DOE/MC/30164-96/C0577

Concrete Decontamination by Electro-Hydraulic Scabbling

Authors:

V. Goldfarb
R. Gannon

Contractor:

TEXTRON Defense Systems
2385 Revere Beach Parkway
Everett, Massachusetts 02149

Contract Number:

DE-AC21-93MC30164

Conference Title:

Environmental Technology Development Through Industry Partnership

Conference Location:

Morgantown, West Virginia

Conference Dates:

October 3-5, 1995

Conference Sponsor:

U.S. Department of Energy, Office of Environmental Management,
Morgantown Energy Technology Center

3.4 Concrete Decontamination by Electro-Hydraulic Scabbling

V. Goldfarb (617-381-4325)
R. Gannon (617-381-4630)
Textron Defense Systems
2385 Revere Beach Parkway
Everett, MA 02149

Abstract

Textron Defense Systems (TDS) is developing an electro-hydraulic device that has the potential for faster, safer, and less expensive scabbling of contaminated concrete surfaces. In the device, shock waves and cavitating bubbles are produced in water by the electric pulses, and the direct and reflected shock waves impinging on the concrete surface result in the crushing and cracking of the concrete. Pulse energy, frequency, and traverse speed control the depth of the scabbling action. Performance thus far has demonstrated the capability of a prototype unit to process a swath 24" wide, up to 3/4" deep at a linear velocity of up to 6 feet per hour, i.e., at a scabbling rate of 12 sq. ft. per hour.

Introduction

Contamination of concrete structures by radionuclides, hazardous metals, and organic substances (including PCB's) occurs at many DOE nuclear weapon sites, as well as at many utility power generation stations. In many instances the contaminants penetrate into the concrete to a significant depth. Removal of the concrete surface layer is considered as the most effective decontamination technology. By scabbling, the mass of concrete is divided into a) contaminated debris (rubble) of relatively small volume, and b) clean bulk concrete structure.

Research sponsored by the U.S. Department of Energy's Morgantown Energy Technology Center, under contract DE-AC21-93MC30164 with Textron Defense Systems, 2385 Revere Beach Parkway, Everett, MA 02149; telefax: 617-381-4160.

TDS is developing Electro-Hydraulic Scabbling (EHS), a cost-efficient, rapid, controllable concrete scabbling technique based on the Electro-Hydraulic effect (EH).

The EH system delivers strong pulses to the concrete surface by means of powerful shock waves originated by electric discharges and propagated through water between the dis charge channel and the concrete. The high impulse pressure, developed at the liquid-solid interface, results in stresses that can controllably deform, crack, or break a whole solid body or spall the surface layer. Accordingly, EH has found applications for crushing and grinding of minerals, drilling of rocks, forming of metals, cleaning of surfaces, and demolition of foundations.

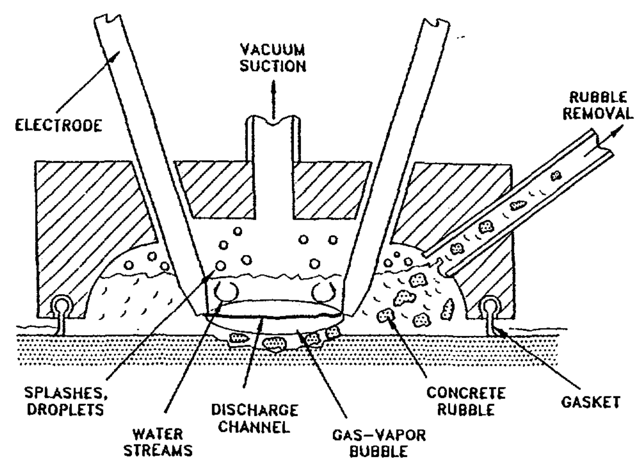


Figure 1

A variety of electromechanical configurations can be used for concrete EHS. In the device shown in Figure 1, the electric discharge takes place between two cylindrical electrodes.

