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CONTAMINATED CONCRETE SURFACE LAYER REMOVAL

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Equipment is being developed to economically remove contaminated concrete surfaces in nuclear facilities. To be effective this equipment should minimize personnel radiation exposure, minimize the volume of material removed, and perform the operation quickly with the least amount of energy. Several methods for removing concrete surfaces are evaluated for use in decontaminating such facilities. Two unique methods especially suited for decontamination are described: one, the water cannon, is a device that fires a high-velocity jet of fluid causing spallation of the concrete surface; the other, a concrete spaller, is a tool that exerts radial pressure against the sides of a pre-drilled shallow cylindrical hole causing spallation to occur. Each method includes a means for containing airborne contamination. Results of tests show that these techniques can rapidly and economically remove surfaces, and leave minimal rubble for controlled disposal.

INTRODUCTION

The concrete walls, floors and ceilings of many nuclear facilities have become contaminated with radioactive particles because of accidental spills or releases of vapors and fine particles. It is desirable to reduce the quantity of contaminated rubble that must be handled during the decommissioning of surplus nuclear facilities and to provide an easier method for cleaning smaller contaminated areas. The amount of contaminated material can be reduced by removing the contaminated concrete surface. Several contaminated surface removal methods are available.

This paper presents criteria for selecting a suitable removal technique. Currently used concrete surface removal techniques are summarized and detailed descriptions of two new techniques are presented. These techniques, the water cannon and the concrete spaller, have been developed or adapted at Pacific Northwest Laboratory.

BACKGROUND

The choice of a contamination removal method depends on the type of contamination, the depth of contamination and the type of surface.

If contamination has not penetrated the concrete significantly, vacuuming the surface and then scrubbing it with mild soap and water or solvents sometimes successfully decontaminates the concrete.[1] For facilities which are to be used again, paint is used to fix low-level contamination in place. However, when the contamination has penetrated to the extent that it cannot be cleaned as described above, and it emits excessive radiation, it is necessary to remove the surface layer of the concrete.

In some clean-up operations of the past, whole walls were removed because this was faster than removing only the contaminated surface. But, the high cost of storing contaminated materials requires economical surface removal techniques to minimize the quantity of rubble which must be placed in controlled storage facilities.

There are many ways to remove contaminated concrete surfaces and these methods have been used with varying degrees of success. A suitable removal method should satisfy the following criteria. It should:

- minimize the exposure of personnel to harmful radiation or toxic materials,

- minimize the volume of removed material that must be placed into controlled storage (i.e., remove no more material than is necessary to clean the surface), and

- perform the removal operation as quickly as possible using the least amount of energy.

These considerations and the techniques which are discussed apply equally to the decontamination of nonnuclear facilities.

CONCRETE SURFACE REMOVAL TECHNIQUES

Many techniques have been used for removing contaminated concrete surfaces in nuclear facilities. Table I provides a listing of common methods for reducing the contamination level, as well as two methods now under development. All of these techniques are aimed at keeping the contamination spreading once it has been removed. The size of the facility to be cleaned plays an important part in determining the technique which physically can be used. (For example, an impactor mounted on a back hoe will not fit into a small room.)

Sand blasting and flame spalling,[2] where intense heat is applied to concrete surfaces, remove only minimal surface depth. However, they produce large quantities of small, contamination particles. A large exhaust and air filtration system is needed with these methods.[3] These two techniques are also relatively slow.

Two surface removal methods are used more extensively than the rest. Those two methods are jack hammers and impactors. Jack hammers, which are powered by compressed air, are readily available and are easily operated by one man. They are used to chip off the surface material deep enough to remove the contamination. Because they are difficult to position on walls and ceilings, jack hammers are used primarily on floors. Impactors, which are similar in operation to a jack hammer but are much larger, have been used successfully in several decontamination projects. A pick or chisel point is driven into the concrete surface with high energy impacts at several times per second. The impactors are powered by either air or hydraulics and are held and positioned by linkages typical of those found on tractor-mounted back hoes and excavators.

Table I. Comparison of Various Concrete Surface Removal Techniques.

Technique	Limitation	Type of Rubble Produced	Estimated Size of Air Filtration System Required	Estimated Relative Speed at Which a Unit of Surface Area Can Be Removed
Jack Hammer	Awkward to use on walls	Medium-sized pieces and	Medium	Fast
Sand Blasting		Small particles	Large	Slow
Flame Spalling	Heat may cause undesirable chemical reactions	Small particles	Large	Slow
Impactor Powered by Air or Hydraulics	Limited large accessable facilities	Medium-sized pieces and small particles	Medium	Fast
Water Cannon				
Handheld Modified 458 Magnum Rifle		Small pieces coated with glycerine and gun powder combustion products	Small	Slow (5-6 min/ft^2)
Rapid Fire Model	Limited large accessable facilities	Small pieces coated with water	Small	Fast (6-10 sec/ft^2)
Concrete Spaller with 38 Pound Air Drill to Make Holes		Medium-sized pieces and small particles	Small	Medium Fast (50-60 sec/ft^2)

(a) The water cannon is presently being evaluated for surface removal. The stated performance is a best estimate.

