DOE/MC/30164--4000
(DE95000074)

Concrete Decontamination by Electro-Hydraulic Scabbling (EHS)

Topical Report

November 1994

Work Performed Under Contract No.: DE-AC21-93MC30164

For

U.S. Department of Energy
Office of Environmental Management
Office of Technology Development
Washington, DC

U.S. Department of Energy
Office of Fossil Energy
Morgantown Energy Technology Center
Morgantown, West Virginia

By
TEXTRON Defense Systems
Everett, Massachusetts

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Distribution Category UC-940

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November 1994

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1.0 SUMMARY AND CONCLUSIONS

Under Contract No. DE-AC21-93MC30164, Textron Defense Systems (TDS) is developing Electro-Hydraulic Scabbling (EHS) technology and equipment for decontaminating concrete structures from radionuclides, organic substances, and hazardous metals. This wet scabbling technique involves the generation of powerful shock waves and intense cavitation by a strong pulsed electric discharge in a water layer at the concrete surface. High impulse pressure results in stresses which crack and peel off a concrete layer of a controllable thickness. Scabbling produces contaminated debris of relatively small volume which can be easily removed, leaving clean bulk concrete.

The primary objective of the first phase of the three-phase project is to prove the technical feasibility of EH technology for the controlled scabbling and decontamination of concrete by conducting laboratory experiments, analyzing test data, and projecting technical performance and process economics. Phase I of the program is completed.

Based on the Phase I work and on discussions with DOE plant operators and commercial equipment suppliers, we conclude that EH scabbling/concrete decontamination technology is technically feasible and economically promising.

To meet Phase 1 objectives, the following tasks were performed.

- Provided environmental information to assist in determining the appropriate level of National Environmental Policy Act (NEPA) documentation for Phase I.

- Designed and assembled laboratory test rig to scabble 30"x20"x5" concrete blocks.

- Made multiple hardware changes to improve scabbling performance and to prolong the lifetime of the components. Also, the system was modified to allow scabbling of relatively large areas of concrete floor.

- Conducted concrete scabbling to characterize process in terms of energy efficiency, processing rate, scabbling depth, properties of debris, consumption of water and electrodes.

- Conducted scabbling experiments with concrete impregnated by materials simulating surface layer contamination.

- Analyzed experimental results and characteristic process features, and developed a conceptual design of larger EHS units. Figure 1-1 shows block diagram of integrated EHS system mounted on a motorized chassis.

- Projected performance parameters (see Table 1-1) for a subscale, single-module system and for a full-scale three-module industrial system.

- Estimated EHS costs for these units capital equipment cost and operating cost (see Tables 1-2 and 1-3). Labor cost (controlled by processing rate), capital replacement, and equipment costs are the most important cost factors, cost of consumables being much lower.

- Studied information on the alternative concrete decontamination techniques and discussed concrete decontamination issues at DOE sites (Oak Ridge/Martin Marietta, Fernald/Fermco) and with potential Phase II and III project participants. As a result

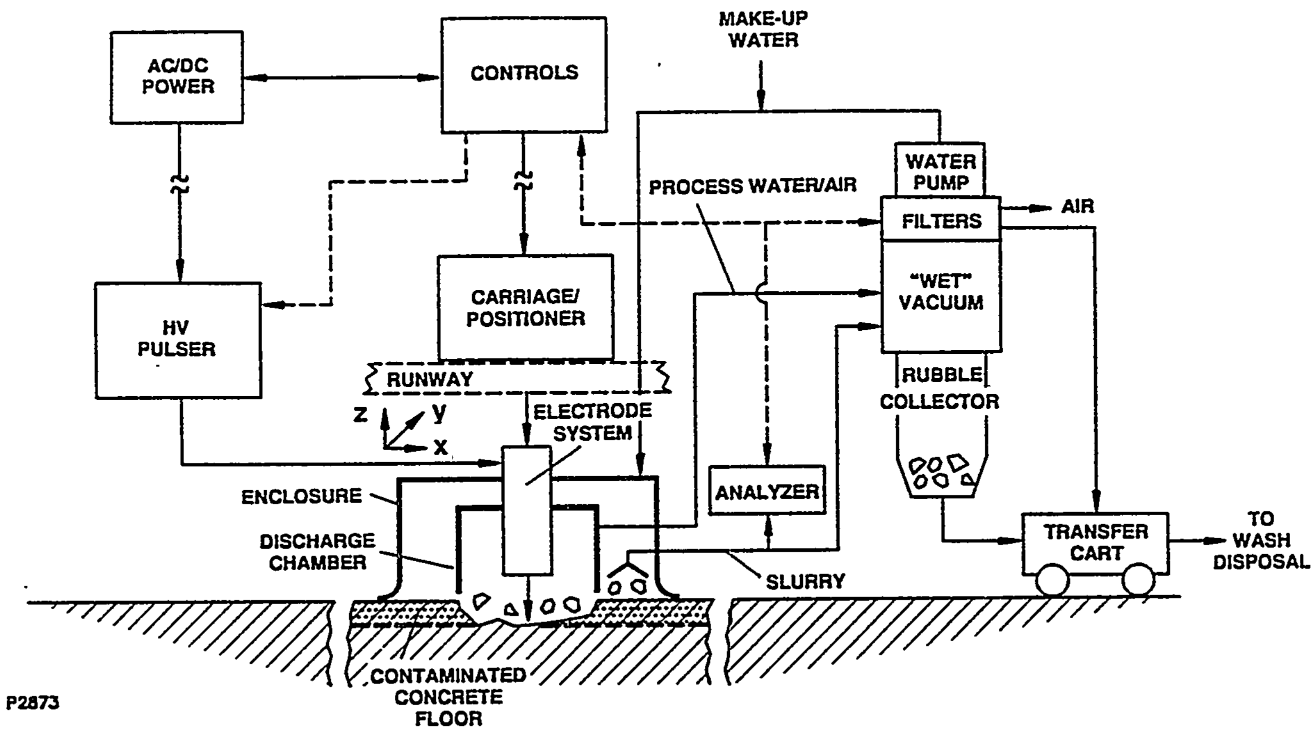


Figure 1-1 Block Diagram of Integrated EHS System

TABLE 1-1

PROJECTED PERFORMANCE OF INDUSTRIAL PROTOTYPE EHS MODULE

Parameter	Option A (High Voltage)	Option B (Super-High Voltage)
Scabbling Depth, cm	0.5-2.5	0.4-1.5
Width of Scabbling Trail, cm		
per electrode	4-6	2.0-4.0
per module	20-30	20-40
Scabbling Rate*, m^2/hr (ft^2/hr)	5 (54)	5 (54)
Scabbling Rate*, kg/hr	125	125
Electric Energy Consumption, kWh/m^2	5	2.6
Water Consumption, gal/m^2	3	3
Electrode (steel) Consumption per electrode, cm/m^2	2	0.2
Decontamination (as surface uranium activity, counts/min/100 cm^2)		
initial	1000-10,000	1000-10,000
final	100-500	100-500

*for 1 cm (~ 3/8") scabbling depth

TABLE 1-2

PRELIMINARY ESTIMATE OF EHS CAPITAL COST (K$)

Item	1-Module Prototype A(HV)	1-Module Prototype B(SHV)	3-Module Full-scale A
Electric Pulser	55	37	132
EHS Module	25	24	67
Slurry Management System	32	32	58
Carriage/Positioner with Controls	27	27	37
EHS System Integration, Testing (Labor)	15	15	25
Total EHS System Cost	**154**	**135**	**319**
Including:			
Components	94	80	200
Labor	60	55	119
Cost of One-Year Lifetime Components	17	10	35
Cost of Five-Year Lifetime Components	77	70	165

TABLE 1-3

PRELIMINARY ESTIMATE OF EHS DECONTAMINATION COST(1)

Item	Single Module	Three Modules
Processing Rate	10,000 m^2/year 5 m^2/hr	30,000 m^2/year 15 m^2/hr
Consumables		
Electricity(2)	0.48	0.43
Water	0.04	0.04
Electrodes, Other	0.12	0.12
Subtotal	**0.64**	**0.59**
Capital Cost(3)	5.4	3.8
Labor Cost(4)	7.9	3.2
Total(5)	**14 (1.3 $/ft^2)**	**7.6 (0.7 $/ft^2)**

Main Assumptions and Remarks:

(1) $/$m^2$. Numbers are for 1/4" scabbling, averaged between design options A (HV) and B (SHV).

(2) At 0.1 $/kWh rate.

(3) For 2000 net operating hours per year, five years service life, one year lifetime for some components. Engineering/design expenses not included.

(4) 2000 hrs/year operators time plus 500-1000 hrs/year setup and maintenance time; 75 $/hr labor cost, including overhead and management expenses, but not including health physics services.

(5) Waste disposal is not included.

of these laboratory demonstrations and site visits, Fermco has indicated in writing their interest in providing a host test site for EHS at Fernald, and Pentek, a decontamination equipment supplier, has indicated interest and has signed confidentiality statements to work with TDS in the commercialization of EHS.

Tasks performed in Phase I led to the following conclusions.

- The appropriate level of National Environmental Policy Act (NEPA) documentation required to complete Phase I was determined to be an Appendix B Categorical Exclusion (CX-B). The determination was reached after reviewing project information and examining Subpart D, Appendix B classifications in 10 CFR 1021.

- It was shown that EHS can be controlled to scabble between 3/16" and 1" surface layer in a single pass from bare or painted concrete.

- Accordingly, the technique is suitable for two applications: decontamination of (i) large concrete surfaces, and (ii) local defects deeply penetrated by contaminants. Horizontal surfaces (floor, blocks) were processed in the tests; however, it is evident that moderate hardware modifications will make EHS decontamination of vertical surfaces (walls) also possible.

- A single electrode pair forms a 1.5" to 2.5" wide scabbled swath. Wider areas can be processed either by employing multiple adjoining passes and/or by using a multielectrode scabbler. The processing rate and energy efficiency increase with multiple/adjoining passes.

- Depth and rate of removal can be controlled by varying the pulse energy, pulse frequency, and velocity of the scabbler travel over the concrete surface.

- Scabbling nonuniformity is defined by the concrete structure - local defects, density variations, and gravel size. Concrete exposed by scabbling is suitable for resurfacing.

- EHS removes concrete "contaminants," transferring them to a slurry. To prevent recontamination, contact between the slurry and concrete surface for water-soluble contaminants (e.g., ^{137} Cs salts) should be limited by a few minutes; for nonsoluble materials (e.g., uranium oxides or salts), an hour or more of contact is allowable. After slurry removal by wet-vacuuming, the concrete surface remains essentially radionuclide-free.

- A processing rate of up to 10 ft^2/hr was achieved for 3/8" deep scabbling with the single-electrode EHS unit . A four-electrode module should provide more than 40 ft^2/hr, which is suitable for many applications. A three-module system would match rates claimed for shallower (1/16" to 1/8") decontamination by dry scabblers.

- Maximum continuous operation time was 40 min., with 5 ft^2 concrete floor area scabbled to average 7/16" depth.

- The consumption of electric energy per unit area varies from 4 kWh/m^2 to 7 kWh/m^2 depending on the depth of scabbling. Use of a super-high voltage process is under development; this option promises 3-4 times higher energy efficiency.

- Water consumption and water/concrete slurry flow issues were partially addressed. A series of design modifications to reduce the water use to the projected 0.5-1 gal/ft^2 is under consideration.

We are projecting the following EHS advantages, benefits, and improvements:

- Reduction in health and safety risks. to the public and workers, and reduction in environmental risks.
- Decreased capital, operating, and maintenance costs (particularly for deep (> 1/4") scabbling).
- Reduced time for decontamination and decommissioning.
- Reduced quantity of secondary and final waste.
- Minimized spread of contaminants.

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, the cost of scabbling contaminated concrete surfaces is estimated to range between 1 and 2 $\$/ft^2$ for scabbling depths of between 0.25 and 1.0 inches. Further reduction in these costs can be expected as design improvements are introduced.

On the basis of the favorable test results and ccst projections the commercialization of EHS is being explored (see Appendices). Discussions and EHS demonstrations for equipment suppliers and service providers for the D and D industry have been made, and business relationships are being discussed. A host test site at Fernald has been offered by Fermco and Oak Ridge.

TDS strongly recommends the continuation of the development of the EHS process. Phase II of the project will be comprised of: (i) the formation of a team to pursue the commercial potential of EHS; (ii) the design and construction of a prototype EHS system; (iii) performance testing of the EHS system at a DOE facility; and (iv) cost analysis and market projections for EHS.

Phase III will be dedicated to long-term operation and durability testing at a contaminated DOE host site.

2.0 INTRODUCTION

2.1 CONCRETE DECONTAMINATION BY ELECTRO-HYDRAULIC SCABBLING CONCEPT

Contamination of concrete structures by radionuclides, hazardous metals, and organic substances (including PCB's) occurs at many DOE sites. Removal of the concrete surface layer is considered as the most effective decontamination technology, especially where the contaminants such as uranium and plutonium compounds, isotopes of cesium, cobalt, and strontium penetrate to a significant (up to 1/2-1 inch) depth. By deep scabbling, the whole mass of concrete structure is subdivided into contaminated debris (rubble) of relatively small volume and clean bulk concrete structure.

Textron Defense Systems (TDS) is developing Electro-Hydraulic Scabbling (EHS), characterized conceptually in Figure 2-1. This rapid, controllable concrete scabbling technique is based on the Electro-Hydraulic effect. This term summarizes several physical and chemical phenomena which accompany high voltage spark discharges in water (or other liquid).

A strong, short spark-like electric discharge in liquid (Figure 2-2) is accompanied by:

- Generation and propagation of an extremely intense shock wave (pressures of up to 100,000 atm).
- Generation and pulsation of gaseous/vapor discharge cavity, filled by liquid vapors (cavitation).
- Radiation of electromagnetic (including optical) waves by the discharge channel.

Accordingly, the EH effect has found previous technical applications for crushing and grinding of minerals, drilling of rocks, forming of metals, cleaning of surfaces, and demolition of foundations.

Specifically, when discharge takes place close to the concrete surface, cracks are formed and peeling of material takes place as shown in Figure 2-3. By varying the parameters of the electric discharge, e.g., energy, duration, repetition rate, etc., the depth of peeling, i.e., scabbling, can be controlled. A somewhat different mode of operation is also possible: when electrodes are placed very close to the concrete surface (or brought in contact with the surface), and voltage exceeds electric breakdown strength of concrete, the current pulse may propagate directly through concrete.

In this case, the layer of water (or other liquid or gaseous media with relatively high breakdown properties) acts as an insulator, preventing breakdown over the concrete surface. The two limiting, as well as intermediate, operation modes are illustrated by Figure 2-4. Their occurrences depend on the electric pulse voltage and duration and on the electrode position.

While this mode is not, strictly speaking, an electro-hydraulic phenomenon, the modes share many features (short electric pulse, presence of water, same character of concrete peeling); therefore we will consider the associated scabbling technique under the common EHS title.

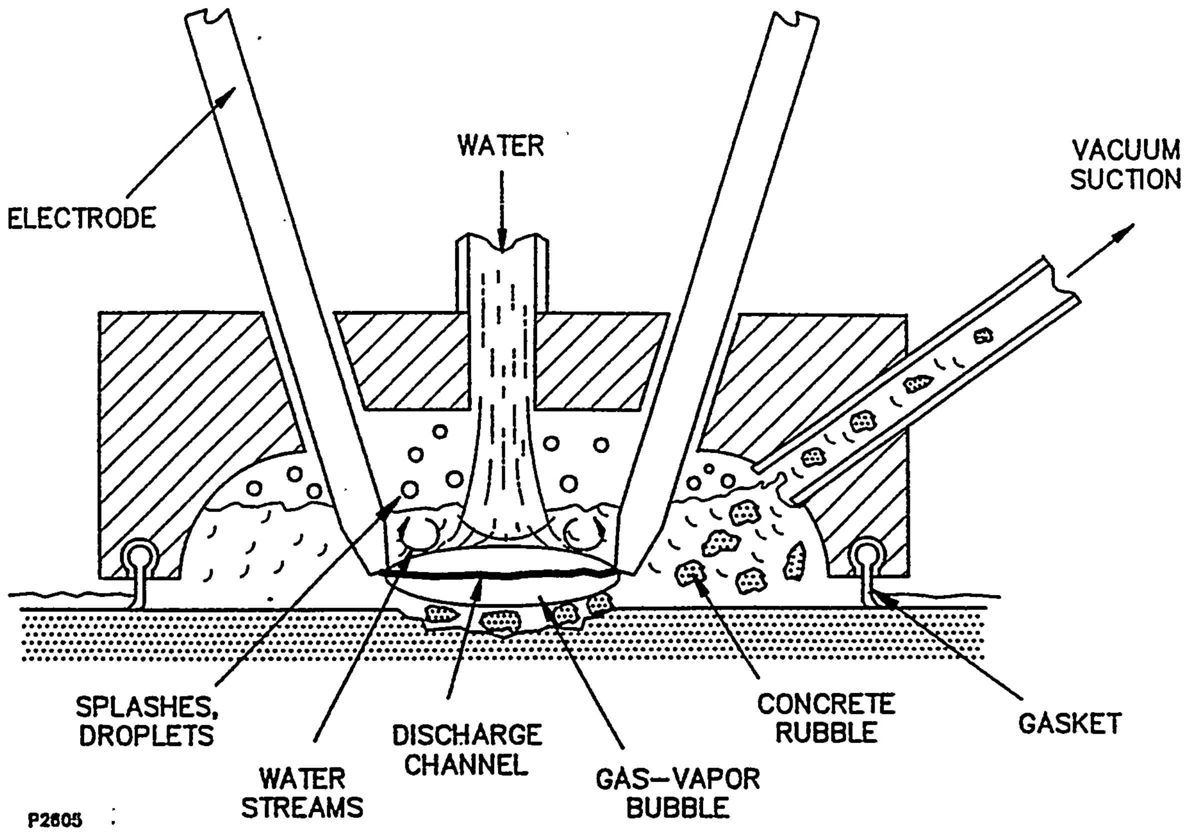


Figure 2-1 Conceptual Drawing of EHS Head

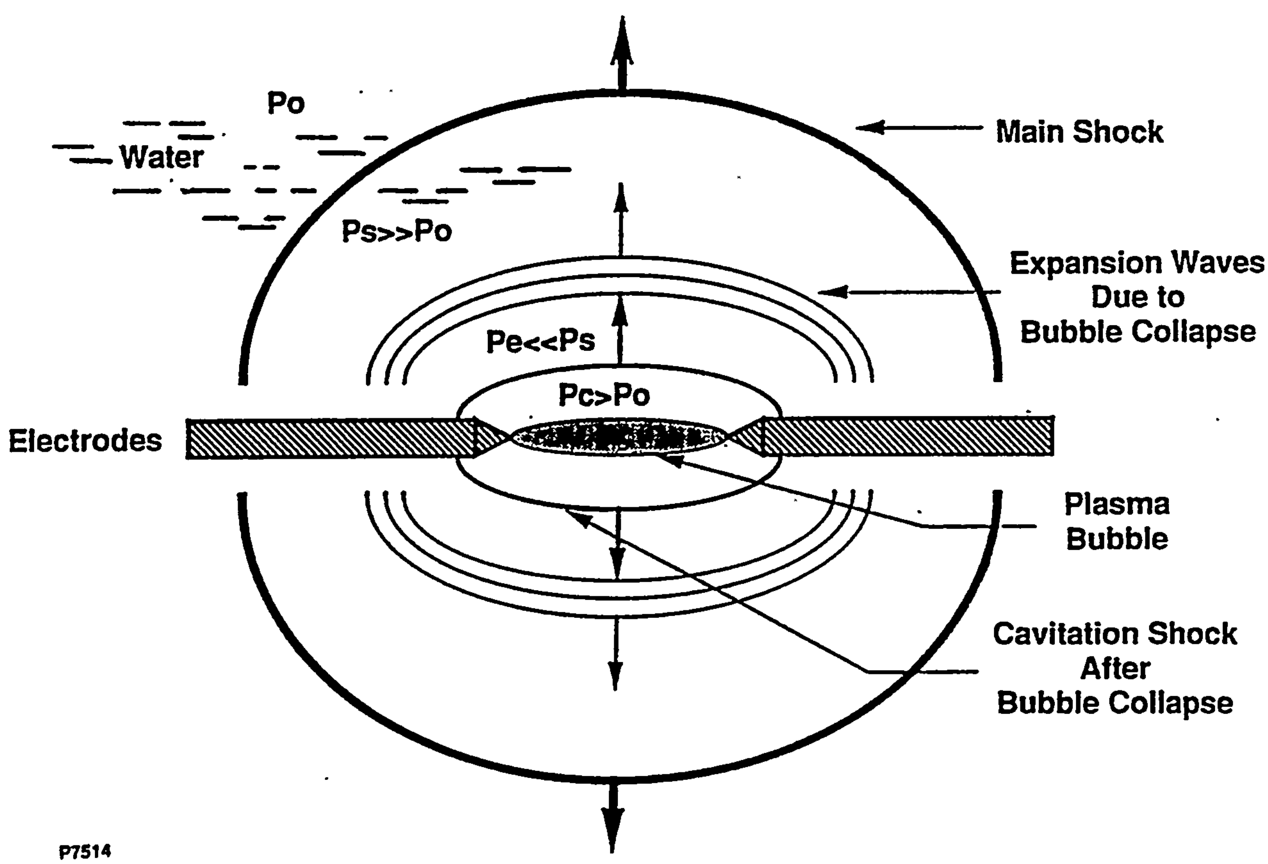


Figure 2-2 Conceptual Drawing of EH Effect

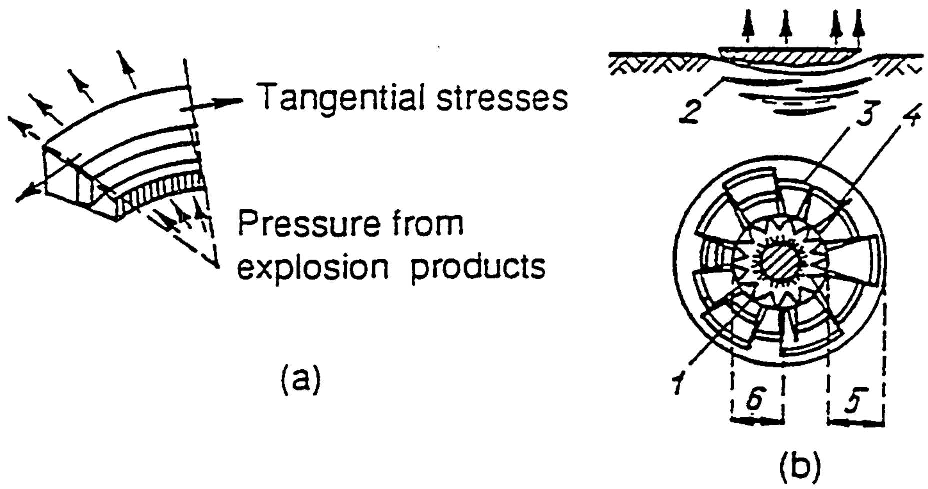


Figure 2-3 Schematic of Generation of Tangential Stresses in Material under Action of Explosion (a), and Peeling of Material at a Liquid-Solid Interface due to the Shock Wave Reflection - 1-location of explosion, 2-peeling, 3-concentric cracks, 4-radial cracks, 5-cracking zone, 6-compression crushing zone (Ref. 15)

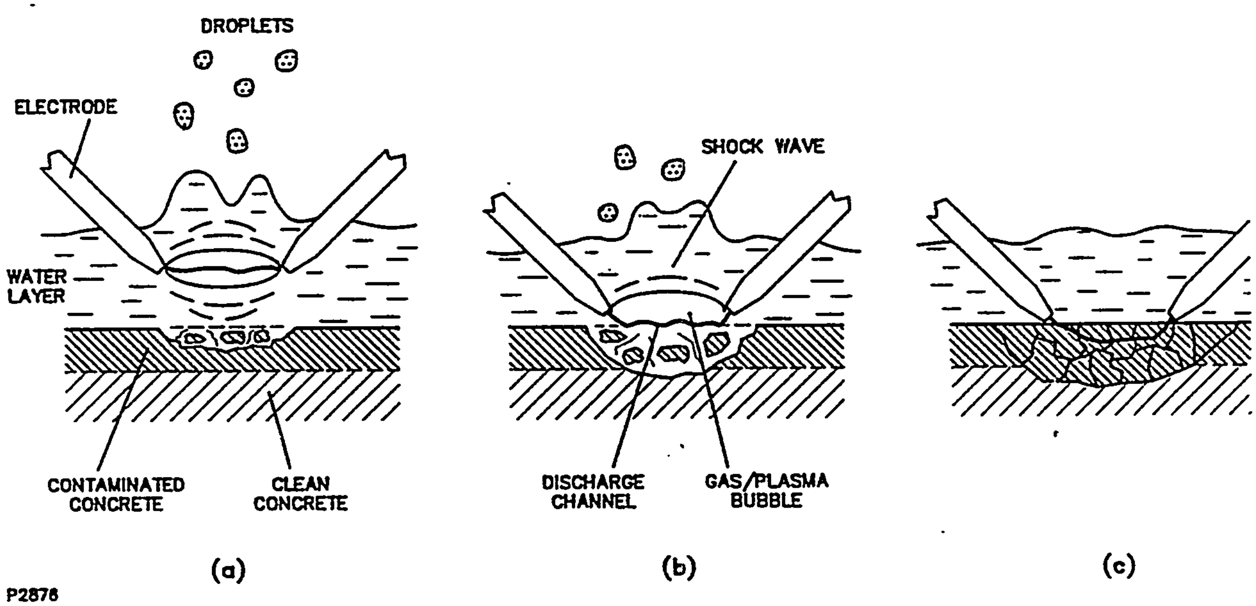


Figure 2-4 Comparison of Three Scabbling Modes
Electric Discharge Propagates
(a) Through Water (b) Along Concrete Surface
(c) Through Concrete

2.2 PROGRAM OBJECTIVES

2.2.1 General Objectives

Concrete structures, walls, floors, ceilings, etc., contaminated by radionuclides, heavy metals, and organics are major elements at practically all DOE sites. Because the contamination varies in type, concentration, and especially depth of penetration into the concrete, many techniques do not guarantee complete decontamination. For instance, even combined water flushing, high pressure spraying, strippable coating application, and hands-on wiping of internal concrete surfaces of the Three Mile Island Unit 2 reactor building did not reduce dose rates to acceptable levels.[1]

If the remaining surface and structure are decontaminated to a satisfactory level, the building may be reused or disposed of as nonhazardous, nonradioactive waste. Just as important, the amount of secondary waste - hazardous, radioactive concrete rubble - would be much lower than in the case of demolition of the whole structure. According to estimates provided in the D&D ID document, up to one inch penetration can be expected. This estimate agrees with data from the Three Mile Island reactor building data, where up to 20 mm deep contamination of concrete surfaces by both liquid- and vapor-borne substances has been detected.[2]

The discussion indicates that the successful concrete scabbling technique should provide:

- High productivity (high scabbling rate).
- Cost effectiveness (including cost of equipment, consumables, and labor).
- Scabbling depth control.
- Low volume of secondary waste (including process water).
- Ability to remove, transport, separate, and store the secondary waste.
- Environment/health safety (including remote control of operation).

Integration of real-time characterization of both the waste and the remaining concrete surface is desirable. Also, availability of a mobile unit (providing flexibility in application at a variety of sites, convenience and time saving in operation and equipment preparation) would be a considerable advantage.

It is projected that EHS technology will provide a sizable improvement over other available concrete decontamination techniques. Reduced energy and water consumption, dust generation, plus rapid processing of the concrete surface should result in a faster, less expensive and safer cleaning procedure. The main advantages from the development of EHS technology are listed in Figure 2-5.

2.2.2 Phase I Objectives

The primary objective of the first phase of the three-phase project was to prove the technical feasibility of EH technology for scabbling and decontamination of concrete by conducting laboratory experiments, analyzing test data, and projecting technical performance and process economics.

- HIGH POWER INPUT (energy per unit volume)

  ⟶ HIGH DECONTAMINATION RATE

- BETTER PROCESS CONTROLLABILITY, BROAD RANGE OF SCABBLING DEPTH

  ⟶ APPLICABLE FOR LARGE CONCRETE SURFACES AND DEEP LOCAL DECONTAMINATION

- LOWER (THAN MANY OTHERS) ENERGY CONSUMPTION

- LOW WATER CONSUMPTION

  ⟶ LESS SECONDARY WASTE

- NO DUST FORMATION

- REASONABLE EQUIPMENT AND OPERATING COSTS

- OTHER POTENTIAL USES FOR GENERIC EH TECHNOLOGY

Figure 2-5 Projected EHS Advantages, Benefits, and Improvements

Experiments which are a central part of Phase I had to begin with processing of clean concrete and proceed with concrete impregnated with compounds physically and chemically simulating those typical of the environment in DOE facilities.

A specialized laboratory rig had to be designed and built to conduct scabbling tests and auxiliary experiments with the following specific objectives:

1. To prove the technical feasibility of controlled, reasonably uniform concrete EH scabbling.

2. To select and optimize design of the EHS head.

3. To prove the feasibility of wet vacuuming technique to remove the rubble and to transfer sludge to separator/container.

4. To define the range of operating parameters.

5. To monitor removal and further distribution of simulating contaminants.

6. To characterize EHS performance, providing data for the design of a subscale EHS system.

7. To make preliminary estimates of the EHS economics.

2.3 BACKGROUND

2.3.1 Concrete Decontamination Techniques

Among the known and used techniques for decontamination of concrete, some chemical methods[3-5] involve only surface deposits of contaminants, a thin layer of paint, or a very thin layer of concrete itself. At the other end of the scale are demolition methods,[6-13] which involve destruction of the whole building, of a concrete body, or at least removal of a substantial part of its thickness (e.g., 3-4 inch thick concrete layer depth-limited by the reinforcing bars). We will not consider these techniques, limiting our discussion to methods allowing scabbling depth in the range from about 0.1" to 1".

Methods for removal of near-surface concrete layer, which are either commercially available or are at various stages of development, are classified in Table 2-1. In Table 2-2, a more detailed listing of some thermal and electrical techniques is provided (see also Ref. 3).

Electro-hydraulic scabbling, which is the subject of this program, can be compared with some other techniques. In the "Proposal" some of the EHS features and economics were compared to the ones of another "wet" method - decontamination by super-high pressure water jet. Comparison with microwave technique and with dry scabbling methods is made in Section 7.

2.3.2 Basics of the Electro-Hydraulic Effect

In this section we consider features of the EH effect to the extent they affect bordering solids and are important for EH practical uses.

