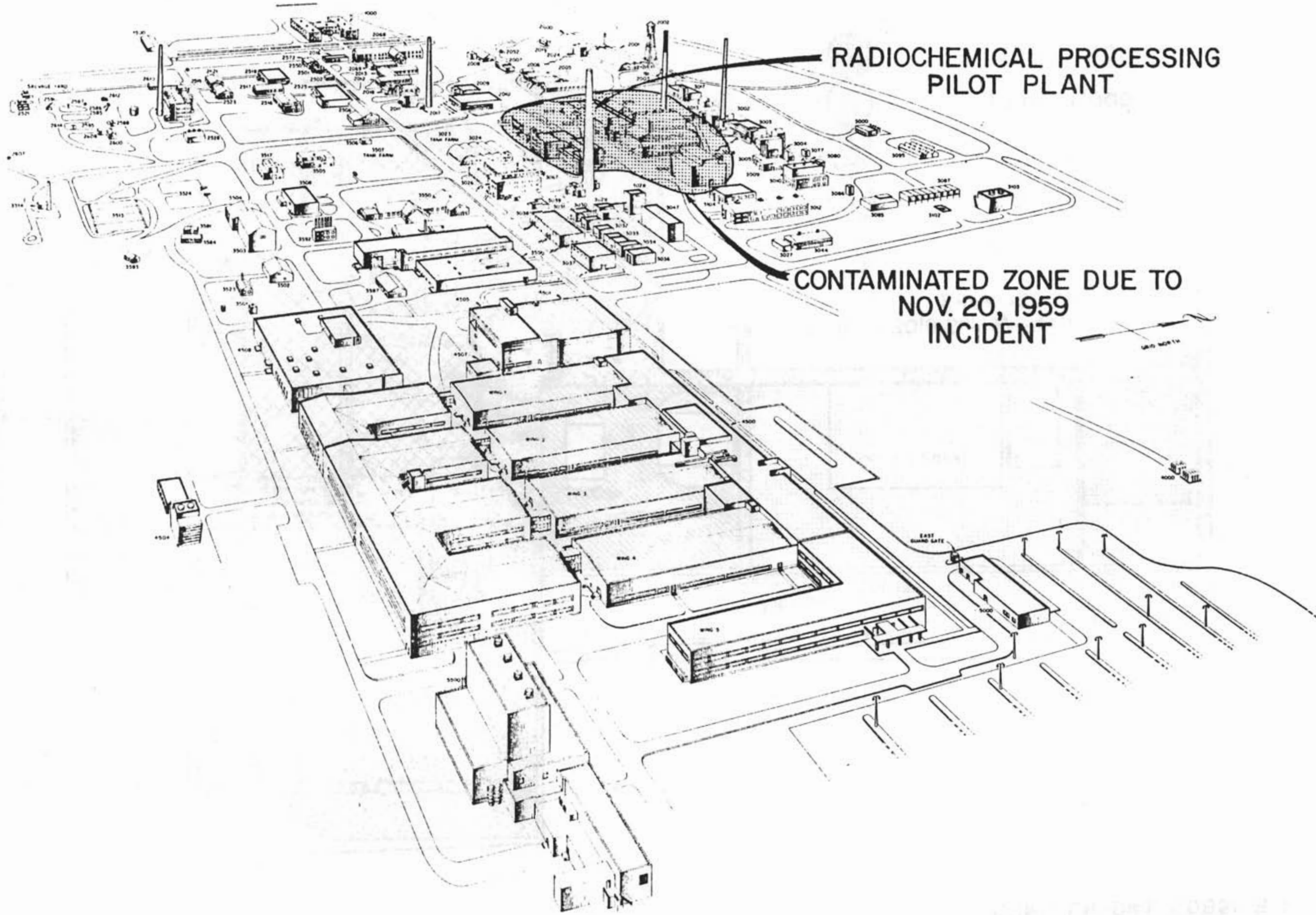

FIGURE 3. Extent of Contamination to the Area Surrounding Building 3019

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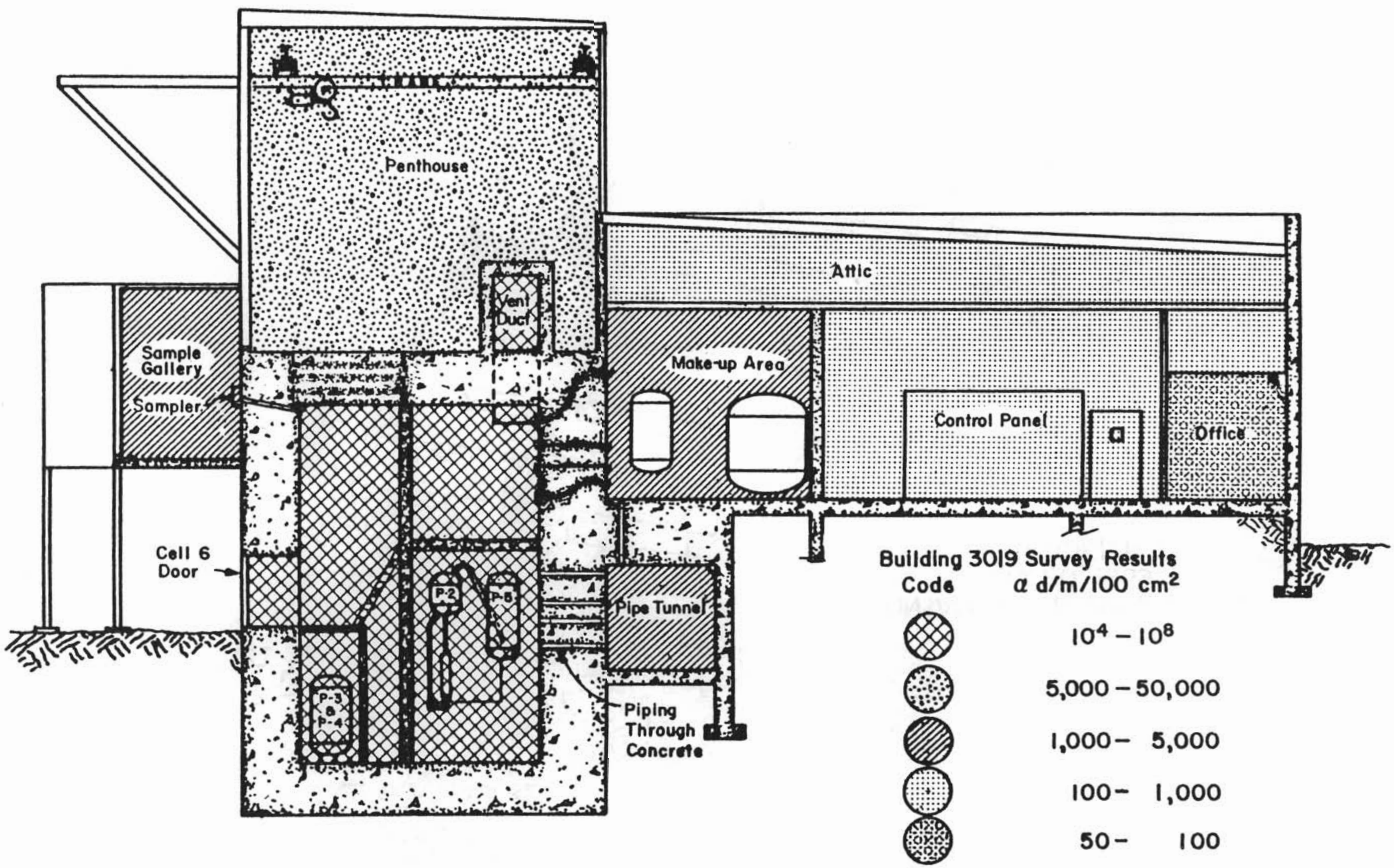

FIGURE 4. Building 3019 Cross Section Showing Contamination Levels

TABLE 2. Required Residual Contamination Limits, alpha dis/min/100 cm^2

	Direct Reading	Transferable
Maximum	300	30
Average[(a)]	≤30	≤3

(a) Requires a minimum of ten samples with at least one sample from each square meter of surface.

DECONTAMINATION OF CONCRETE ADJACENT TO CELLS

The decontamination of concrete surfaces, particularly the floors, was a formidable task. Since the plutonium was released as an aerosol of fine particles of plutonium oxide, extensive vacuuming was the first action taken. The use of any type of solution simply forced the plutonium into the porous concrete, resulting in low levels of transferable contamination but high levels as determined by the direct-reading meter. The concrete walls and ceilings were contaminated to a much lesser extent since the aerosol obviously deposited on horizontal surfaces. The problem of decontamination of the floor areas was further complicated since the ceilings and walls were decontaminated first. We were aware from the start that the floors were the most difficult areas to decontaminate, and we made no attempt to cover them with plastic during decontamination of the ceilings and walls to avoid the solids disposal problem. We opted to use harsh measures on the floors as the final action.

The bare concrete floor in the area adjacent to the offices was decontaminated by grinding with a terrazzo machine, since this floor was relatively smooth and unattacked by chemicals; therefore, the removal of between 0.04 and 0.08 cm of concrete was sufficient to eliminate essentially all the contamination. The operation was performed with the floor wet, and the resultant water, containing the concrete, was vacuumed up with an industrial vacuum cleaner and then emptied into 208-liter (55-gal) drums for disposal.

The area adjacent to the cell, due to penetrations into the cell, was contaminated to a transferable level of 1000 to 5000 dis/min/100 cm^2, again primarily on the horizontal surfaces. A photograph of this area, during resurfacing, is shown in Fig. 5. This floor proved impossible to decontaminate due to its "honeycombed" condition, which was primarily caused by chemical attack by nitric acid over several years. It was necessary to remove several centimeters of the floor with jackhammers and pour a new concrete floor. You will note the stainless steel supports cast in the concrete. The floor was subsequently covered with stainless steel.

DECONTAMINATION OF CELL INTERIORS

Decontamination of the cell interiors was much more difficult due to the maze of piping, vessels, electrical conduit, etc. Of course, these interiors, contaminated to levels between 10^5 and 10^8 dis/min/100 cm^2, could never be decontaminated to the aforementioned limits for painting. However, we were successful in reducing the transferable contamination level to ~1000 dis/min/100 cm^2, with direct readings approximately ten times greater than the transferable level. Decontamination was accomplished by first inserting a "greenhouse" into an existing doorway which could be used to direct a high-pressure detergent solution onto the most highly contaminated surfaces. A photograph of this greenhouse, taken from inside the cell, is shown in Fig. 6. After initial decontamination had been completed, the operator entered the cell, as shown in Fig. 7. Pressure to the wand was supplied by a high-pressure jet cleaner[a] (Fig. 8) located outside the cell.

The effectiveness of the decontamination program, as indicated by the quantity of plutonium in the spent solution, is shown in Fig. 9. The original 100,000 liters of solution consisted of ~50,000 liters of various detergents and oxalic acid and 50,000 liters of water. Additional spraying with sulfamic acid failed to remove a significant amount of plutonium. Further plutonium removal was accomplished by using an HNO_3-NaF solution and the TURCO 4501-A, 4502 treatment.[b] During this period, the contamination on the painted

(a) Manufactured by Sellers, Corp., Horsham, Pennsylvania.
(b) Solution obtained from Turco Products, Inc., Division of Purex Corp., Carson, California.