Both methods produce dust which is typically removed from the vicinity by pulling the dust laden air into an exhaust duct. Filters remove and collect the dust for proper disposal.

Water spray is also used to keep dust from spreading as light coatings of water hold the dust to the bigger rubble. Care must be taken not to apply so much water that it flows off the rubble, spreading contamination.

WATER CANNON

The water cannon removes concrete surfaces by shooting very high pressure jets of liquid at the surface causing it to spall. The advantages of this method are that no initial surface preparation is needed and the equipment does not contact the surface. The rubble which is removed by the water cannon is in small pieces and is coated with liquid. Because of the liquid, little or no dust is generated.

Two different versions of the water cannon have been developed which are applicable to concrete surface removal. One is a modified 458 Magnum rifle which shoots solidified glycerine through a nozzle.[5] The second version uses stored compressed gas to drive a piston which forces water through a small diameter nozzle.[6]

A 458 Magnum rifle has been modified by replacing the standard barrel with a shorter smooth-bored barrel. The end of the barrel is threaded to accept a nozzle which reduces the inside diameter from 0 45 in. to 0 17 in.

A 9-in. shield in the shape of a funnel has been placed around the nozzle in order to protect the operator and to funnel the rubble into a vacuum hose mounted on the shield. The rubble consists of pieces which are 1/2 in. to 3/4 in. in diameter and small particles which are all coated with glycerine. The size of the rubble allows it to be easily transported to a collection bin by a vacuum system. The shield extends 1 in. beyond the end of the nozzle so that it can be placed against the surface and the correct nozzle-to-surface distance will always be achieved.

The gun fires projectiles made of solidified glycerine, 2 in. long and 0.45 in. in diameter. The glycerine projectiles are propelled by gun powder loaded into a conventional cartridge case. When the gun is fired, the glycerine accelerates down the barrel and is extruded through the nozzle emerging at a very high velocity.

Wax is placed in the cartridge case to hold the powder in place and when the gun is fired the wax helps to create a moving seal to keep the combustion gas from passing around the glycerine.

The modified 458 Magnum rifle version of the water cannon has been extensively tested. Spall craters averaging between 3 and 4 in. in diameter and 3/4 in. deep in the center are typically obtained. This is shown in Figure 1. The shots are spaced about 3 in. apart in a triangular pattern. In a test conducted on nuclear reactor-grade concrete, 24 shots were required to remove one square foot of surface (See Figure 2). This took 5 to 6 minutes. Size variations appear to be determined primarily by the type and distribution of the aggregate within the concrete. For example, if hard round river gravel aggregate is struck by the shot of glycerine "head-on", small spalls will generally result. The best spalls occur when the glycerine can work around and behind the embedded aggregate.

The 458 Magnum water cannon is positioned and held by hand and can by operated as fast as a person can reload and position the gun (See Figure 3). This hand held spaller is suitable for cleaning small areas where large equipment would be impractical.

Figure 1. Single 458 Magnum Water Cannon Spall.

Figure 2. Test Panel Spalled by the 458 Magnum Water Cannon (1 ft^2).

Figure 3. 458 Magnum Water Cannon Being Fired.

A second type of water cannon is also being investigated for spalling concrete surfaces. While the water cannon described above uses gun powder to drive glycerine through a nozzle, the second type uses compressed gas to drive a piston to impact a small quantity of water and force it through a nozzle (See Figure 4).

The gas which drives the piston is compressed by a hydraulic impactor which will allow firing rates of up to 5 times per second. Water is added after each shot into a chamber in front of the piston.

The unit is mounted on a back hoe or excavator and is operated in a manner similar to a concrete or rock breaker. As a result, the unit is usable only in rooms which are large enough to accommodate the equipment.

Like the 458 Magnum water cannon, a funnel-like shield will be placed around the nozzle to protect the operators and remove debris.

The advantages of this water cannon over most other surface removal techniques are: 1) it is expected to have a removal rate of one square foot in 6 to 10 seconds, and 2) the water that is fired by the cannon coats the rubble pieces and particles which helps to minimize the possibility of spreading contamination.

Figure 4. Schematic of a Water Cannon Basic Components.

CONCRETE SPALLER

The concrete spaller is a device which has been developed specifically for removing concrete surfaces by Pacific Northwest Laboratory (PNL). This device was developed to satisfy the need for a method of removing only the top layer of a contaminated surface. Also, the device was designed to be lightweight, easy to handle, and conveniently used on any contaminated surface without spreading the contamination.

The concrete spaller consists of three basic parts: a hydraulic cylinder, a push rod,-and a bit with expanding wedges. The hydraulic cylinder, which is attached at one end, activates a push rod, which is installed inside the bit (See Figure 5).

The bit is a piece of steel tubing, the inside diameter of which is tapered at one end. A circular wedge is machined into the tubing at the tapered end. The bit is split into 4 equally spaced segments parallel to its central axis.

Inside the tubing is placed a push rod with an outside diameter slightly smaller than the inside of the bit. This rod is also tapered at one end which matches the tapered end of the tubing.