A strong and short (pulsed) electric discharge in liquid is accompanied by the propagation of shock waves and cavitation effects. The EH effect shares common features with phenomena associated with conventional (chemical) underwater explosions. However, what is more

TABLE 2-1

CONCRETE DEMOLITION AND DECONTAMINATION TECHNIQUES

Mechanical	-	Chains and Saws
	-	Pneumatic Tools
Explosives	-	Small Multicharges
Thermal	-	Flame Jets, Plasma Jets
	-	Laser and E-Beams
	-	Microwaves
Blasting	-	Dry Scabbling: Abrasives
	-	Frozen Pellets
	-	High Pressure Water Jets
Electric	-	DC or Induction Heating of Re-bars
	-	Microwaves
	-	Wet Scabbling: Electro-Hydraulic

TABLE 2-2

CLASSIFICATION OF THERMAL AND/OR ELECTRICAL METHODS OF CONCRETE DEMOLITION

<u>Boring and Cutting Concrete with High Temperature Flame, Plasma, and Laser</u>	<u>Cracking and Peeling Concrete by Electronically Heating Reinforcing Steel</u>	<u>Breaking and Peeling Concrete by Directly Applying Electrical Energy to Concrete</u>
Thermal Flame Lance	Direct Electrical Heating of Reinforcing Steel	Microwave
Powder Flame Lance		High Frequency and High Voltage
Jet Flame Lance	Induced Electrical Heating of Reinforcing Steel	Electric Discharge
Plasma Powder Flame Lance		
Plasma Jet		
Laser Beam		
Electron Beam		
Arc Heating		

important for many applications, the multiparameter nature of the "electric explosion" provides more possibilities for process control than are available for ordinary explosions.

By varying the parameters of the electric discharge - energy, duration, repetition rate - conditions most favorable for certain effects can be generated.

Shock waves are most effective for crashing. It has been shown by many researchers (see, for instance, Refs. 14-16) that breaking of materials by shock wave impingement is due to formation of radial cracks generated by a compression wave. The growth rate of the cracks reach 7000 μsec. Even more effective are tensile stresses which are developed after reflection of compression waves from free surfaces of solids or from boundaries of body components with different acoustic toughness ($\rho \times a$ = density times sonic velocity). Low tensile strength of brittle, especially inhomogeneous, materials is responsible for this feature. For comminution of materials, e.g., fine grinding, and for scabbling of thin surface layers, after-discharge phenomena - cavitation and explosive boiling of liquid leading to high stress gradients, are of major importance. Motion of particulates in high-velocity liquid currents results in their abrasive wear and breakdown.

The qualitative understanding of EH phenomena may be sufficient for some practical applications, but development of efficient equipment, process optimization, and control requires development of at least semiquantitative theory. This development, initiated by pioneering, mostly experimental, works of Yutkin(17) in the 50's and 60's was conducted mainly by Russian researchers(18-22) and borrowed ideas and approaches from several fields of physics and mechanics, specifically physics of electric discharges, theory of explosions and shock waves, and knowledge of mechanical properties and strength of solids, especially rock, minerals, and building materials.

On the basis of electric discharge physics, approximate theories describing expansion of discharge channel in liquid have been developed. The theories estimate (i) transfer of electric energy into mechanical energy, (ii) total and partial hydrodynamic efficiencies vs. discharge geometry and electrical parameters, and (iii) pressure at shock wave front vs. distance.

The shock wave pressure can reach very high values. Results of theoretical calculations(18) of the initial values of:

a) velocity (v) of discharge channel expansion;

b) plasma temperature (T);

c) shock front pressure (pf); and

d) efficiency of transformation of electric energy input into shock wave energy (acoustic efficiency)

are shown in Table 2-3. Pressure drops rather rapidly (as $p_f = p_o(r_o/r)^{1.7}$), but still remains quite high - in the order of tens of atmospheres even at 1m distance from the discharge.

Much slower than shock wave phenomenon is a process of growing and subsequent oscillation of the discharge cavity with a characteristic time of about one millisecond.(23)

Data in Table 2-4 illustrates dependencies of the shock wave, (η_{sh}) i.e., acoustic, and cavitation (η_c) efficiencies on characteristic parameters of a discharge circuit. Partition of energy input between other forms for underwater explosion of TNT, electric explosion of thin

TABLE 2-3

THEORETICAL VALUES OF INITIAL DISCHARGE AND SHOCK WAVE PARAMETERS

$\dot{N}/\delta$ W/s · m	V, m/s	T, K	P_f, kg/cm^2	V_f, m/s	η_{sh}, %
10^{14}	280	12,100	640	1,650	27.3
10^{15}	440	17,700	2,020	1,900	30.4
10^{16}	800	26,000	6,400	2,490	33.2
$3 \cdot 10^{16}$	1,000	30,300	10,120	2,870	34.0
10^{17}	1,410	38,200	20,200	3,600	35.7

$\dot{N}/\delta$ - Rate of Power Increase Related to Electrode Gap Length

TABLE 2-4

HYDRAULIC (CAVITATION) (η_c), ACOUSTIC (η_{sh}), AND TOTAL $\eta = \eta_c + \eta_{sh}$ EFFICIENCY OF EH DISCHARGE VS. CAPACITANCE (C), INDUCTANCE (L), DISCHARGE GAP (δ), AND CHARACTERISTIC DISCHARGE PARAMETERS $x = U^2L^2\,[LC]^{1/2}$ AND $y = \delta/L\,[LC]^{1/2}$

U, kv	C, μF	L, μH	δ,mm	η_{sh}	x	y	η_c	η
20	10	10	20	0.30	400	0.20	0.27	0.57
10	10	10	10	0.29	100	0.10	0.25	0.54
5	10	10	10	0.27	025	0.10	0.12	0.39
5	10	1	5	0.31	8,000	1.60	0.20	0.54
10	10	1	10	0.31	30,000	3.00	0.07	0.38
10	100	1	10	0.31	10,000	1.00	0.07	0.38
10	10	30	10	0.27	006	0.20	0.10	0.37

wire and electric spark is given in Table 2-5. In the next section, the effect of these electro-hydrodynamic phenomena on solids subject to destruction is considered in more detail.

2.3.3 Quantitative Characterization of EH Destruction of Solids

To better understand the mechanism of destruction of materials by EH pulses, a similarity with the destruction produced by conventional (chemical) explosions can be used. It has been shown,(24) for instance, that under certain conditions EH explosion has the same pressure field as chemical explosion if corresponding energies E(ch) and E(el) are interrelated as

$$E(ch)_{sh} = 1.75\ \eta_{sh}E(el) \quad \text{and} \quad E(ch)_c = 2.7\ \eta_c E(el)$$

where η_{sh} and η_c are efficiencies of shock wave and cavitation action, respectively.

Two material destruction mechanisms are usually considered: a) fracture by propagation of direct compression wave, and b) peeling, resulting from tension stresses accompanying propagation of the reflected wave.

For minerals and building materials, tension strength usually is 5 to 20 times lower than compression strength (for concrete this ratio is in the 6 to 10 range); therefore, the second mechanism is usually more important. The effect of the explosion changes with distance: in the near zone compression and comminution of material by gases/vapors from chemical/electric explosion takes place; at larger distances (loosening zone) cracks are formed by compressive or, more probably, tensile stresses.

The destruction mode is correlated with acoustical toughness of materials.(16) Materials with $\rho a > 2 \times 10^6 g/cm^2$ s are destroyed by stress waves, and with $\rho a < 5 \times 10^5$ mostly by the direct action of gases generated by explosion; for intermediate values of ρa both mechanisms are of importance. For concrete ρa, i.e., is rather low. Therefore, an EH explosion of relatively long duration and low voltage is expected to be more efficient.

Theories of material destruction by chemical and electric explosions (e.g., in Refs. 14, 17, 24-27), when used for the prediction of material removal by surface indentation, agree reasonably well with experimental data. It has been found, specifically, that

- Energy consumed for destruction depends on material properties as

  $$E \sim \theta^{1/3}$$

  where hardness θ is proportional to Young modulus or compression strength. For most building materials and rock $0.2 < \theta < 3$, with concrete values in narrower 0.5 to 1.5 range.

- Depth h and radius R of indentation produced by EH explosion

  $$h_I = h_0\,(CU^2/\theta)^{1/3},\ R_I = R_0\,(CU^2/\theta)^{1/3},$$

  where capacitance (C) is in μF, voltage (U) in kV. Here h_0 = 0.6....1.3 and R_0 = 0.9....1.1 are weak functions of indentation shape, which depends, in turn, on the size of the explosion source (i.e., the discharge gap). For concrete, R = 0.2.....0.4 h. Some data characterizing these relationships numerically are provided in Table 2-6. According to semiempirical relationships, depth of indentation for average concrete can be estimated as $h_{con} = 0.5\,(CU^2)^{1/3}$.

TABLE 2-5

ENERGY PARTITION (%) FOR EXPLOSIONS IN WATER

Mode	Type of Explosion		
	Chemical (TNT)	Wire	EH
Acoustic (Shock Wave)	63	58	30
Cavitation (Bubble Formation)	31	27	22
Radiative and Conductive Losses	6	15	48

TABLE 2-6

DEPTH (h_I) AND DIAMETER (d_I) OF INDENTATION (CAVITIES) IN SOLID MATERIALS VS. EH DISCHARGE CIRCUIT PARAMETERS

δ, mm	C, μF	U, kV	d_I, mm	h_I, mm
1.1	2.0	5	2.7	1.7
1.1	2.0	7	3.5	2.7
1.1	2.0	10	4.9	3.1
3.0	2.0	10	11.2	13.8
3.0	0.5	20	15.0	16.8

Efficiency of energy transfer to a solid body and specific energy consumption (q) depend strongly on the location of the explosion source: it is usually rather low (~ 2%) for an unrestricted "surface" source, and 10-20 times higher for a source located in a blast-hole.

Both theoretical estimates and experiments indicate that specific energy is

$$q_{surf} = \frac{CU^2/2}{2/3\pi R^3} = 11\,\theta$$

and

$$q_{hole} = 0.6\,\theta$$

for surface and blast-hole explosion, respectively. For concrete with $\theta = 1$, $q_{surf} = 110$ J/cm^3 and $q_{hole} = 6$ J/g· Evidently, for higher energy efficiency, the configuration of EHS device (electrode geometry, their distance from the surface, etc.) should be chosen to provide some directed action of the electric explosion.

A substantial volume of experimental data has been accumulated in relation to EH drilling which has already been mentioned as one of the main EH applications. The rate of EH drilling can be estimated using the following expression:

$$dh/dt = n^{\alpha}(CU^2/\theta)^{1/3}$$

where n is number of discharges and $\alpha(\theta)$ is about 0.5 for $2 < \theta < 10$.

Figure 2-6 (from Ref. 24) illustrates the dependency for concrete. The drilling rate decreases with number of pulses; the initial rate (which should be close to the scabbling rate) is the highest. Theoretical and experimental data for drilling rates compared in Table 2-7 reasonably agree.

Size distribution of lumps and particles produced by the near-surface explosions is of practical importance. It has been shown that characteristic lump size depends mostly on the pulse energy, material hardness, and rate of power delivery defined by parameters of the electric circuit. Table 2-8 shows typical EH data in comparison with data for chemical explosions. It is important, that characteristic size can be varied by changing $\dot{N}$ (or current rise time). This opportunity does not exist in chemical explosions.

2.3.4 Projection of EHS Energy Requirements

The main parameters defining EHS performance are scabbling rate (i.e., square meters per hour) and energy consumption. The relative importance of the two parameters depends on circumstances which are rather specific for the limited volume of DOE-related decontamination work to be performed: it matters whether the pace of decontamination or the decontamination expense are of greater concern. Also, the two parameters are interdependent: clearly, decontamination can be accomplished rapidly even with low productivity and high specific energy consumption, but at a higher cost.

For the estimates, the energy efficiency value is needed. The sequence of energy transformations is schematized in Figure 2-7. With 10% electric circuit losses, about 50% of input (AC) energy remains in the water, but only a small part of this amount (from 2% to 40%, according to experimental data and theoretical estimates) is effectively transformed into energy

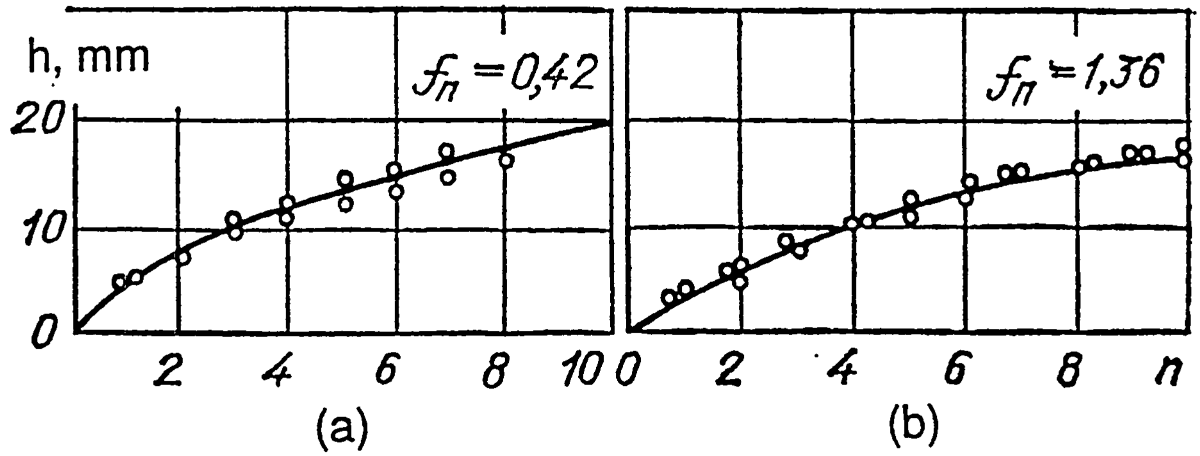


Figure 2-6 Depth of Drilling Hole in (a) Medium Strength and (b) High Strength Concrete vs. Number of 100 J (10 kV, 2 μF) Electric Pulses through 5 mm Discharge Gap

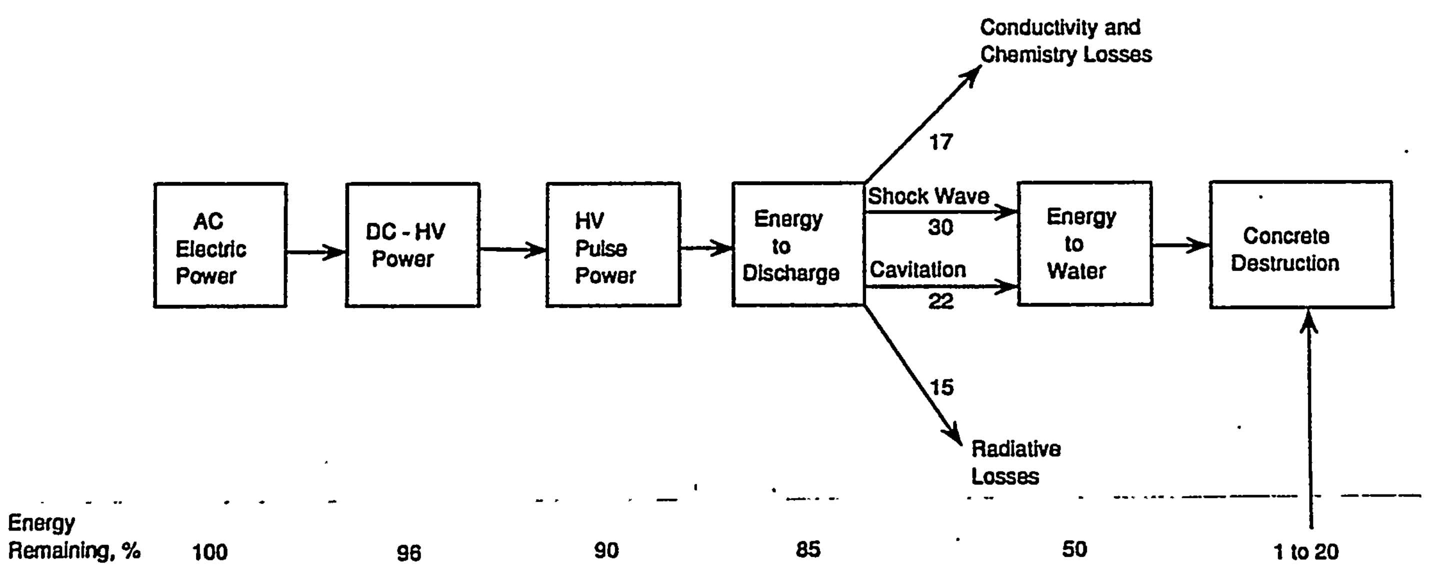


Figure 2-7 Schematic of Energy Transfer from Energy Power Supply to Concrete Destruction

TABLE 2-7

COMPARISON OF CALCULATED AND MEASURED DRILLING RATES

Material	θ	E_o,J	dh/dt, mm/min Experiment	dh/dt, mm/min Calculations
Concrete	0.8	350.0	50	54
Granite	10.0	350.0	20	22
Shale	2.0	62.0	50	48

TABLE 2-8

CHARACTERISTIC SIZE (mm) OF RUBBLE VS. INPUT POWER INCREASE RATE

Explosion	$\dot{N}/\delta$, W/s · m	Shale	Rock
Electric	10^{15}	9.1	3.4
	10^{16}	16.0	5.3
	10^{17}	29.0	10.7
TNT	-----	25.0	15.5

for concrete disintegration. The actual value depends as much on intelligent selection of the discharge parameters and electrode/discharge geometry, as on conditions for propagation of shock waves and explosion products. As already mentioned, EH explosions in a restricted volume provide an efficiency close to the upper limit, while unrestricted explosions, e.g., in case of scabbling, result in efficiencies not exceeding a few percent. For preliminary estimates, 0.5 to 1.5% of "wall-plug to rubble" efficiency may be assumed.

Using concrete strength data, we obtain a specific energy required to crush various makes of concrete from infinite size (bulk) to 100 microns in the 50 to 150 J/cm^3 range. To calculate the specific energy required to crush concrete to other characteristic dimensions (D), the scaling proposed by Bond can be used:

$$E \sim 1/D^{1/2}$$

The medium (weighted) size of concrete rubble, measured in Ref. 37 demolition experiments was about 20 mm; it can be expected (and actually shown in our tests) that for "milder" surface scabbling, the size is less. Assuming D=3 mm, we arrive at specific energy requirements of 9 to 27 J/cm^3 range. At 1% of concrete destruction efficiency, this corresponds to the energy consumption of 900 to 2700 J/cm^3, 400 to 1200 J/g, or 110 to 330 kWh/t. These values agree reasonably with direct energy consumption measurements made for the full range of applications from fine grinding to demolition and splitting of heavy rock and concrete panels; typically, specific energies of 5 (demolition) to 50 (grinding) kWh/t are quoted for materials of hardness comparable to that of concrete. Summarizing available data, we arrive at the conclusion that a specific destruction energy at about 200 kWh/t can be used as a conservative basis for a priori estimations. By 1 cm deep scabbling, 25 kg of concrete is removed per 1 m^2; therefore, 5 kWh/m^2 energy consumption can be expected for EHS.

2.3.5 Applications of EH Effect

Several technical applications of EH effect have been developed and some of them have found rather broad industrial applications. We present these to illustrate that, while EH use for decontamination is a new concept, there is a solid body of work for other applications. One way to classify these applications is to consider them by the industrial area.

2.3.5.1 Processing of Minerals[17,23,24,28]

EH comminution - crushing, coarse and fine grinding of minerals and abrasives - is a viable alternative to mechanical technologies when contamination of materials and/or dust formation should be avoided.

Industrial installations have been developed in Russia; one of them includes three sequential EH processing stages reducing mineral sizes to 2 mm and, finally, to 5 microns. Typical energy consumption is 100-300 J/g (30-90 kWh/t).

The EH comminution is most efficient when materials are highly inhomogeneous and/or anisotropic. It has been shown recently[30] that an economically viable approach is to use EH as a pretreatment to mechanical comminution.

2.3.5.2 Mining[17,24,28,31-35]

Two applications should be mentioned here:

a) EH drilling of rocks can compete successfully with mechanical, thermal (flame and plasma) and explosion technologies. Table 2-9 provides some drilling data.

Compared to other techniques, EH drilling has a potentially maximum rate, primarily due to high power that can be transferred to rock. While specific (per unit volume) energy can be somewhat higher than for advanced mechanical methods, it is much lower than for many novel technologies, including plasma, laser, and microwave.

b) For splitting of large boulders or rock (e.g., produced by explosive blasting), the discharge head is positioned in a small bore hole filled with water; electric explosion produces high tensile stresses in the rock surrounding the hole. About 8 kJ is required to split 1 m^3 of granite with one to three discharges.

2.3.5.3 Machine - Building[23,24,36]

EH cleaning (shaking, core removal, etc.) of castings is broadly used in Russian foundries: several hundred units with capacities from 1 to 40 tons are in operation and are now available commercially. Electric discharge takes place between the electrode and grounded body of casting submerged in a water tank. Cleaning of the interior of process tanks and containers by EH-generated cavitation and liquid streams has been tried.

2.3.5.4 Building Industry

Two EH technologies will be considered in this section:

a) EH compaction (consolidation) of building materials (specifically, from utility wastes) and soils has been developed, and industrial equipment for this purpose is available. The compaction takes place mainly due to removal of a gaseous component which is replaced by water and solid soil. Productivity of the unit and specific energy input are about 50 m^3/hr and 0.1 kWh/m, respectively.

b) EH demolition of concrete structures is a relatively new application, described in Refs. 37 and 38. The technique is, in principle, similar to the one used for splitting boulders and rock: the EH head is positioned in predrilled shallow bores; electric explosion results in separation of concrete from rebars. A specific EH feature, namely, effectiveness in destruction of inhomogeneous materials, is exploited here.

A pilot design pictured in Figure 2-8 is used for demolition of reinforced concrete panels weighing over one ton. Several pneumatically controlled heads are used. Performance data of the unit are given in Table 2-10. Two important features are of interest:

- The rebar structure remains intact after processing, and can be reused.
- Rather large primary concrete rubble can be reduced in size by an ancillary EH crusher, and used, after fresh material makeup, for making concrete similar to the initial material.

2.3.5.5 Other Applications

Among other applications are:

a) Surface sparking which is broadly used to take solid (powdered) samples from the surface for the purpose of composition analysis. Use of EH mini-explosions generates water suspension, which can be immediately transferred to an analytical instrument (e.g., ICP-ES, mass-spectrometer or X-ray spectrometer) for real-time characterization.

TABLE 2-9

EH RADIAL DRILLING DATA*

Rock	Charging Voltage (kV)	Capacitance (μF)	Drilling Rate (cm/min)	Spark Energy (Joules)	Specific Energy (Joules/cm^3)
Clay	25	0.2	12	62.5	39
Shale	25	0.2	5	62.5	95
Quartz	25	0.2	2	62.5	235
Marble	30	0.1	1	40	340
Diabase	30	0.1	0.3	40	1130

*for 3 cm dia., 4-5 cm hole, 2 Hz

TABLE 2-10

PERFORMANCE OF EH DEMOLITION UNIT (REF. 37)

Parameter	Interior Panel	Exterior Panel
Volume	0.31	0.32
Concrete Mass, kg	668	815
Metal Mass, kg	30.5	33.3
Energy Consumption, kWh	4.2	9.0
Specific Energy, kWh/t	6.28	11.04

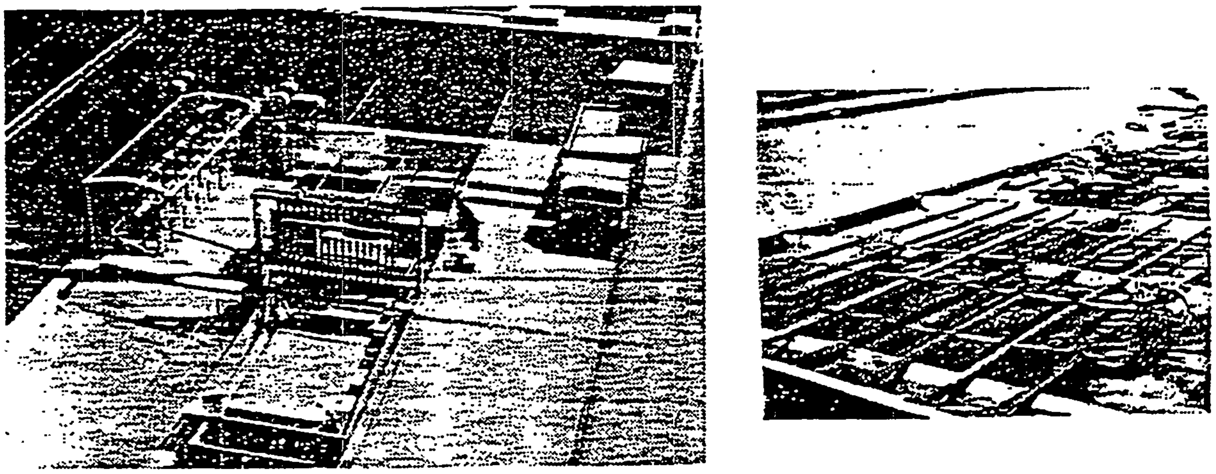


Figure 2-8 Installation for Demolition of Concrete Structures (Ref. 38)
(a) General View, (b) Rebar Structure after Demolition

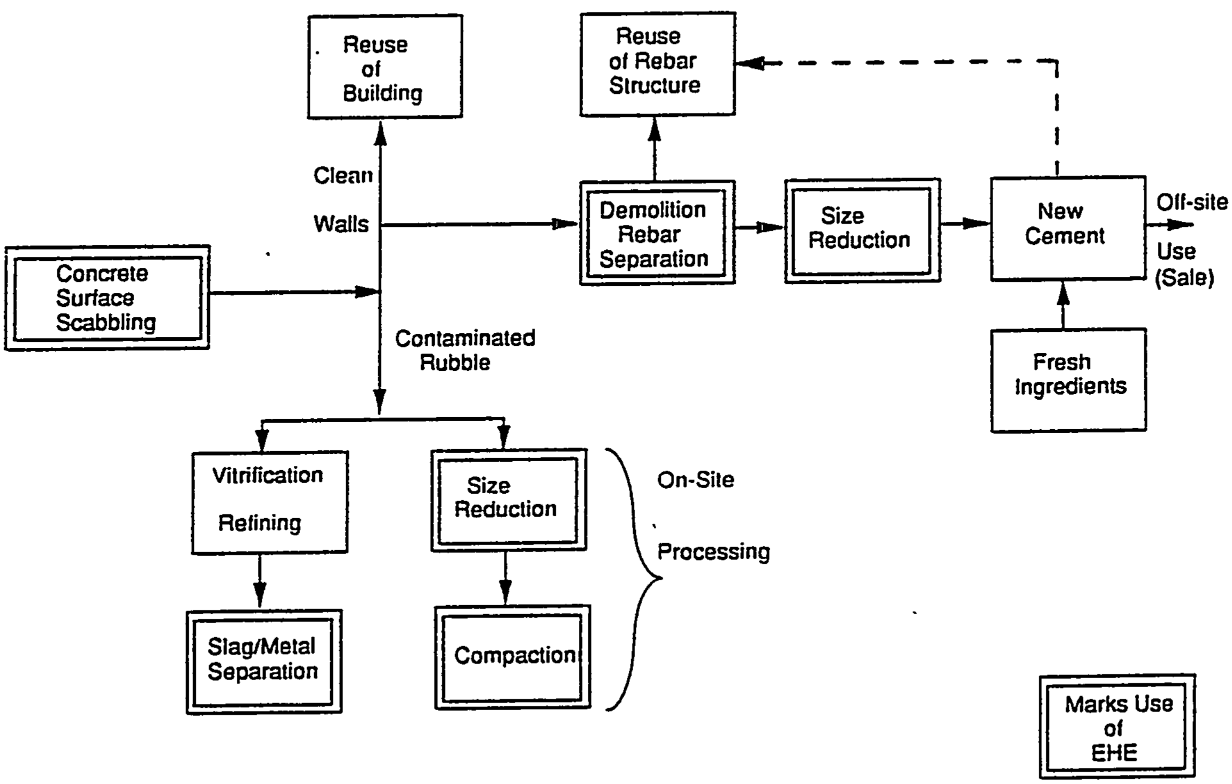


Figure 2-9 Suggested Uses of Electrohydraulics in Decontamination, Demolition, Disposal, and Reuse of Concrete Structures

b) Generation of strong acoustic waves ← ocean waters (acoustic sonar system[39]).

c) Water pumping.[22]

The listing shows a rather broad spectrum of EH effect-applications, several already in commercial use. Some of the applications, especially for drilling, compaction, and demolition, satisfy requirements rather similar to those for scabbling. As illustrated by Figure 2-9, the uses of EH technology in the D&D field besides scabbling are apparent.

3.0 BASIC CONCRETE SCABBLING LABORATORY EXPERIMENTS

The basic experiments were conducted to establish conceptual feasibility of the EHS technique, to develop hardware with a lifetime sufficient for short laboratory trials and at least a prospective for industrial applications, and to gather semiqualitative performance data. In this task, design, assembly and countless modifications of hardware were intervened with scabbling trials; therefore it is expedient to consider them together in chronological order.

3.1 INITIAL LABORATORY SETUP AND EXPERIMENTS

The laboratory experimental program started in October 1993 by assembling a test rig (Figure 3-1) which included HV power supply (pulser), water tank/water circulation loop, and discharge chamber/processing heads mounted on a support with a one-dimensional motor drive. A conceptual schematic of the pulser is shown in Figure 3-1a; typical current and voltage records are presented in Figure 3-1b. Concrete blocks (Figure 3-2) with 20"x20" and 20"x30" surface area and 4" to 5" thick could be placed on a supporting metal grate.

The first experiments were directed toward development of design and selection of materials allowing single and multipulse operation of the unit without fast erosion and/or fracture of the electric discharge chamber. Several simple designs and materials were tried (see sketches in Figure 3-3) until a configuration satisfactory for at least a few hundred pulses could be selected.

Formation of cavities over the surface of concrete blocks under a discharge camera held in a fixed position has been observed. According to these qualitative tests, substantial removal of concrete takes place only with electrodes located very close to the concrete surface. This indicates that concrete surface discharge, or possibly higher voltage (and very short) discharge through the surface concrete layer, may be more efficient than discharge through the bulk of water.

It was also established that a heavy, strong, shock-resistant discharge chamber support/positioner is required.

The "static chamber" experiments were followed by scabbling tests using discharge chambers of open and enclosed designs moving over the concrete block surface. About 1" wide, 1/4" deep grooves were formed with a single electrode pair chamber moving at 1.5"/min. rate and delivering 800 J (nominal) pulses at 1 Hz frequency. It became clear after several experiments that the process "head"/discharge chamber is too weak mechanically even for laboratory tests.

Strong vibration affected a moving frame, drive, and discharge head. These components were redesigned and reassembled. The changes included:

1) Enclosed EH head made of molded acetal plastics (Figure 3-4a).

2) Open (except rubber skirt to prevent water spillage) EH heads made of G-10 composite (Figure 3-4b,c).