EHS System Design Considerations

A block diagram of a "generic" EHS system is shown in Figure 2.

selection of the electrode configuration (for instance, rod-to-rod (point-to-point) vs. rail-to-rail (line-to-line)) for specific conditions is one of the major design considerations.

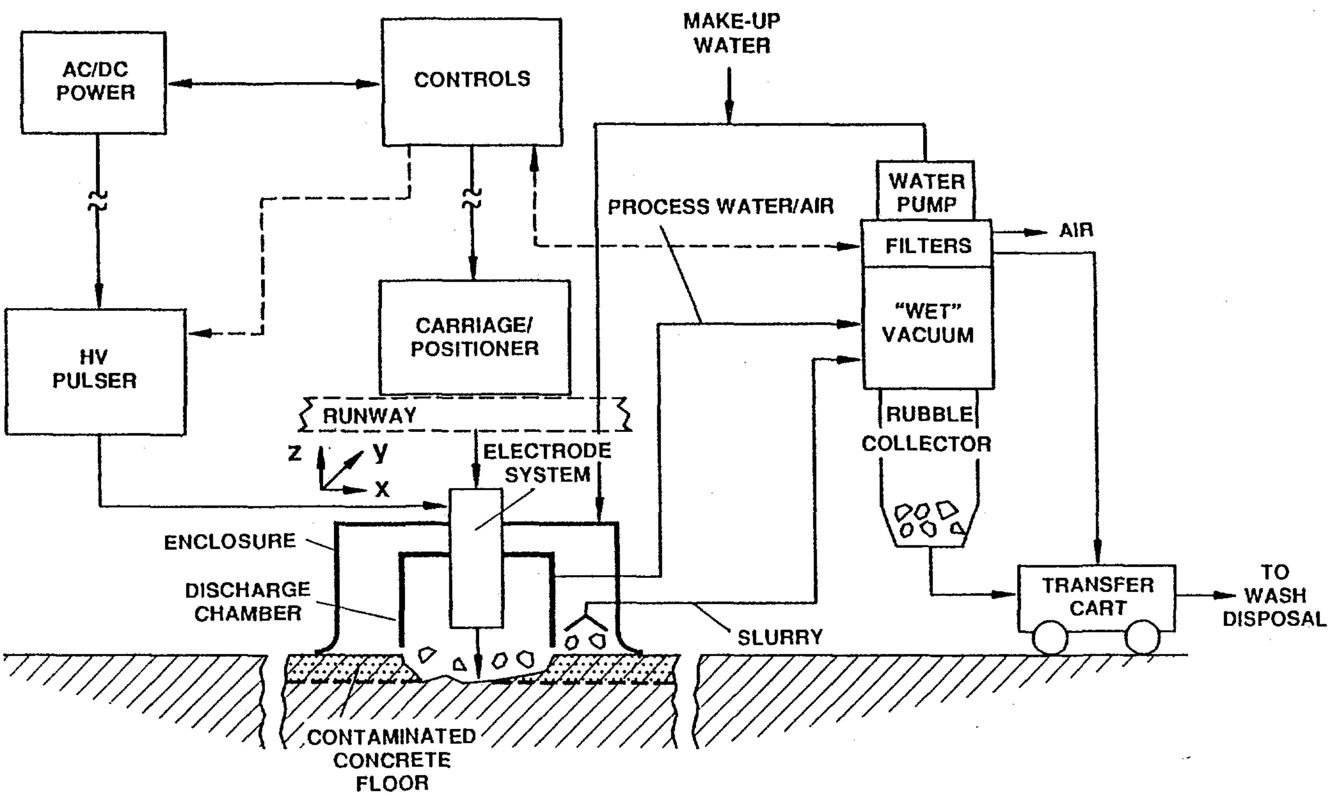


Figure 2

The electric power supply consists of two main units. The first, which can be remote, includes the high voltage DC supply (charger of capacitors) for the electric pulser and the AC supply for auxiliaries - motors, fans, controls. etc. The second unit - Pulse Forming Network (PFN) - should be located close to the EHS tool (module); low inductance of the connecting cables is required to generate short pulses with steep fronts. The DC power supply will operate at 20 to 100 kV, providing pulses of 500 to 4,000 J energy; a spark-gap switch with a function generator controls the repetition rate.