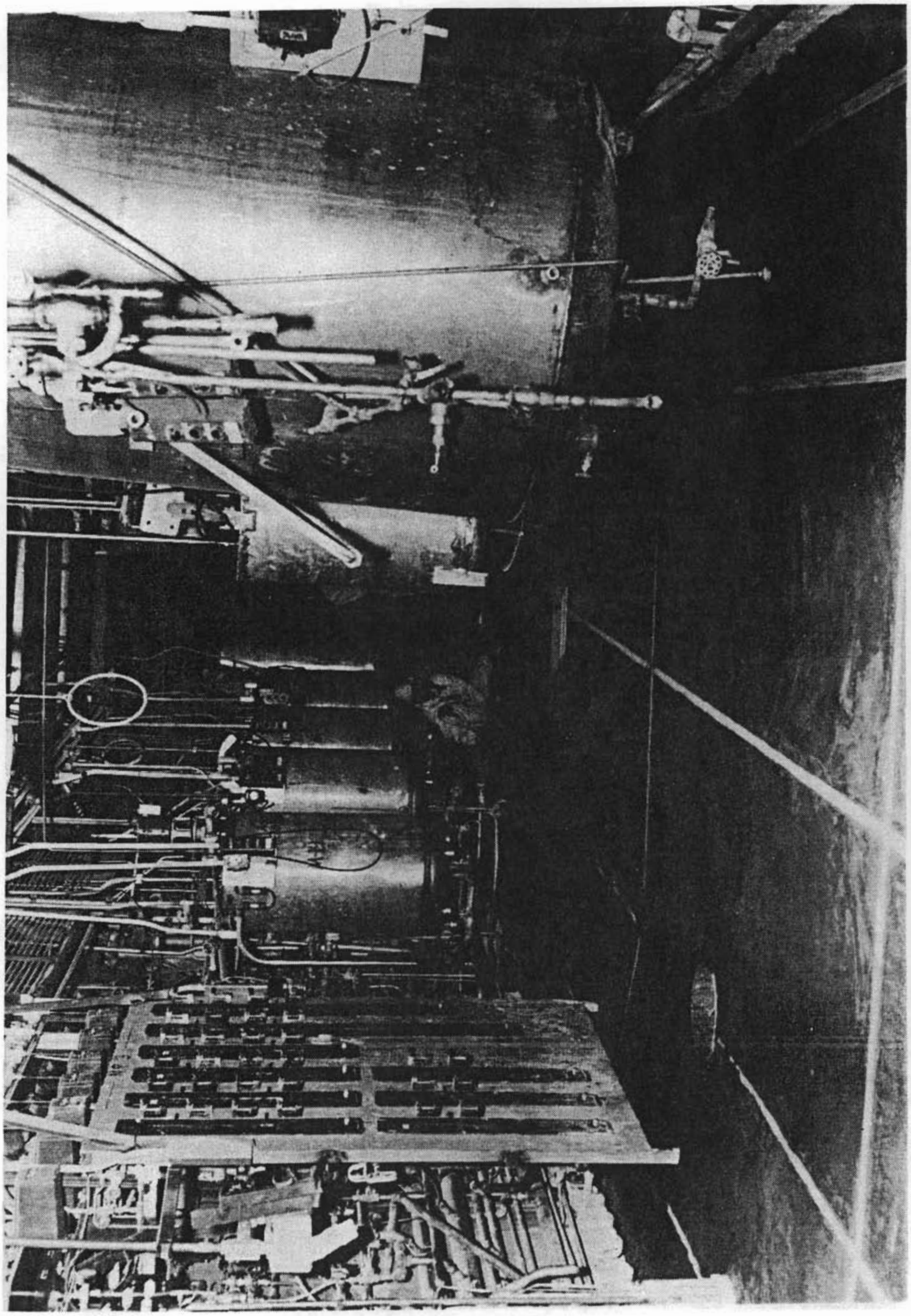

FIGURE 5. Makeup Area During Decontamination After Explosion

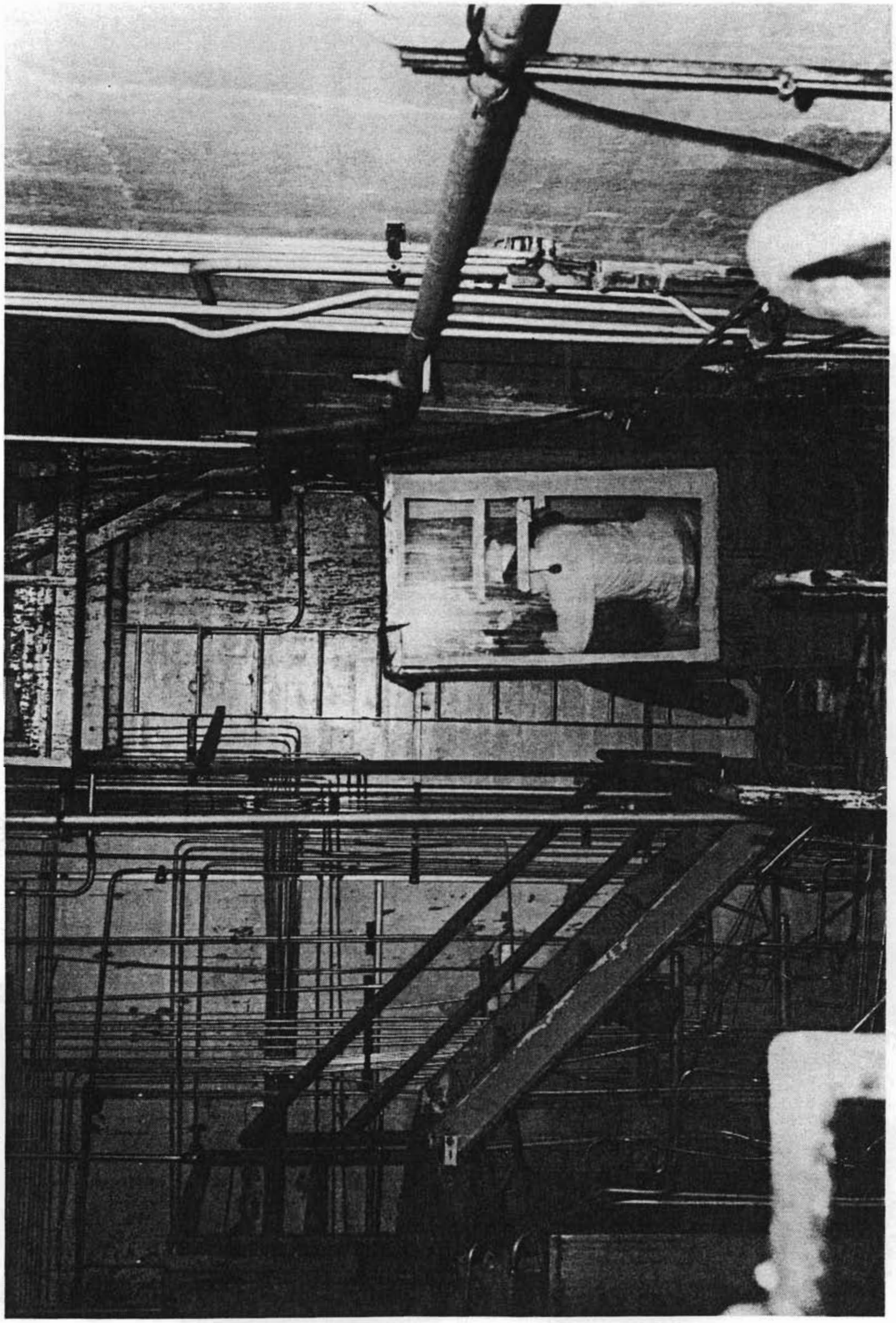

FIGURE 6. In-Cell Greenhouse

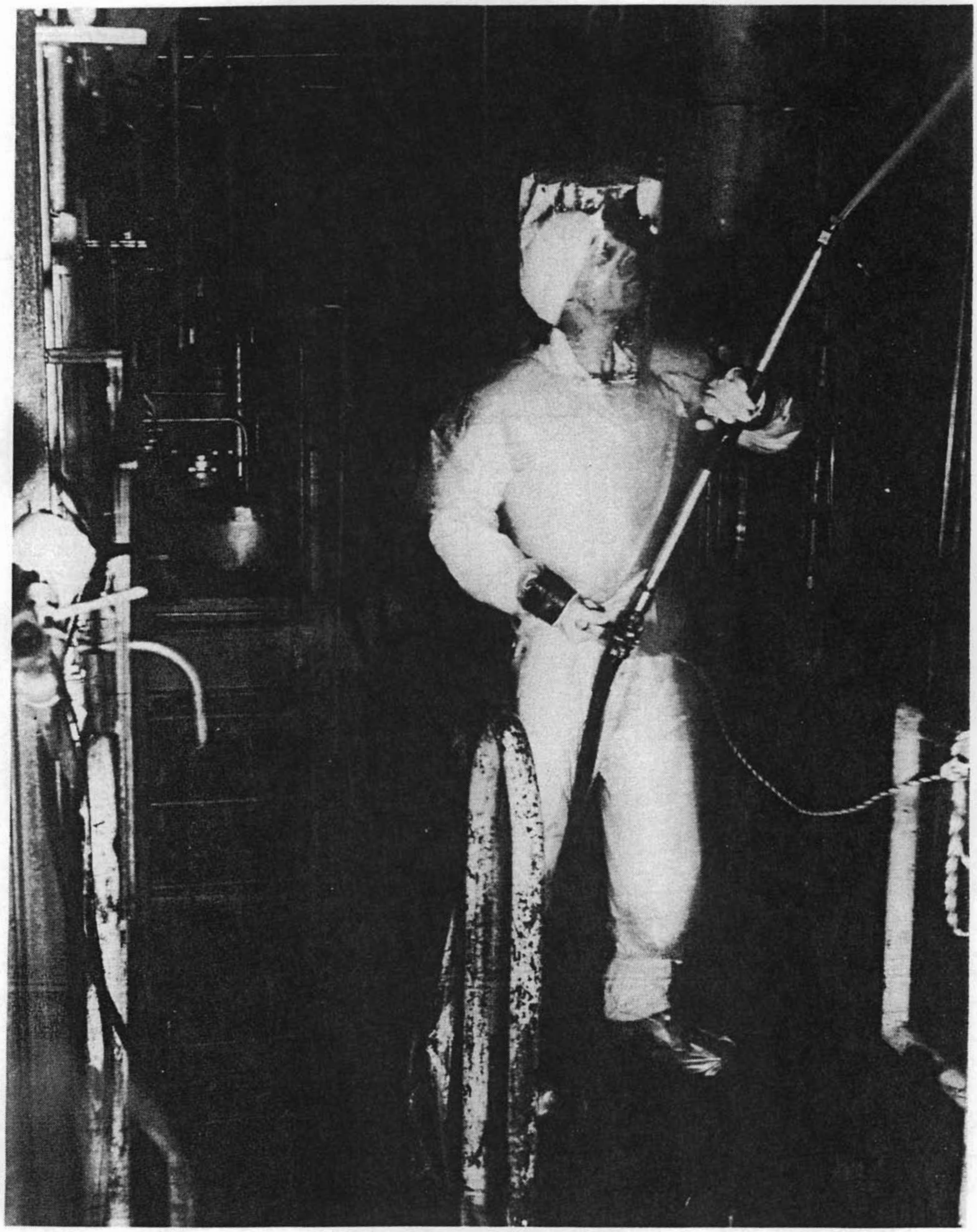

FIGURE 7. In-Cell Decontamination

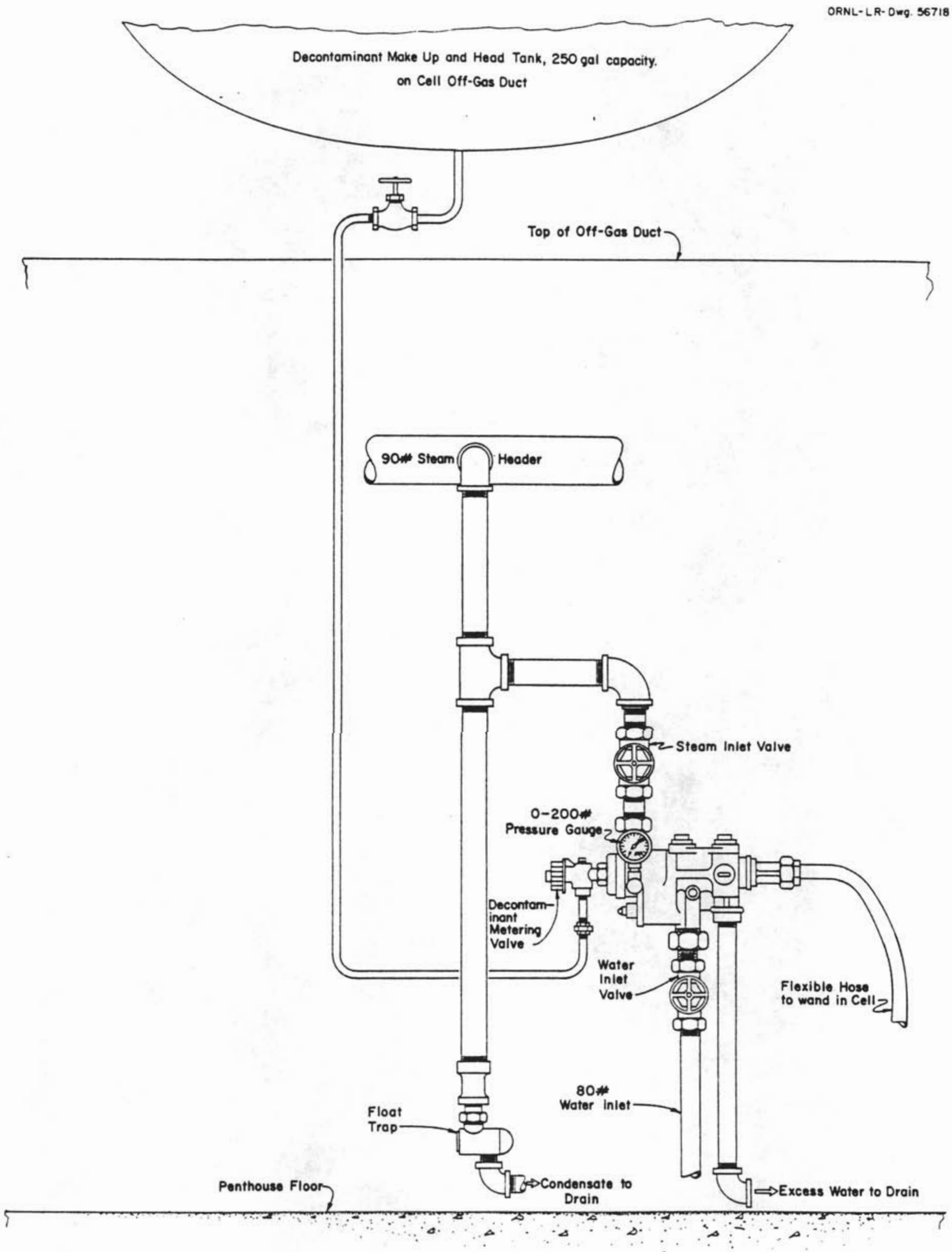

FIGURE 8. Sellers "Super Booster" Hydraulic Jet Cleaner

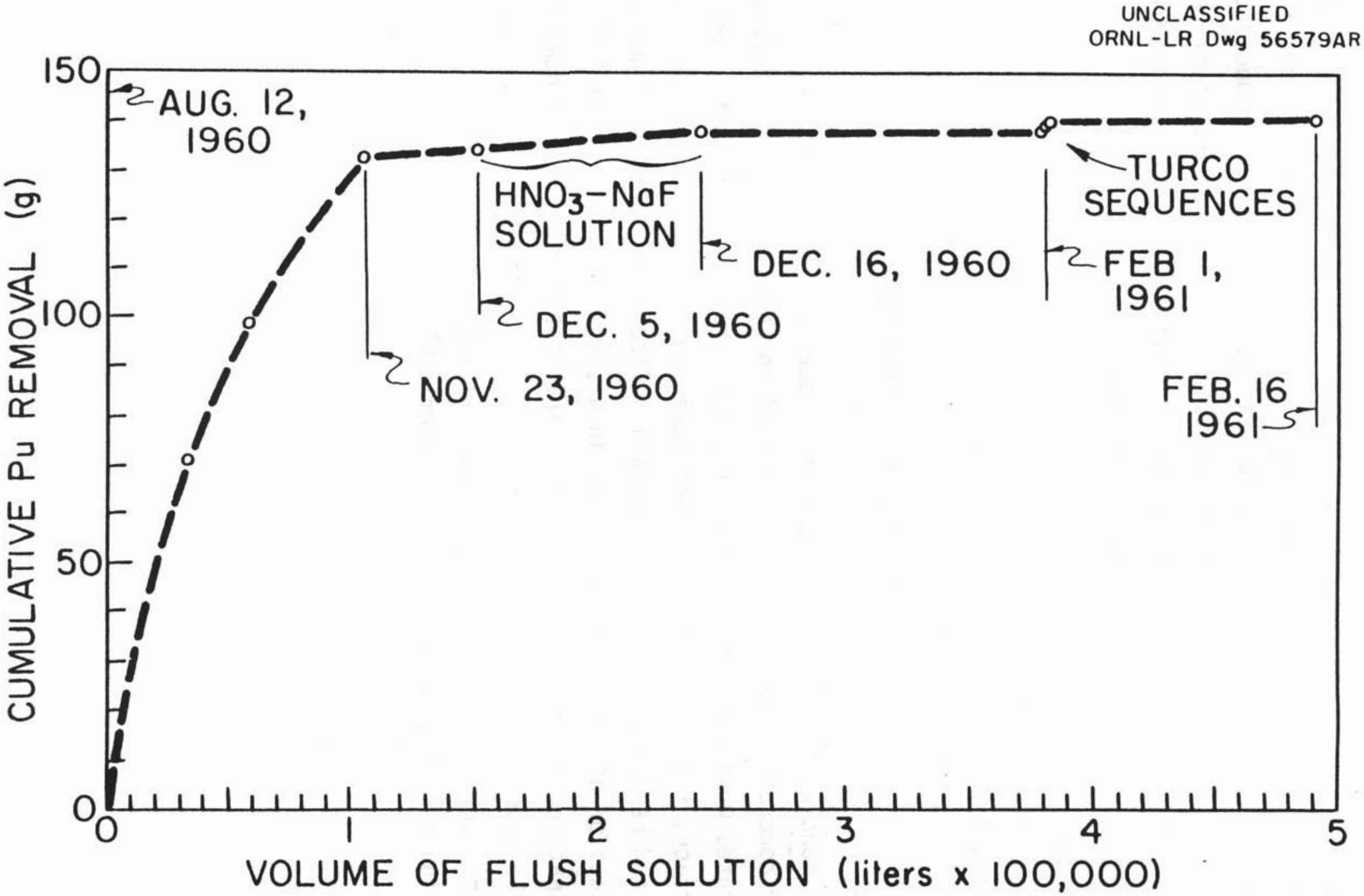

FIGURE 9. Plutonium Removal versus Volume of Flush Solution

concrete surfaces was reduced from 5 x 10^6 dis/min/100 cm^2 to 770 dis/min/100 cm^2. The stainless steel surfaces in the immediate area of the explosion, which originally smeared 6 x 10^7 dis/min/100 cm^2, were reduced to 2.8 x 10^3 dis/min/100 cm^2, but the direct readings on the stainless steel remained >7 x 10^5 dis/min/100 cm^2. One must conclude that covering concrete with stainless steel only complicates decontamination.

We have often used wet sandblasting to decontaminate concrete cell interiors after equipment removal. This is an effective method provided all equipment, piping, and conduit are removed.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, one must take every precaution to prevent the contamination of concrete; however, in the event of an accident, decontamination is facilitated when a concrete surface has been treated. Obviously, the smoother the surface, the easier it is to decontaminate. Walls should have a smooth finish and be painted with a hard enamel. Floors should be finished with fiberglass or at least an epoxy paint in areas with a high probability of contamination, and floors in areas that are less likely to be contaminated should be covered with vinyl sheet or tile. The use of exotic and expensive coverings such as stainless steel result in a much more costly initial installation and often result in a more formidable decontamination problem.

THREE MILE ISLAND CONCRETE DECONTAMINATION EXPERIENCE

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A discussion is presented of concrete decontamination needs, both past and future, resulting from the March 28, 1979 accident at the Three Mile Island Unit II power facility. Included therein is a description of initial facility conditions immediately following the accident, the immediate post accident recovery phase, long term activities for recovery of the Diesel Generator Building, Auxiliary Building, Fuel Hanlding Building and Service Building and initial planning for Reactor Building decontamination.

Discussion is included of specific decontamination projects associated with both coated and uncoated concrete surfaces. Identification of methods and equipment employed to achieve controlled access to facility components is presented. Source and level of contamination are identified to enable correlation to methods utilized.

INTRODUCTION

Within the first several hours following the March 28, 1979 accident at Three Mile Island, the volume of liquid waste generated from immediate recovery operations exceed the retention capacity of station tankage resulting in the flooding of the lower levels (281 EL) of the Auxiliary Building and Fuel Handling Building (Aux/FHB). The most common flow path experienced to the building general areas was via backed up floor drains emanating from the Auxiliary Building Sump. Most of this effluent was of a low activity level (<1.0 μc/ml) produced prior to the loss of fuel cladding integrity. Once fuel integrity was breached, although the excess effluent volume was then small, the activity contained therein (up to 100 μc/ml) resulted in significant deposition of activity to the general building environment.