The concrete spaller is operated by inserting the action end of the bit into a pre-drilled hole, approximately 2 in. deep and 1 in. diameter. The hydraulic cylinder, powered by a 10,000-psi

Figure 5. Schematic of a Concrete Spaller.

pump, is then activated, forcing the push rod toward the end of the bit. Two things cause the spalling to take place. First, the wedges are forced radially outward embedding into the walls of the hole. Second, when the tip of the push rod reaches the bottom of the drilled hole, it forces the wedges away from the bottom, causing the spalling to take place.

The initial hole drilling is the time-consuming portion of the use of the concrete spaller. Three different types of drills were tested to determine the most efficient: a compressed air powered drill (38-lb model), an electric core drill, and an electric rotary hammer. The electric core drill was discarded because it produced a fine dust and was also very slow. (Drilling a 2 in. deep hole required 90-120 seconds.) Although the electric rotary hammer was able to drill a 2 in. deep hole in 30 to 40 seconds, the compressed air powered drill was shown to be more efficient as it was able to drill the hole in 10 to 15 seconds. Both the electric rotary hammer and the compressed air powered drill produces small chips which are more easily handled by the air filtration system. To keep the drilling chips from contaminating the air, a vacuum attachment is placed around the drill bit to remove the chips generated during the drilling operation.

The holes were drilled in a triangular pattern. Tests show that the optimum space between the holes is 8 in. With 8-in. spacing, some areas of the surface were not removed due to variations in the distribution of the aggregate within the concrete. It is therefore necessary to redrill and spall the remaining surface. Closer spacing of holes is less efficient since more holes are ultimately being drilled than by using 8-in. spacing, even though additional holes to remove the random remaining surface are needed (See Table II).

Table II. Hole Spacing Versus Number of Holes Required.

Spacing Between Holes, in.	Average Number of Holes Required for 1 yd^2 of Surface	% of Additional Holes Required Compared With 8 in. Spacing
4	93	299
5	59	155
6	41	77
7	30	30
8	23	--

The concrete spaller has been tested on various surfaces on the Hanford Nuclear Reservation. Figure 6 illustrates the spalling which resulted from two tests and a panel which has been drilled and is ready to be spalled. As can be seen, small areas of surface were left intact when the panels were spalled. These areas were later removed by drilling additional holes and spalling again.

Figure 7 shows the drilled panel in Figure 6 after spalling and the spaller tool used to remove the surface. Note that the rubble produced by the spalling is conveniently sized for easy handling and that much pf the surface layer of the rubble remains intact, holding the contamination fixed. According to this testing, approximately 53 seconds were required to drill and spall one square foot of surface area (or approximately 8 minutes to remove one square yard).

As with other surface removal techniques, if the spalled surface is still contaminated, it can be redrilled and spalled a second time.

Figure 6. Test Panels Spalled by Concrete Spaller (1 yd^2).

Figure 7. Concrete Spaller Next to a Spalled Test Panel.

FUTURE EQUIPMENT

Contamination removal equipment of the future will likely be remotely operated. The operators will possibly be stationed within view of the spalling operation, but far enough removed to reduce the amount of radiation exposure. In some circumstances the machine operation may be viewed by television and controlled from a remote location. Quite possibly, future machinery might be fully automated, so that it will operate unattended.

Included with the surface removal tools will be machinery to handle the contaminated rubble. Big pieces will be conveyed to a loading station for packing into airtight disposal boxes. Small chips and dust will be moved by a vacuum system to separators for removal and placement in storage containers.

The physical dimensions of future equipment will depend on the size of the facility. With facilities varying in size from very large canyon buildings with 60 to 80 ft high walls to small control and equipment rooms, various specialized tools and rubble handling systems will be needed.

CONCLUSIONS

Several techniques are presently used for removing contaminated concrete surfaces. So far, none of them have been developed to the extent that they meet all three of these requirements: minimal radiation exposure, removing only the contaminated portion of the surface, and performing the removal in the least amount of time. The two techniques discussed in this paper, the water cannon and the concrete spaller, are felt to be promising developments toward equipment that will meet the needs of future decontamination projects.