The EH processing module is the central component of the system. It carries single or multiple electrode pairs. Optimization and

To achieve high energy efficiency, it is important to maximize pressure transfer to the concrete surface. Interelectrode gap and distance between electrodes and concrete surface (clearance) are among the variables to be optimized. In most cases, the clearance should be as small as possible, without mechanical damage of electrodes in the event they are "dragged" over the surface. At very high operating voltages, when electric discharge propagates directly through concrete, the electrodes should contact the surface. Electrode materials should be selected to minimize electro-thermo-chemical erosion.

In all designs, a 1 to 4 inch deep water layer should be maintained over the concrete surface. Water provides the media for shock wave propagation and, for short high voltage pulses, acts as an electrical insulation preventing breakdown through the air apart from the surface. It also prevents dust generation and, finally, allows retention and removal of concrete rubble (debris).

The rubble (sludge) is removed either by a solids-tolerant pump or by a wet vacuum type device, and collected in a drum. Wet rubble is separated by a proper filter while filtered process water (plus some make-up fresh water) is returned into a scabbling chamber.

The chamber contains a scabbling module mounted on a positioner. Its principal function is to isolate the process area/volume to prevent the spread of water and contaminated rubble over the surrounding floor. The perimeter of the chamber bottom should have a flexible gasket; the chamber is "sealed" against the concrete surface (e.g., floor) by generating reduced pressure inside the chamber with an appropriate blower. Surface scabbling proceeds in a semi-batch fashion. The X-Y-Z (or X-Z) positioner moves the scabbling module within the sealed chamber; after scabbling of an isolated area is completed, rubble and water are removed (sucked out), the chamber is moved to the next position, and the next scabbling cycle begins. A motorized carriage is used to move the chamber over the concrete surface.

The EHS system also contains a control station that can consist of various degrees of sophistication (from manual to completely computerized) to coordinate functions of scabbling proper, water/rubble flows, and mechanical traverses. These controls should be protected against EM noise generated by electric pulses.

The EHS design should be customized with respect to the type of surface area, its dimensions, orientation (vertical vs. horizontal), and the presence of obstacles or inclusions over/in the concrete construction. Reasonably flat floors, isolated concrete blocks that can be placed into water-filled tanks, and walls and bottoms of tanks themselves are examples of configurations that would require the simplest design of the scabbling module and chamber.

Design and Testing of Laboratory and Prototype EHS Units

Two EHS units were designed, assembled, and tested to demonstrate the technical feasibility of the EHS concept and to generate preliminary engineering data in order to develop system requirements and economic projections.

The first unit, shown schematically in Figure 3, was used to explore a range of operating parameters, as well as several electrode arrangements while scabbling the surface of a 3x2 sq. ft., 6" thick concrete slab immersed in a tank of water.