Coincident with the foregoing, several small process tanks (Boric Acid Makeup Tank, Core Flood Makeup Tank) overflowed due to back-pressure from systems containing reactor coolant. Reactor coolant of medium (10 μc/ml) to high (100 μc/ml) activity thus replaced normally non-contaminated fluid in several process systems in turn contributing additional contaminents via vents and drains to the building's environment in areas not normally expected.

The balance of area contamination from initially spilled effluent included the lower level (281 EL) of both Diesel Generator Building bays (D/G), the containment annulus and the lower level (281 EL) of the Service Building (M-20 area).

In the immediate months following the accident, many areas and cubicles in the Aux/FHB remained unaccessable due to excessive levels of activity contained within piping systems. In most cases, the governing dose was I-131. Lack of accessability precluded the possibility of routine maintenance for systems integrity. Developing leaks from valve packing, flanges, pump seals and instrumentation, in some cases containing pure reactor coolant, continued to deposit additional contaminents on area floors, walls and components.

General floor areas of the Aux/FHB were coated with a three coat epoxy system with a one foot vertical splash shield on all walls. The D/G Building floors were uncoated but sealed with a single coat of silicone equivalent sealer. The balance of contaminated surfaces were both uncoated and unsealed.

Due to operating restrictions on specialized demineralizers used to clean up Aux/FHB liquid inventory, no chemical agents have been employed to date for any concrete surface decontamination.

DIESEL GENERATOR BUILDING

The D/G Building is connected to the Aux/FHB by a single personnel door located on the 281 EL. Spill effluent seepage under this door resulted in the introduction of contaminents to the building lower levels. Areas immediately adjacent to the access door were the most severly affected with average smearable measured a 3×10^6 DPM. This was due to the low velocity of the spill effluent as it seeped under the closed door. The balance of the lower level was typically in the 1×10^6 DPM range.

Immediately following the accident, the D/G Building was designated as the entry point to commence Aux/FHB decontamination. To properly stage the entry area, conventional scrubbing and wet vaccing was employed working in two passes from the D/G Building entrance towards the D/G - Aux/FHB access door. The effects a good seal coat were evidenced in that the two passes reduced the general area to less than 1000 DPM. Immediately adjacent to the access door, several passes over a three week period were needed to achieve levels less than 1000 DPM. Activity leaching was generally not a problem except in a small area adjacent to the access door. Here, herculite covering was employed to sweat the concrete over several weeks unitl such time as the area remained clean.

GENERAL FLOOR AREAS

Floor areas on the 281 EL Aux/FHB were initially flooded to a depth of three to six inches. After pump down, surface rinsing was not employed due to capacity limitations on water inventory storage. Accordingly, initial smearable levels exceeded 15 x 10^6 DPM. Waste level dose rates were typically one to three R/hr with hot spots measured at 5-10 R/hr emanating from surface contamination.

Commercial grade floor buffers and industrial grade wet vacs were employed for first pass decontamination efforts. All effluent was wet vacced direct to 17-H drums due to the aforementioned tankage restrictions, producing in some drums containing only several gallons, does rates up to 15 R/hr. Continued progress in the aforementioned manner over a six week period reduced general area smearable to approximately 500,000 DPM. Following initial first passes which were made with SCUBA units for respiratory protection, all subsequent decontamination efforts were made with supplied air hoods.