ACKNOWLEDGMENT

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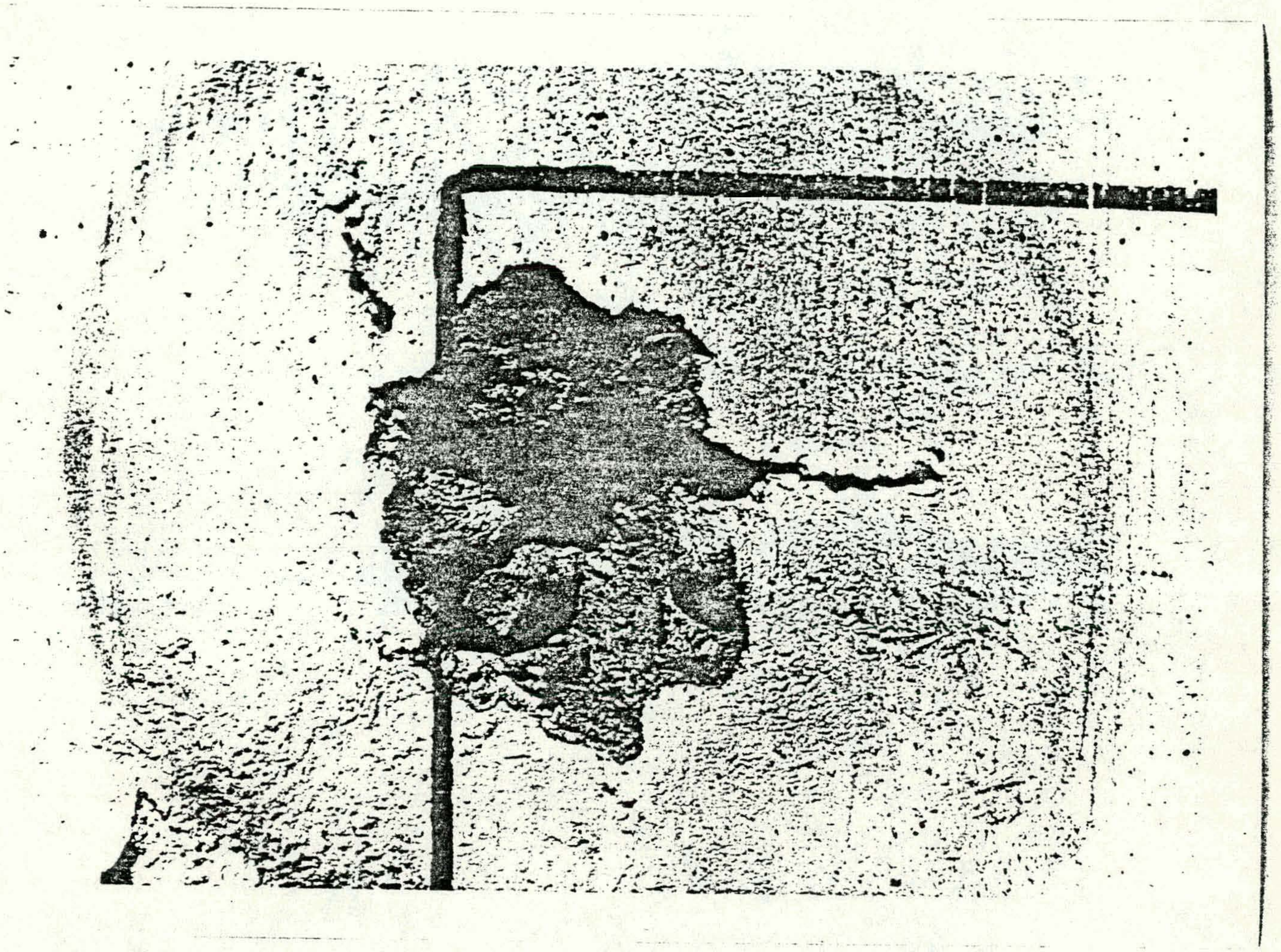