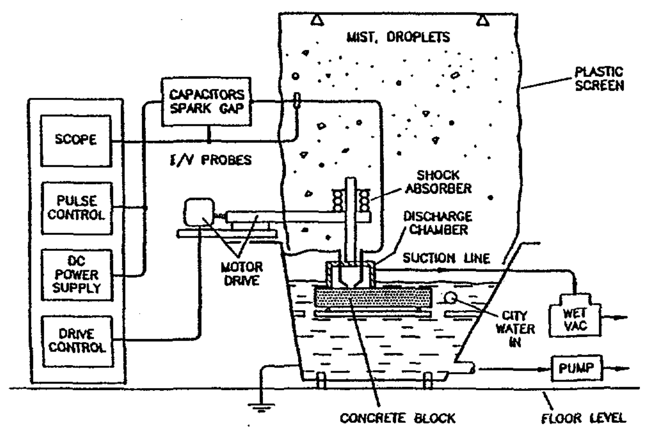
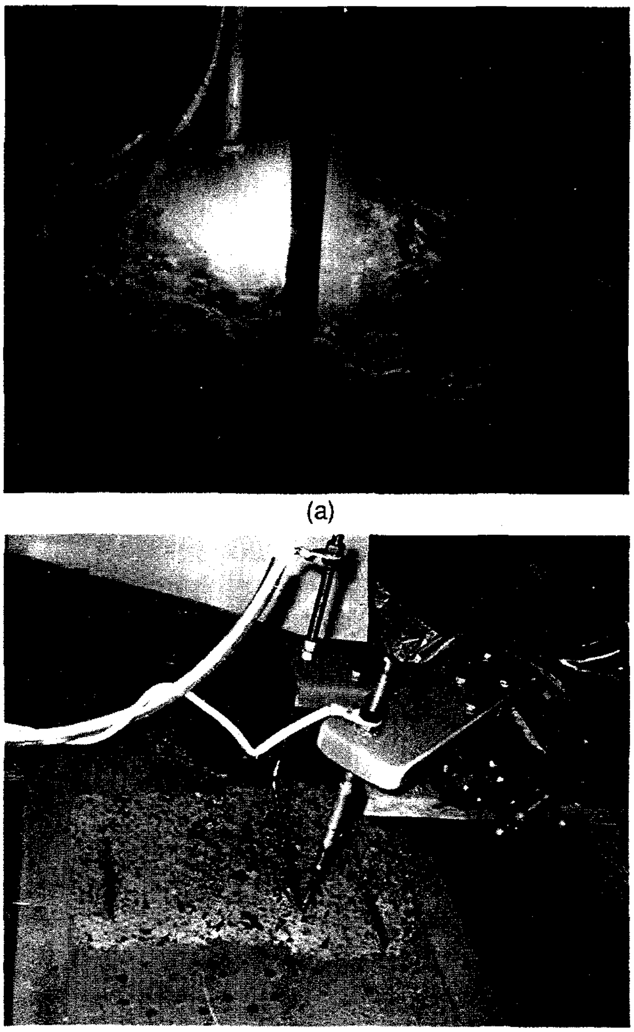


Figure 3

The unit was equipped with a 18 to 25 kV power supply which delivered 800 to 2200 J pulses of 5 to 15 microsecond duration at 0.5 to 3 Hz frequency. About 50% of the stored energy is released in a 6 to 12 mm discharge gap between a single pair of steel rod electrodes. Instantaneous appearances of the EH discharge over concrete surfaces before (a) and after (b) water splash formation are shown in Figure 4.

A range of operating parameters and a summary of the scabbling results are listed in Table 1.



(a)

(b)

Figure 4

Table 1. Range of Operating Conditions and Results for Laboratory Units

Operating Voltage	18-25 kV
Storage Capacitance	3.7-7.4 μF
Pulse Energy	800-2200 J
Operating Frequency	0.5-3.0 Hz
Average DC Power	1.5-4 kW
Electrode Velocity Continuous Traverse	1-12 inch/min
Scabbling Depth	0.2"-1.0"
Scabbling Trace Width	1.5"-3"
Depth of Water Layer	0.2"-1.5"
Concrete Removed, Volume/Pulse	0.4-1.2 cm^3 (0.05-0.25 cu. in.)
Rubble Particle Size	0.1<d>0.75 in.
Concrete Area Processed	10-30 sq in./sq./min
Energy Consumption	400-1500 J/g concrete

The second, larger unit (see Figure 5 schematic) was designed to explore EHS in a configuration applicable to concrete floor decontamination.

After testing several multielectrode configurations operating from either common or individual parallel pulsers, we chose the simplest design with a single pair of wide plate electrodes. A scabbling module with 24"-wide electrodes is shown in Figure 6 (top and bottom views, on a positioner inside the scabbling chamber).