Concrete coatings encounted were generally in fair condition. Failure to repair final construction phase damage, to protect surface areas from penetration of hot welding slag and to ensure complete sealing of grouted pedestals permitted high beta activity contaminents to penetrate into the coating. In most open areas, fixed beta activity continues to be the governing dose factor.

Core bore analysis has indicated that although significant beta activity penetrated the paint layers, initial concrete sealing prior to coating protected much of the bare concrete from significant activity penetration. Test applications to date indicate no major concrete removal will be required to the Aux/FHB to complete facility decontamination. Scarification, etching, possible fixation and recoating are not comtemplated for final general area recovery schedule for late 1980.

Present 281 EL general area non-fixed conditions are less than 5000 DPM. Due to the aforementioned activity entrapment within the coating layers, considerable care is being exercised to maintain coating integrity during recovery phase construction activities. Failure to do so has on occasion liberated activity that has produced up to 500,000 DPM smearable.

ELEVATOR PIT

A combination personnel/freight elevator services the three floors of the Aux/FHB. Post accident spillage on 281 EL flooded the elevator pit to a depth of eight feet. Concrete wall surfaces on three sides were not finished or sealed after forms were stripped. The fourth wall is built of unsealed solid block. The pit floor received only a hand trowel finish after pour and also was not sealed. Both the walls and floor were exposed to liquid activity in the 30 μc/ml range for several days following which the pit was pumped. Approximately four inches of water were left over the floor to preclude airborne potential until decontamination could be started.

Approximately five weeks following the accident, the first phase of pit decontamination commenced consisting of installation of oil absorbent media to remove heavy grease and oil emitting from lubricated elevator cables, pulleys, cab rails and mounts. Dose rates at the elevator door looking down into the pit were 7 R/hr at the initial phase of decontamination thus necessitating hydro blasting to lower area levels for pit access. The need to return the elevator to service to support construction recovery efforts was critical and thus authorization was received to utilize 250 gallons for initial dose rate reduction. After initial blasting with extended probes and pumping of the effluent through a disposable filter and thence to a floor drain, levels at the door were reduced to 1 R/hr. With the aforementioned restriction on chemical usage and lack of additional waste liquid inventory, three subsequent pit entries were made with decontamination efforts limited to hand scrubbing and wet vac removal of the effluent. These activities lowered the area dose rate at the door to 300 mr/hr, this still being an unacceptable level to return the elevator to service. At this point, general area in the cab when lowered to the 281 EL was approximately 400 to 700 mr/hr.

Over the next several days, surface smearable conditions escalated substantially between cleanings indicating the presence of significant leaching, particularly from the walls. Typical one square foot smears that measure 5 mr/hr after cleaning were duplicated 48 hours later and produced levels up to 100 mr/hr on the swipe cloth. At this point, it was evident that continued hand scrubbing on a periodic basis to clean leachate without the benefit of chemical penetrant to lift activity out to the surface would not lower cab dose rates on a time scale consistant with the need to return the elevator to service. Additionally, concern was evidenced that the vertical movement of the cab up the shaft would serve as an eductor to liberate airborned activity from the leachate.

Restricting time schedule thus necessitated the installation of 1/2 inch lead sheet on the floor and walls and sealing of the entire surface with a heavy coating of strippable paint. Such actions reduced the cab dose rate to approximately 25 mr/hr and the elevator was returned to service.

Subsequent core bore analysis indicated activity had penetrated approximately 0.125 inches (0.32 cm) into both the block wall and the trowel finished floor. Correspondingly, the remaining three walls that received no finish work of any kind after form removal had activity penetration to a depth of 0.8 inches (2.0 cm). It is anticipated that some concrete removal will be required coupled with chemical etching to effect complete recovery of the elevator pit. This activity is now scheduled for early 1981.

CONTAINMENT ANNULUS

Located on the 281 EL between the Auxiliary Building and the Reactor Building is a normally unattended area housing miscellaneous reactor coolant auxiliary piping, the station seismometer, various electrical penetrations and access to some Reactor Building post tensioning components. The area was never sealed or coated. Likewise, floor areas were covered with substantial concrete splatter from construction phase containment pours. A dust and dirt layer up to 0.5 inches (1.25 cm) covered the entire floor area. Two floor drains in the annulus are tied into the building sump floor drain system and thus like other areas on 281 EL Aux/FHB, several inches of contaminated liquid covered the area for several days following the accident.

Initial entries to the area due to dose rate restrictions were restricted until late September 1979. At the time, waste liquid inventory remained critical and hydro blasting could not be utilized. Four separate entries were made to scrub and wet vac the area. General area dose rates at start were 1-3 R/hr with hot spots of 5 R/hr. Beta ranged from 2 Rad to 10 Rad. Upon completion of four decontamination passes, the gamma was reduced to approximately 200-300 mr/hr. Conversely little reduction in beta was noted thus indicating significant fission product activity had penetrated and adhered to the exceedingly rough concrete surface. Physical removal of some concrete spatter revealed a high beta concentration.

To continue recovery efforts in an expeditious manner, strippable coating was applied to seal the floor surfaces and minimize continued contribution of airborne contaminents. As with other previously discussed concrete areas, final decontamination of the containment annulus has been deferred until late 1980. At that time, due to its unusual rough texture, it is anticipated that grinding, diamond cutting and/or scarification will be necessary to remove remaining fixed contaminents. The use of air hammers for gross concrete removal is not contemplated at this time.

SEAL INJECTION VALVE ROOM

The Seal Injection Valve Room (SIVR) is located on the 281 EL and like other areas previously discussed, was flooded immediately following the accident. The room primarily contains piping and valves to provide reactor coolant pump seal injection. Additional piping includes some portions of the reactor makeup system. Much of the fluids contained within these systems became highly contaminated following the accident from loss of fuel cladding integrity.

Just prior to the accident, the entire floor area was skim coated with a fresh concrete pour to a depth of two inches (5.0 cm) to level out grade and pitch to floor drains. This new pour was uncoated and unsealed at the time of the accident. Initial flooding of the surface coupled with major leakage of reactor coolant from several fittings on a seal injection flow instrument rack produced contact dose rates on the floor of 550 R/hr and 5900 Rad beta, much of this activity emanating from the buildup of gross boron deposits in the immediate leak area. Boron buildup was noted to have plugged the cubicle floor drain.

To commence cubicle recovery, remote hydro blasting was employed to open the floor drain and clean the floor area of the access corridor which initially measured 50 to 70 R/hr at waist level. This action was taken to permit personnel entry to the end of the access corridor for visual observation of general cubicle conditions.

Reducing the access corridor to 2 R/hr (most of the corridor was coated and sealed, not covered by a skim coat of unfinished concrete) permitted cubicle entry which determined the presence of gross boron over 60% of the floor area. Prior hydro blasting of the access corridor and floor drain having produced poor air conditions in the immediate work area (1×10^{-7} μc/cc) it was elected to commence dissolvement of the remaining boron deposits and spill particulate using a remote hot water rinse at very low flow rates. Conventional lawn sprinklers installed from the access corridor and extended lances from access ports on the floor above (305 EL) were employed over a three day period to dissolve essentially all residue and transport the activity to the floor drain system. All activities were monitored via closed circuit television.

Subsequent surveys of floor dose rates verified that significant activity had penetrated the two inch uncoated skim coat in the cubicle proper. With all visible evidence of particulate removed, contact dose rates remained at 200 R/hr. Some concern has been evicenced for the chemical interaction of Strontium with the calcium in the concrete thus contributing to the retained activity. Present plans call for eventual movement into the cubicle on a piece meal basis using portable shielding of both solid block and sheet lead. Heavy rubber mats will be utilized to contain beta dose emanating from the floor. Cutting and removal of the entire skim coat in individual small sections will then proceed requiring numerous entries to effect complete contaminent removal.

SUMMARY

1. Although spilled effluent activity levels at times approached 100 μc/ml, seal coating of general areas prior to final painting has been demonstrated to very effective in minimizing activity penetration of concrete slabs in the general floor and cubicle areas.

2. Untreated, but trowel finished, concrete areas were generally penetrated to a depth of 0.250 inches (0.625 cm) and will be recovered via use of chemical etching without extensive surface removal.

3. Untreated and non-troweled surfaces experienced contaminent penetration to a depth of up to 0.8 inches (2.0 cm). Surface removal via mechanical means followed by chemical etching will be required to complete decontamination operations.

4. Isotopic distribution of concrete contaminents immediately following the accident primarily consisted of Iodine 131. Following decay of the iodine, Cesium 134 and 137 along with Strontium 89 became governing isotopes. Due to the short operating history of the station, only trace amounts of Cobalt have been detected in the contaminents.

5. Limitations on the use of chemicals to surface etch activity (protection of sensitive demineralizers) and coatings/sealants to temporary fix activity (potential fume damage to building charcoal ventilation systems) significantly affected the ability to completely decontaminate affected concrete surfaces. For future planning, all facilities should incorporate specialized chemical authorization for decontamination use on concrete in existing operational procedures thus negating the delays experienced at Three Mile Island.

6. Planning for initial Reactor Building decontamination has incorporated the lessons learned in the Aux/FHB relative to cleaning of severely contaminated concrete surfaces. All similar areas in the containment have been identified, marked on appropriate drawings and have been assigned a "method" for removal or fixation of expected contaminents.

   Qualification and test programs are now underway to establish criteria and equipment needs for both coated and uncoated surfaces. Several of the major large surfaces such as the uncoated hollow block stairwell enclosure will be test qualified prior to initial containment entry.

The significance of long term submergence of the lower elevation floor and wall coating has been evaluated based upon observed conditions of pedestals and pump bases in the Aux/FHB. Coating failure is anticipated in several locations thus prompting the development of programs for rapid coating removal where required to lower area dose from entrapped contaminents.

7. To facilitate recovery of known concrete problem areas in the Reactor Building, time versus dose rate plots are being maintained of corresponding conditions in Aux/FHB. Data obtained therein, particularly that from fission product contaminated areas such as the Seal Injection cubicle will be utilized to schedule decontamination programs according to removal or fixation with shielding as required consistent with the need to reach the "ready for reconstruction" phase as soon as possible.

A SUMMARY REVIEW OF MOUND FACILITY'S EXPERIENCE IN DECONTAMINATION OF CONCRETE

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Mound Facility has effectively decontaminated and/or decommissioned four major facilities since 1949 and is currently in the process of partially decontaminating two more facilities. In addition, many minor areas have been decontaminated and/or decommissioned. Many of these projects involved the decontamination of concrete surfaces.

Most of the current concrete decontamination work involves surfaces that are contaminated with plutonium-238. Approximately 60,000 sq. ft of concrete floors will have to be decontaminated in Mound's current Decontamination and Decommissioning (D&D) Project. Although most of these surfaces are partially protected by a barrier (tile or paint), contaminated water and acid have penetrated these barriers.

The technique for decontaminating these floors is as follows:

- o Gross decontamination of room
- o Removal of tile floor barrier
- o Monitoring of floor contamination
- o Removal of higher contamination spots
- o Installation of temporary floor contamination barrier
- o Final decontamination of room

*Mound Facility is operated by Monsanto Research Corporation for the U.S. Department of Energy under Contract No. DE-AC04-76-DP00053.

- o Decontamination of remaining floor contamination
- o Final monitoring of floor
- o Resurfacing of floor

The initial cleaning of the floor involves standard water and detergent. Acids are not used in cleaning as they tend to drive the contamination deeper into the concrete surface.

Next, the floor tile is manually removed inside a temporary enclosure under negative and filtered ventilation. Finally, layers of contaminated concrete are mechanically removed inside the ventilated enclosure. The suspected depth and surface area of contamination determines the type of mechanical tool used.