Figure 1

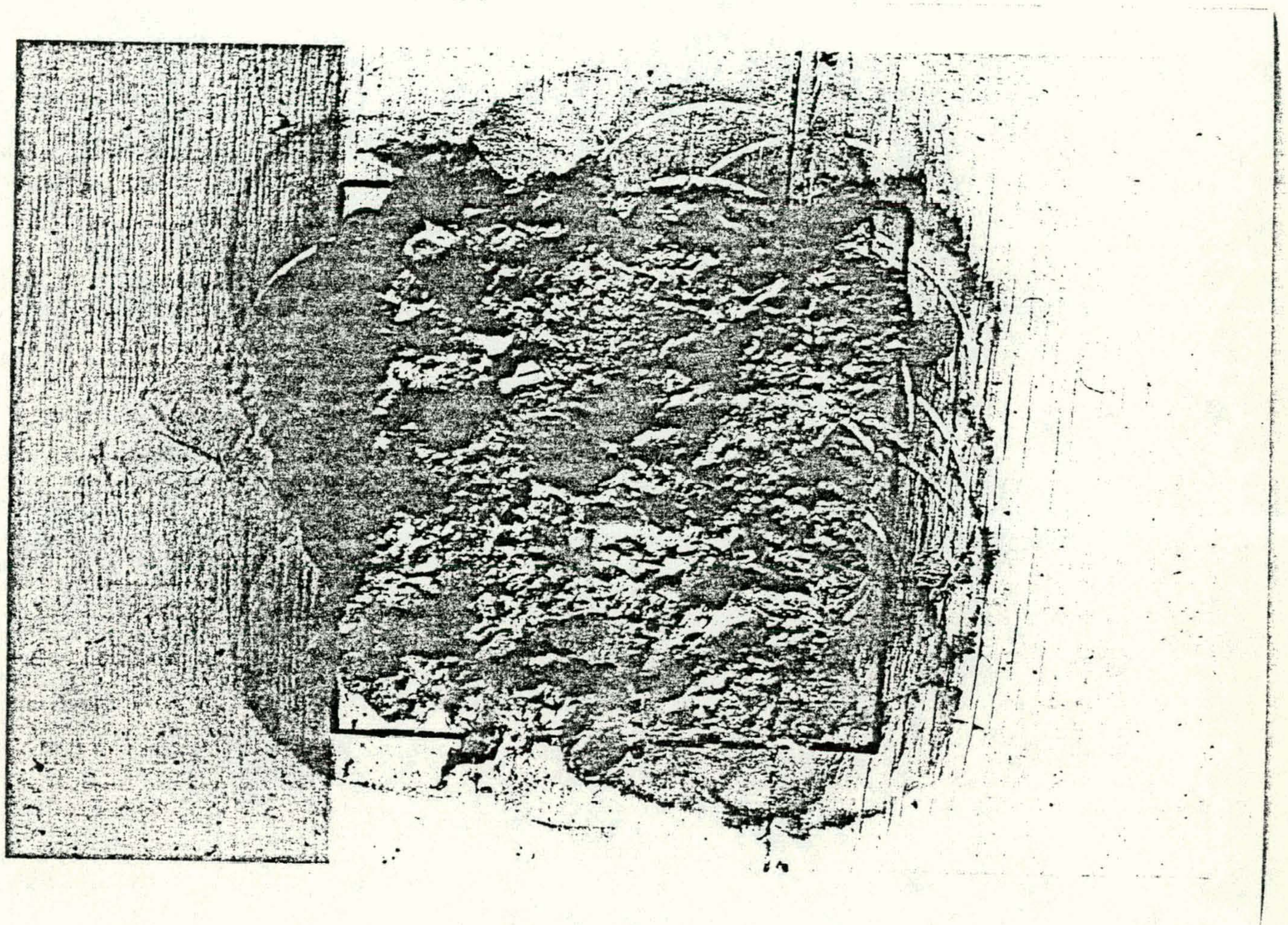


Figure 2