The module is mounted on a motorized positioner traversing the concrete floor in a X-direction by 1" to 2" steps and lifting electrodes (Z-direction) during each step. A scabbling chamber of 3x3x2.5 ft. dimensions is made of fiberglass sheets and is supported by a forklift. The scabbling chamber, together with a top blower/vacuum, rubble collecting drum, diaphragm pump and power supply (25 kV, 8 kW installed DC power) and control cabinet nearby, is shown in Figure 7.

In Figure 8, the appearance of a 2' x 2' floor area scabbled to average 3/8" depth is shown. Operating parameters and characteristic

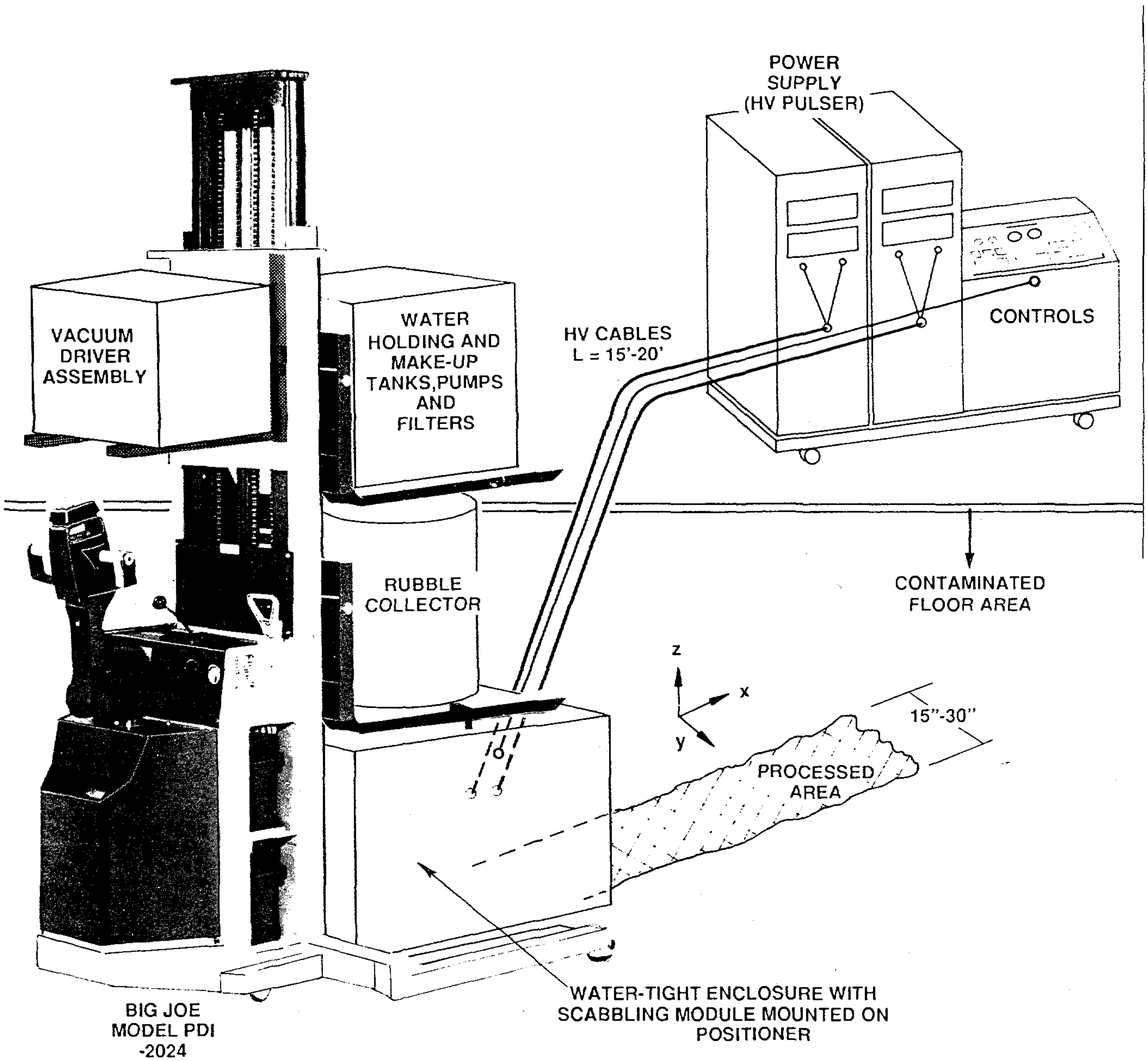

POWER
SUPPLY
(HV PULSER)
VACUUM
DRIVER
ASSEMBLY
WATER
HOLDING AND
MAKE-UP
TANKS,PUMPS
AND
FILTERS
HV CABLES
L = 15'-20'
CONTROLS
RUBBLE
COLLECTOR
CONTAMINATED
FLOOR AREA
z
x
y
15"-30"
PROCESSED
AREA
BIG JOE
MODEL PDI
-2024
WATER-TIGHT ENCLOSURE WITH
SCABBLING MODULE MOUNTED ON
POSITIONER