In summary, several generic methods of concrete decontamination can be utilized:

Chemical	--	water, detergent, acids, paint remover, strippable paint, etc.
Rotary	--	sanders, grinders, scarifiers, etc.
Impact	--	pressure washers (hydrolasers), particle blasters, scabblers, needlers, spallers, paving and rock breakers, ram hoes, etc.

The particular method used depends on several factors:

- o surface and area involved
- o depth of contamination
- o cost and availability of equipment
- o usage safety and radiological control
- o waste generated

INTRODUCTION

Mound Facility has four buildings that have been used for the past 20 years for plutonium-238 programs, primarily production of heat sources. These facilities have been excessed and are undergoing Decontamination and Decommissioning (D&D) Operations. Approximately 60,000 sq. ft of concrete floors and 125,000 sq. ft of concrete and/or concrete block walls will require decontamination. Hydrolaser (pressure washing), chemical, pavement breaker and Vacu-Blast decontamination techniques have been practiced the past several years but not within a "conditional or unconditional release" D&D mode. Consequently, exact data have not been collected. Thus, most data in this paper, except for contamination levels and equipment costs, has been estimated.

HYDROLASER (PRESSURE WASHER) DECONTAMINATION

Hydrolasers, commonly called "pressure washers" have been used for several years at Mound Facility for decontamination of a variety of surfaces which includes concrete, metals, equipment, and piping. The single largest effort to date was the D&D of the Special Metallurgical (SM) Building (Figure 1), a plutonium-238 fuel fabrication and recovery facility, work began in 1968 and concluded in September 1972. Five hundred and eighty-five feet of gloveboxes, all interior walls, a drop ceiling and associated support equipment were removed, leaving a hollow shell with 13,000 sq. ft of concrete floor, 12-ft tall metal walls and a metal ceiling. All surfaces were decontaminated via pressure washing and/or manual scrubbing followed by pressure washing.

Pressure washing was chosen because of a critical need for speed in removing gross alpha contamination. Average contamination levels were greater than 2 million counts per minute with several "hot spots". The pressure washer unit chosen was capable of 10,000 psi at 12 gal/min; however, an average pressure of 7,000 psi using a fan-shaped nozzle was chosen for decontamination of the concrete floor. Figure 2 shows a general flowsheet of the operation including processing of the wastewater. A crew of five men was used for pressure washing: one to operate the gun to perform the actual cleaning; three to direct the water by "sweeping" to the building drains that were connected to a collection and storage tank; and one to maintain and operate the remotely located control unit. This crew was able to clean 300-400 sq. ft per 8-hr shift that included two entries per shift. Each crew member was dressed in a bubblesuit with supplied air. The gun was fitted with a deadman switch for safety purposes and a padded bar that was placed against the shoulder. The nozzle was positioned approximately 2 in. from the concrete surface at a slight angle to force the water forward and away from the operator and cleaned surfaces. Wastewater from the storage tank was transferred to an existing waste disposal facility for processing. Approximately 99% of the water was completely decontaminated; the remainder was packaged as contaminated waste.

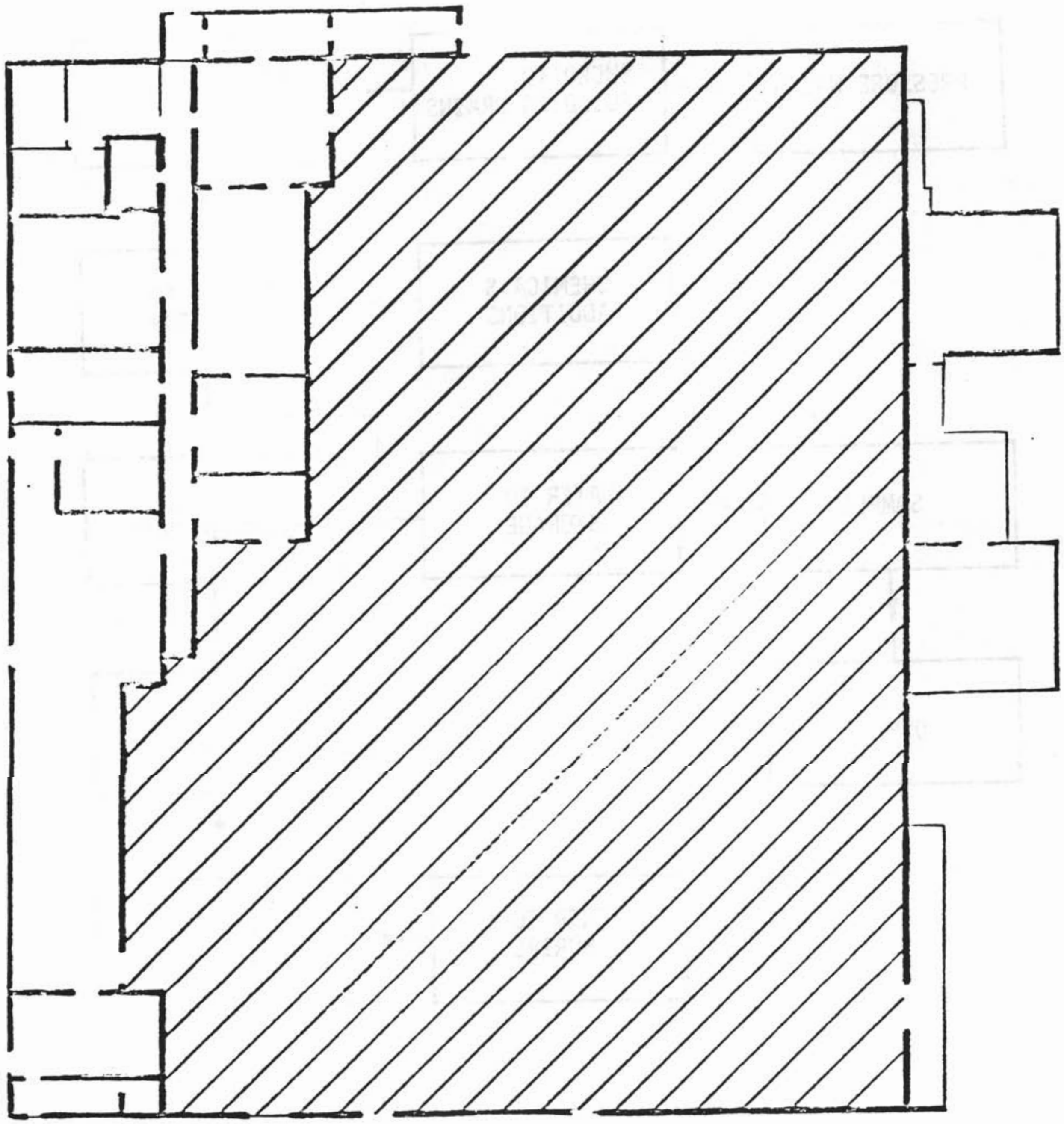

FIGURE 1. FLOOR PLAN OF SM BUILDING
Shaded Areas Indicate Decontaminated Concrete

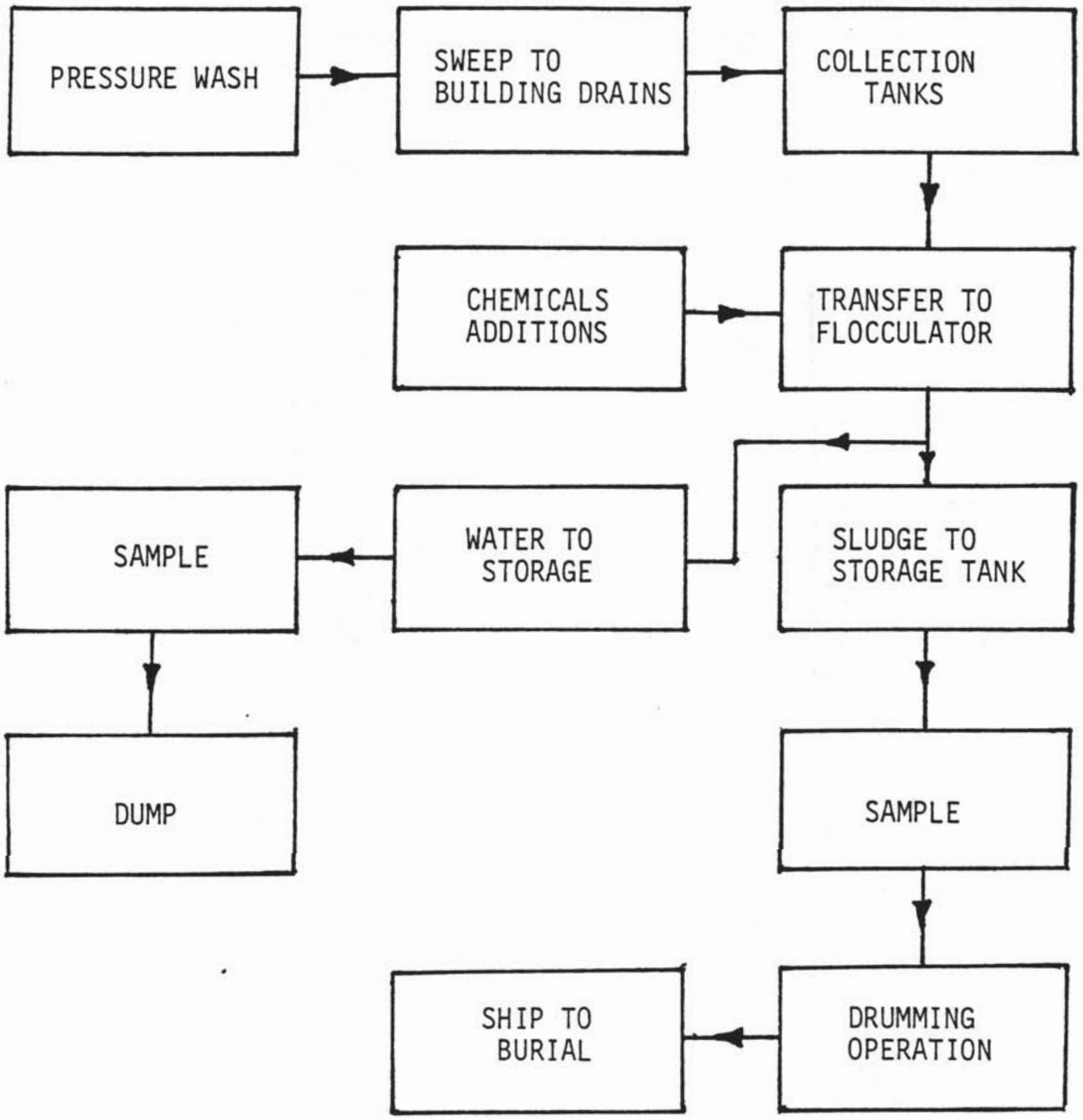

FIGURE 2. GENERAL FLOWSHEET OF PRESSURE AND WATER TREATMENT PROCESS

Pressure washing at 7,000 psi using a fan nozzle will not decontaminate concrete surfaces to conditional or unconditional release levels. The average wipe level after pressure washing was 50,000 cpm. In an attempt to further reduce contamination, the floor was scrubbed with nitric acid, hydrochloric acid, Vani-SOL, and Calci-solve followed by pressure washing. This procedure reduced the contamination level to 10,000 cpm/100 sq. cm direct reading and 2,000 cpm swipeable as of October 1973; it had not significantly changed as of May 1980. The surface was cleaned four times to obtain these levels. Assuming 350 sq. ft decontaminated per shift, the total cost of the project is estimated in Table 1.

TABLE 1. Cost for Pressure Washing the SM Facility Concrete Floor

Total Mandays required	300
Total Cost of Processing Water	$ 5,594
Cost of Hydrolaser	$35,000
Bubblesuits, airhose, handgloves, misc.	$12,000

Advantages of decontamination via pressure washing are:

- Excellent for rapid decontamination of gross alpha concentration
- Equipment contamination is minimal
- Excellent for unorthodox geometries
- No airborne contamination generated
- No significant setup time

Disadvantages of decontamination via pressure washing:

- High pressure is a potential hazard for personal injury
- Large volumes of water that require collection and disposal
- Operators are limited to 30 min per 4 hr
- Alpha particles are probably driven farther into the concrete
- Conditional and unconditional release levels cannot be obtained

PAVEMENT BREAKER

Several small concrete decontamination projects have been completed using a pavement breaker with compressed air. A 6-in. thick concrete pad covered with a 2-in. concrete cap and topped with floor tile totaling 960 sq. ft was recently completed (R143, 145, 147). Floor tile was removed exposing the 2-in. concrete cap that remained covered with black mastic. Concrete was broken within a plastic enclosure in such a manner that resulting pieces landed on unbroken concrete. Larger pieces were manually placed in a drum or plywood box followed by shoveling and vacuuming of small particles and dust.