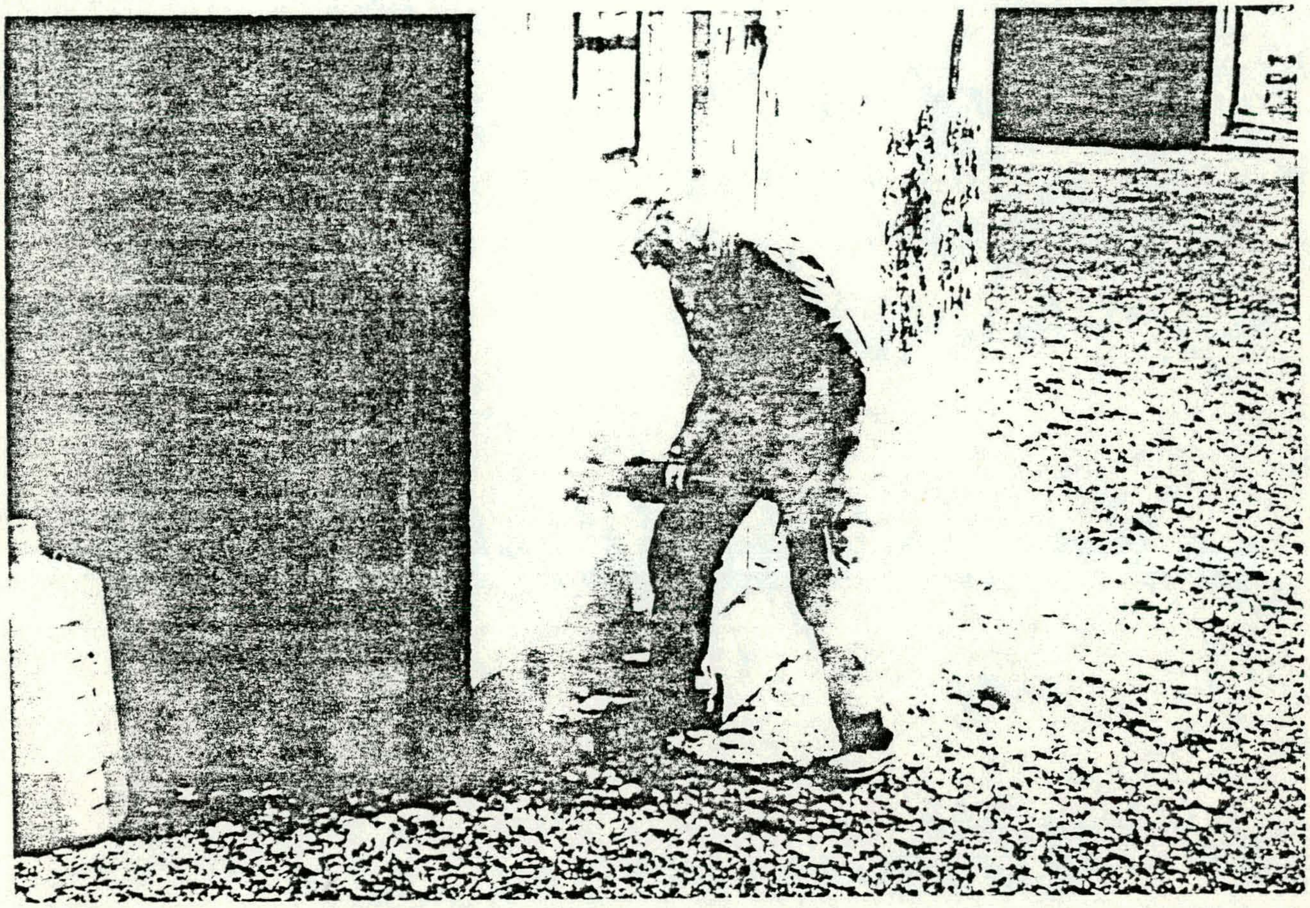
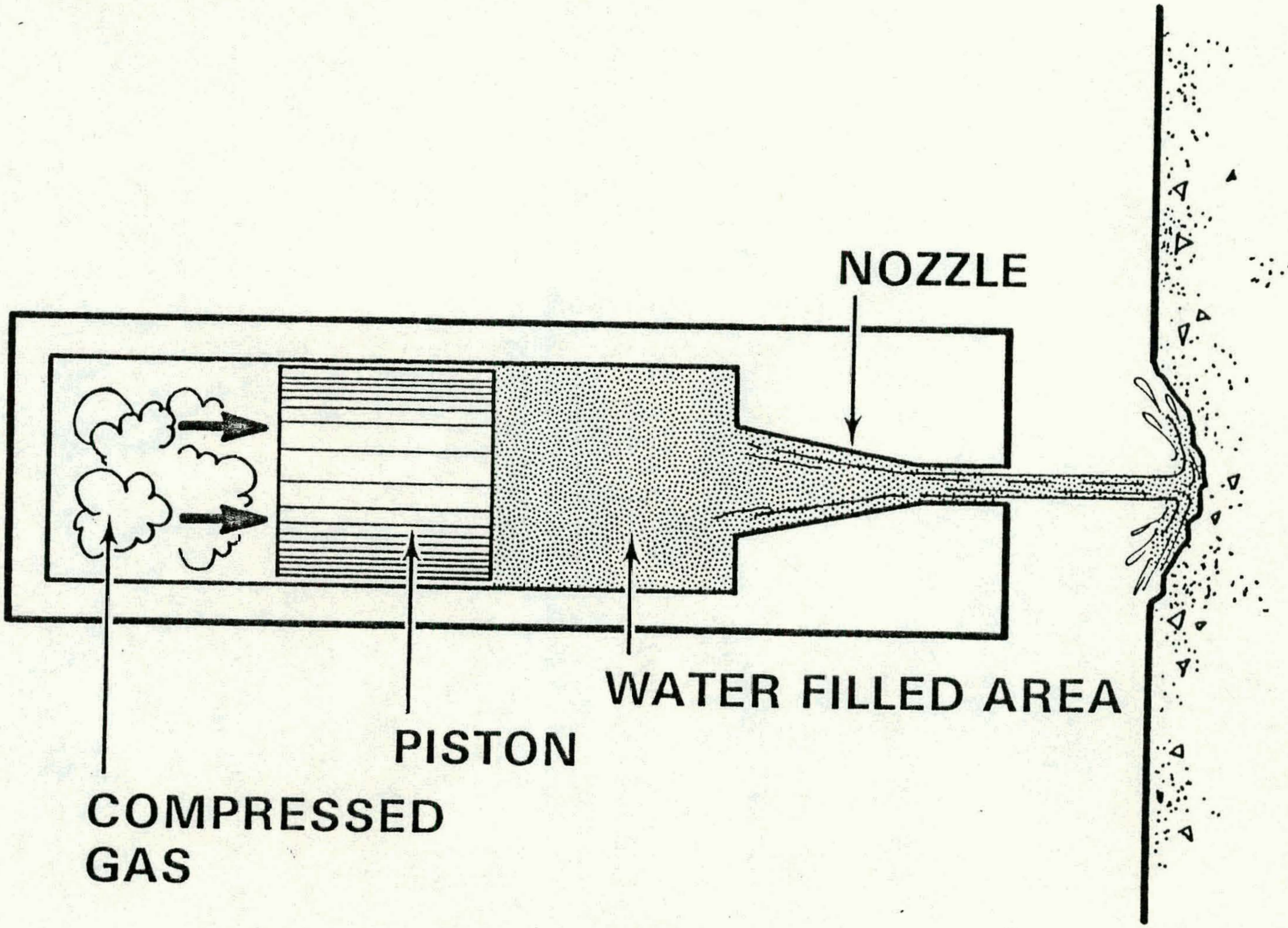