3) Heavy EH head support and transport mechanism; this mechanism is based on a milling machine installed next to the water tank (Figure 3-5).

Test runs made with this hardware demonstrated improved mechanical stability. Simultaneously, some changes were introduced in the electrical subsystems: a new stand

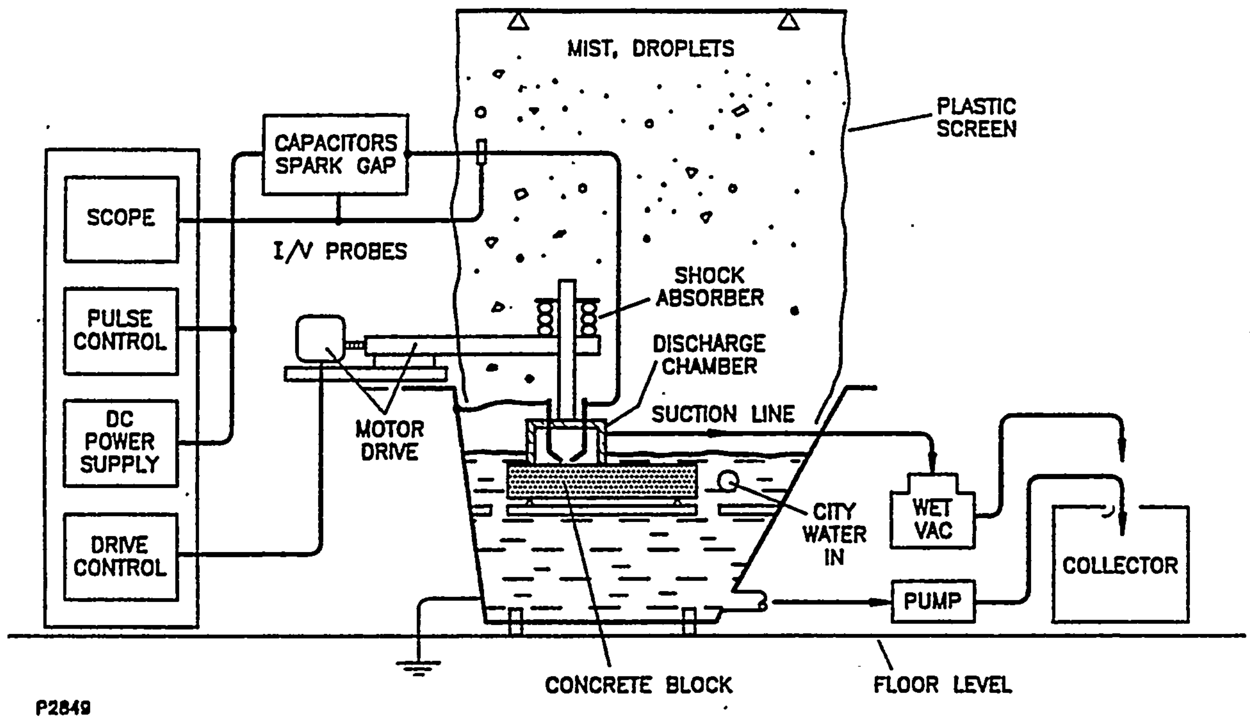


Figure 3-1 Laboratory Setup for EHS of Concrete Slabs

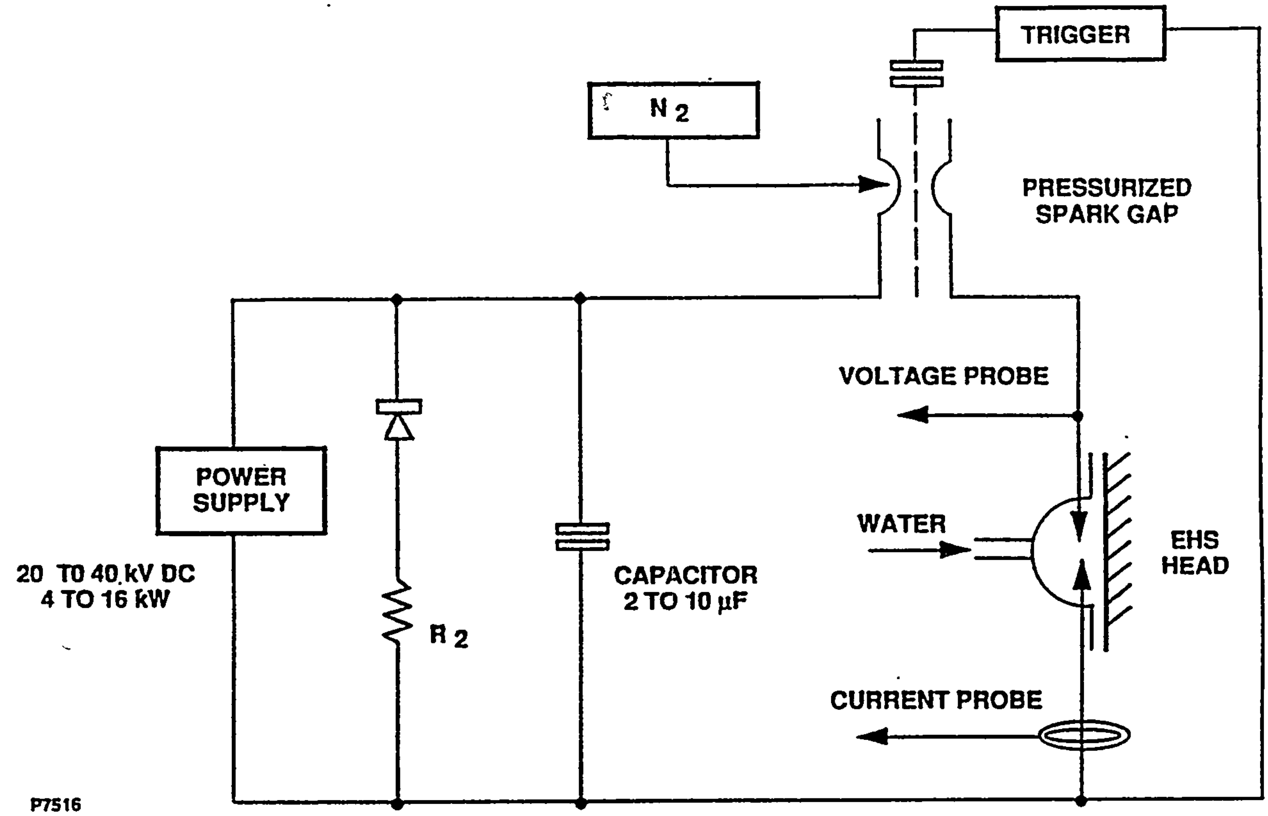


Figure 3-1a Conceptual Schematic of High Voltage Pulse Generator

Electric parameters:

C = 2 to 4 mkF, U = 15 to 22 kV

Pulse power (nominal) 200 to 600 J

Pulse duration 2 to 4 mks

Pulse repatition rate 0 (single pulse) to 5 Hz

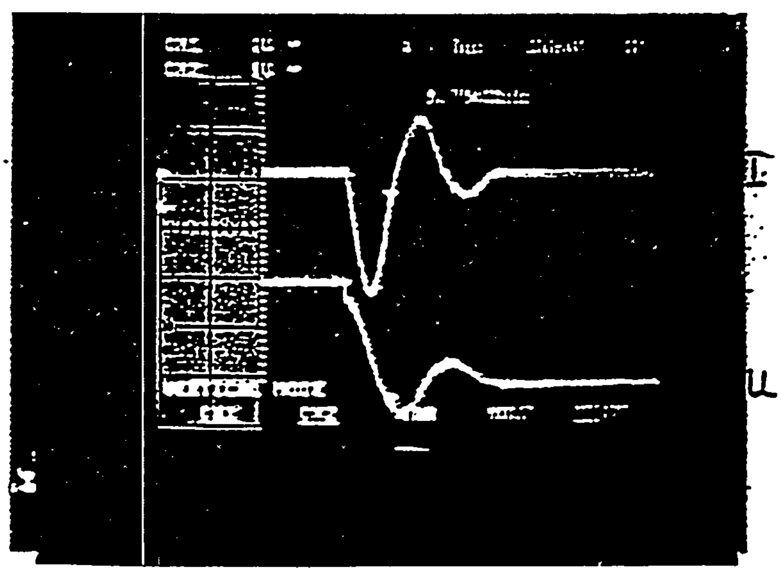


Figure 3-1b EH Discharge Current and Pulse Shape

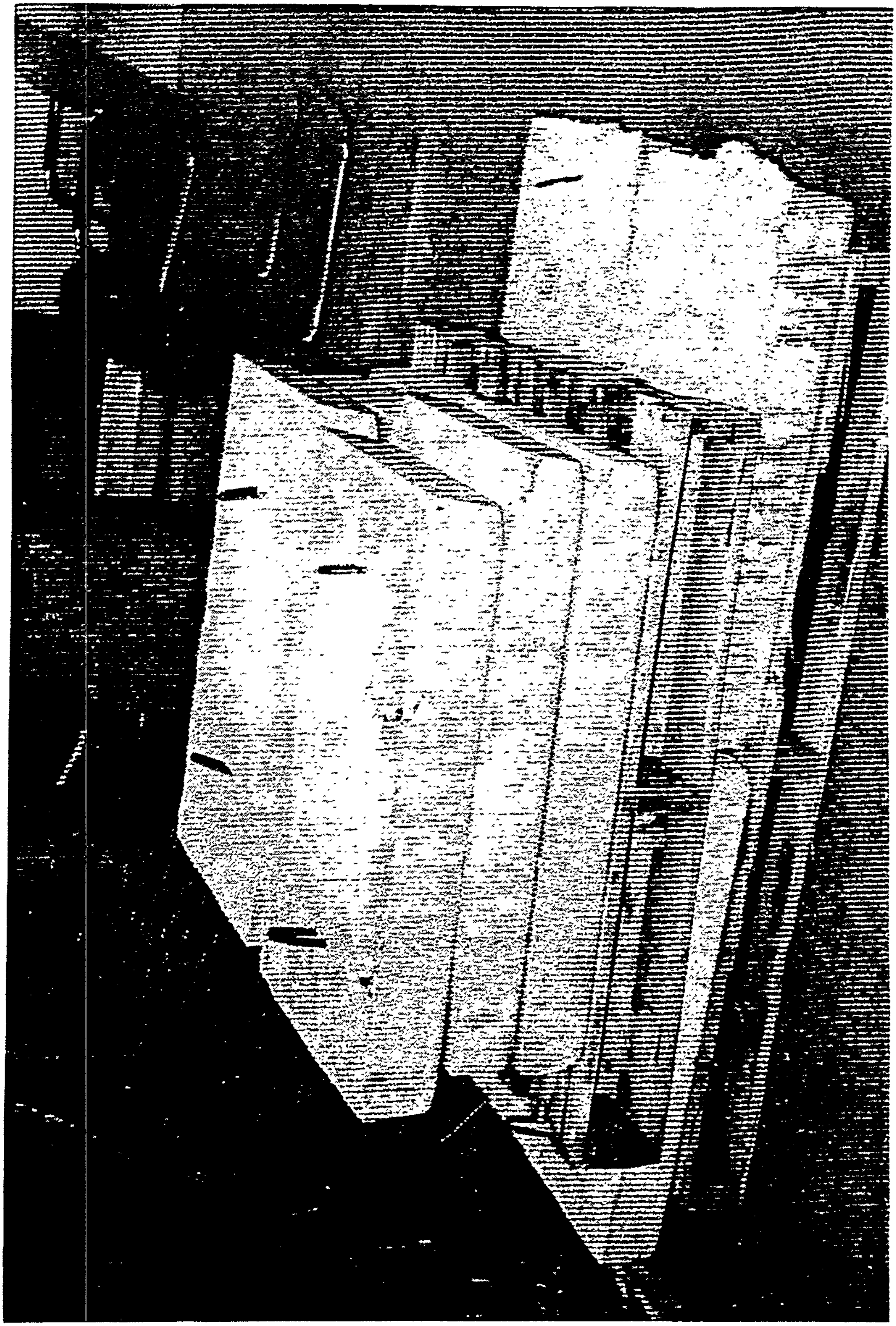


Figure 3-2 Concrete Slabs Prepared for Scabbling

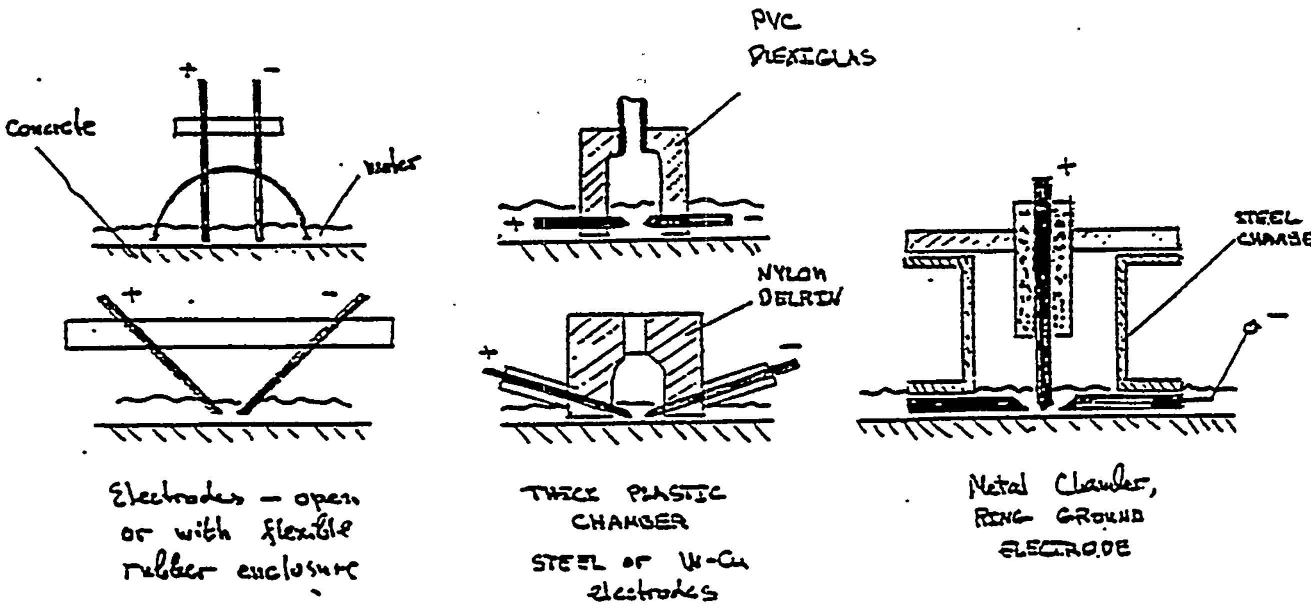


Figure 3-3 Electrode and Discharge Chamber Development History

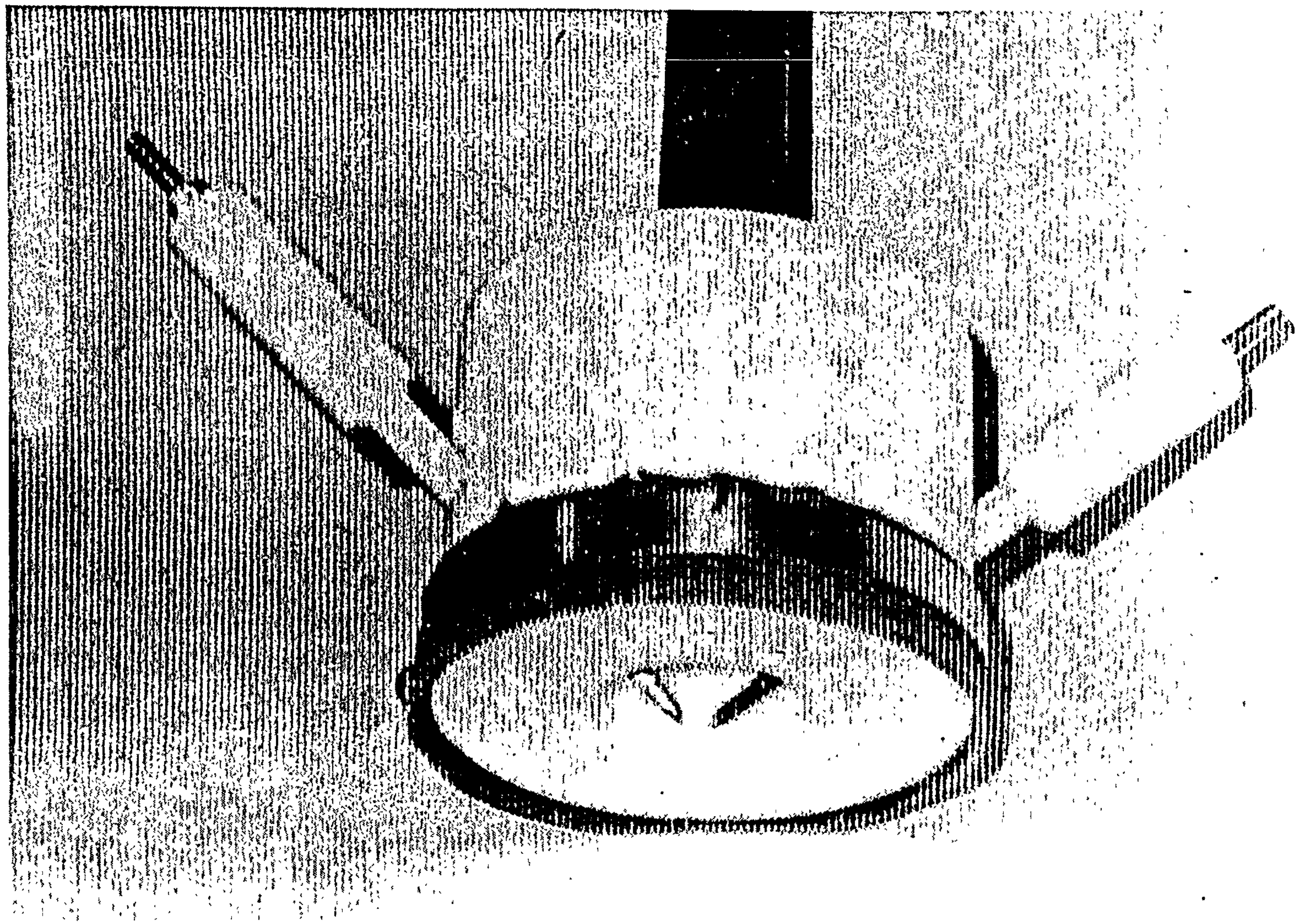


Figure 3-4 Discharge/Scabbling Chambers used in Laboratory Experiments
a) Enclosed, made of Acetal Plastics
b) and c) Open, made of G-10 Composite

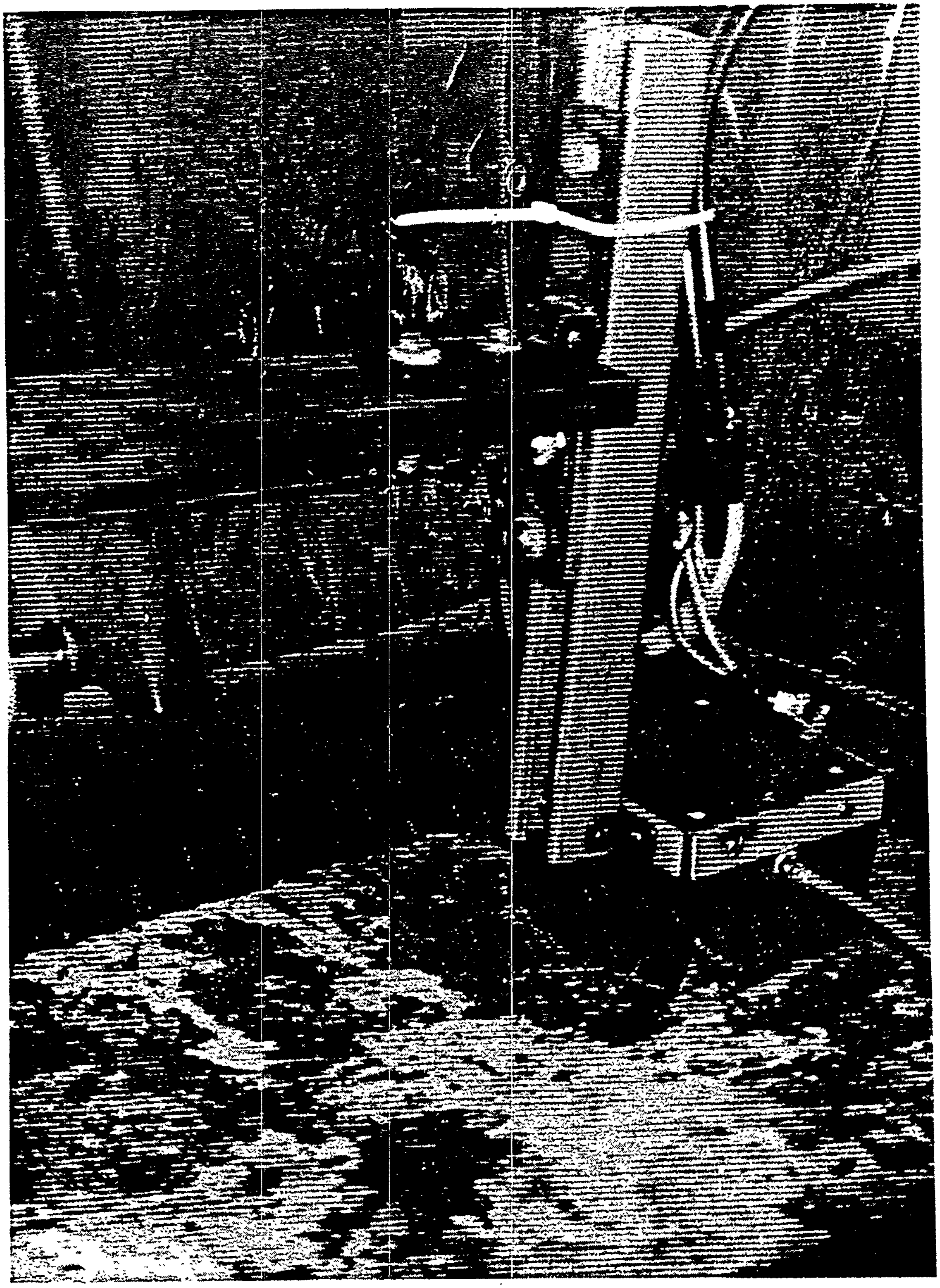
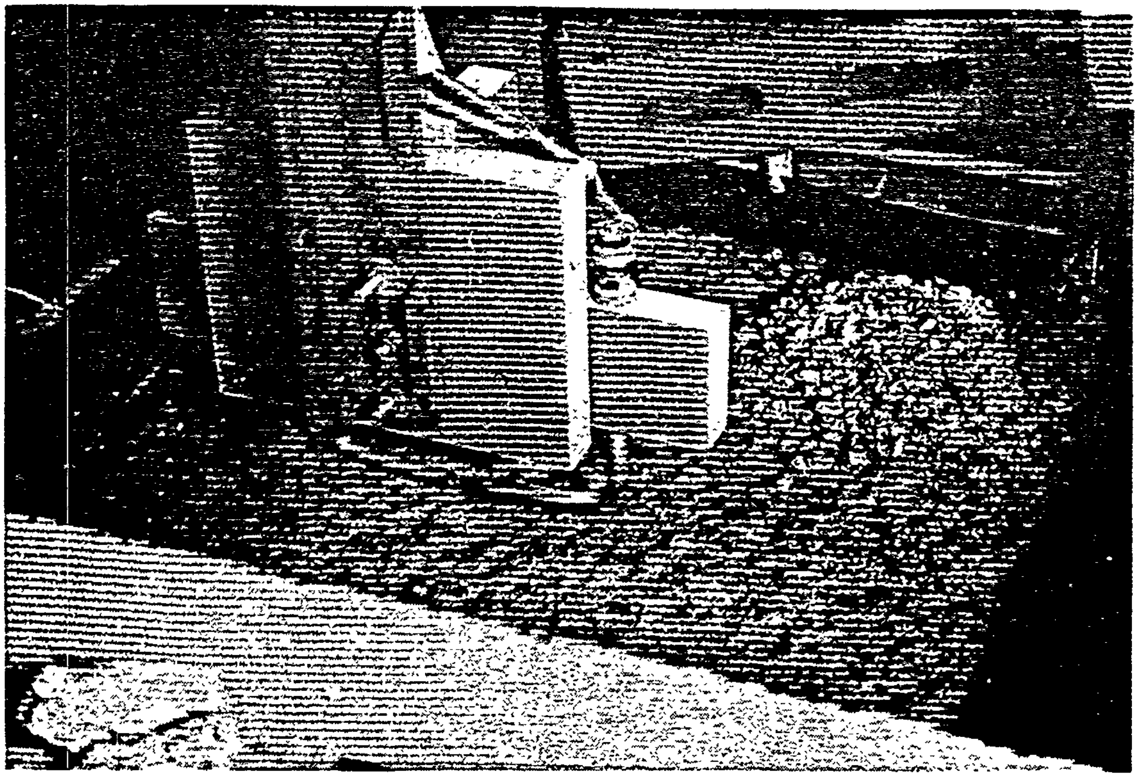


Figure 3-4b



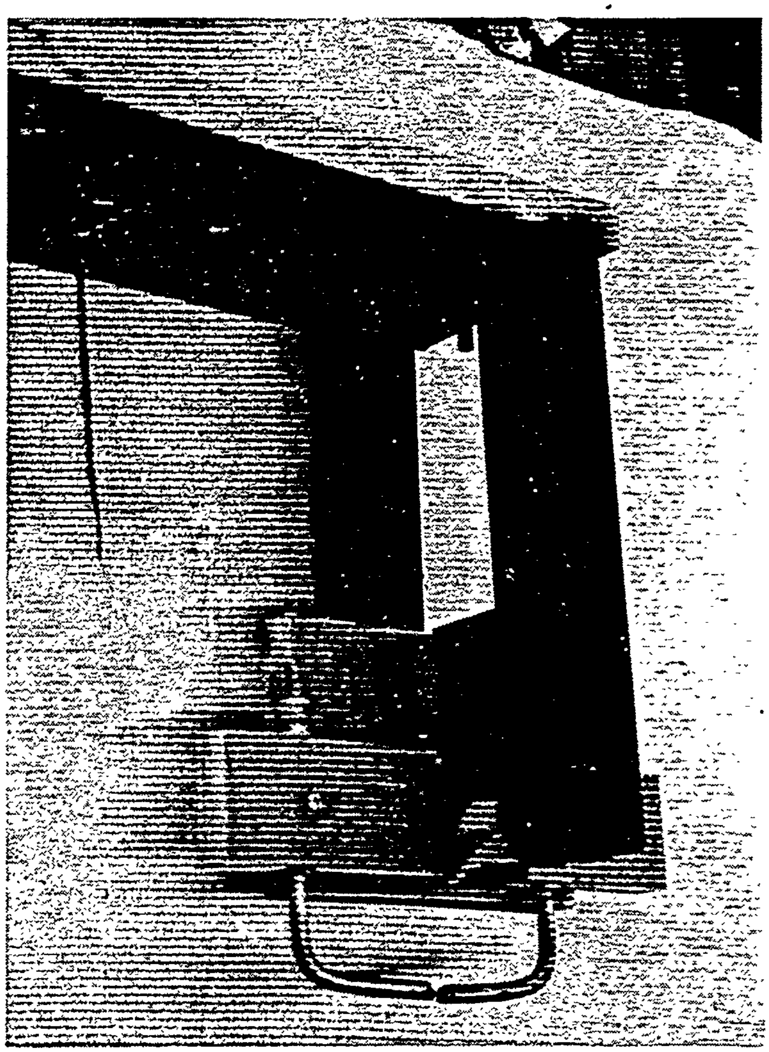


Figure 3-4c

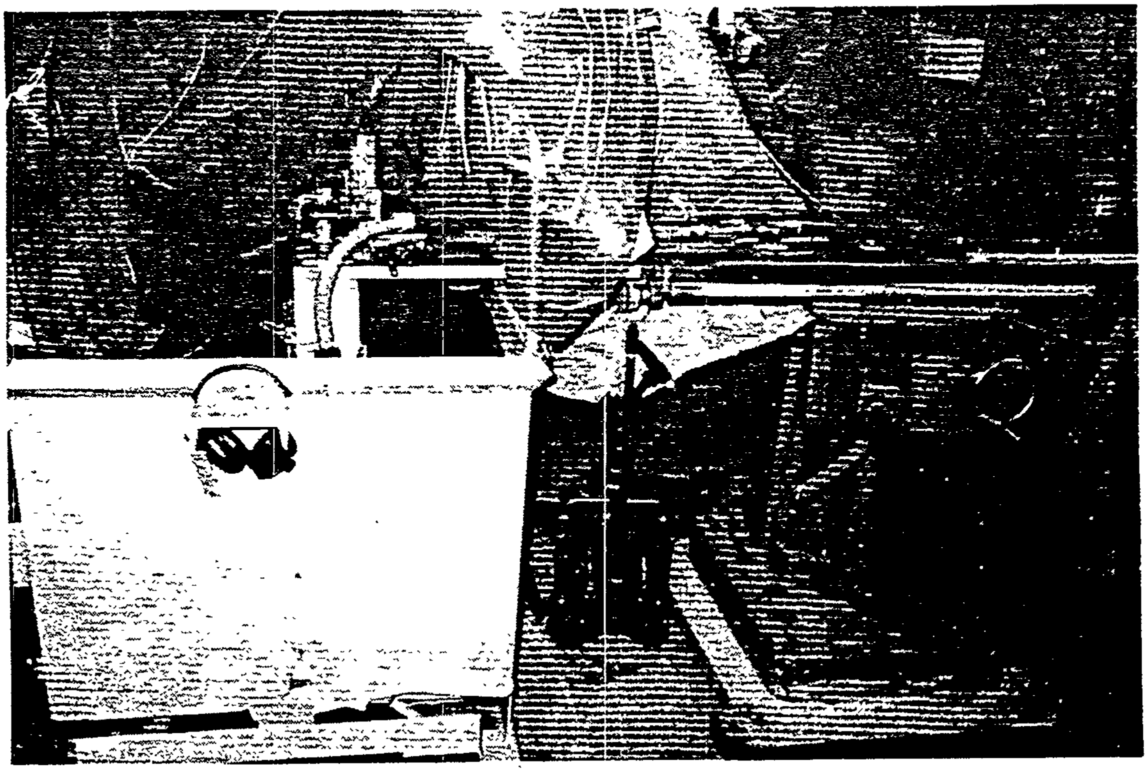


Figure 3-5 Scabbling Head Support and Positioning Mechanism

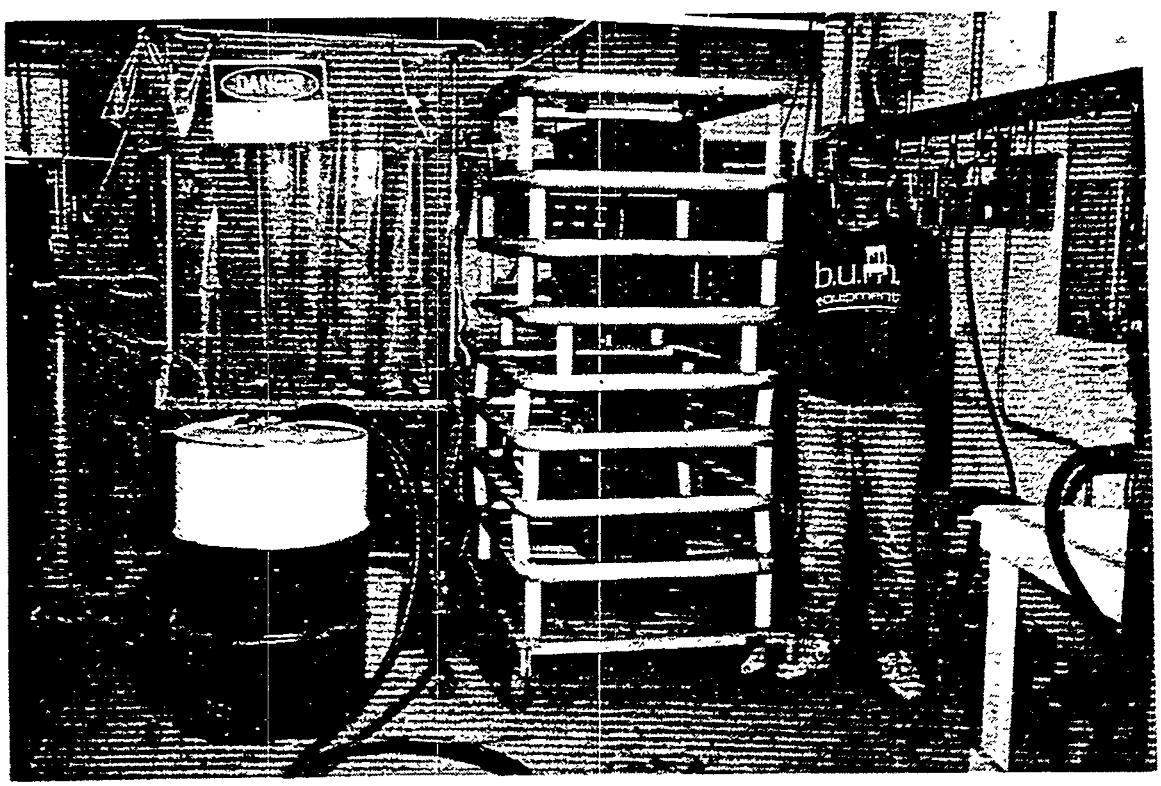


Figure 3-6 Capacitor Stand (Four 1.74 μF capacitors connected in parallel)

holding four capacitors (7.4 μF total) has been installed (Figure 3-6), and electrical connectors were improved to make possible operation at higher current levels and up to 2000 J single pulse energy.