Contamination control while using the pavement breaker is accomplished inside a plastic enclosure measuring 3.5 ft W x 8 ft L x 7 ft H. Enclosures 10 and 12 ft long also are available. Sleeves are provided for insertion of 0.5-in. diam aluminum rods that are bolted together to form a supporting framework. Negative and filtered ventilation is maintained inside the tent via the use of one or more shop vacuum sweepers fitted with absolute filters or a unitized exhauster built in-house that is adjustable from 100 to 500 cfm compared to 25 cfm per vacuum sweeper. Contamination levels determine the amount of airflow that is used. After an area is decontaminated the enclosure is moved to an adjacent area until the project is completed. The floor surface was marked in 2.5-ft squares and the highest cpm reading for each individual square was recorded. Table 2 illustrates the number of 2.5 ft squares within the respective contamination ranges. Direct readings taken after the removal of the cap were nondetectable except for approximately 2 sq. ft with a reading of 2,000 cpm that was removed by additional chipping. Air level within the enclosure averaged 103 cpm for a 1-hr sample. The mastic that remained embedded in the concrete after removal of the floor tile is credited with "fixing" the alpha particles since previous experience indicated higher quantities of airborne contamination could be expected. The total cost of the project is summarized in Table 3.

TABLE 2. R143/145/147 Contamination Levels Before Concrete Cap Removal -- Direct Readings

Counts/min (x1000)	No. of 2.5-ft^2 Sections Within Counting Range
0-50	67
50-100	23
100-200	44
200-300	6
300-400	13
400-500	8
500-1000	20
1000-1500	14
$>$ 1500	5

TABLE 3. Cost of R143/145/147 Concrete Cap Removal

COST	
Total Manhours	200
Total Number of TRU 55-gal Drums	120
Total Plywood boxes 4x2x7 ft	1
Cost of Bubblesuits	$1,200
Cost of Pavement Breaker, Tent, Misc.	$1,200

VACU-BLAST® DECONTAMINATION

An off-the-shelf Utility Vacu-Blaster has been used for concrete decontamination. This Utility Vacu-Blaster is a complete blast system consisting of a direct pressure blast generator, blast gun, pneumatic recovery system, abrasive reclaimer, dust collector, and vacuum pump. The system is designed for operation from a source of clean, dry, compressed air at 70 to 100 psi at 90 cpm (Figure 3). Figure 3, a simplified diagram, shows the path by which compressed air forces the abrasive from a pressure generator (A) through a hose (B) to the blast nozzle and inner cone of the gun (C). Vacuum draws the cleanings and spent abrasive through a hose (D) to a reclaimer (E) where the abrasive is air washed and returned to (A). Cleanings are drawn into the cyclone (F) where they are stored in a jar (G). A HEPA filter cleans the air before it is exhausted. All cleanings and abrasives are retained in the completely enclosed system. The Vacu-Blaster is controlled by an air valve (H) at the gun, that actuates a diaphragm air valve (I) through an air hose (J). G-25 or G-50 grit is recommended for use on concrete floors.

The gun is moved across the floor at point blank range and cleans a *2-in. wide path for the Model A-2 Blaster. The depth of concrete removed* is directly proportional to the speed of this movement.

Activation of the air valve for Model A-2 Blaster provides for a continuous 12-min blast. After de-activation of the air valve, the abrasive is automatically regenerated in less than one minute. Large models are now available with longer blast times. For example, the Vacu-Blast supplier in Ohio has indicated that a Super Utility Model is capable of cleaning more than 400 sq. ft per day to a depth of 3 to 4 mils using G-25 to G-50 chilled iron grit. Approximately 98% of the grit and dust is reclaimed with a 5% per hour grit loss. The Super Utility Model costs $7,600; the grit costs $400/ton for the G-25 to G-50.

The small Model A-2 Utility Blaster has been used at Mound for plutonium-238 spot contamination for 6 yr. Unfortunately, data was not collected concerning removal rates and costs. However, in 1976, a

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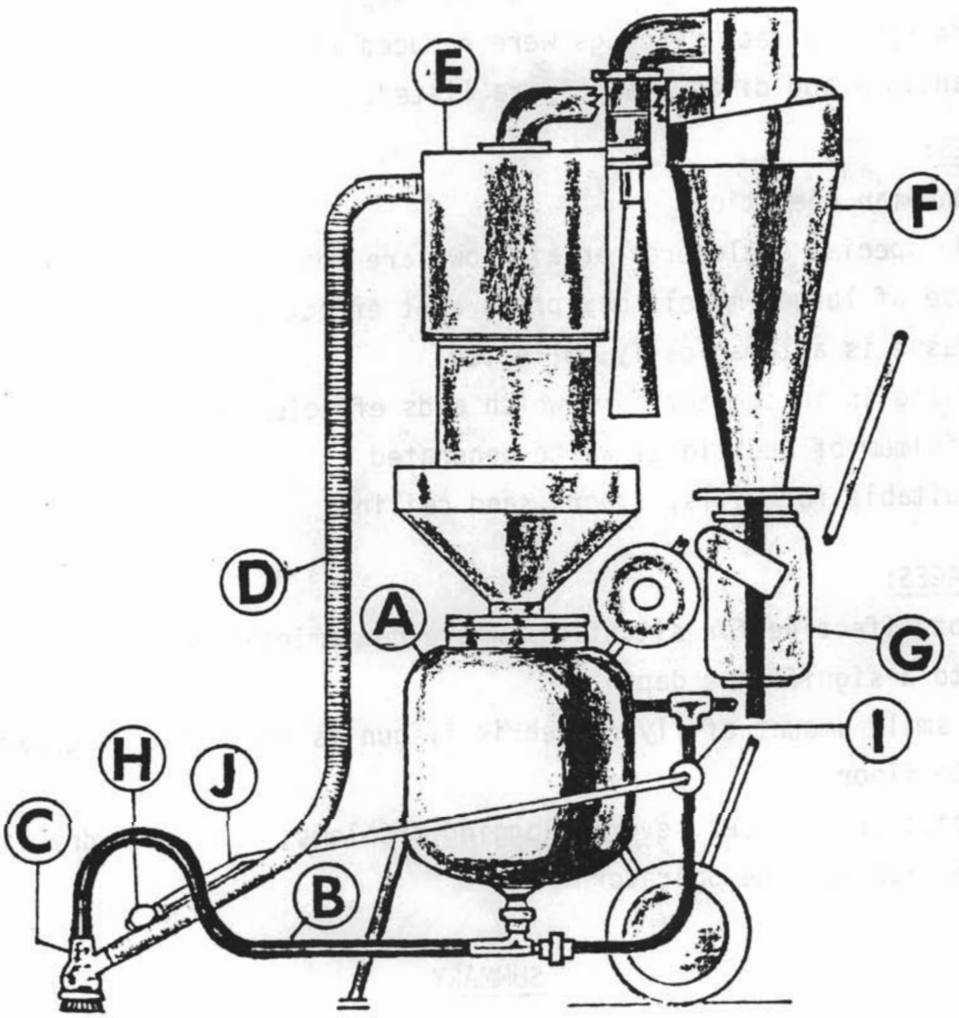

FIGURE 3: SIMPLIFIED DIAGRAM OF UTILITY VACUUM BLASTER

thorium contaminated concrete floor (3650 sq. ft) was decontaminated using the Vacu-Blaster. The operators estimated a decontamination rate of 15 to 20 sq. ft per 8-hr shift. Average swipe levels were reduced from 3500 to 44 cpm. Direct readings were reduced from 500,000 to 13,800 cpm. Some advantages and disadvantages are listed.

ADVANTAGES:

- One-man operation
- No special enclosures or airflows are required
- Use of larger models may prove cost effective
- Waste is automatically collected
- Waste is in compact form which aids efficient packaging
- Minimum of additional waste generated
- Suitable for walls, floors, and ceilings

DISADVANTAGES:

- Not effective for situations where contamination has penetrated to a significant depth
- A small amount of flying debris if gun is not maintained parallel to floor
- Moist grit causes severe clogging problems, must have dry air
- Tedious for one operator

SUMMARY

Chemical cleaning and/or pressure washing of concrete floors is useful for decontamination of gross quantities of alpha. Levels below 2000 cpm are difficult to obtain even when used in combination with mechanical scrubbing. Pressure washing is not feasible unless a collection and processing system is readily available.

Use of an off-the-shelf Utility Vacu-Blaster appears to have more advantages than disadvantages except in situations where contamination has penetrated to significant depths. Their most significant use may prove to be for walls rather than floors. Utility VACU-BLASTERS are currently in use at four nuclear facilities in Ohio.

Finally, two additional off-the-shelf tools will be evaluated -- scabblers and scarifying machines. Scarifying machines are available from the Marindus Company of Englewood, New Jersey. Three models are available: FR-100; FR-200, and FR-300. A rotating drum is fitted with flails. Vacuum pickup attachments are available. With pneumatic operation the FR-100 is capable of removing, in one pass, concrete 0.062 in. deep by 4.25 in. wide. The remaining two models are available with electric, gasoline, or pneumatic motors. The FR-200 carves a path 0.062 in. deep by 8 in. wide, and the FR-300, a path 0.125 in. deep by 12 in. wide, per manufacturer's specification. Respective costs, including flails, are $1000, $2500, and $4000.

HIGH-PRESSURE WATER JET APPLICATIONS IN RADIOACTIVELY CONTAMINATED FACILITIES

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High pressure water jetting is a new tool, which significantly increases productivity while meeting the environmental regulations, for effective removal of radioactively contaminated concrete.

A field study program was undertaken to assess the applicability of continuous jets for concrete removal. Performance curves were generated for concrete and reinforced concrete. Jet pressures ranged from 70 to 275 MPa (10 to 40 ksi). Nozzle diameters of 0.4 and 0.5 mm (0.016 and 0.020 in.) with double orifices were studied with linear traversing speeds from 2.54 to 15 cm/sec (1 to 6 ips) and nozzle rotational speeds from 300 to 900 rpm.

INTRODUCTION

Nuclear power plants and facilities are proteckted by thick concrete walls. When these failities are to be deactivated, sections of these thick concrete walls have to be removed and buried because of radioactive contamination. If the contaminated portion of concrete, measuring 1 to 2 in. thick, can be removed adequately, the rest of the concrete walls can be handled as non-contaminated concrete, which can be removed easily by conventional demolition techniques. New methods, which can significantly increase productivity while meeting the environmental regulations, are required for effective removal of the contaminated concrete.

High-pressure jet cutting systems are tools which offer the promise of meeting the performance category, while also meeting the environmental restrictions. Recently, IITRI completed a program for the National Science Foundation involving laboratory and field studies of using the water jet technology for cutting concrete. This program showed the feasibility of using the water jet to remove three to four inches of surface concrete in a rapid, environmentally safe manner.

RESEARCH PROGRAM

A two-task work plan was followed to achieve the program objective.