Figure 3

Fig. 4

WATER CANNON



CONCRETE SPALLER

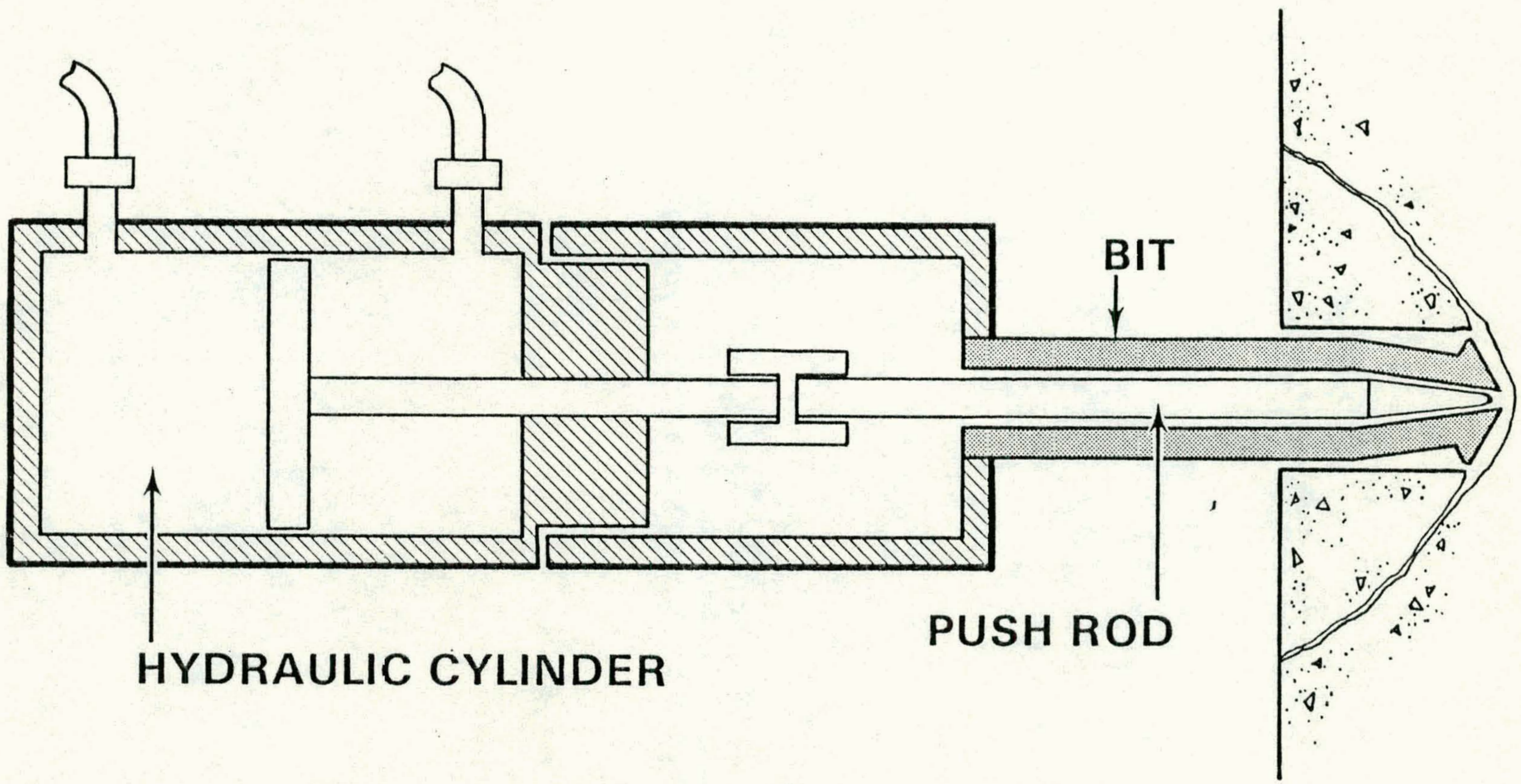


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Fig. 5.
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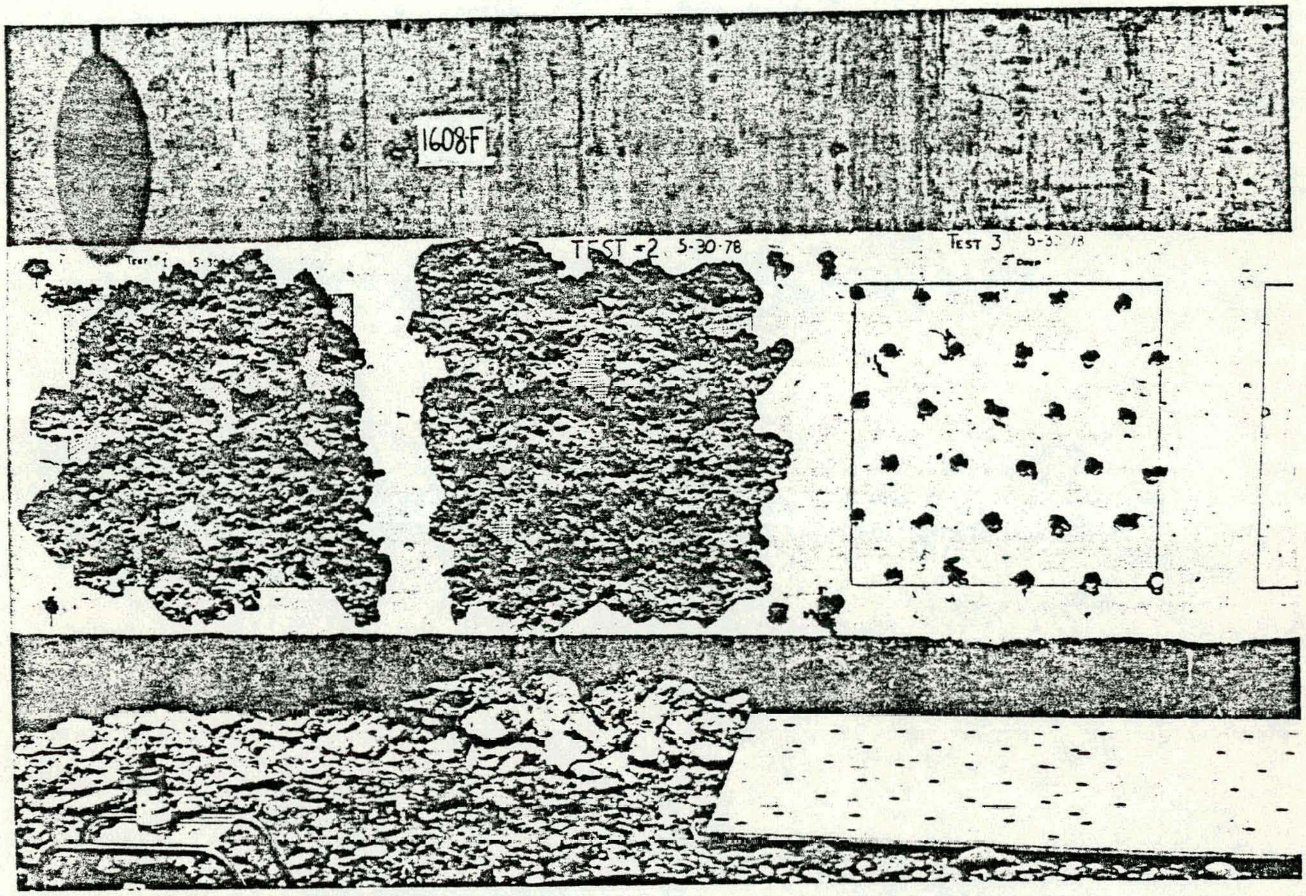