An overall view of the new rig assembly is shown in photograph, Figure 3-7.

It was made clear by these experiments that scabbling of concrete surface is technically feasible. On the other hand, the experiments indicated that

1) In spite of several design and hardware improvements, mechanical strength of the EH head and its support is still inadequate for continuous (more than several hundred pulses and 1000 J/pulse and higher) stored energy operation.

2) Energy efficiency of scabbling is reduced substantially by "misfiring," i.e., discharge taking place above the water layer.

These two issues are discussed below.

Mechanical Design Issue

While use of acetal plastic for the "enclosed" option of the discharge chamber allows operation at several hundred Joules, these chambers fail after a number of pulses corresponding to about 250 kJ of the total energy input. Further improvement of this design may still be possible by decreasing stress concentration spots and especially by using external steel pipe to enforce the plastic enclosure.

We decided though to concentrate the effort on the "open" type of the EH head, where sidewise water expansion is not wall-limited. Simultaneously, a steel frame was made for more solid and symmetrical attachment of the EH head to the positioner's arm. Two configurations were tested for energy pulses up to 1500 J; no mechanical damage occurred at 1000 kJ total energy input.

Discharge "Misfire" Issue

The discharge misfire is a phenomenon of electric discharge taking place not between designated (scabbling) electrodes but elsewhere, usually between the positive ("hot") electrode and another part of a discharge chamber of distributed "ground." Its occurrence results in nonproductive use of the stored energy. The "misfire" may result from faulty insulation, improper selection/distribution of electric resistances between parallel electric circuits, such as excessive length of a scabbling discharge gap, too low water level in the discharge chamber, too short distance between electrode holders or any other current conductors located above the water layer.

This issue, if not resolved, can be a serious obstacle for the application of the EHS technique. Depending on water layer depths, interelectrode distance and voltage, from 20 to 80% of all discharges "misfires" and a substantial fraction of the total stored energy are lost.

One possible situation is illustrated by Figure 3-8. Here, instead of breaking down the discharge gap at the electrode tips in the close vicinity of the target concrete surface, the discharge takes place between the electrodes above the water layer. Electrode spots are visible all along the exposed electrode surfaces, which means that discharge runs either across the water surface, across the wetted bottom surface of the discharge holder, or in the droplet containing air.

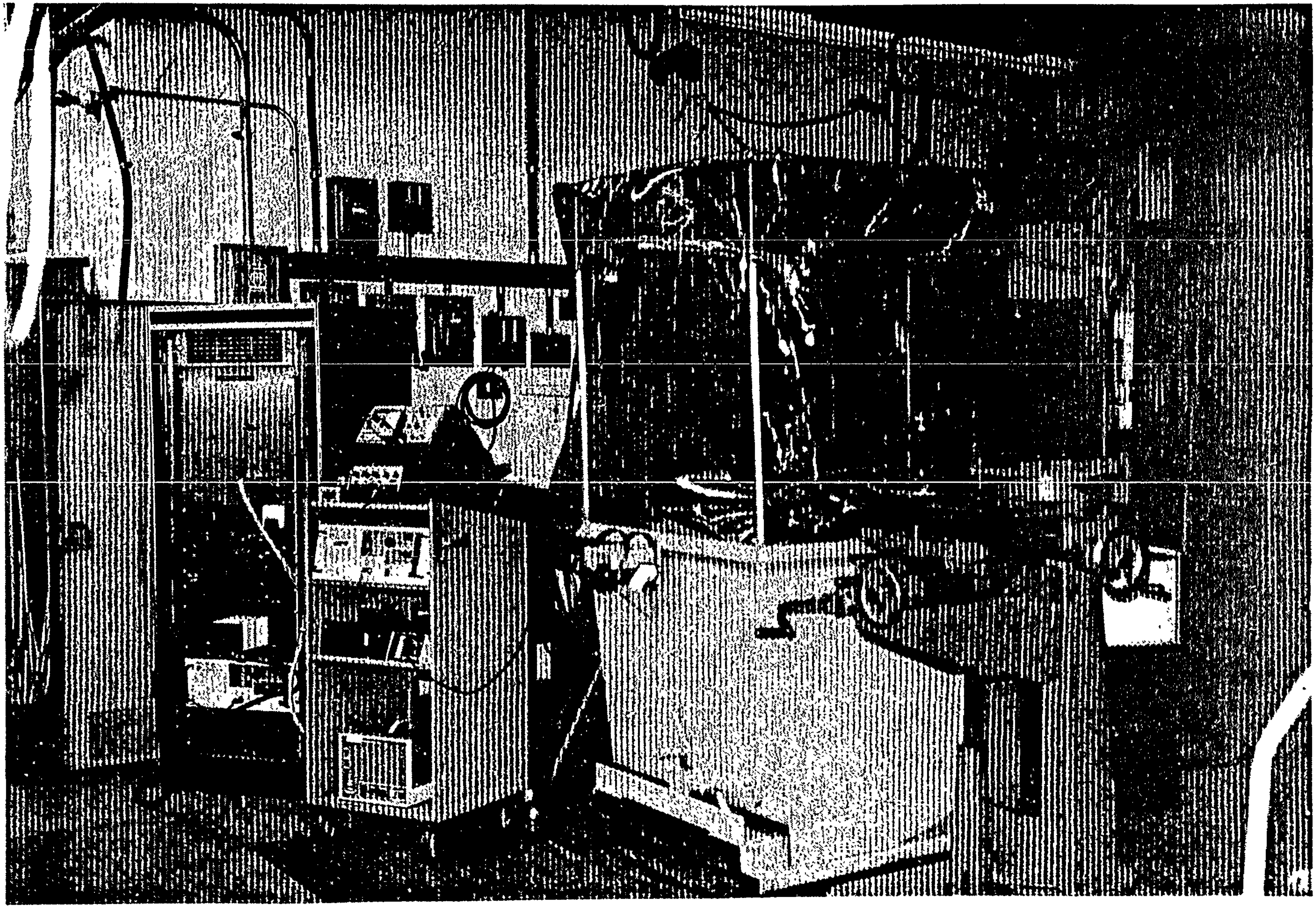


Figure 3-7 Overall View of the Laboratory Rig (First Setup)

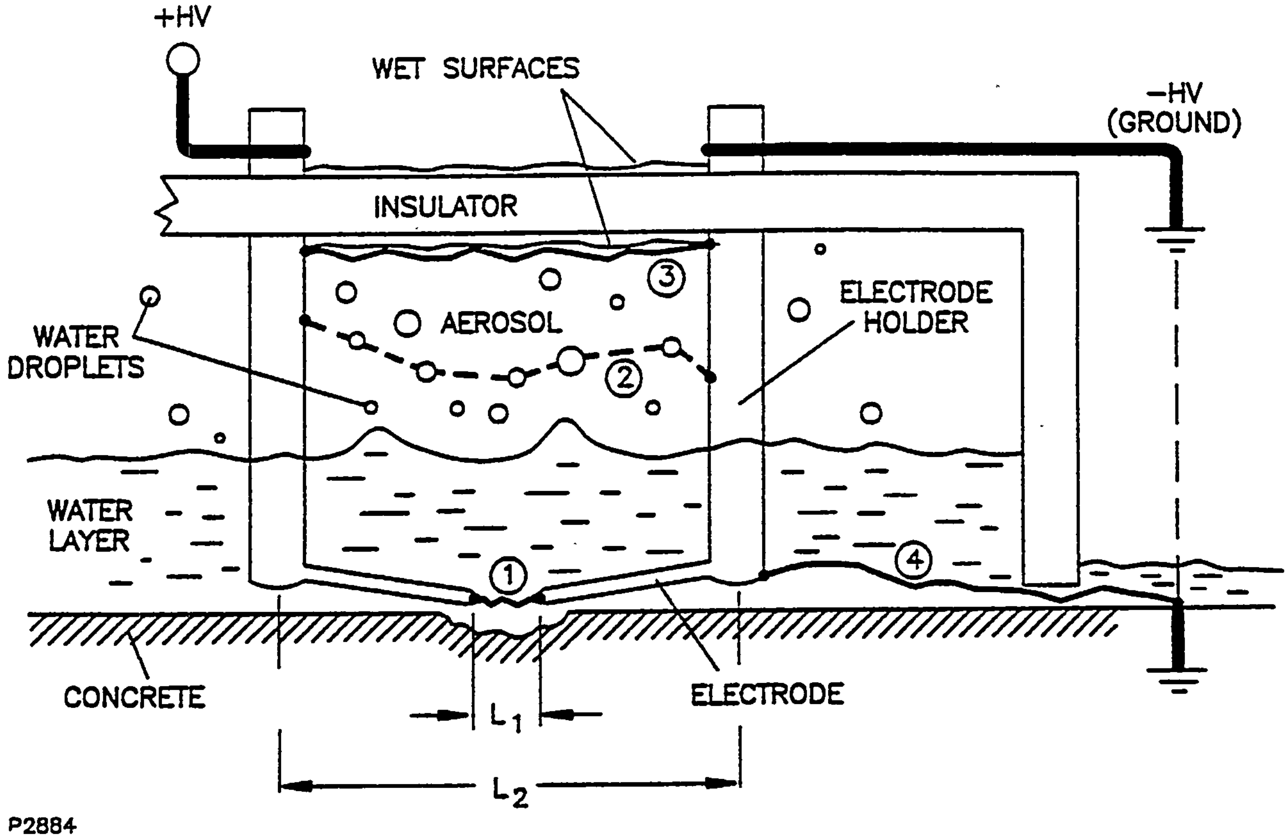


Figure 3-8 Schematics of a Proper EH Discharge Location (1) and of Possible Misfire Routes and Current Leakage Channels (2,3,4)

The last hypothesis is most probable. It is known since the "classical" work of Macky, English and Loeb that water droplets may initiate corona discharge and breakdown in electric fields as low as 6 kV/cm, i.e., 5 times lower than in dry air. Formation of water "spikes" on the droplet surfaces by electrostatic forces is responsible for the phenomenon.

Several techniques were tried to avoid the "misfires" or at least to reduce their number to a few percent of the total:

- Insulation of the electrodes (except the very tips).
- Increasing distance between the open (upper) parts of the electrodes by increasing an angle between them or using L-shaped electrodes (as in Figure 3-9).
- Blowing air above the water surface (to dry electrodes and bottom surface of the holding plate and remove water droplets from the interelectrode space).
- Shorten the interelectrode gap.
- Sharpening the electrode tips.
- Varying the water layer depth.
- Varying (mostly lowering) the operating voltage.
- Shortening of the electric pulse (to start discharge in water <u>before</u> discharge through the aerosol takes place).

Basically, all these techniques either make breakdown <u>in</u> water easier or prevent breakdown in the aerosol <u>over</u> the water surface.

Some of these measures were found either ineffective or impractical. Shortening of the discharge gap (L_1) to interelectrode distance (L_2) ratio (see Figure 3-8) seems to be most promising. Another opportunity would be to lower the operating voltage.

The effect of this parameter is explainable: for a given gap, the pulse generator voltage should be barely enough to make a breakdown at the shortest distance, i.e., at the electrode tips; at higher voltages (e.g., at 20 kV vs. minimum 12 kV required), the breakdown which is controlled by a pressurized spark gap of the PFN, the discharge can take place at any location.

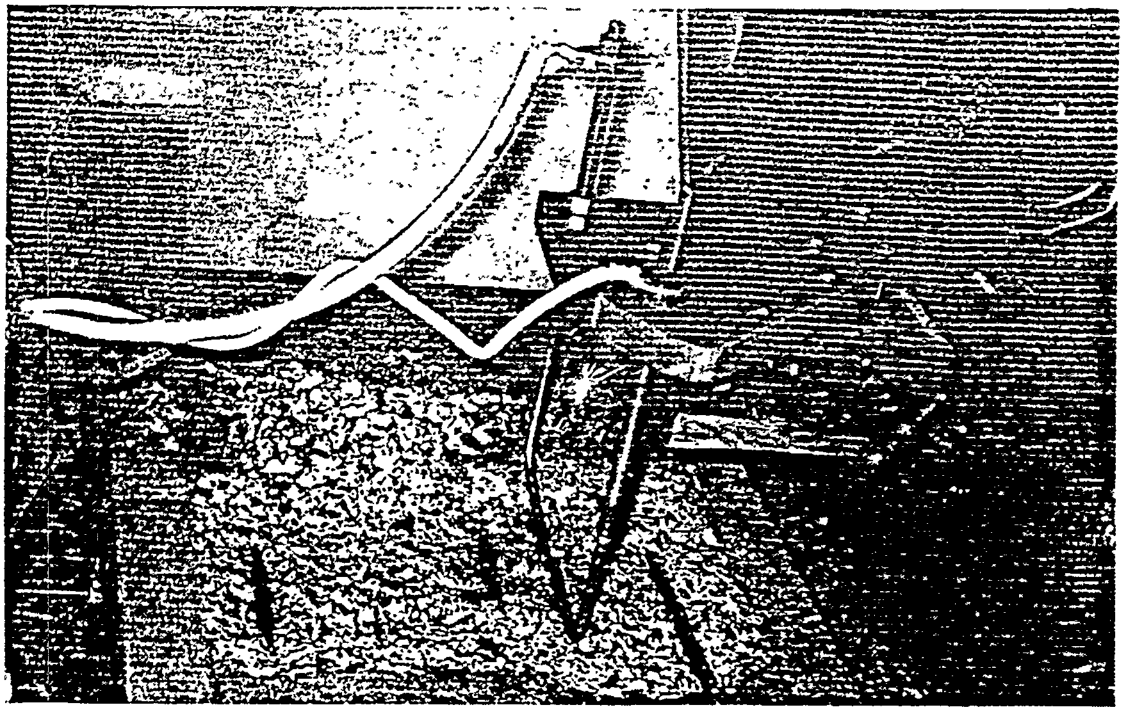
Limiting the gap length and the voltage has its negatives:

a) to keep energy input high, the capacitance should be increased, which also results in higher inductance;

b) with shorter interelectrode gap, lesser fraction of the stored energy may be delivered.

A series of scabbling tests were conducted while the "misfire" issue was studied. 30"x20"x4 " concrete blocks were processed under a 1" deep water level. The concrete has 4000 psi compressive strength and the following composition (in lbs/sq. yd):

Cement	625
Gravel	1728
Sand	1209
Water	295



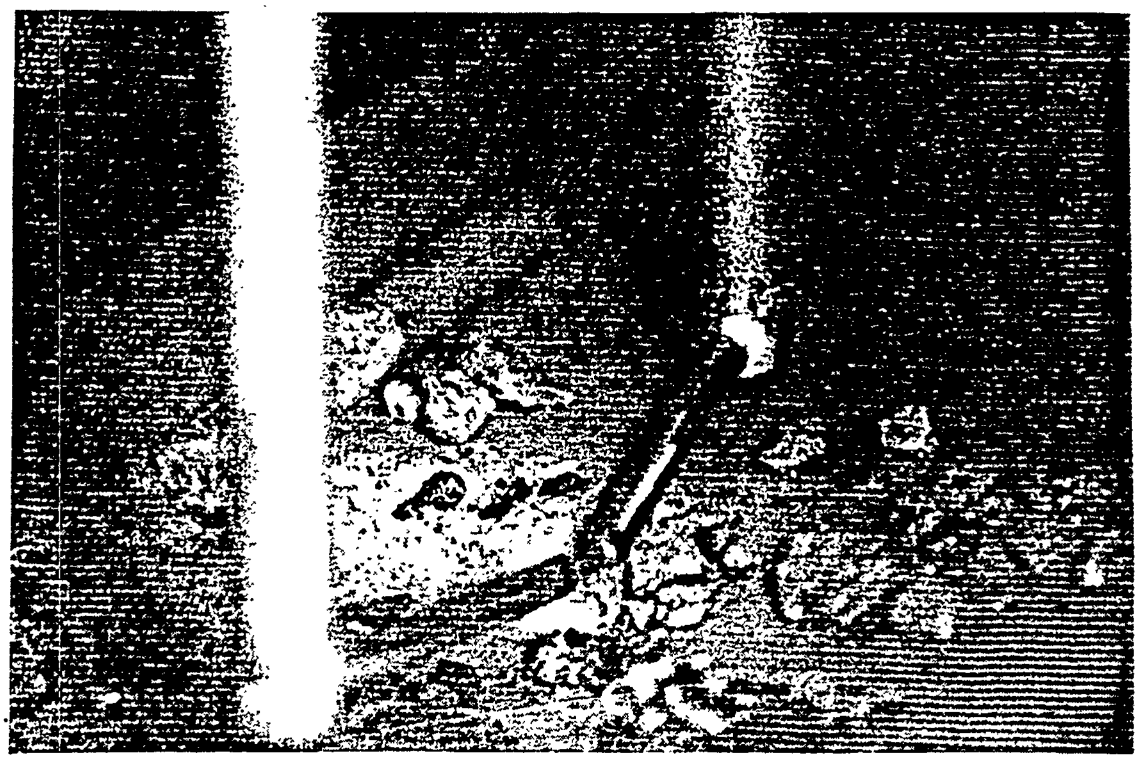


Figure 3-9 L-Shaped Electrode Configuration used to Prevent Misfire. Appearance of Scabbled Surfaces and Concrete Debris are also Shown

Each block is reinforced by two 1/2" steel bars; this reinforcement is equivalent to 0.015 g/g steel-to-concrete weight ratio, which is within the limits indicated by Energetics, Inc.

Limited areas of these concrete blocks were processed in a single, one-dimensional passage of the open type EHS head. In Figures 3-4 and 3-9, the surface appearance after scabbling is shown. The energy of each pulse was 1400 J (nominal, i.e., capacitor-stored), which (according to 50% electric energy efficiency - see below) corresponds to 700 J released in the electrode gap. Pulser frequency was about 1 Hz so that 60 pulses were delivered per one inch of the EHS head travel. In this case the average "misfire" fraction was still about 40%.

With 2.5" trace width and 0.4" average depth, one cu. inch or 40 g of concrete is removed per inch of single transfer. A gross energy consumption is then 5250 J/cm^3 or 2100 J/g, which is very high. By factoring in electric and "misfire" losses, both of which we hope to lower or eliminate, we obtain more reasonable, while still rather high, scabbling energy consumption of 1750 J/cm^3 or 700 J/g.

The misfire phenomenon is not inherent for the EH technique, but requires attention to details of the discharge chamber design, choice of materials, circuit components, and operating parameters. These issues should be readdressed at each redesign and configuration change that is made during the EHS system scale-up and improvements. Specifically, the following automatic process controls and design modifications planned for the Phase II prototype EHS unit should exclude the misfire events altogether or reduce their frequency to an insignificant number:

- Water level control
- Electrode gap control
- Electrode configuration with controllable or self-adjustable electrode clearance
- Elimination of air-exposed conducting elements above the water level

Experience gained during Phase I assures that the misfire issue will be positively resolved.

3.2 CONCRETE SCABBLING WITH IMPROVED HARDWARE

Further improvements of the "open" type EHS head were implemented providing solid positioning of the electrodes in a contact with (initial, untreated) concrete surface and reduction of the "misfire" events to less than 5% of the total number of pulses. In the improved design in Figure 3-10 and others following, interelectrode distance could be changed periodically to compensate for electrode erosion.

In addition, changes were made in the electrical design. Some electric circuit components - cables, spark gap, resistors - were substituted by other models, providing better performance and lifetime.

With the modified setup, discharge pattern observation and semiqualitative measurements were made to identify the range of main parameters for stable operation.

Figure 3-11 (photograph - made in darkness with open camera shutter) shows 40 kA(max), 10 μs discharge through a 1" deep water layer. Weak tracers over the water surface correspond to the initial stage of shock wave formation.

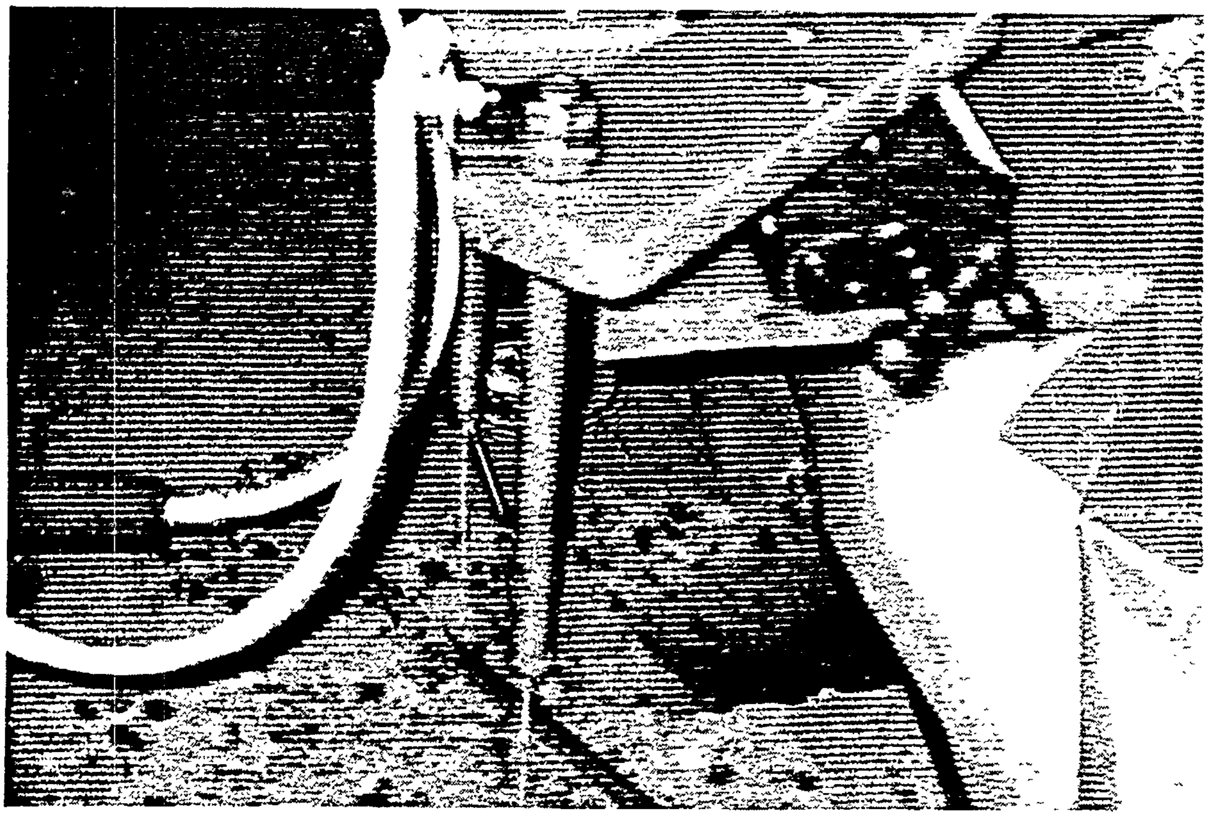


Figure 3-10 Electrode Holder with Gap Adjustment Support.

Breakthrough of a concrete block is taking place with high energy input per unit length of a scabbling trail.

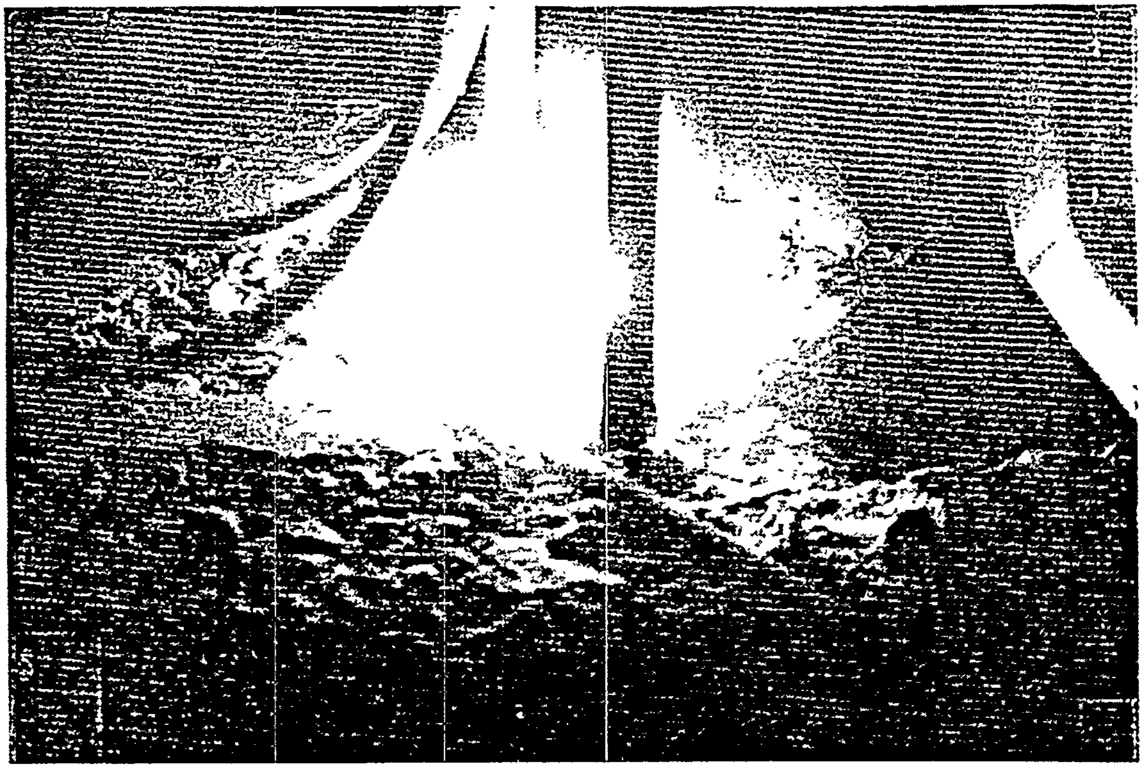


Figure 3-11 Appearance of EH Discharge through the Water Layer at T < 20 μsec

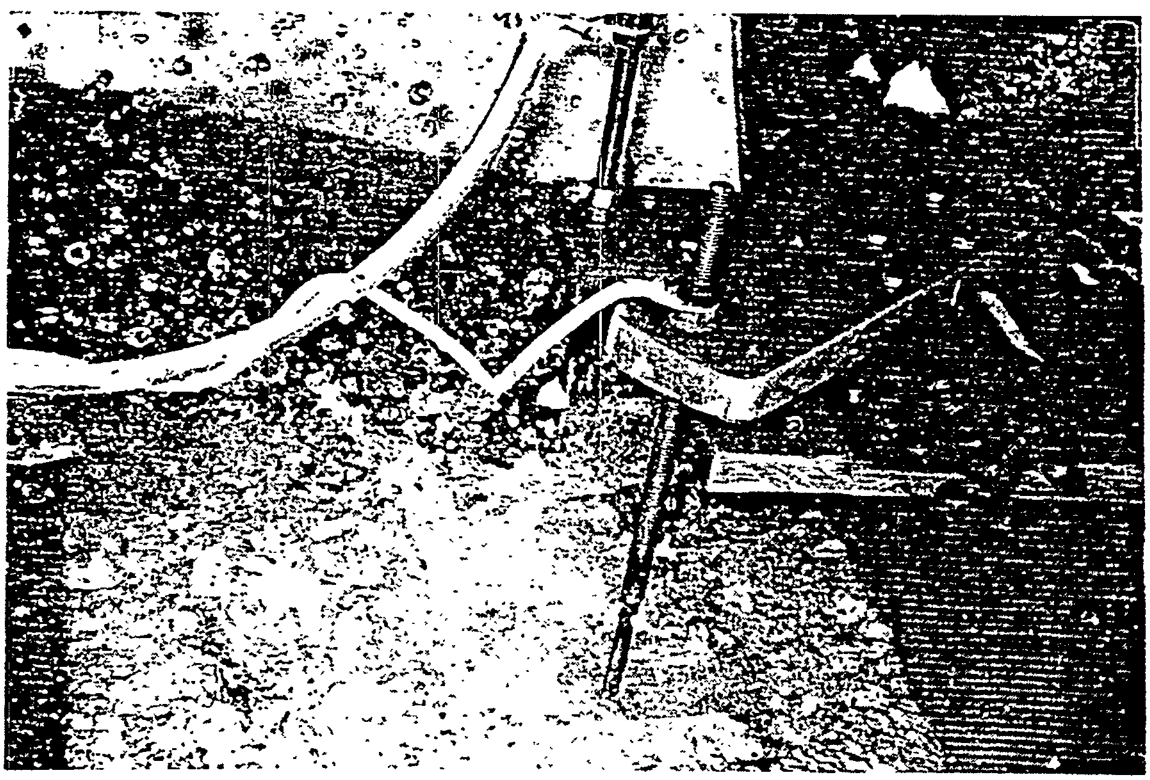


Figure 3-12 After-Discharge Water Splash/Droplet Formation at T > 1 msec

In Figure 3-12 (photograph - made with flashlamp illumination) the later stage (50-200 msec) of the phenomenon showing the formation of the water splash and droplets is shown.