Task 1 - Design and Fabrication of Traversing Mechanism

In this task, the design and fabrication of the traversing mechanism for the water jet unit was performed in the IITRI laboratory. This phase included: (1) the design and fabrication of the traversing system hody; (2) the design and fabrication of the tower which carries the swivel, the rotating tube with a dual nozzle, and the power system for the nozzle rotation; and (3) the design and installation of a step motor system for the incremental feeding of the dual nozzle into the concrete. Figures 1 and 2 show the traversing mechanism. The platform which carries the tower and the dual nozzle is capable of traveling back and forth (x-direction at a speed variable from zero to 15.25 cm/sec (6 ips). A DC motor is connected by driving a chain to two ball screws installed

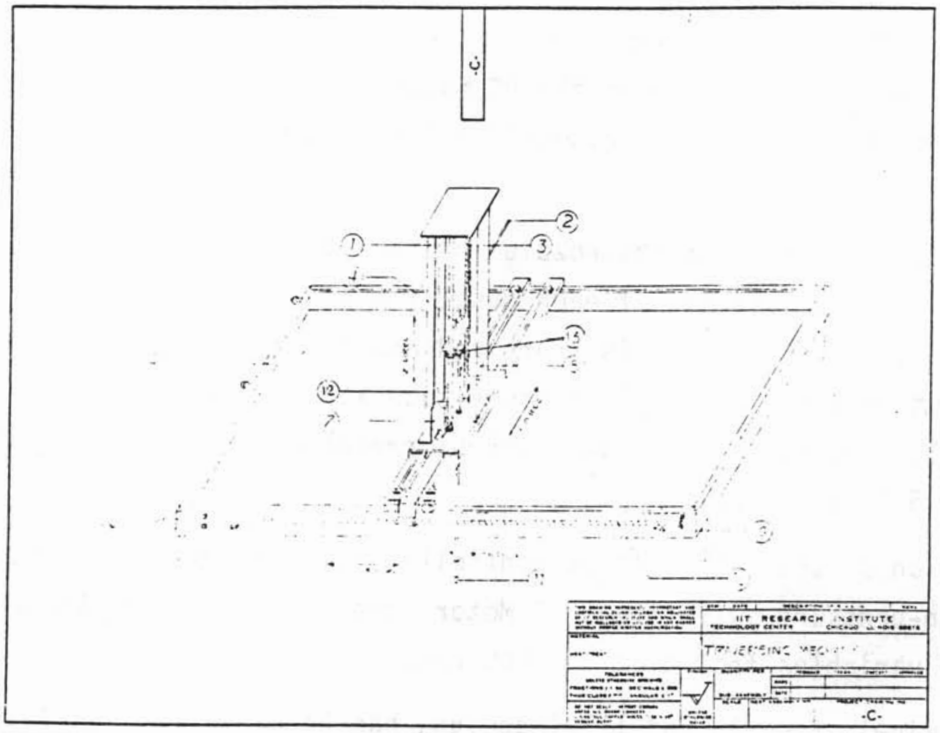

Figure 1 Schematic of the Traversing Mechanism

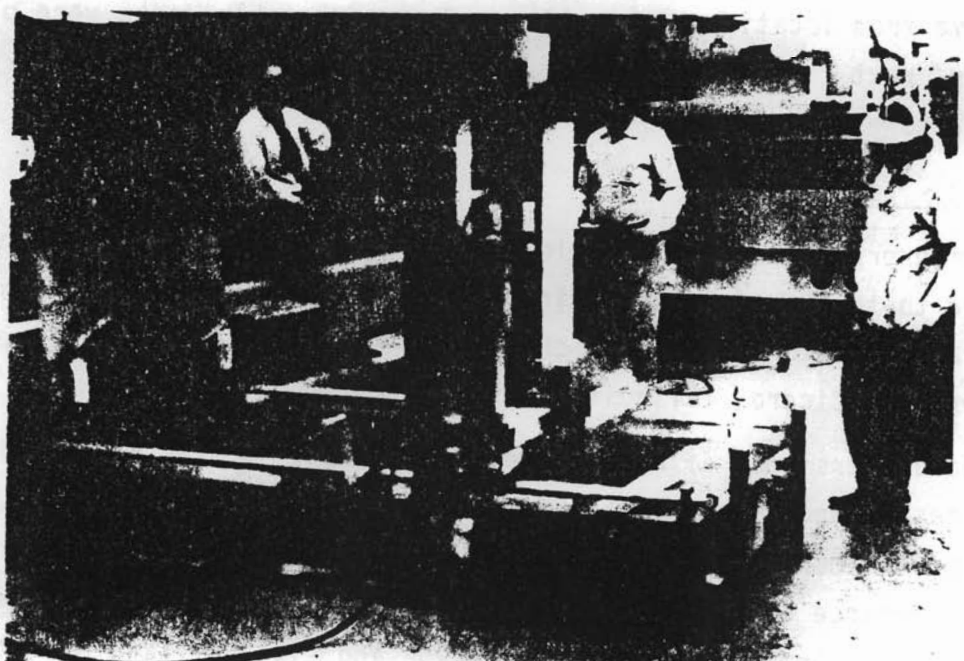

Figure 2 Traversing Mechanism

on each side of the main frame (Fig. 1), and the two ball screw nuts are attached to the platform. When the ball screws turn, the platform moves back and forth. The traversing distance is adjusted by two limit switched which activate the reversing mechanism of the DC motor. The left and right motion (y-direction) of the platform is accomplished by rotating a ball screw manually (Fig. 1).

The feeding motion of the nozzle into the concrete is achieved by a step motor. With the completion of each pass, the step motor. With the completion of each pass, the step motor is energized and rotates a 1 in. screw with a non-rotating nut that has the high-pressure tube attached along with the dual nozzle, Fig. 1. The feeding distance can be preset and can be varied from zero to 3.82 cm (1.5 in.) per pass.

Rotation of the dual nozzles controlled by connecting the rotating segment of the high-pressure swivel to a DC Motor, capable of turning the dual nozzle with speed variables from zero to 1000 rpm.

The swivel, Fig. 3, and IITRI design, has been tested for 30 hr continuously at 310 MN/m^2 (45,000 psi) water pressure and 600 rpm without leakage indicated. Four wheels, one on each corner of the traversing mechanism, make it easy to move from location to location. Four adjustable jacks were placed on each corner, next to the wheels, for correcting and adjusting the perpendicularity of the tower.

<u>Task 2 - Field Test</u>

The high-pressure water jet field unit, with the traversing mechanism, was transported to the testing area, with the cooperation of the Illinois Department of Transportation (I-DOT) which was the bridge deck on 26th Street and Cicero Avenue in Cicero, Illinois.

The parameters that affect cutting of pavement surface were optimized during this task. Specifically, the jet parameters (jet pressure, traversing speed, number of nozzles, nozzle rotational speed) were varied to determine the optimum performance of the water jet. Tests were performed on concrete blocks with compressive strength and aggregate type and size similar to that for concrete used in highways. The nozzle geometry was of the venturi type (i.e.,

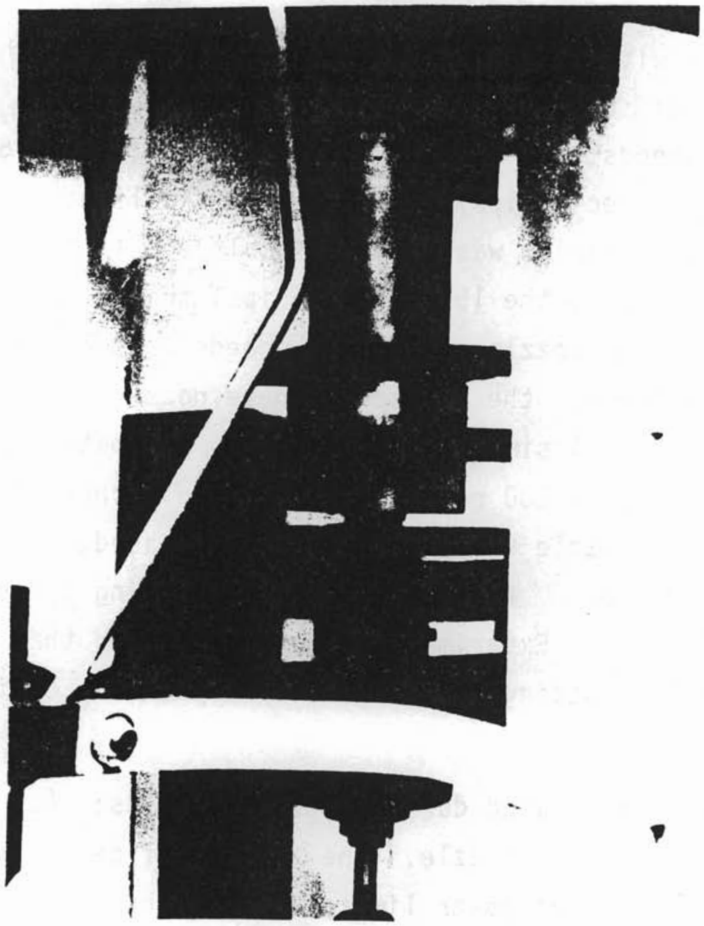

Figure 3 Swivel

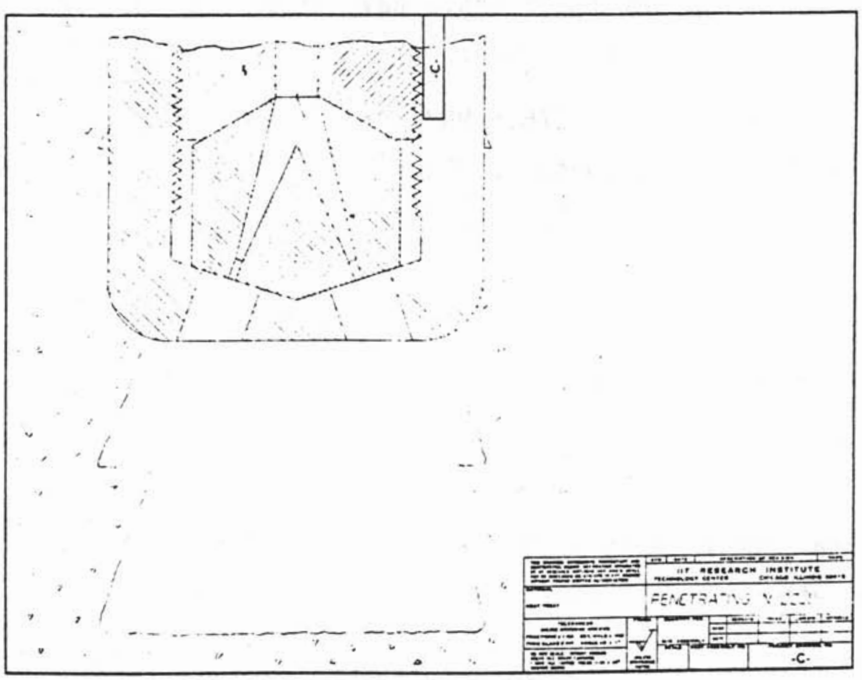

Figure 4 Dual Nozzle

circular cross-section with L/P ratio of 2.0 to 3.0), Fig 4. Three jet pressures were investigated: 68.9, 206.7, and 275.6 MN/m^2 (10, 30, and 40 ksi); and three traversing speeds: 5, 10, and 15.2 cm/sec (2,4, and 6 ips). At high traversing speeds, 15 cm/sec (6 ips), reversing of the linear motion of the motion of the traversing mechanism was very difficult due to the high speed of the system. For this reason, the 15 cm/sec (6 ips) traversing speed was lowered to 12.7 cm/sec. Three nozzle rotational speeds were chosen for investigation: 200, 500, and 700 rpm. the choice of these nozzle rotational speeds was based on a computer graphical simulation of the two jet patterns shown in Figs. 5 and 6. At low speed, i.e., 200 rpm, a small area of concrete was removed as shown in Fig. 5. As the nozzle rotational speed increased, the area of concrete removal was increased. Figure 6 shows the cutting pattern with a 400 rpm nozzle rotational speed. Experimental work determined that the rotational speed does not affect the cutting rate significantly if one caries the speed from 400 to 700 rpm.

Two nozzles were investigated during the field tests: (a) a dual-orifice nozzle, and (b) a three-orifice nozzle. The three-orifice was tested only at the low jet pressure because of power limitations of the field unit. Two orifice diameters were also investigated: (a) 0.4 mm (0.016 in) and (b) 0.5 mm (0.020 in.).