Figure 6

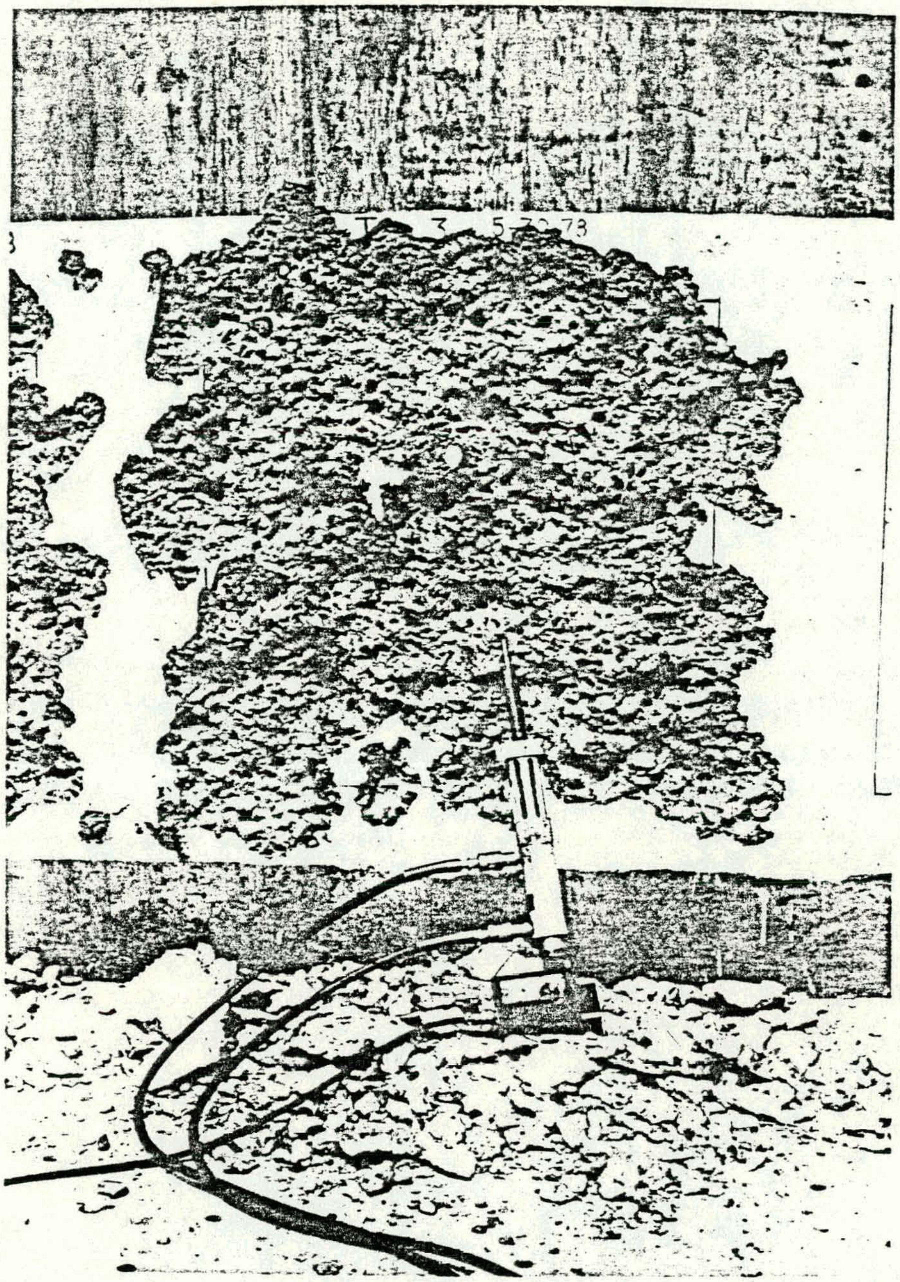

Figure 7