The following range of conditions has been selected for scabbling operation:

Capacitance (4 capacitors connected in parallel)	7.4 μF
Inductance	1 to 2 μH
Voltage	21 to 23 kV
Spark Gap	5 to 8 mm
Electrode Diameter	6 to 9 mm
Stored Energy (nominal single pulse energy)	1600 to 2000 J

Scabbling trials were made with 30 x 20 x 4 (L x W x H) blocks of regular concrete. Single passes (traverses) 6 to 12 inches long were made with EH head transfer speed between 0.8 and 1.5 inch/min and pulse repetition rate of 0.8 to 1.3 Hz.

A groove 2 to 3 inches wide and 0.5 to 1.3 inches deep was made by the treatment. To process a wider surface area, 3 to 5 parallel passes were made. An example of the processed (in 3 passes) area is shown in Figure 3-10. Part of the debris produced is in the back; steel rebars which are located 3/4" deep are exposed. Figure 3-13 shows a schematic of electrode movement during scabbling and vertical profile of the groove formed by 2 passes.

The scabbling energy efficiency - nominal 950 J/g - was still rather low, but there is twice the improvement compared to the earlier results.

It has been observed in these trials that at very low EH head velocity or by providing a large number of pulses (100 to 200) locally, the 4" concrete plate can be disintegrated completely with the formation of large (3 to 8 inches) concrete pieces and releasing the reinforcing bars. This mode of operation, which requires several times less energy, can not be characterized as "scabbling" but could be of interest for some demolition applications.

After reliable scabbling operation with "open" electrode configuration was demonstrated, we concentrated on the development of an enclosed process chamber with a goal to provide:

a) protection against splashing of water and concrete debris (both of which, in real applications, could be contaminated);

b) removal of the debris by directed, minimum possible consumption, water flow;

c) prospects for operation over vertical concrete surfaces.

It was obvious from the earlier experiments that a small size, completely water-filled chamber cannot, due to high mechanical shock stresses, withstand prolonged operation. Therefore, several versions of comparatively large-volume enclosures were tried.

Having the enclosed chambers, it was possible to address important issues of water level control, process water recirculation, and rubble removal from the concrete surface. The main problem is to have 2" - 3" of water in the chamber (to avoid over-the surface electric breakdown - misfires) while keeping the water coverage over the surrounding concrete areas as shallow as

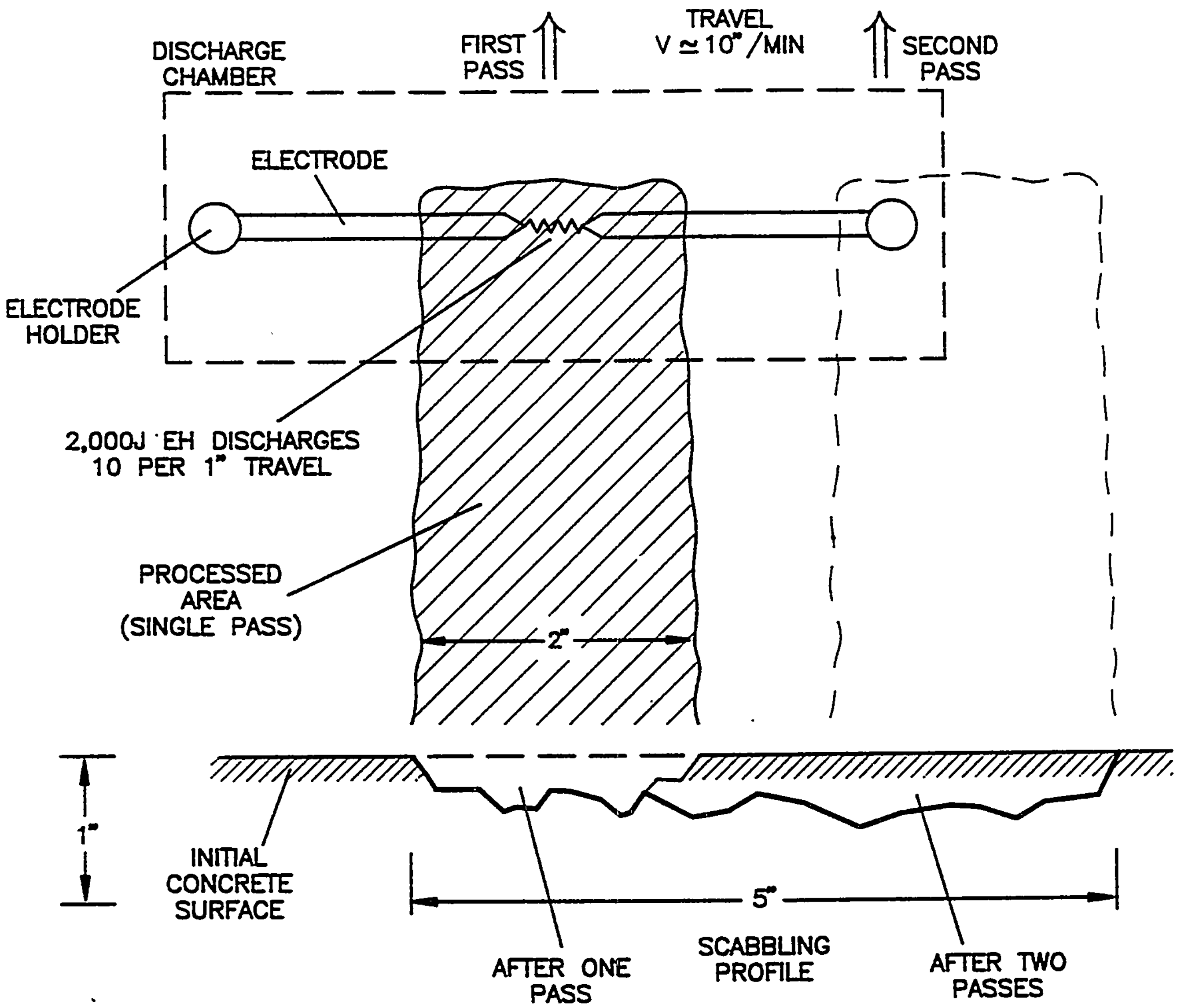


Figure 3-13 Schematics of Scabbling Groove Formation by Single and Two Adjacent Passes of Processing Head

possible. This water level difference has to be maintained despite water loss from the chamber. The loss is inevitable due to

- camera sliding over concrete surface which prevents gasket-type tightening
- strong pressure/water level fluctuation in the chamber
- presence of concrete debris on the surface, and, especially
- formation of rather deep grooves by the scabbling process

In addition, the pump should be able to pick up and transfer to a collector rubble pieces of various sizes (up to 3/4" of original gravel); it should also be self-priming and tolerable to a presence of solid fraction.

Some water and slurry diaphragms, propagating cavity, and centrifugal pumps were tried, but all of them did not meet a combination of at least most of the requirements. As a result, we arrived at a conclusion that the function of water level control and of water recirculation/rubble removal has to be separated in the following manner:

a) The water level should be controlled by a wet vacuum system connected to a discharge chamber. This system is pumping mostly air (providing necessary negative pressure), and some water+ fine debris splashed by the discharge pulses.

b) The rubble should be removed, together with some water from the concrete surface outside (and adjacent to) the chamber - from the scabbling groove in the first place. Either a pump or, more probably, another wet vacuum can fulfill this task.

The design/operation problem is to coordinate functioning of these to system and to reduce total water consumption an to avoid "flooding" of the large concrete surface area.

At this stage of development only the first function (a) has been implemented. A new chamber made of 1" thick G-10 fiberglass plates is connected to a 2-3 HP wet vacuum unit. The pressure and water level in the chamber is controlled by a valve in the connecting hose. Water (and some air) is entering the chamber from a 1/4 to 1/2" pool over the concrete surface, or from the independent source of makeup water through a gap between the concrete surface and lower edge of the chamber wall. A rubber gasket has been tried at this edge, but was not too useful when actual scabbling was performed and deep surface groove was formed.

This chamber is also equipped with a modified electrode support which allows independent vertical positioning of one of the electrodes. In photos Figures 3-14 and 3-15a, the chamber is shown either closed or with sides removed in a position for scabbling of epoxy-painted concrete block. The same concrete block is shown in Figure 3-15b after two scabbling passes. The paint did not affect the scabbling process or performance.

3.3 CONCRETE FLOOR SCABBLING TRIALS

Experiments described above demonstrate EHS feasibility for "old" and "new" (aged) concrete blocks specifically made for this program. While the type and quality of these concrete blocks should be similar to those regularly used for floor covering, it was of interest to confirm this directly, and to perform scabbling under conditions similar to those expected for industrial buildings, including DOE sites.

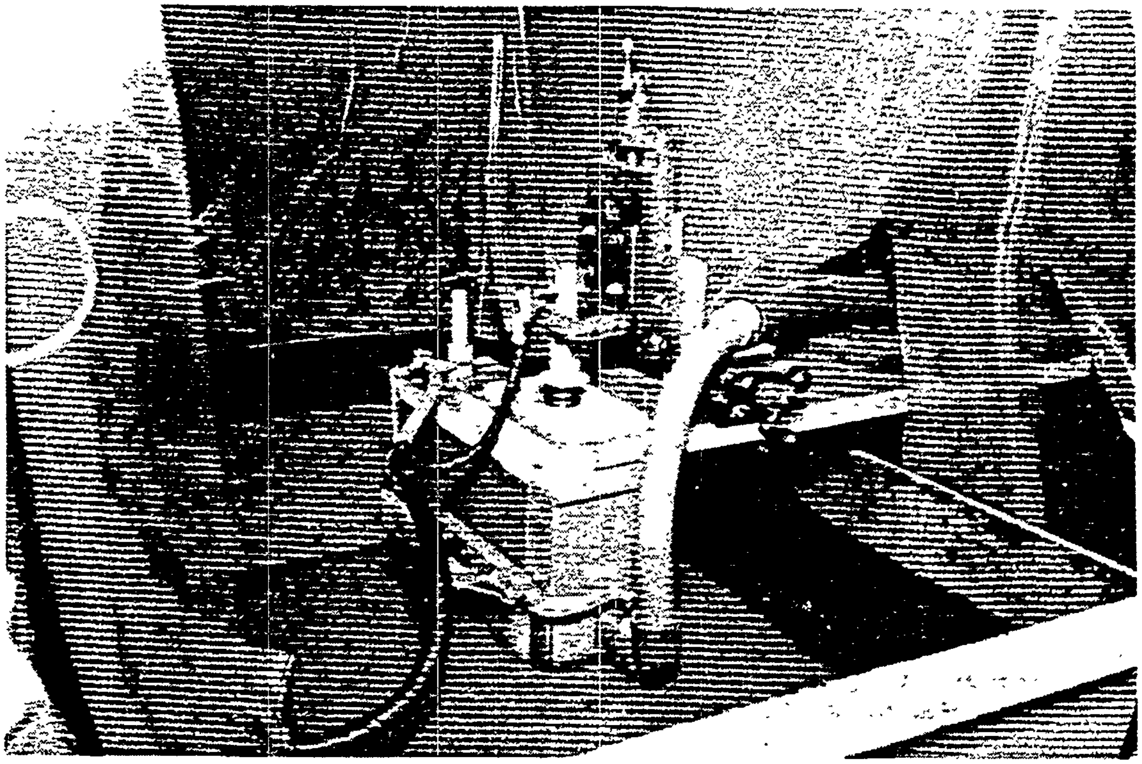
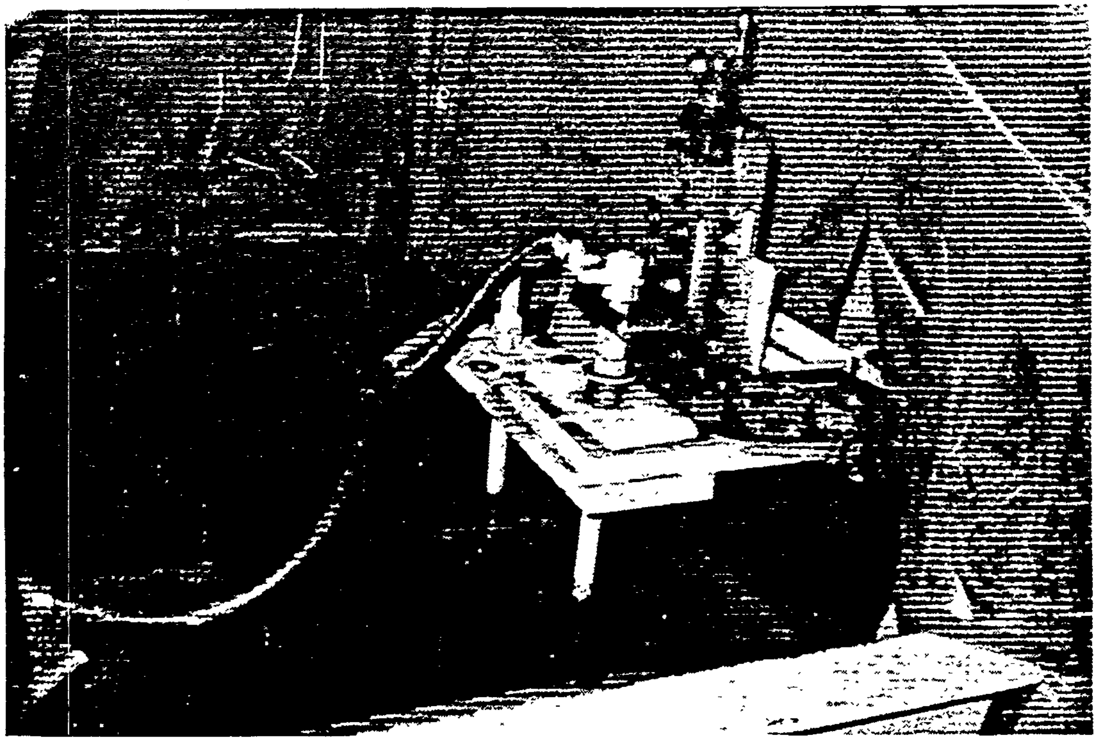
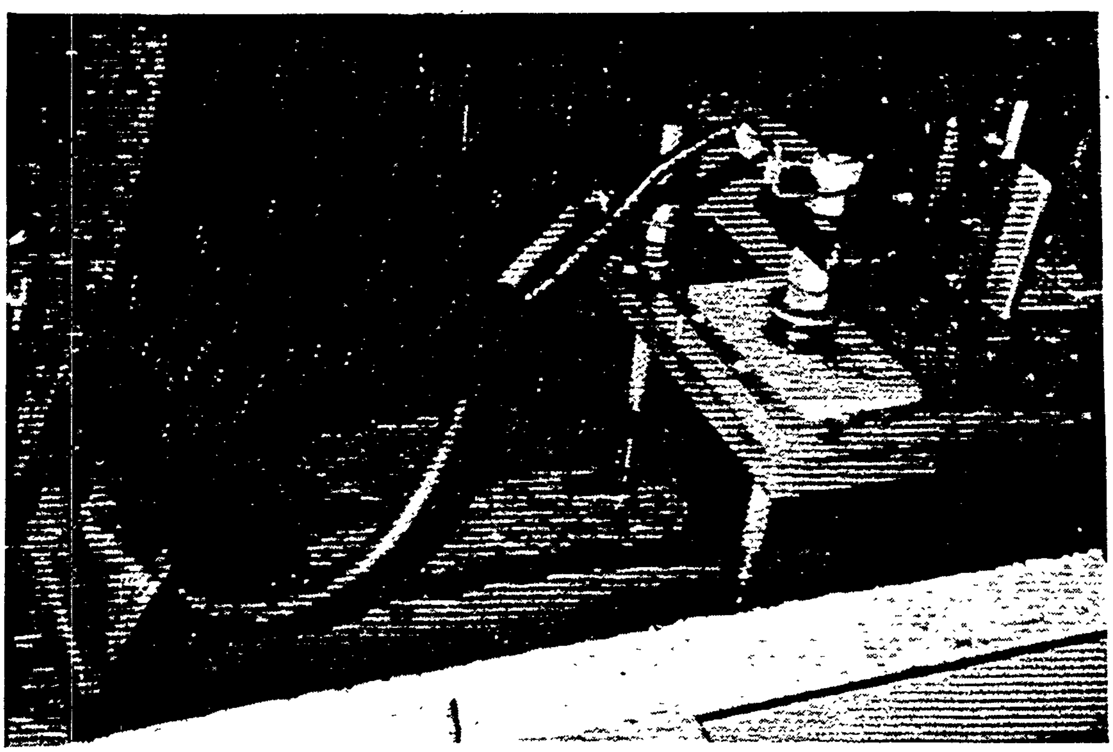


Figure 3-14 Enclosed G-10 Scabbling Chamber with Adjustable Interelectrode Gap and Electrode Clearance Supports



(a)



(b)

Figure 3-15 Scabbling Chamber (with side walls removed) Prepared for Processing of Epoxy-Coated Concrete Block (a), and After the Two-Pass processing is Accomplished (b)

The experimental rig has been modified to make possible scabbling of an actual, old concrete floor. Two 4' by 8' concrete floor areas in Building 2 of the TDS facility have been isolated by a 2" high angle plastic barrier attached by either sticky tape or RTV compound. The areas could be covered by a 1/8" to 1 1/2" deep water layer and scabbled by the X-Y traversing process chamber. This arrangement is shown schematically in Figure 3-16 and in photos Figure 3-17.

A new chamber was assembled with special attention given to its integrity under the influence of strong vibrations. The chamber was equipped with three independent screw-type electrode supports, allowing clearance and electrode gap control. Also, provision was made for installation of the second discharge chamber for simultaneous scabbling with two electrode pairs (to form a wider scabbling groove). The chamber support was modified to provide more stiffness and more precise unit positioning.

Even with a tighter chamber, water splashing takes place, especially through the scabbling-formed groove. To prevent the spread of water and debris, a plexiglass (transparent for the process observation) outer shield of a glove-box type with access to the electrode positioner has been installed. These hardware modifications are illustrated by Figure 3-18.

A water flow system was equipped with two wet vacuum units to control the water level, and to remove concrete/water slurry and recirculate water directly into the chamber(s) or to the isolated floor area. No attempts to filter/clean the return water were made at this stage.

Additions and modifications also involved the electrical part of the installation:

a) A second (independent) pulser was assembled with a new 7 kW DC power supply (from Maxwell Lab.) and a single, compact 10 μF capacitor (from NWL).

b) Components of both pulsers (including spare ALE DC power supply) and supplies for motor drives were consolidated in three shielded cabinets (see Figure 3-19).

Several scabbling trials were made to shake down the improved setup to prepare for the scabbling process demonstrations. Figure 3-20 shows scabbling trails made over the floor areas with one or two simultaneously operating discharge chambers. The main operating parameters used and the performance level achieved in these "real floor" tests were in the same range as in "block in the tank" experiments.

Quantitative results obtained in both block and floor scabbling tests are described in the next section.

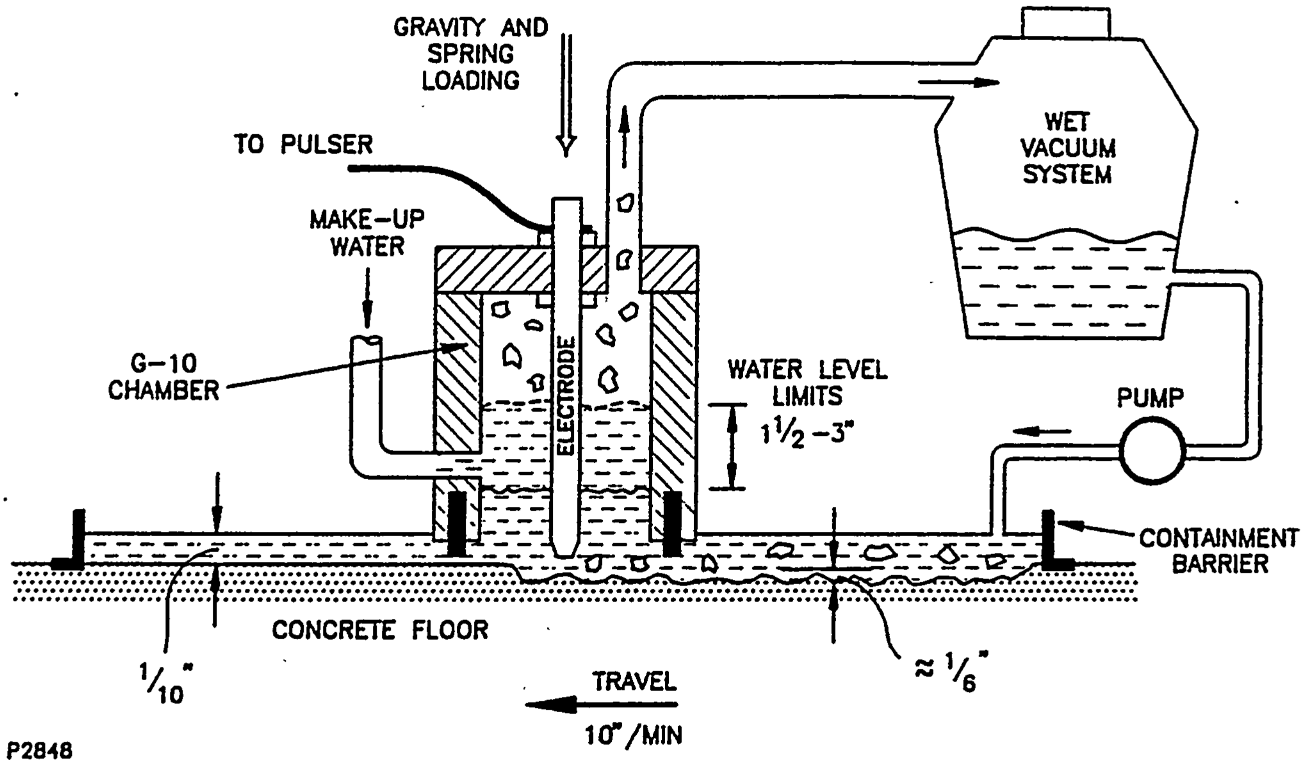


Figure 3-16 Schematics of EHS Laboratory Setup for Decontamination of Concrete Floor

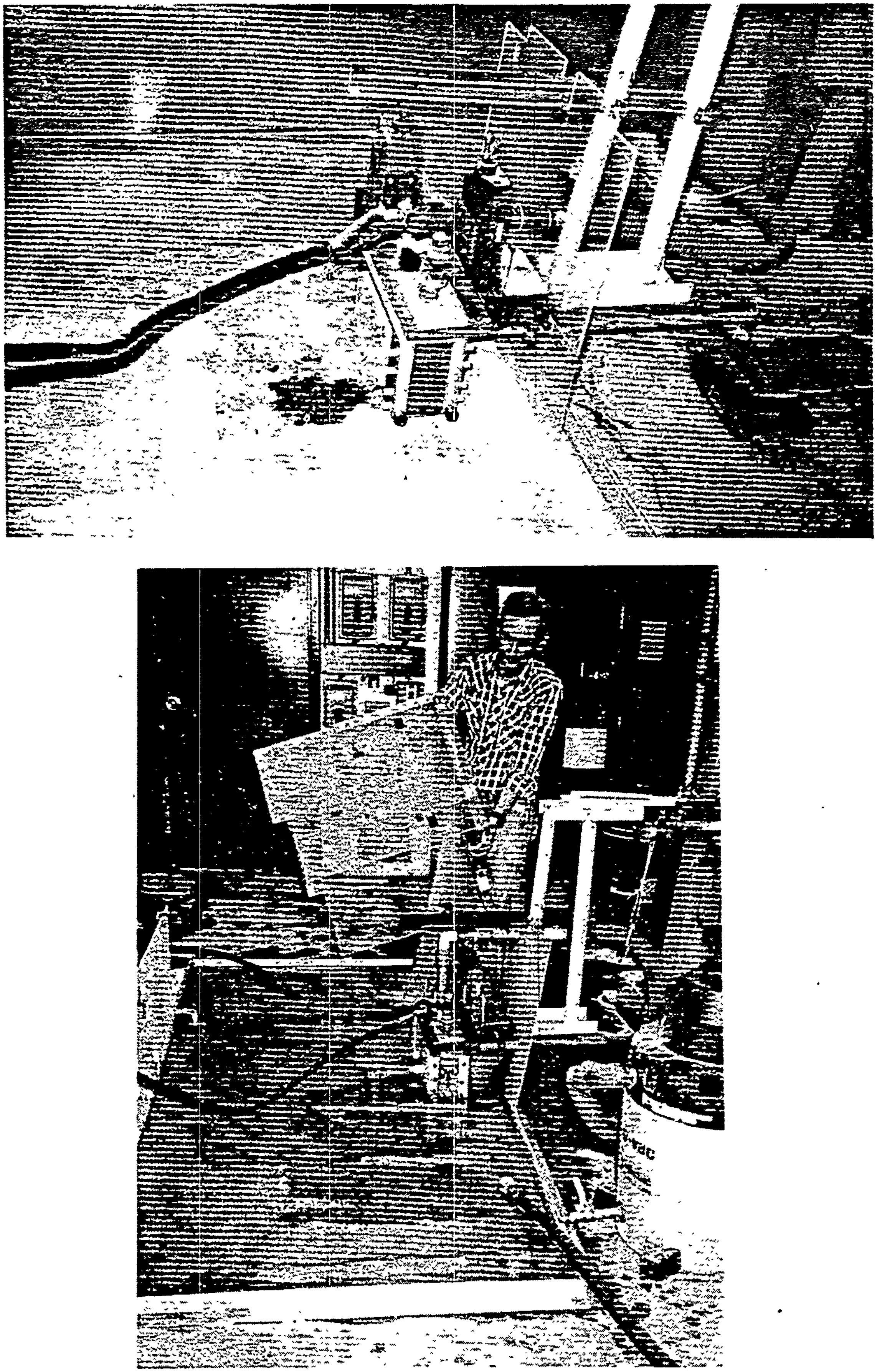


Figure 3-17 Laboratory Setup for Scabbling of Floor Areas Insulated by Plastic Barriers

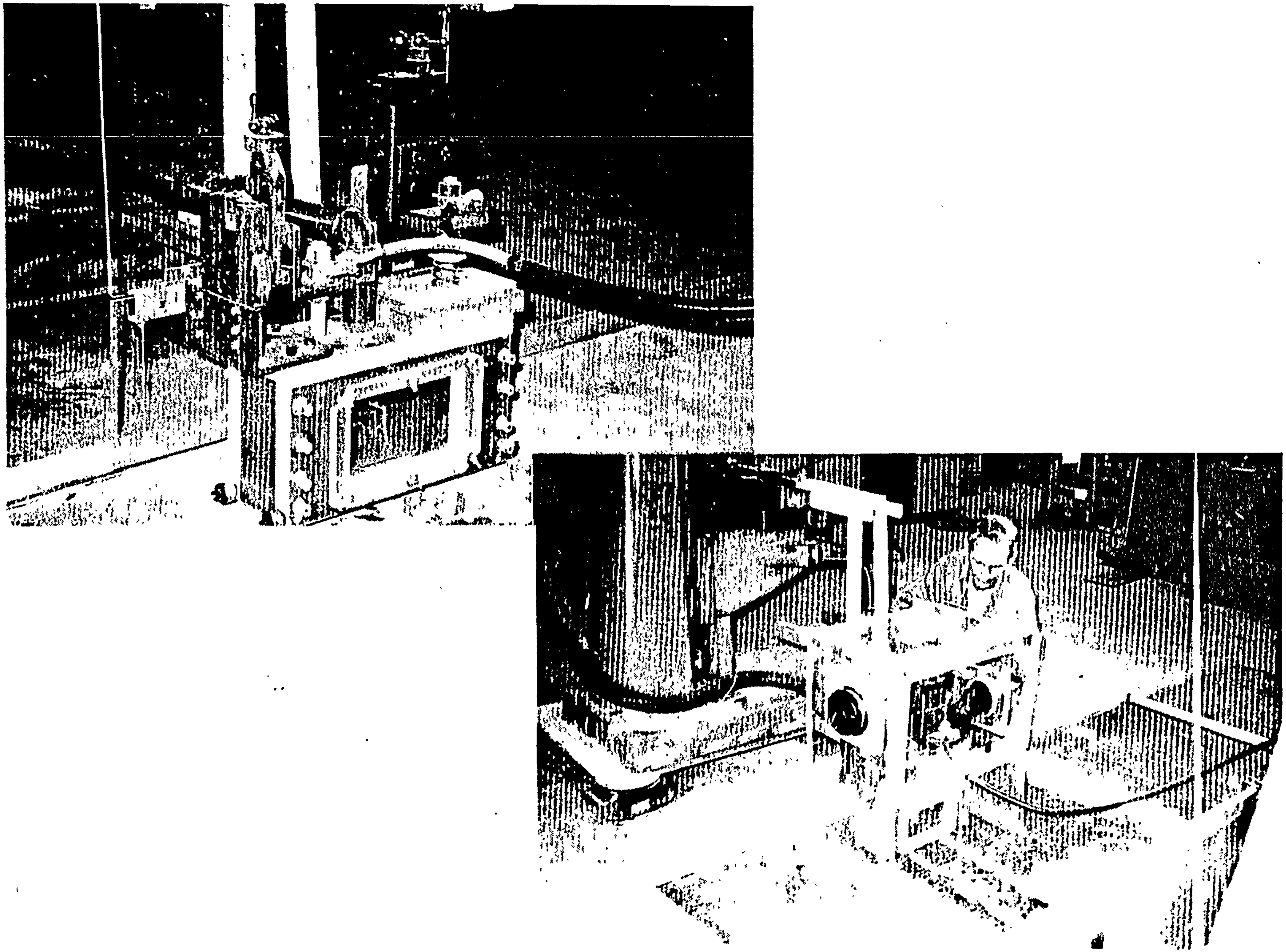


Figure 3-18 Modified Scabbling Chambers with Complete Electrode Gap and Clearance Adjustment and Water Splash-Preventing Plastic Enclosure