Figure 5

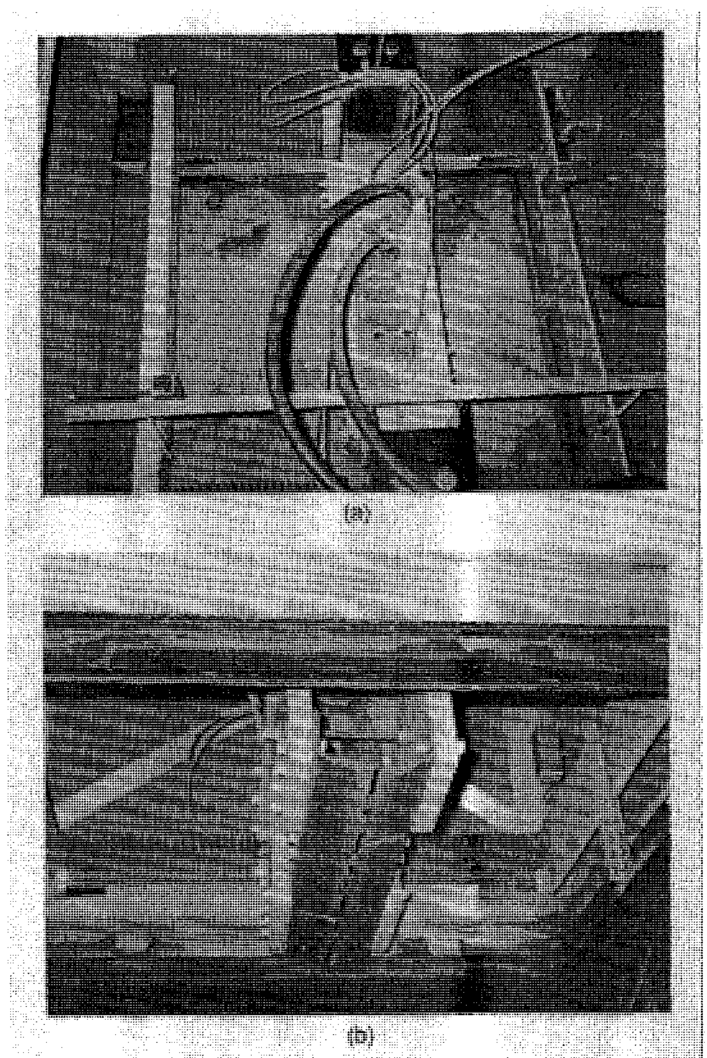


Figure 6

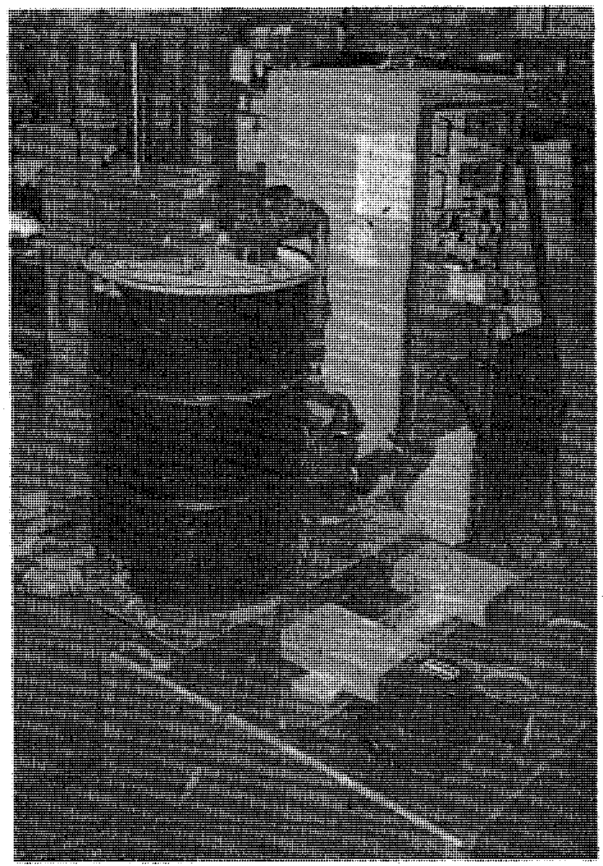


Figure 7

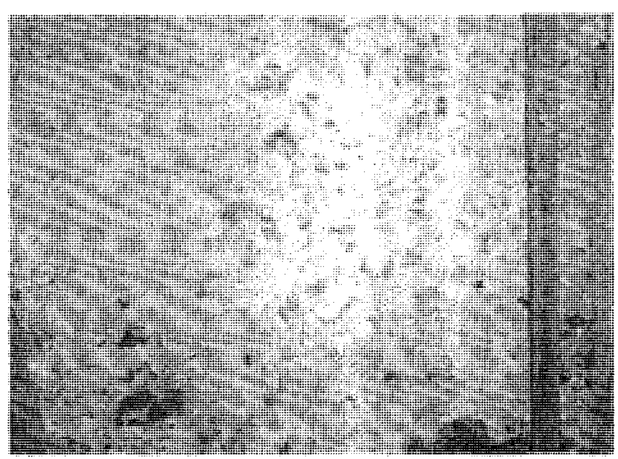


Figure 8

scabbling performance of this prototype unit are listed in Table 2.

Table 2. Range of Operating Conditions and Results for Prototype Units

Operating Voltage	21-28 kV
Storage Capacitance	10-13 μF
Pulse Energy	2.5-3.8 kJ
Operating Frequency	1.2-2.5 Hz
Average DC Power	2.5-6.0 kW
Water Layer Depth	3"-4"
Scabbling Chamber Vacuum	(-4)-(-7) in. H_2O
Module Effective Velocity (stepwise traverse)	1-2 in./min.
Traverse Step Length	1"-2"
Scabbling Trace Width	22"-26"
Scabbling Depth	1/4"-3/4"
Scabbling Rate	10-15 sq.ft./hr.
Energy Consumption (scabbling proper)	0.3-0.5 kWh/sq.ft.

An optional EHS unit employing a HV (120 kV) power supply has been also assembled. According to preliminary experiments, higher voltage and shorter discharge propagates directly through a surface concrete layer and provides two to four times higher scabbling energy efficiency. In addition, the power supply is smaller in size.

Concrete blocks and a floor with metal inclusions (re-bars, pipes) were scabbled without difficulty. In a few experiments, concrete contaminated by depleted uranium or cesium salts was scabbled; substantial reduction of the contaminant concentration in the concrete took place.