The results of the series field tests have shown that for the present power, 82 kW (110 hp), of the field unit, the optimum parameters are:

- Jet pressure, 276.5 MN/m^2 (40,000 psi)
- Traversing speed, 5.0 cm/sec (2 ips)
- Number of nozzles, 2 (dual)
- Nozzle orifice diameter, 0.5 mm (0.020 in.)
- Nozzle rotational speed, 600 rpm.

The most important aspect of this program was the optimization of partial depth repair of concrete bridge decks, which is similar to the radioactively contaminated concrete of the nuclear planes.

Partial depth repair tests were performed with the objective of removing the surface concrete. The periphery of the patch was marked by Illinois De-

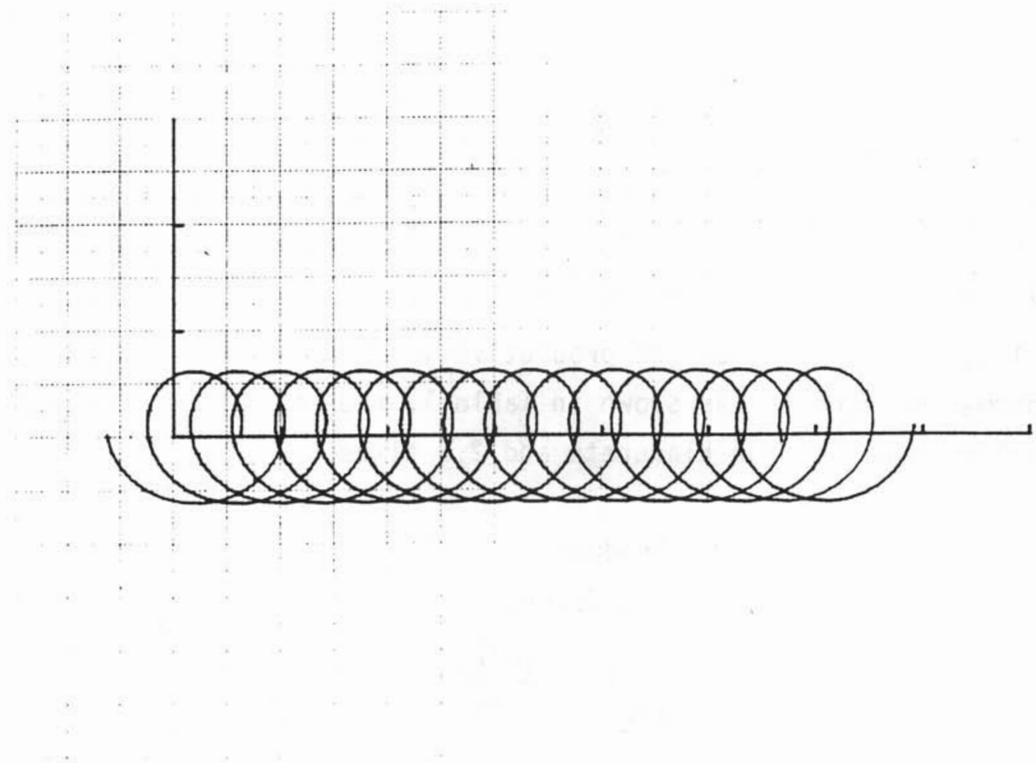

Figure 5 Cutting Patterns with 200 rpm and 2 ips

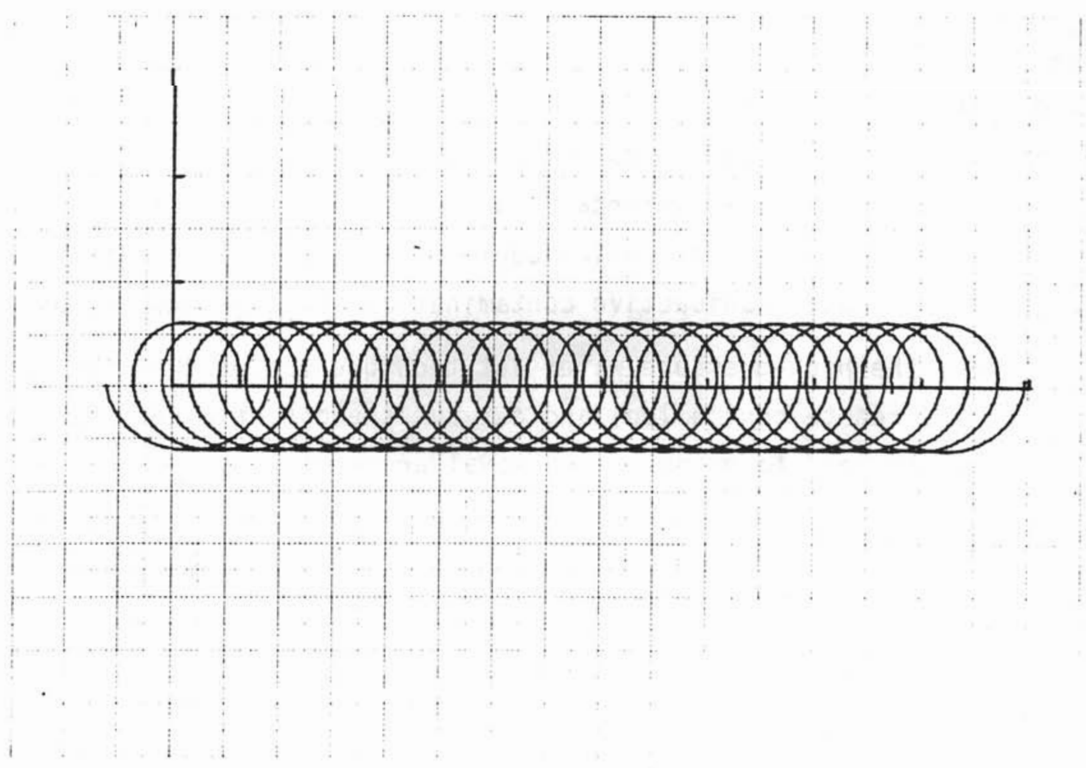

Figure 6 Cutting Patterns with 400 rpm and 2 ips

partment of Transportation personnel after examination of the concrete using an ultrasonic test method. The shape of the patch periphery was an orthogonal parallelogram, and the patch depths were 6.3 to 7.6 cm (2.5 to 3 in.) 127 cm (0.5 in.) below the reinforced bars as shown in Fig. 7. Productivity was 1.13 m^2 (12.25 ft^2) x 6.35 cm (2.5 in.) depth of surface removed per hour of work.

Table 1 compares the water jet productivity with conventional methods, i.e., jackhammer Klarcrete. As shown in Table 1, the water jet productivity is two times higher than that for Klarcrete and 2.5 times that for the jackhammer.

TABLE 1. Productivity of Water Jet VS. Coventional Methods

	Productivity		Power	
Method	m^2/hr	(ft^2/hr)	kW	hp
Water Jet	1.13	(12.25)	82	110
Klarcrete	0.57	(6.2)	193	260
Jackhammer	0.46	(5.0)	74.5	110

CONCLUSIONS

In addition to high productivity, the water jet is an environmentally acceptable tool. Its noise level is much lower than a jackhammer, and it does not create any dust. This is an important consideration in that the possibility of airborne radioactive particles, which could be ingested is eliminated. Also, water recycling eliminated radioactive contamination of large amounts of water.

In addition, the high-pressure water jet techique can be automated and operated by one man, remote controlled, and can cut the concrete very accurately, thus eliminating the need to precut the removal area with a saw and eliminating tool wearing because no tool comes in contact with the concrete.

ACKNOWLEDGMENTS

This work was sponsored by the National Science Foundation with Mr. A. Schwartzkopf acting as the program monitor. His advice and guidance, and the suggestions of the steering committe for this project, are greatly appreciated.

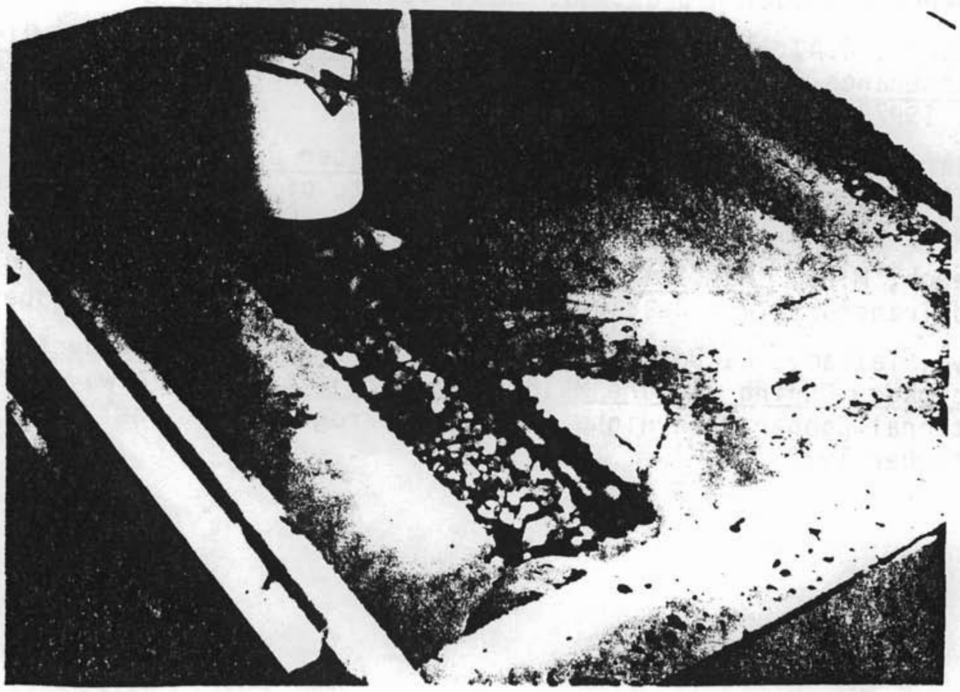

FIGURE 7

Bridge Deck Patching Using Water Jet

Messrs. R. Suchanek, W. Hamilton, F. Cyrnek, and J. Anderson were responsible for conducting much of the testing and construction of the field equipment; their help was invaluable to the project.

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AGENDA

CONCRETE DECONTAMINATION WORKSHOP

WEDNESDAY, May 28, 1980

7:15 REGISTRATION

8:00 INTRODUCTION

8:15 SESSION I

1. Concrete Decontamination and Demolition Methods - Roy Bauer
2. Equipment for Removal of Contaminated Concrete Surfaces - Mike Halter
3. Techniques and Equipment Used for Concrete Decontamination - Barry Woods
4. Diamond Blade Grinding as a Means for Removing Surface Contamination from Concrete - Tom Lynch

Discussion

12:00 LUNCH

1:00 SESSION II

1. Innovative Techniques for Removing Concrete Surfaces - John McFarland
2. Decontamination of Large Horizontal Concrete Surfaces Outdoors - Marcel Barbier
3. Surface Removal with Explosives - Sid Woodcock
4. Removal of Thick Concrete Structures - Bob Miller
5. Surface Removal with Shaped Charges - Mark Loizeaux
6. Experiences in Removing Surfaces with Explosives - Ken Anderson

Discussion

5:00 ADJOURNMENT

THURSDAY, May 29, 1980

8:00 SESSION III

1. Decontamination of Concrete Surfaces at the Los Alamos Scientific Laboratory - Jim Cox

2. Restoration of an Irradiated Fuel Storage Facility - Bob Miller

3, Organic Moderated Reactor Experiment Concrete Demolition - Don Smith

4. Concrete Decontamination Experience at Atomics International - Fred Schrag

5. Discussion of Concrete Decontamination During Decommissioning of Peach Bottom Unit 1, HTGR - John Andrews

6. Decontamination of Concrete Surfaces in Bldg. 3019, ORNL - John Parrott

Discussion

12:00 LUNCH

1:00 SESSION IV

1. Three Mile Island Concrete Decontamination Experience - Bruce Irving

2. A Summary Review of Mound Facility's Experience in Decontamination of Concrete - Jack Geichman

3. High Pressure Water Jet Applications in Radioactively Contaminated Facilities - John Hilaris

Discussion

4:00 SUMMARY AND CLOSING

5:00 ADJOURNMENT

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