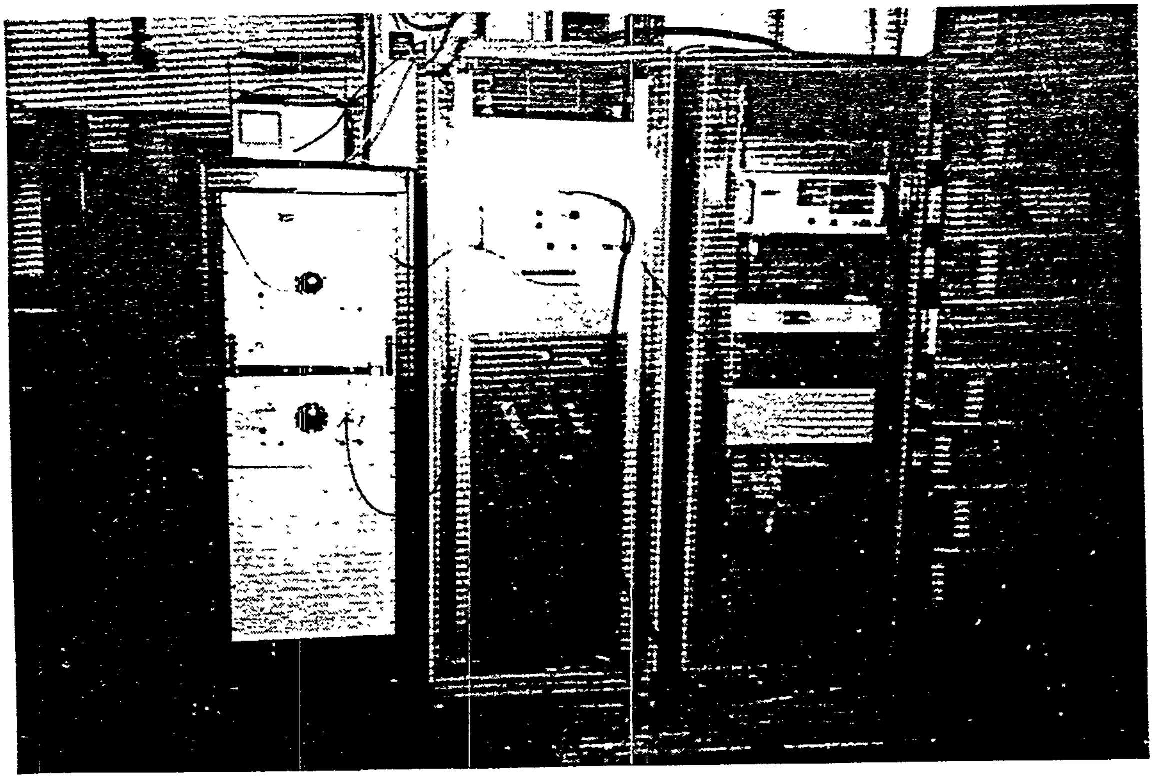


Figure 3-19 Electric Power Supply (with two pulsers and motor drives) Assembled for Two-Heads Floor Scabbling

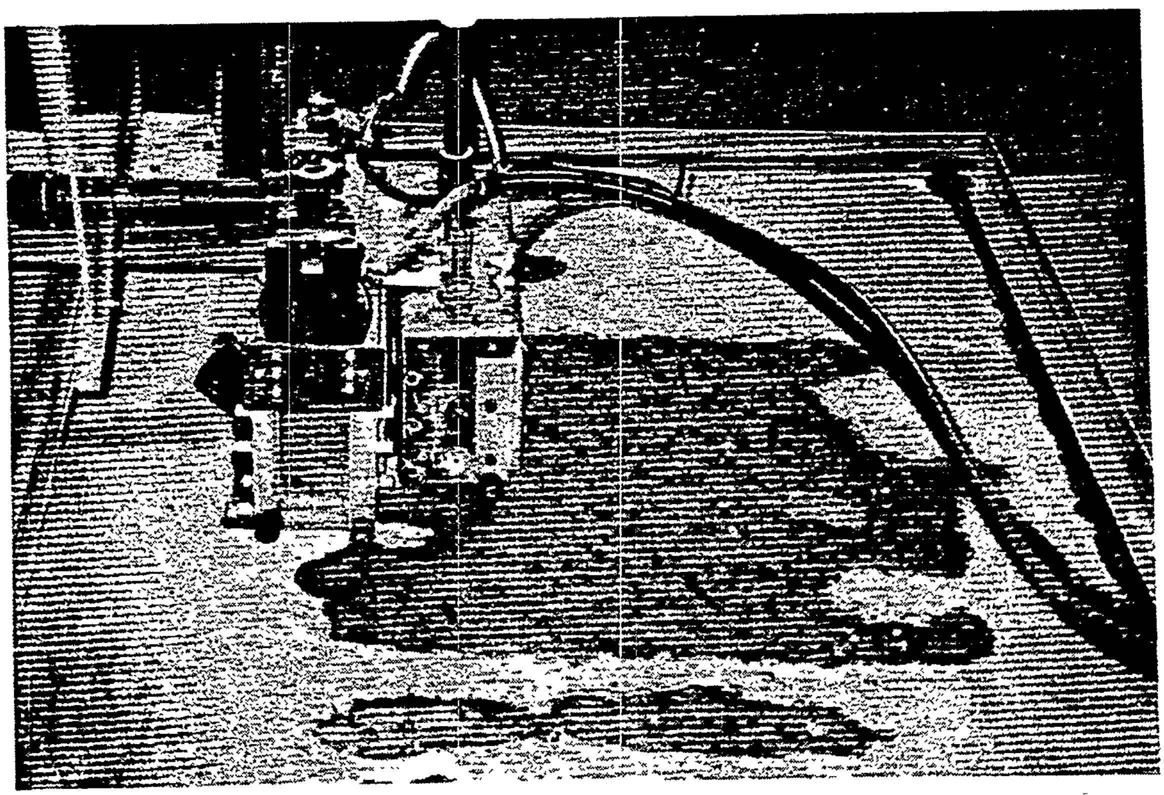


Figure 3-20 Appearance of Concrete Floor Processed with Two-Head Scabbling Module

4.0 QUANTITATIVE CHARACTERIZATION OF CONCRETE EHS

4.1 MEASUREMENTS OF MAIN PARAMETERS

4.1.1 Electrical Measurements

Parameters of electric circuit and EH discharge were measured by conventional methods:

- Discharge voltage (initial, i.e., capacitor charging voltage) was defined from DC power supply voltage meter, or, vs. time, from the oscillograms. Textronics 2430 oscilloscope with 1: 1000 voltage divider was used.
- Discharge current was measured by recording time-dependent signal from the current transducer; A Pearson coil with 100 A/V sensitivity and a 1:100 attenuator were used.

Typical voltage and current traces are shown in Figure 4-1.

From the same records, discharge character (oscillating vs. highly damped) duration, period of oscillations, and current rise time could be defined. Also, an important circuit characteristic - total inductance - could be defined.

The total electric pulse energy could be obtained as energy stored in the capacitor. This nominal value is referred to throughout the efficiency evaluation. The actual pulse energy could be lower; this happens when pulse energy and/or repetition rate is high and power of the DC charger is not sufficient to maintain initial charging voltage. The "undercharging" becomes evident from both reduced instantaneous readings of the charger's voltmeter, and from voltage oscillograms. With the ALE DC charger, the undercharging begins at 2000 J (nominal) single-pulse energy E_0 and 2 ± 0.2 Hz frequency f. These numbers agree well with nominal $N_0 = 4$ kW power of this power supply. True pulse energy could be calculated as E = IUdt. At $E_0 f > N_0$, E becomes less than E_0.

It is worth mentioning here that when calculating AC power consumption, which is an ultimate value of practical interest, it should be taken into account that modern (resonance circuit) DC power supplies have high, up to 90 %, efficiency. Therefore, the "wall plug" energy consumption is only about 10% higher than that measured on a DC side.

A short pulse is expected to be more efficient for concrete fracture if shock wave is the principal impact mechanism. It was of interest therefore to see the effect of circuit elements on the circuit inductance and pulse length. It follows from Table 4-1 data that single wire cables (especially inter-capacitors, connectors, and electrode holders) provide major input into total inductance and pulse length. Lengthening of the coaxial cable between the pulser terminal and processing head by a few meters is (with other inductances rather high) not a major factor.

To shorten the pulse, lower capacitance should be used with higher voltage or higher pulse rate to retain the same energy input. For a capacitance given, a more compact circuit arrangement and use of a single, low L capacitor would shorten the pulse moderately (see line 2 of the Table).

While inductance of the discharge channel is negligible, its active resistance is comparable to the resistance of other circuit elements. Accordingly, current pulse shape and value change with the electrode gap length (see Figures 4-1b and Table 4-2).

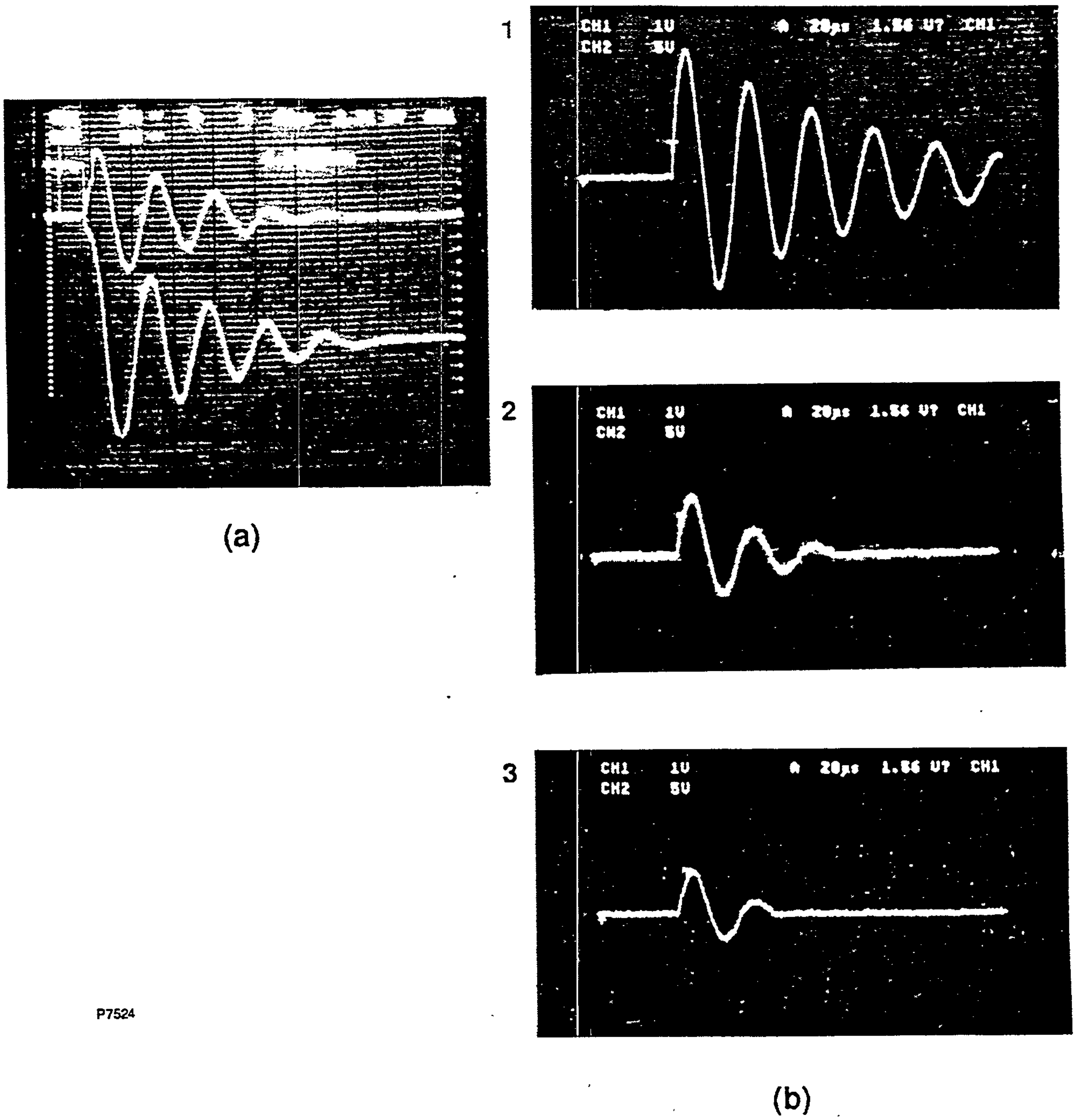


Figure 4-1 Current and Voltage Oscillograms of EH Discharge
a) Typical U and I traces for short, low resistance discharge gap. Characteristic sharp initial voltage drop can be seen.
b) Change of current pulse shape with electrode gap length L:
1 - L = 1 mm, 2 - L = 9mm, 3 - L = 13 mm

TABLE 4-1

INDUCTANCE AND PULSED LENGTH FOR VARIOUS DISCHARGE CIRCUIT PARAMETERS

C, μF	ℓ^*_{eq}, m	L_c/μH	d, cm	T_{meas}, μs	L_t, μH
7.4	1.9	1.9	2	26	2.4
3.7	1.9	1.9	2	19	1.6
1.85	1.9	1.9	2	9	1.2
7.4	2.7	2.7	2	31	3.2
7.4	2.7	2.7	0.5	31	3.2

Here:

$\ell_{eq} = \ell$ (single wire) + ℓ (coaxial) x 0.2

L_c - calculated total cable inductance

L_t - total (measured) inductance

d - discharge gap

T - full current period

TABLE 4-2

ELECTRIC CIRCUIT (ACTIVE) RESISTANCE VS. ELECTRODE GAP LENGTH AND VOLTAGE

Electrode Gap ℓ, mm	U, kV	I_{max}, kA	R, Ohm
< 0.5	15	20	0.10
< 0.5	18	25	-
< 0.5	20	27	-
< 0.5	23	30	0.10
2.5	23	30	-
5.0	23	28	0.17
7.5	23	25	-
10.0	23	15	0.25
12.5	23	11	-
15.0	23	9	0.36

4.1.2 Measurements of Discharge Energy

Due to a variety of circuit losses, both E and E_0 values still do not provide discharge energy, i.e., energy released in the spark gap proper. This portion of energy available for EH processing depends on the relationship between the spark gap resistance and total circuit impedance which should be optimized. In our experiments, the energy E_g released in the discharge gap was obtained by calorimetry, i.e., by measuring heating of water (few liters volume in the enclosed thermally-insulated container) by a few hundred electric pulses. The thermal effect of the discharge Q (calculated as $Q = 4.18 \cdot m\ \Delta T^*$, where ΔT^* is the change in water bath temperature corrected for heat losses) related to nominal E_0 or actual E discharge energy provides efficiency η of energy transfer to the electrode gap.

Results of calorimetric measurements provided in Table 4-3 indicate that somewhat more than half of the stored energy is released in the discharge channel and transferred to the water bath. Within a relatively narrow range of pulse energy, only a weak trend toward energy transfer increase can be mentioned.

4.1.3 Mechanical Impact of EH Discharge onto Solid Surface (Concrete)

Attempts were made to measure pressure in water at various distances from the discharge. These efforts were not successful, because:

a) powerful discharge generates strong electric noise which affects the piezo sensor;

b) distances we are interested in are small - always less than 1" - therefore, very small and protected sensors are required. Due to the small distance, the shock wave arrives to the sensor in a short time, which precludes separation of the electric noise signal from the pressure signal.

Another method we used in some instances involves measuring the impact through deformation of a ductile metal plate as a pressure wave target. Copper and aluminum plates 0.5 mm to 1 mm thick were placed at a certain distance from the electrode gap. EH discharge results in plastic deformation of the plate; depth of the indentation can be used as a relative measure of the shock wave strength vs. distance and pulse energy.

Table 4-4 contains some data obtained by this technique. Mechanical impact weakens with distance (clearance), but slower than efficiency of cavity formation on the concrete surface (see Section 4.2.2 below).

We did not pursue this technique because direct measurements of concrete cavity formation provides basically the same relative data.

An absolute value of the EH-generated force can be, in principle, obtained by comparing EH plate deformation with the one made by known mechanical impulse. The technique can be useful if more detailed characterization/optimization of the EH effect and concrete breakdown mechanism is needed in the future.

An interesting feature observed in these experiments at short target distances was a local deformation which takes place in the vicinity of electrode tips, showing high pressure concentration at these locations. It is quite probable that destruction/cracking of concrete is initiated at these points.

TABLE 4-3

CALORIMETRIC DATA ON DISCHARGE ENERGY TRANSFER

Conditions: $C = 7.4\ \mu F$, $L = 0.4"$, $V_W = 0.5$ gal

U, kV	E_1, J	n	E_T, kJ	ΔT^*, °C	Q, kJ	η, %
15	830	100	83	5.3	42	51
20	1480	100	148	9.7	77	52
25	2320	100	232	16.3	130	56
20	1480	200	296	19.8	157	53
20	1480	200	296	20.1	160	54

*E_1 - single pulse energy, E_T - total stored energy, n - number of pulses

TABLE 4-4

MECHANICAL IMPACT OF EH DISCHARGE ON COPPER SHEET TARGET

Clearance	Pulse Energy, J	Maximum Deformation Sag, mm
0	1070	5.5
1/16	1070	5.2
	1960	8.0
1/8	1070	4.0
	1960	7.0
1/4	1070	3.5
	1960	5.5
1/2	1070	2.5
	1960	4.0

4.1.4 Electric Erosion of Electrodes

The electric erosion of EH discharge electrodes made of low carbon steel was measured by weighing them before and after making a certain number of pulses in the bulk (far from concrete surface) clean water. The total erosion under scabbling conditions can be somewhat higher due to additional material loss resulting from mechanical friction (scratching) of the concrete surface in the absence of clearance. The mechanical erosion component is less important (comprising < 10% of total) than electric, at least with moderate vertical pressure applied through the discharge chamber support.

Results of erosion measurements presented in Table 4-5 for "pre-sparked" electrode with (approximately) hemispherical tips indicate that:

- Measured erosion rate is low compared to electrothermal erosion characteristic for strong pulsed discharge in air. Evidently, intense cooling of electrode tips by turbulent water streams prevents formation (or reduces lifetime) of liquid metal arc spots.
- Anode (positive) electrode is eroding more rapidly than cathode (negative, ground).
- Erosion rate is not changing substantially with time (number of pulses); a weak trend toward erosion decrease could be mentioned.
- Erosion rate per unit energy input (specific erosion $\Delta m/E_t$) is somewhat less for higher single pass energies.
- Average specific erosion of about 0.7 mg/kJ results in (combined - cathode and anode) electrode recess of 1 to 2 cm/hr depending on energy and frequency of pulses. To compensate for erosion, motorized support should provide continuous or stepwise gap adjustment.

4.1.5 Characterization of Concrete Rubble formed by Scabbling

Size distribution of the EHS-generated concrete rubble has been obtained by the sieve analysis. The collected rubble was dried and assorted using a standard set of sieves and a shaker. Results of these measurements, as well as those of simulating contaminant contents in the rubble, are provided in Section 6.

4.2 MEASUREMENTS OF CONCRETE SCABBLING RATE AND ENERGY EFFICIENCY

4.2.1 Introduction

There are many interrelated parameters and conditions which affect the rate and energy efficiency of scabbling. Among others performed under Task 4 of the program, the most systematic were measurements of depth and volume of concrete cavities or grooves produced by EH discharge between either static or moving ("Scabbling" mode) electrodes. The first type of experiments, designated as "Single Cavity" mode, were made using laboratory rig (Figure 3-7) and concrete slabs (Figure 3-2) or similar. The cavities produced by EH pulses were evaluated vs. pulse power voltage, pulse energy, number of pulses, electrode gap length, and electrode clearance. In the second series of tests ("Scabbling" or "Area" mode), the grooves produced by discharge chamber traverse over either concrete slabs or over concrete floor sections isolated by water barriers (as in Figure 3-18). In addition to factors considered in the single cavity mode,

TABLE 4-5

ELECTRODE EROSION, Δm (mg)

Conditions: Carbon Steel, 3/8" diameter L = 0.4", C = 7.4 μF, f = 2 Hz

	Single Pulse Energy 1070 J				2320 J			
No Pulses	Cathode Δm	Anode Δm	Total $\Delta m/E_t$ mg/kJ	ΔL mm/hr	Cathode Δm	Anode Δm	Total $\Delta m/E_t$	ΔL
200	52	115	0.79*	-	0.23	0.41	0.64	-
600	135	310	0.69	-	0.22	0.39	0.61	-
Average			0.74	10.5	0.22	0.40	0.62	18.8 mm

*e.g., $\Delta m/E_t = 52 + 115/1070 \times 200 = 0.79$ mg/kJ

TABLE 4-6

CONCRETE SURFACE SINGLE CAVITY VOLUME VS. ELECTRODE CLEARANCE*
(Two series of experiments at $E_1 = 1480$ J, n = 5)

Clearance, in.	Cavity Volume, cm^3 I	II
0	3.8	5.0
1/16	3.2	3.0
1/8	2.2	1.6
1/4	0.9	1.3
1/2	0.5	0

*Distance between electrode tips and concrete surface scabbling grooves were evaluated vs. traverse velocity and number of pulses per unit track length.

Simple linear measurements were combined with measurements of cavity/groove volume and sometimes with rubble weight measurements. The volume measurements were made by filling the cavity/groove with either water or, as shown in Figure 4-2 and more conveniently, with dry sand.

4.2.2 Single Cavity Data

Dependence of single cavity volume on the single pulse energy and on the number of pulses is shown in Figure 4-3. Characteristically, the cavity is not formed until certain energy is delivered by a single pulse or by a sequence of pulses. After this threshold is passed, cavity volume increases approximately in proportion to a total energy input or even faster. The faster increase can be explained by weakening of concrete structure by latent defects (cracks) generated by initial pulses. The volume increase is slowing down after a cavity of substantial volume is formed. Most probably, increased distance between the electrodes and the cavity walls is responsible for the slowdown.

This explanation is confirmed by some data presented in Figure 4-4 where cavity volume is plotted vs. the number of pulses.

In general, the cavity volume also "saturates" after a certain number of pulses; but when electrodes are moved downwards into the cavity, expansion of the cavity proceeds further.

There is no clear correlation between the cavity volume and electrode gap; at least the correlation is concealed by a substantial data scatter which is related mostly to the inhomogeneous concrete structure and strength.

To the contrary, dependence of the cavity volume from the electrode position above the surface (clearance) is quite pronounced. According to Table 4-6, an increase of clearance results in a strong decrease of cavity volume and corresponding loss of the energy efficiency of the crashing process. The cavity volume decreases with clearance even more rapidly than strength of mechanical impact (see Table 4-4). Presumably, increase of clearance reduces not only shock wave pressure but also cavitation effects - phenomenon which is not affecting ductile deformation of a metal target.

High pressure shock wave mechanism alone cannot explain the strong cavity volume vs. clearance dependency. In our opinion, it is important to take into account that EH discharge-generated stresses in concrete are not distributed uniformly: stress concentration takes place at the electrode tips where high current density gradients are known to be sources of high velocity gas or, as in our case, liquid jets. These cavitating jets dissipate at rather small distances from the electrode discharge spots, therefore even a small clearance can be detrimental for the concrete spalling.

4.2.3 Scabbling Mode Data

Basic scabbling trials (Task 3 of the program) were concluded by achieving - with a single electrode pair processing chamber - characteristic scabbling rates and energy consumption shown in Table 4-7. By power supply, design and operation improvements which followed, the parameters were brought to a level characterized by Table 4-8.

In the subsequent experiments, parametric study of scabbling rate and energy consumption was completed. A set of constant and variable parameters is shown in Table 4-9,

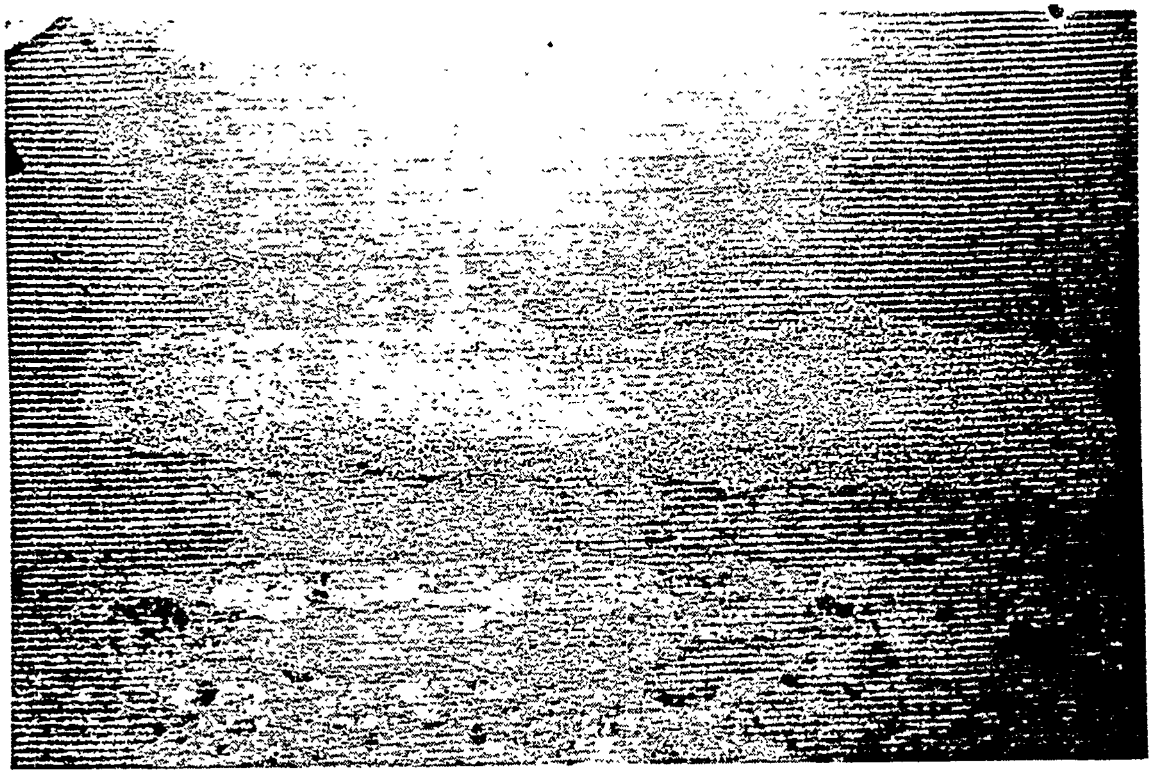


Figure 4-2 Scabbling Grooves on the Concrete Floor Sand-filled for Volume Measurements

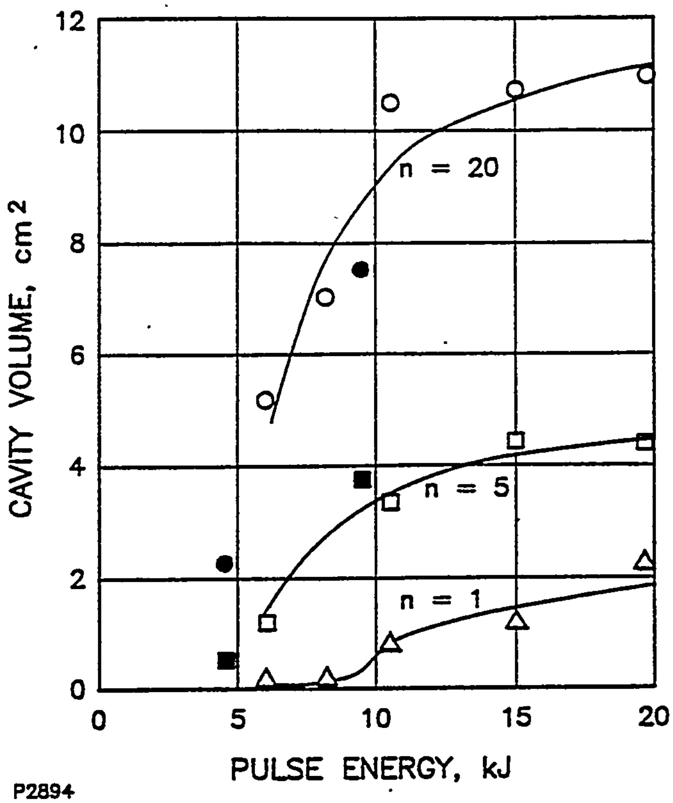


Figure 4-3 Concrete Surface Single Cavity Volume vs. Energy and Number of Pulses
L = 1/4", 13 kV < U < 23 kV,
C = 7.4 µF (except for • - C = 3.7 µF ■ - C = 1.85 µF)

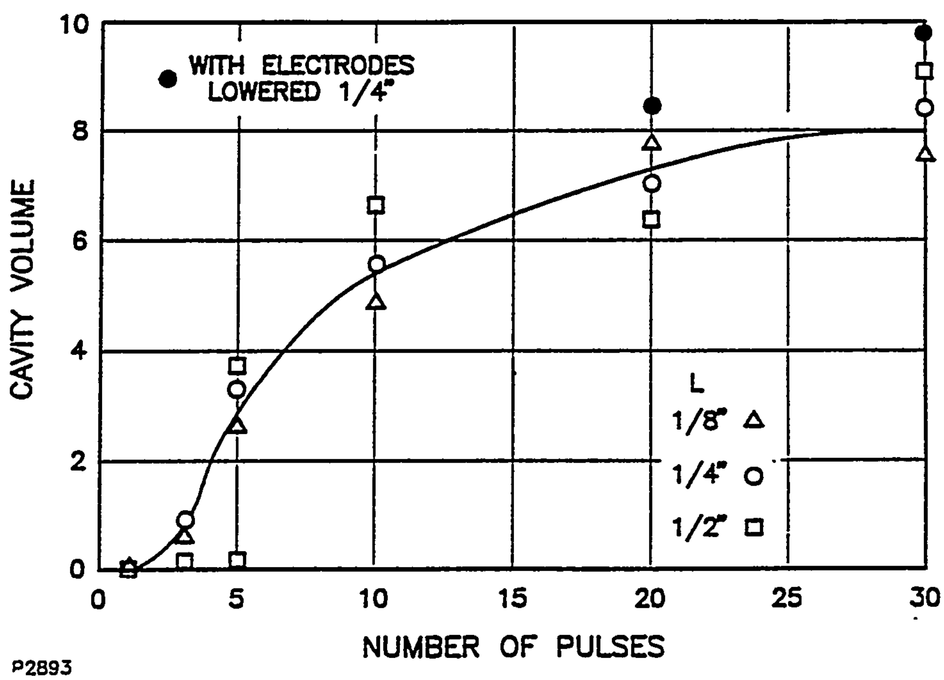


Figure 4-4 Concrete Surface Single Cavity Volume vs. Number of Pulses (n) and Electrode Gap L
E_1 = 830 J (15 kV, 7.4 µF), clearance < 1/16"

TABLE 4-7

OPERATING AND PERFORMANCE DATA CHARACTERISTIC JANUARY-FEBRUARY 1994 SCABBLING TRIALS

Pulse Energy (nominal, stored)	1900 J
Energy Delivered to the Discharge	50 J
EH Head Velocity	30 mm/min
Pulse Repetition Rate	50/min
Total Number of Pulses	2100
Total Energy	4000 kJ
Area Processed	870 cm^2
Processing Time	40 min
Scabbling Depth (average)	2,1 cm
Concrete Removed, Volume	1800 cm^3
Concrete Removed, Mass	4300 g
Concrete Removed, Per Pulse	2 g
Scabbling Energy (nominal)	950 J/g
Specific Scabbling Discharge Energy	475 J/g
Scabbling Rate	1.2 ft^2/hr

TABLE 4-8

RANGE OF OPERATING PARAMETERS AND PERFORMANCE LEVEL ACHIEVED IN MARCH-APRIL 1994 TRIALS

Operating voltage	17.0 - 24.5 kV	
Storage capacitance	7.4 μF (constant)	
Energy (stored) per pulse	1,000 - 2,200 J	
Traverse rate	2.2 - 6.6"/min	
Traverse length	6 - 15"	
Number of pulses per traverse	30 -600	
Pulse frequency	1 - 2 Hz	
Electrode gap	0.25 - 0.40 "	
Water level	1.0 - 1.2 "	
Scabbling width	3.7 - 7.6 cm	(1.5" - 3.0")
Scabbling depths	0.4 - 1.3 cm	(5/32 - 1/2")
Area scabbled	60 - 180 cm^2	
Concrete mass removed	60 - 140 g	
Energy consumption per unit area	1.0 to 4.0 kJ/cm^2	
Energy consumption per unit mass	0.6 to 2.6 kJ/g	
Scabbling rate (single electrode pair)	5 - 10 sq. in. per min. (2 - 4 sq. ft. per hour)	

TABLE 4-9

OPERATING CONDITIONS FOR PERFORMANCE PARAMETRIC STUDY

Constant Parameters: C = 7.4" μF, L = 0.35", water level 1", clearance < 1/16"

Trial No.	Velocity in/min (cm/s)	U, kV	E_1, J	E/ℓ_c, kJ/cm f = 1 Hz	f = 2 Hz
1,2	2 (0.08)	18	1070	12.4	24.8
3,4	2 (0.08)	23	1960	22.7	45.4
5,6	4 (0.17)	18	1070	6.2	12.4
7,8	4 (0.17)	23	1960	11.3	22.7
9,10	6 (0.25)	18	1070	4.1	8.2
11,12	6 (0.25)	23	1960	7.6	15.2
13,14	10 (0.42)	18	1070	2.5	5.0
15,16	10 (0.42)	23	1960	4.5	9.0

and measured scabbling area S, average depth <h>, volume V, rubble mass M*, and specific (per unit of concrete mass) energy consumption E/M are given in Table 4-10. The following conclusions are based on these data, corresponding Figure 4-5 plots, and results of several other scabbling runs made for conditions beyond the Table 4-8 ranges:

- Energy input per unit length of a scabbling trail (E/l) is a convenient practical reference parameter which defines scabbling depth, area and energy consumption for unit mass (or volume) of removed concrete.