Field experiments planned for the near future at the DOE Fernald site should provide data to evaluate decontamination efficiency of the EHS technology. It may also be of interest to explore the capability of the EH technique to destroy organic contaminants in a concrete sludge due to absorption of the intense UV radiation generated by the discharge.

Conclusions

The feasibility of concrete surface scabbling using the electro-hydraulic technique has been demonstrated. Using engineering and design data developed during the preliminary development tests, costs of scabbling contaminated concrete surfaces is estimated to range between 5 and 20 $\$/m^2$ for scabbling depths of between 0.25 and 1.0 inches. Further reduction in these costs can be expected as design improvements are introduced.

Acknowledgements

The development of the EH scabbling process has benefited by the managerial and technical contributions of METC CORs Mary Beth Ashbaugh, Kelly Pearce, and James Longenbach. The project was initiated in October 1993 as part of the technology development focus (EM50) of the DOE Decontamination and Decommissioning Program. The commencement of Phase III to define the operating procedure and performance specifications of a commercial prototype unit at a DOE site is anticipated for November 1995.

References

1. Yasunaka, H., et al., "Microwave Irradiation Technology for Contaminated Concrete Surface Removal," 2nd RILEM Int. Sympos. on Demolition and Reuse of Concrete, Chapman-Hall, London (1988).

2. Hashish, M., "Waterjet Surface Cleaning for Nuclear Facility," J. Eng. Ind. Trans. ASME, VIII, No. 3, p. 269 (Aug. 1989).

3. Tonkonogov, J.P., "Dielectric Relaxation, Electric Breakdown and Disintegration of Rock, Moscow," Nedra (1975).

4. Pokrovskii, G.I., "Explosion," Moscow (1967).

5. Maurer, W.C., "Novel Drilling Techniques," Pergamon Press, Oxford (1969).

6. Khannkaev, A.N., Physical Processes in Explosive Rock Disintegration, Izv. Ac. Sci. USSR, Moscow (1958).

7. Yutkin, L.A., "Electrohydraulic Effect, " Mashgiz, Moscow (1955).

8. Arsent'ev, V.V., Theory of Development of Impulse Electric Discharge of Liquids, Porc. IV Conf. On Dielectric Breakdown, p. 199, Leningrad (1964).

9. Gavrilov, G.N. et al., J. Techn. Physics USSR, 47 p. 1506 (1977).

10. Okun' I.A., J. Techn. Physics USSR, 41, p. 292 (1971).

11. "Electric Discharge in Liquids and Its Technical Applications," Conference Proceedings, Kiev (1976).

12. Bek'klovskii, V.G., et al., Acoustic Journal, 20, p. 23 (1974).

13. Zinovyev, N.T., Obogashchenie Rud, No. 4, 43 (1989).

14. Zinovyev, N.T., et al., "On Concrete Demolition by Electric Discharges," 2nd RILEM Int. Sympos. on Demolition and Reuse of Concrete, Chapman-Hall, London (1988).

15. Agaev, R.G., et al., "Electrounnaya Obraboka Materialov," 22, No. 4 (1968).

16. Gavrilov, G.N., Gorobenko, C.G., Mulushevsky, P.P., Ryabinin, A.G., Pulsed Discharge "Technology for Processing Minerals," Kiev (1979).

17. Titkov, N.I., et al., "Drilling with Electric Discharge in Liquids," Neft. Khoz. USSR 35 10 (1957).

18. V. Ya, Petrov, V. Yuv, Gorn. Zh., NO10, 119 (1989).

19. Lawrence, L.G., "Electrohydraulic Effect," Electron World, 81, p.44 (1969).

20. Epstein. E.F., et al., "New Methods of Crushing Rocks," Moscow (1960).

21. Jigit, E., Johnston, H., Maroudas, N., Trans. Inst. Chem. Eng. 47, p. 332 (1969).

DISCLAIMER