- For a given single pulse energy, scabbling rate, both surface and volume related, is practically constant for a constant value of scanning velocity pulse frequency ratio v/f. One of these two parameters can be conveniently used for the scabbling process control.

- For constant E/l values, the scabbling rate and energy efficiency do not depend significantly on the single pulse energy as soon as this energy is not too low (< 500J) or too high (> 3000J). Below the low threshold, the cavity and groove are not forming, while above the second threshold complete disintegration of the concrete slab (4-6 inches thick) may take place (as in trial No. 4, Tables 4-8 and 4-9).

- Width of the scabbling trial increases moderately with scabbling depths, therefore, with increasing energy input mass and volume of concrete rubble increases faster than scabbling depth.

- Energy efficiency of scabbling M/E is in 1 to 2 g/kJ range being higher for deeper scabbling.

Another series of hardware changes and operation refinements was implemented since the completion of the parameter study. As a result, the range of EHS module operating parameters was broadened and performance characteristics improved. In Table 4-11, typical and maximum (or best) operating parameters are shown. Achieved performance characteristics are presented for shallow and moderately deep scabbling in Table 4-12.

4.3 CONCRETE RUBBLE CONTAINMENT AND REMOVAL CONSIDERATIONS

Part of the laboratory trials were accompanied by removal of slurry consisting of concrete rubble and process water. The following conclusions were made on the basis of these qualitative experiments:

- It would be difficult to build and operate a completely enclosed scabbling (discharge) chamber because flexible gaskets which should isolate the chamber interior from the surrounding concrete surface would be affected by a combination of shock waves and friction over concrete surface. Closing the gap between the lower chamber bottom and a groove remaining in concrete in the wake of the chamber is particularly difficult.

- A scabbling process employing a partially enclosed discharge chamber results in the spreading of slurry/rubble in all directions over a rather large (several square feet) floor area. Under these conditions, it is difficult to remove slurry, including a coarse fraction of the rubble, whereas the scabbling is still in progress. A processing

*$M = V \times \rho$; for regular concrete $\rho = 2.4\ g/cm^3$, $M(g) = V(cm^3) \times 2.4$.

TABLE 4-10

EH SCABBLING PARAMETRIC STUDY DATA

Trial No.	f = 1 Hz S cm²	h cm	V cm³/min	M g/min	E/M kJ/g	Trial No.	f = 2 Hz S cm²	h cm	V cm³/min	M g/min	E/M kJ/g
1	31	1.2	37	89	0.74	2	39	2.5	98	235	0.54
3	34	2.5	86	207	0.58	4	-	-	-	-	-
5	50	0.7	35	84	0.79	6	56	1.6	91	220	0.58
7	55	1.3	71	170	0.70	8	65	2.8	183	440	0.53
9	64	0.5	32	76	0.87	10	69	1.1	76	182	0.70
11	75	0.8	62	150	0.80	12	88	1.8	158	380	0.62
13	90	0.3	27	67	0.98	14	95	0.7	66	158	0.81
15	112	0.5	55	131	0.85	16	118	1.1	130	312	0.75

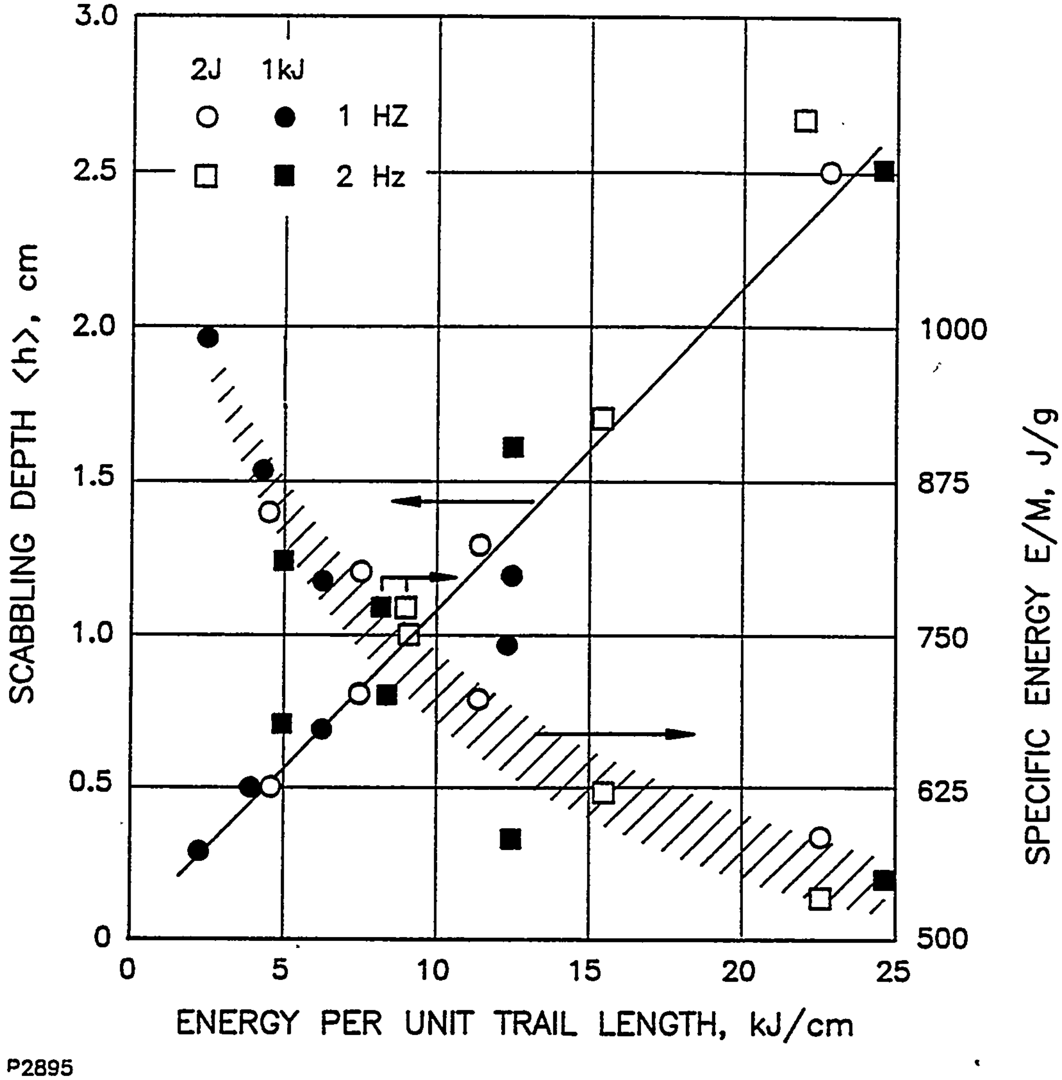


Figure 4-5 Scabbling Depth and Energy Consumption per Unit Mass of Concrete vs. Energy Input per Unit Length of Scabbling Trail

TABLE 4-11

EHS LABORATORY UNIT SPECIFICATION

Item	Typical Value or Range	Maximum (or best) Available
Installed Electric Power, kW		
Single electrode pair	4	6
Two electrode pairs	8	10
Operating Voltage, kV	20-25	35
Capacitance, per electrode, μF	4-10	17
Discharge Current, kA	20-40	60
Pulse Energy, kJ	1.0-2.5	4.5 (max)
Discharge Duration T/2, μs	12-18	10 (min)
Repetition Rate, per electrode, Hz	1-3	4 (max)
Electrode Gap, cm	0.5-1.2	0.3-1.5
Water Depth, cm	2-4	1.5 (min)
Number of Electrode Pairs	1	2

TABLE 4-12

EHS PERFORMANCE PARAMETERS ACHIEVED WITH LABORATORY UNIT

Parameter	Shallow Scabbling (0.5 cm typical)	Medium Scabbling (1 cm typical)
Scabbling Depth, cm	0.4 (min)	2 (max)
Width of Scabbling Trail*, cm	5.5	7 (max)
Scabbling Rate, m^2/hr	1.2	1.0
Scabbling Rate, kg/hr	14	24
Operating Time, max	40	40
Consumption of:		
Electric Energy, kJ/kg	960	660
Electric Energy, kWh/m^2	3.2	4.5
Water**, gal/m^2	6	6
Electrodes cm/m^2 (cm/hr)	1.5	2.0
Removal of Uranium Contaminant, dpm/100 cm^2 from to	2000 100	N/A

*Per electrode pair, per pass, based on three adjacent passes.
**For static pool or recirculation.

chamber combining both scabbling and waste removal functions would be complicated and less reliable because contradictory requirements with respect to the chamber size, water flow volume, groove formation, etc. have to be met. Removal of slurry by a wet vacuum device as an independent operation does not constitute a problem.

- A second - larger and relatively light - enclosure/slurry barrier can be employed in combination with a rather small discharge chamber(s). A simple "static," 2-3 inches high, plastic barrier attached to the concrete floor and isolating 20 to 50 ft^2 of floor area was used to prevent the spread of the contaminated slurry. Water depth within this enclosure can be maintained in a 1/4" to 3/4" range, with the total amount of water involved being 5-10 gal. Slurry shall be removed after scabbling of the isolated area is accomplished. To prevent recontamination by water-soluble materials, the slurry should not remain over the floor longer than a certain time (tens of minutes for water-soluble contaminants or a few hours for water-insoluble contaminants). This factor, combined with scabbling rate, sets a high limit for the barrier-isolated area size. For instance, for a 40 ft^2/hr scabbling rate, the isolated area should not be larger than 10-20 ft^2 or 50-100 ft^2 for soluble and insoluble contaminants, respectively. If necessary, the isolated area can be increased if slurry is removed periodically after only some fraction of the area is processed.

- While operation with static barriers which could be installed-removed-reinstalled with relative ease was shown to be feasible, its use may be cumbersome and inconvenient at some contaminated sites. A different approach was conceptualized and tried at the end of Phase I of the project. This approach, illustrated by Figure 4-5a schematics, uses a "dynamic" or periodically moving enclosure. The enclosure, which has a foamy gasket at its bottom edge perimeter, provides a water/slurry barrier tightened against concrete either by applying vertical mechanical pressure (loading) or by reducing interior pressure using a vacuum blower. Scabbling takes place within the enclosure after it is secured over a certain floor area and flooded by water to a prescribed height. Size of the enclosure is selected to accomplish scabbling within 10-15 minutes (i.e., it depends on the scabbling rate). Slurry is removed by a wet vacuum device after scabbling is accomplished. The scabbling chamber itself or a separate collector could be used as a "scoop." EHS carriage is used for periodic movement of the enclosure. To avoid friction erosion of the bottom gasket, the enclosure is lifted while traversing the floor. Separate slides provide fine positioning of the discharge chamber(s) within the enclosure. The same slides are used to travel the scoop.

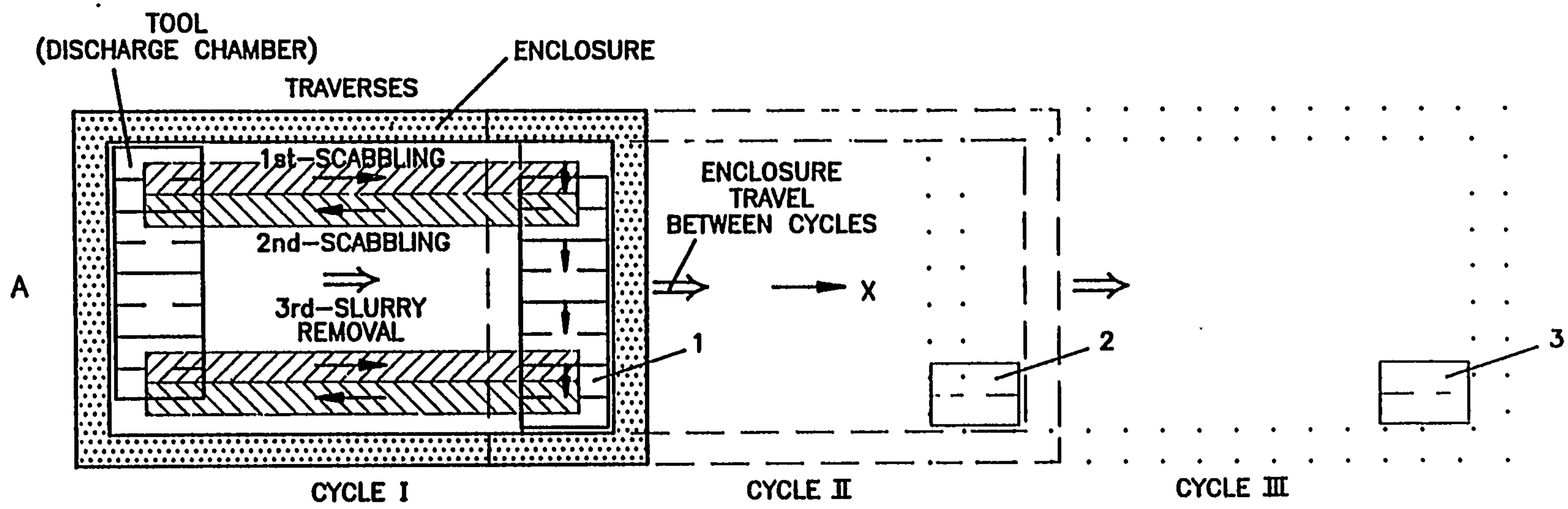
4.4 OTHER OBSERVATIONS AND SEMIQUALITATIVE RESULTS

Some other phenomena and scabbling process peculiarities observed and, in some cases, characterized semiquantitatively in a course of scabbling trials are discussed below:

- Epoxy-paint cover does not change scabbling depth and rate.

- Sharp electrode tips and small electrode diameters benefit (for other similar conditions) scabbling efficiency. It is difficult though to maintain these conditions for a reasonable time; electrode tips are rounded due to erosion, while thin (less than 1/4") electrodes are bent by the EH pulse forces.

- Concrete with a smaller size of gravel component (1/4" vs. regular 3/4") can be scabbled at about a 30% higher rate.



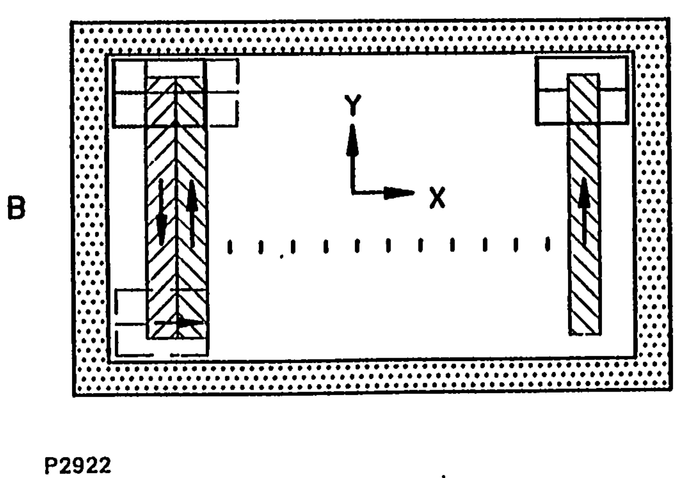


Figure 4-5a Schematics of Scabbling with "Dynamic" Periodically Moving Enclosure
Option A - Scabbling with multielectrode module along single X-axis.
Tool (discharge chamber) positions at the end of Cycles I, II, III.
Option B - Scabbling with single-electrode module along either X or Y-axis (Y-axis scabbling is shown).

- EH breakdown voltage in the vicinity of concrete surface is significantly lower than in the bulk of the liquid. This effect takes place not only in water but also in good insulating liquids. For instance, breakdown through transformer oil takes place at voltages as low as 20 kV for 1 mm clearance, while voltages above 100 kV are required for breakdown in the bulk of oil (e.g., for clearances > 1 cm).

- Discharge "misfires" and current leakages are less pronounced with one or both electrodes/electrode holders covered by rubber-like coatings ("Dip it" trademark is a convenient material). The coating is rapidly removed up to one-two inch distances from the electrode tips but survive for a few hours at larger distances.

- When the level of water in a discharge chamber is sufficient to cover lower ends of electrode holders (i.e., water depth is > 1"), its further increase does not affect EH discharge and scabbling efficiency. On the other hand, too high a water level - discharge chamber almost full - results in

  a) breakdowns across the top of the chamber, and

  b) increased mechanical impact on the chamber walls.

- Water flow through the discharge chamber does not affect the EH discharge as long as the circulation does not produce air bubbles or strong oscillations of the water level.

- Water cleanness and composition - presence of fine rubble and, possibly, of water-soluble alkalies from the concrete - results in some changes in discharge parameters - breakdown voltage, electrode gap resistance, and leakage resistance. These factors affect pulse shape, amplitude and duration in a rather irregular manner. While these phenomena were not studied systematically, we conclude that at reasonably high (for a given discharge gap) over-voltages and energy inputs, discharge parameter changes do not exceed 20%. During tens of minutes of operation, a systematic change of the discharge properties due to accumulation of rubble/chemicals was not significant.

  The water composition effects may become important for longer operation, especially in combination with a high degree of water recirculation. Increase of water conductivity and leakage current may require larger volumes of makeup water and/or appropriate adjustment of circuit parameters (e.g., use of shorter discharges or smaller electrode gaps).

5.0 SUPER-HIGH VOLTAGE CONCRETE SCABBLING (EDS)

5.1 INTRODUCTION

Concrete scabbling by electric discharge can be (as explained in Section 1) realized in two modes of operation (see Figure 2-4): with discharge propagating through the water layer above (or along) the concrete surface; or by discharge propagating directly through the concrete body. The second mode - identified in this section as EDS (Electric Discharge Scabbling) - has prospects to be more energy efficient, but its implementation requires shorter, super-high voltage (SHV > 100 kV) and short pulses to prevent premature electric breakdown through the water layer. In this section, principal features and concepts of destruction of concrete surface layer by electric discharges are described followed by results of EDS scabbling trials.*

5.2 DESTRUCTION OF CONCRETE SURFACE LAYER BY ELECTRIC DISCHARGES . POWER SUPPLY DEFINITION

5.2.1 Introduction

An electric breakdown of solid dielectrics under layer in liquid is used for destruction of bulk and surface of various materials. In Figures 5-1 and 5-2, installations for drilling and passivation of granite are shown, respectively.[40,41]

According to Refs. 37 and 41, surface treatment of natural stone requires 180 to 360 J/cm^3, while for concrete decomposition 110-150 J/cm^3 are needed. A schematic of the electrode system for surface layer destruction is shown in Figure 5-3. Experiments show that at sufficiently high voltage (100-200 kV/cm for concrete), bulk material breakdown may forestall the water breakdown. Expanding discharge channel results in concrete fracture and cavity formation. In this section, breakdown conditions, concrete fracture, and energy deposition criteria are considered. Discharge characteristics resulting in concrete surface destruction, and electric power supply requirements are formulated.

5.2.2 Development of a Spark Channel in Solid Dielectric. Selection of Voltage and Voltage Growth Kinetics

Electric breakdown of dielectrics is faster at higher voltages.[42] The voltage time (V-sec) characteristics of dielectric solids and liquids are different. For slowly increasing voltages, when thermal phenomena prevail, the electric strength of solids is higher than that for (technical) water, while for rapidly (~ 10^{-6} s) growing voltages (avalanche breakdown) discharge in concrete develops more rapidly. Experimental Volt-second characteristics shown in Figure 5-4b,c, which were obtained[43] for configuration 5-4a, confirm this point. The concrete and water curves intersect at t ~ 0.1 µsec for concrete "500" (compression strength 500 kG/cm^2 = 7000 psi) and at 0.4 µsec for concrete "100" (1400 psi).**

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*Most of these trials were performed by Dr. G. Shneerson and his co-workers at St. Petersburg (Russia) Technical University with the participation and under the management of Plasma Plus Co., Los Angeles, CA in accordance with TDS purchase order

**In fact, the intersection would take place at longer times: water curve should be shifted to the left to take into account the difference in the discharge gaps in these experiments.

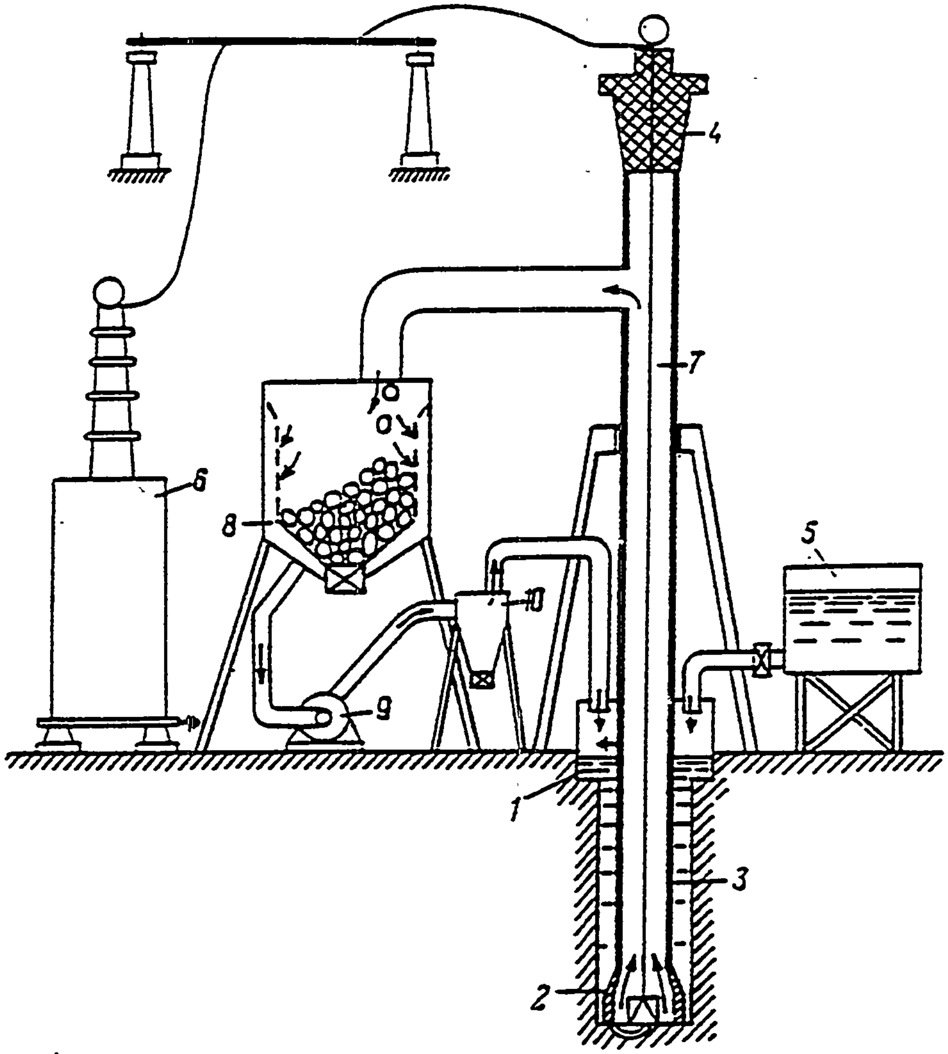


Figure 5-1 Technological Schematics of EH Drilling Rig
1-Conductor, 2-Drilling head, 3-Column, 4-High-Voltage Feedthrough, 5-Water Tank, 6-Pulser, 7-Cable, 8-Rubble Collector, 9-Pump, 10-Cyclone

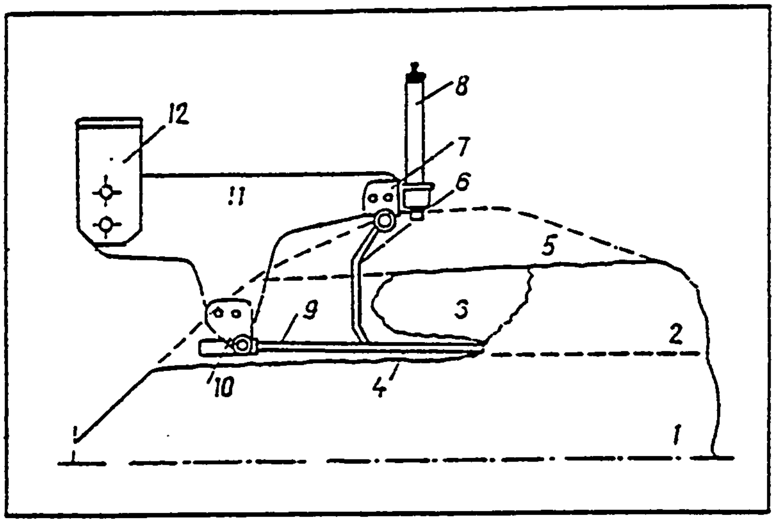


Figure 5-2 Schematics of Rock Processing
1-Rock, 2-Slice to be Removed, 3-Cutoff Section, 4-Slot, 5-First Slice Removed, 6-HV Electrode, 7-Holder, 8-Cables, 9-Grounded Electrode, 10-Holder, 11-Insulator 12-Tool Holder

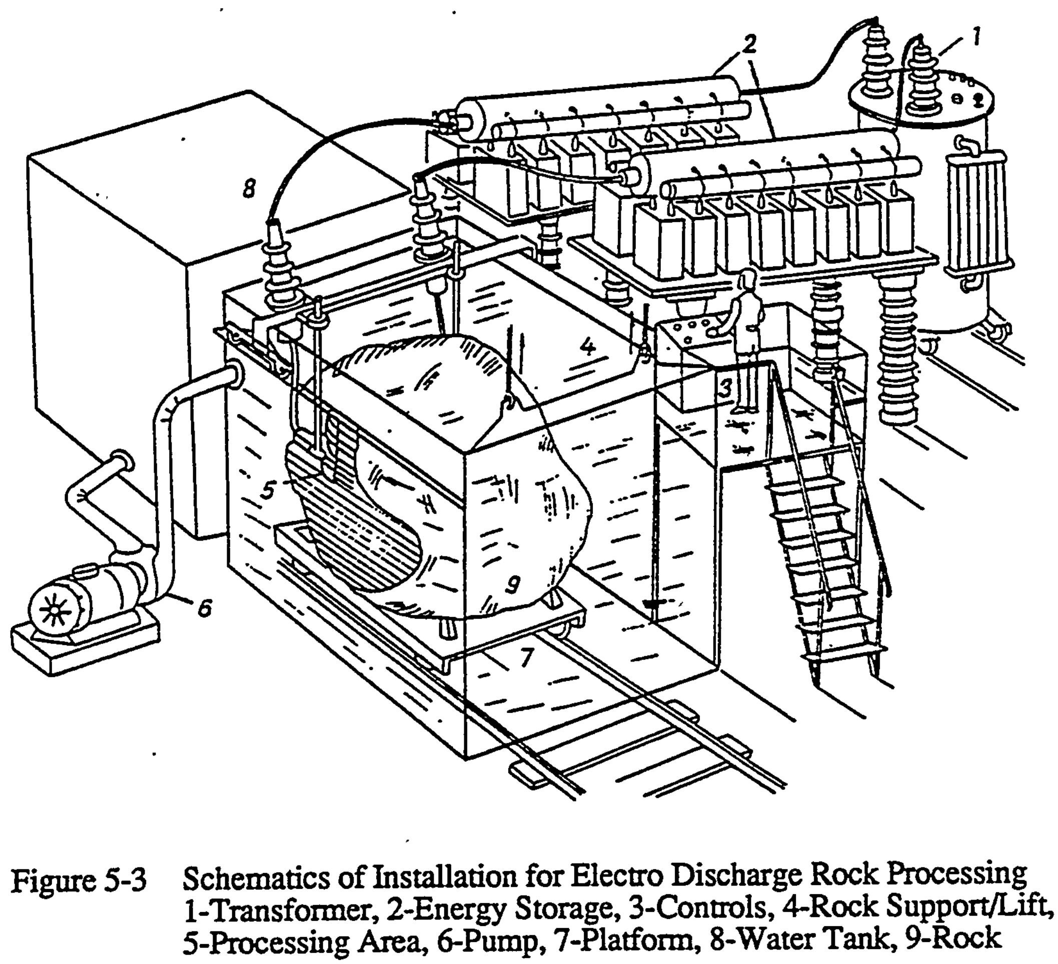
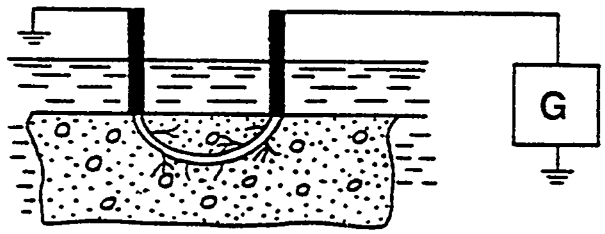
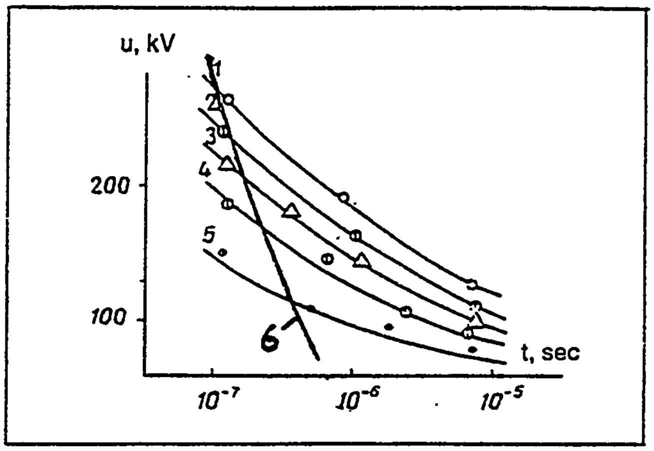


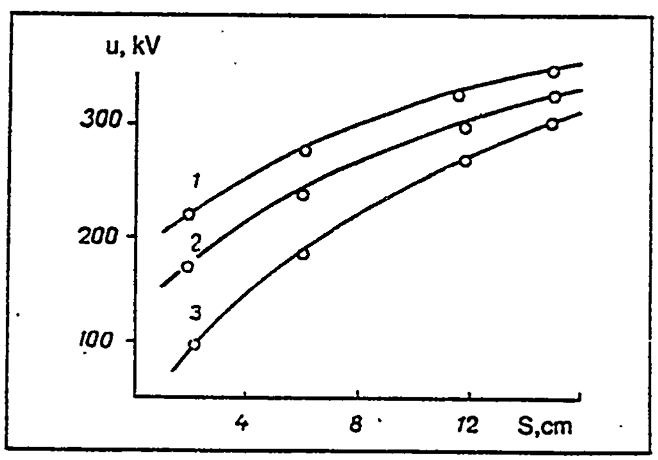
Figure 5-3 Schematics of Installation for Electro Discharge Rock Processing
1-Transformer, 2-Energy Storage, 3-Controls, 4-Rock Support/Lift, 5-Processing Area, 6-Pump, 7-Platform, 8-Water Tank, 9-Rock



a)



b)



c)

Figure 5-4 a) Volt-second Characteristic of Concrete Brands 500(1), 400(2), 300(3), 200(4) and 100(5) for 30 mm gap length; 6-water for 1 = mm gap length
b) Breakdown Voltage of Concrete Brands 500(1), 300(2) and 100(3) for U' = 1100 kV/ms
c) Breakdown Test Setup

For technical water and practical circuit parameters, the characteristic discharge time is several μsec; therefore, applied voltage does not drop substantially before the discharge takes place. A conclusion is reached that the electric strength of concrete is lower than that for technical water for voltage growth times < 10^{-7} s and maximum voltage of the order of 160 kV (for 1 cm gap length).

According to Ref. 43 experiments, the concrete breakdown voltage can be calculated as $U_B = 1.2\ (L^{0.39}\ C^{0.25}/t_d^{0.21})$ (kV) where L is interelectrode distance, C is concrete brand number, t_d is breakdown delay time.

5.2.3 Criteria for the Brittle Fracture of Surface Layer

After the initial (nanosec) stage of the breakdown, a plasma channel can be considered as a cylindrical piston; most of the energy is delivered during the piston expansion stage. Beyond a very narrow near-cylindrical zone where material disintegration takes place, long cracks are formed in the solid body. A cavity is formed when tips of the cracks approach the free surface.

In Refs. 40 and 44, 3 cm long cracks propagating in the Plexiglas with 750 m/sec velocity were observed; with 4 μsec, 35 J/cm^3 discharge cavities of a few cm^3 volume, and 20 cm^2 surface were formed. It follows from these data that the crack propagation time is much longer than the discharge duration. The increase of energy release time is initially accompanied by the increase of destruction volume. Efficiency reaches maximum when the time of crack propagation to the surface equals energy release time T_E; this corresponds to $T_E = 5 \cdot L/\pi c$, where c = 300 m/s for concrete, and L is the interelectrode distance.

According to the Irvine-Griffith theory of brittle fracture, under static conditions the brittle failure takes place when elastic stress at the crack tip reached value

$$\sigma = K/2\pi\rho)^{-0.5} \cdot \phi(\theta)$$

where ρ is distance from the crack tip, θ is azimuthal coordinate, and K is a parameter which is in the (1-5) · 10^6 Pa/m$^{0.5}$ range for ceramics.(45) For practical purposes, the failure criterion can be defined as

$$P_c = K(\pi/)^{0.5}$$

where P_c is pressure in the crack vicinity.

For $\ell = 10^{-2}$ m and K = (1-5) · 10^6, P > (6-30) · 10^6 Pa (= 60-300 atm). Energy required for generation of unit crack surface area is given by

$$W_1 = (1-\nu^2)K^2/E,$$

where E is Young modulus, and ν is Poisson's coefficient. For concrete $E = 2 \cdot 10^{10}$ Pa and W_1 = 400-1000 J/m^2. It follows from this estimate that relatively small (0.4-1.0 J) discharge energy should be sufficient to form cracks with a total 10 cm^2 surface area. The static theory which is adequate for a description of static failure underestimates energy required for the dynamic process. It has been shown (see Ref. 46, for instance) that for times below 10^{-5} s the failure threshold increases significantly due to dynamic viscosity effects. Nevertheless, with even a tenfold increase of W_1, only a few Joules of energy would be required for concrete surface failure. This is a substantially smaller value than the tens of Joules typically released in the discharge channel. In Ref. 47, an assumption is made that the discharge energy is spent mostly for plastic deformation. In this event, 50 to 4000 J/m^2 would be required for crack formation.

In summary, the brittle and plastic failure theories do not provide sufficient basis for a reliable estimation of energy required for destruction/cavity formation. Theories based on surface energy values, which are commonly used for grinding energy estimates, are not directly applicable either.

It seems appropriate therefore to use an approach based on the similarity relations. A dimensionless combination for a brittle body can be written as:(45)

$$\eta = W/KL^{5/2}$$

where interelectrode distance L ~ d (cavity diameter).

According to this expression, for equal volumes of material removed, energy required for disintegration is proportional to the parameter K. Another estimate follows from the energy requirements data for material destruction by chemical explosions. For granite, for instance, this energy is 30 J/cm^3.

At last, results of direct experiments for granite and concrete destruction by electric discharges can be used for scabbling estimates. These data usually involve energy provided by the power generator, with circuitry losses not defined. Therefore, they should be considered as the upper limit of energy released in the discharge channel. According to Ref. 41 values in the 180 to 360 J/cm^3 (70 to 140 J/g) range are typical; lower values, 40 to 80 J/cm^3 (17 to 34 J/g), are provided in Ref. 48. These values do not contradict estimates given above.

In summary:

- The main parameter characterizing volume of material removed (scabbling volume) is energy delivered through the first half-period of current oscillations.
- The destruction threshold is several tens of J/cm^3; this threshold should be specified for materials of interest.
- Similarity relation can be used for scaling.
- Energy per unit channel length can be another useful criterion which should be defined experimentally for a given material.

5.2.4 Main Characteristics of Spark Discharge in Solid Dielectric. Estimates of Energy Release

Characterization of the discharge channel as an electric circuit element allows selection of a power supply parameter which provides conditions for the breakdown and a sufficient energy input. After dielectric breakdown took place, a spark discharge phase begins when the channel resistance decreases toward a few Ohm/cm. For this phase, a cylindrical piston model(49) is used with the channel radius controlled by displacement of the surrounding solid medium. In the model, an energy balance equation can be written as

$$i^2R_p = \gamma/\gamma\text{-}1\ d/dt(\pi r^2 P) - \pi r_k{}^2 dP/dt$$

where r_k is discharge channel radius and $R_p = \pi r_k{}^2\sigma$ -plasma resistance.

Another equation which establishes the relation between pressure P and channel radius has been proposed by Braginsky for gases as a generalization of the flow computation outside the channel:

$$P = B\rho_o(dr/dt)^2$$

where $B \sim 1$ and ρ is the medium density.

It can be assumed for rough estimates that at moderate discharge power (with current rising slower than 10^9-10^{10} A/s), one may neglect compressibility in the region between the channel and the shock wave front.

This approximation yields the following relationship between channel pressure and radius:

$$P = B\rho_o r^{*2}$$

where $B \sim$ const, depending in this case on the discharge regime.

For a first half-period of discharges in dense media, the following empirical relation has been established by Rompe and Weitzel for the first discharge phase when the hydrodynamic flow is not yet established:

$$R = DL\, S^{-0.5}$$

here $S = i^2dt$ is an "action integral" and D is an empirical, material dependent constant. From the last formula, the electric conductivity may be found as a time (i.e., pressure) function.

System of equations can be solved analytically when B=const and current, conductivity and pressure are power functions of time.

For properties typical for rocks, the following discharge parameters should be typical: $D = 500\ Vs^{0.5}m^{-1}$ and $I = 3 \cdot 10^{10}$ A/s, at $t = 1\ \mu s$, $r_k = 8 \cdot 10^{-4}$ m, $\sigma = 1.5 \cdot 10^4\ (\text{Ohm} \cdot \text{m})^{-1}$, $P = 1.1 \cdot 10^{10}$Pa, R = 30 Ohm/m.

It follows from these considerations that the Rompe-Weitzel formula with an empirical constant D provides the channel resistance vs. current and also allows estimation of channel pressure, conductivity, and radius. The energy release in the channel is defined as:

$$W = LW_1 = L\, i^2R_pdt = 2DL\sqrt{S}$$

in preliminary experiments (see below) concrete volume $V = 2\ cm^3$ was removed by a current pulse with i = 17 kA and T/2 = 2 µs which corresponds to $S = 3 \cdot 10^2\ A^2s$. According to Section 5.2.3 estimates, the energy required for removing 2 cm^3 is of the order of 100 J. For L = 1 cm, value of the constant D is expected to be 300 $Vs^{0.5}\ m^{-1}$.

The main results obtained in this section can be summarized as follows:

- Energy release for the electric discharge in solid dielectric can be described by a conventional balance equation with channel radius and pressure relation following the Braginsky formula.

- With this approach, the Rompe-Weitzel relationship results from the energy equation when the conductivity is proportional to the pressure.

- This relationship can be used to calculate electric resistance and energy release when parameter D is known from experiments.

- Estimates for discharge radius, pressure, and conductivity were obtained for various current pulse shapes (i.e., for various i vs. t).

5.2.5 Estimates of EDS Power Supply Parameters

Let us assume on the basis of the preceding discussion that to form a 2 cm long, 2 cm^3 cavity, 200 J energy should be supplied through the first half-period of the current. This corresponds to 20 kA current amplitude, T/2 = 2 μs, D = 300 $Vs^{0.5}$ m^{-1} and channel resistance R = 1 Ohm at t = t/4.

The circuit inductance requirements can be estimated as follows (see Ref. 48). By assuming T = 4 μs and capacitance C = 0.05 μF, we obtain $L = T^2/4\pi^2 C$ = 8 μH and impedance Z = 12.6 Ohm; therefore 20 kA current can be obtained at 250 kV voltage using two capacitors operating below their voltage limit. The 8 μH inductance corresponds to 20 m of conventional cable or 10 m distance between the pulse generator and load.

The actual system would include several (probably 3 or 4) pulse generators operating independently and in parallel to allow reduction in operating frequency for each generator. An optional solution has been suggested in Ref. 41 where a single pulse generator fires several parallel electrode pairs; the discharge runs between one of the pairs, and the pairs alternate in random fashion.

It follows from the estimate that the discharge channel resistance is much lower than the circuit impedance; even if the impedance is somewhat lower, the operating mode still will be oscillating. For the energy stored $W_c = CV^2/2 = 1.5 \cdot 10^3$ J, frequency f = 5 Hz, the average power delivered should be increased to 10 or 12 kW. With a 2 cm^2 area processed by each discharge, $2 \cdot 10^5$ sec or 56 hours will be required to scabble a 100 m^2 area.

To summarize this section:

- A circuit with two series capacitors should be used.

- Capacitors and cables should be selected with close attention to their resource; lowering the operating voltage is one of the possible solutions.

- The following circuit and operating parameters are suggested:

  U = 250 kV
  C = 0.05 μF
  L = 8 μH
  which corresponds to
  I_{max} = 20 kA
  T = 4 μs
  E = 200 J
  R = 1 Ohm
  V(concrete) = 2 cm^3/pulse
  f = 5 Hz
  P = 12 kW
  T(scabbling) = 1.8 m^2/hr

5.3 EXPERIMENTAL EDS TRIALS

5.3.1 Experimental Setup and Concrete Samples

The laboratory setup (Figure 5-5) includes DC power supply, HV pulse generator, trigger generator, processing module and instrumentation. An equivalent circuit is shown in Figure 5-6 and a circuit for electric measurements is presented in Figure 5-7.

A single electrode pair processing module (Figure 5-8) consists of an electrode system and a motorized mechanical traversing device. A multielectrode processing module is shown in Figures 5-9 and (latest design) 5-10.

A concrete sample is placed into the container filled with process fluid (water, oil). Two types of concrete samples were tested: 15 x 15 x 15 cm^3 for the single cavity tests and 20 x 20 x 10 cm^3 for the area scabbling. In both cases the M-300 concrete with 5-20 mm gravel, 35% sand, and 0.6 water/cement ratio has been used.

5.3.2 Test Data

5.3.2.1 Single Cavities

Test results for single cavity experiments are presented in Table 5-1. In Figure 5-11, cavities formed by several pulses with "static" electrodes are shown. Before discussing the data, let us consider typical features:

a) According to current and voltage scans (see example in Figure 5-12), the electrode gap voltage drop and current rise at voltages > 120 kV begin simultaneously after characteristic 100 ns delay; therefore, discharge in concrete is formed earlier than in water. On the other hand, at low voltages (as in Figure 5-13 example) the delay is so long that discharge takes place in water, and the cavity is not formed.

b) There is substantial scatter of the voltage amplitudes and delay time. The scatter may result from local variation of electric conductivity due to its inhomogeneous structure.

   It may be concluded that for most samples voltages in the 150 to 170 kV range and current rise times below 1 μs are acceptable.

Energy efficiency data are of main interest. After a few anomalous results are excluded, the cavity volume vs. energy distribution curve (Figure 5-14) follows normal distribution function

$$F(V) = (2\pi S)^{-0.5} \int \exp\left(-\frac{(V-\overline{V})^2}{2S^2}\right) dV$$

with $\overline{V} = 2.01\ cm^3$, $S = 1.57\ cm^3$, and average specific energy $E = 320\ J/cm^3$ (or 155 J/g).

. As could be expected, the cavity volume decreases drastically for V, 140-150 kV. Above this threshold, the volume depends only weakly on the voltage.

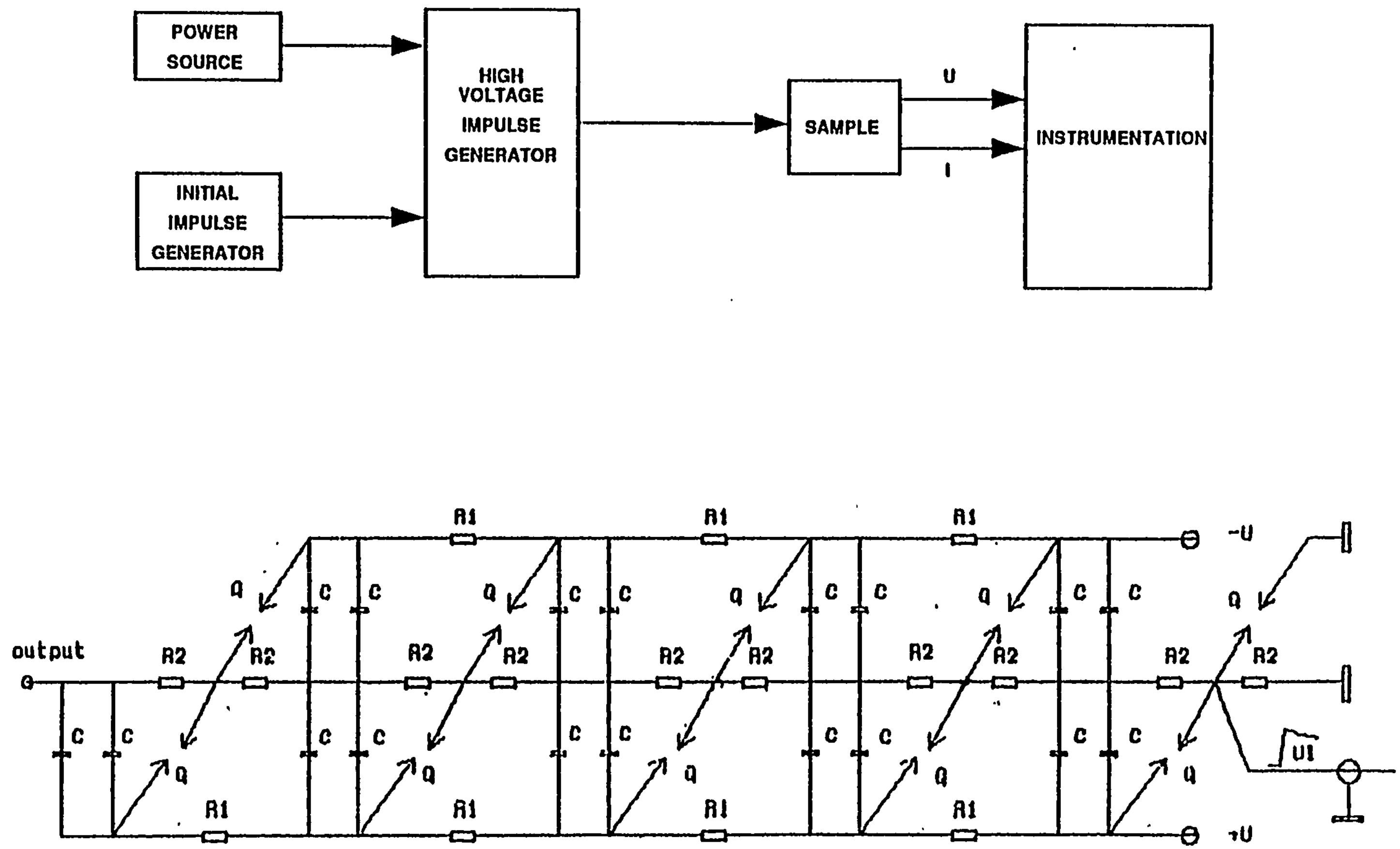


Figure 5-5 Electric Circuit used in SHV Laboratory Experiments

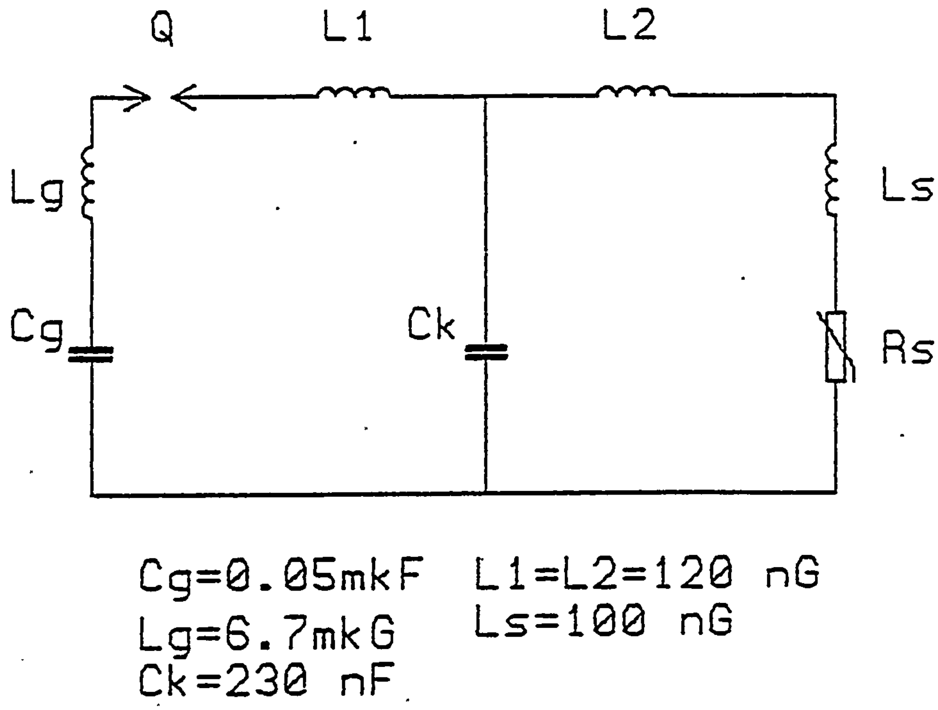


Figure 5-6 Equivalent Circuit of the SHV Power Supply

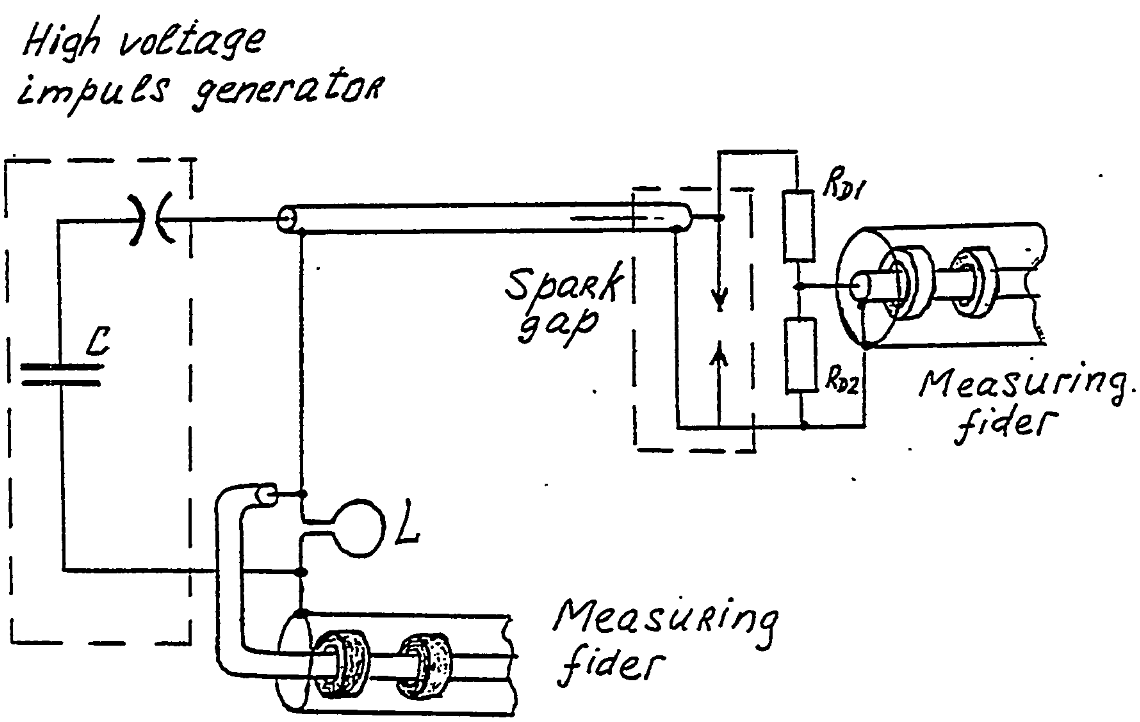


Figure 5-7 Instrumentation for SHV Measurements

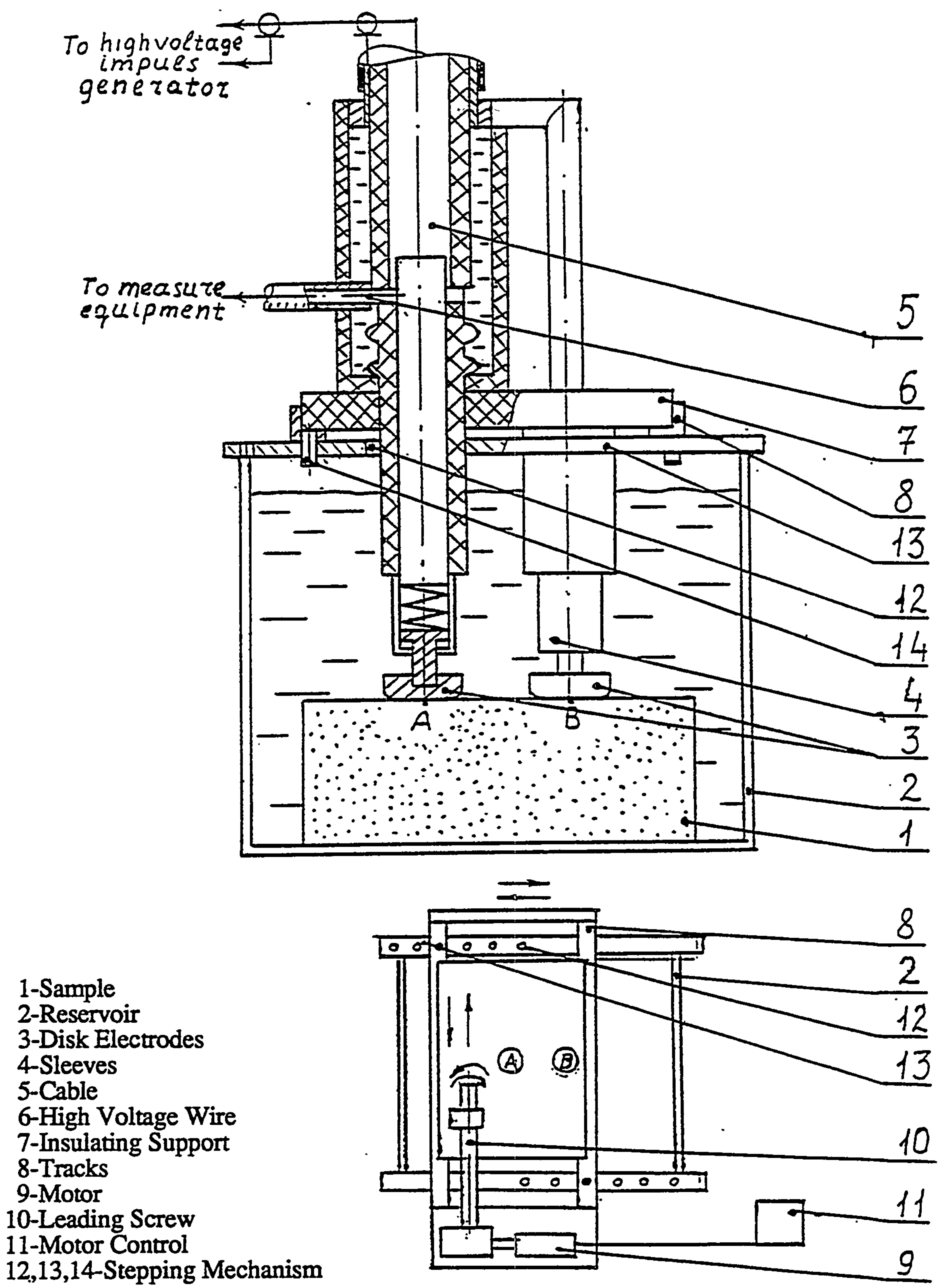


Figure 5-8 Single Electrode (pair) Scabbling Module

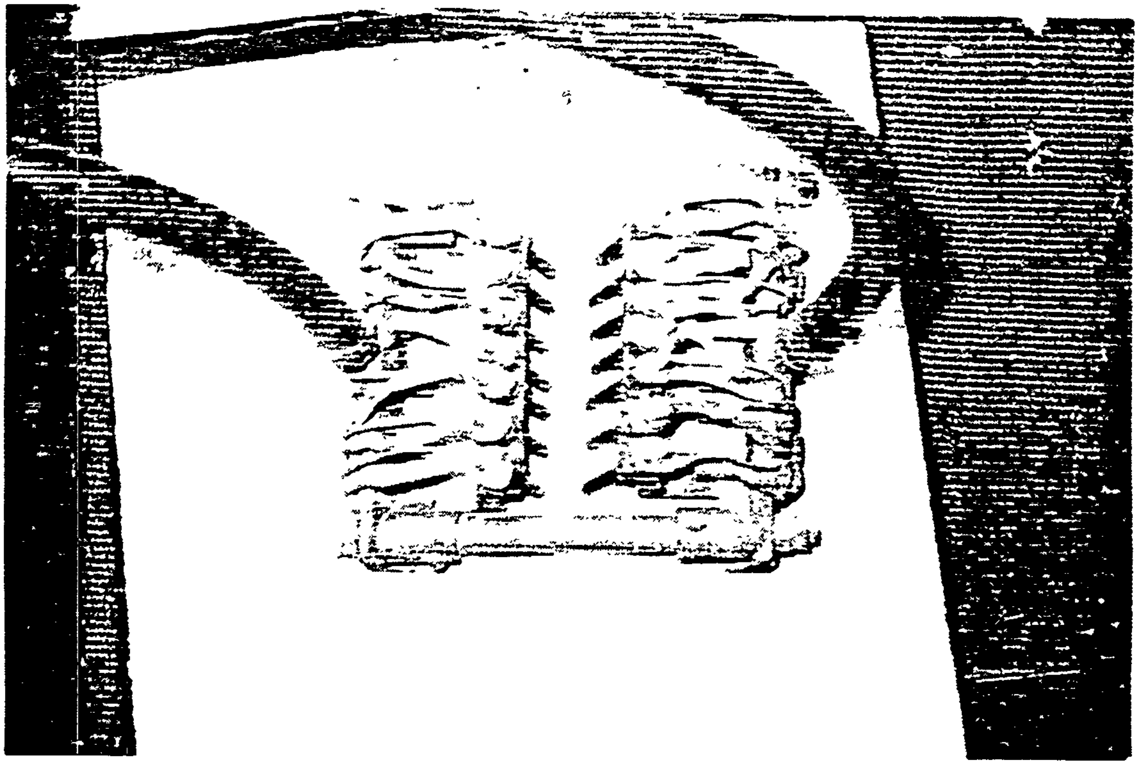


Figure 5-9 Multielectrode Scabbling Module (Early Design)

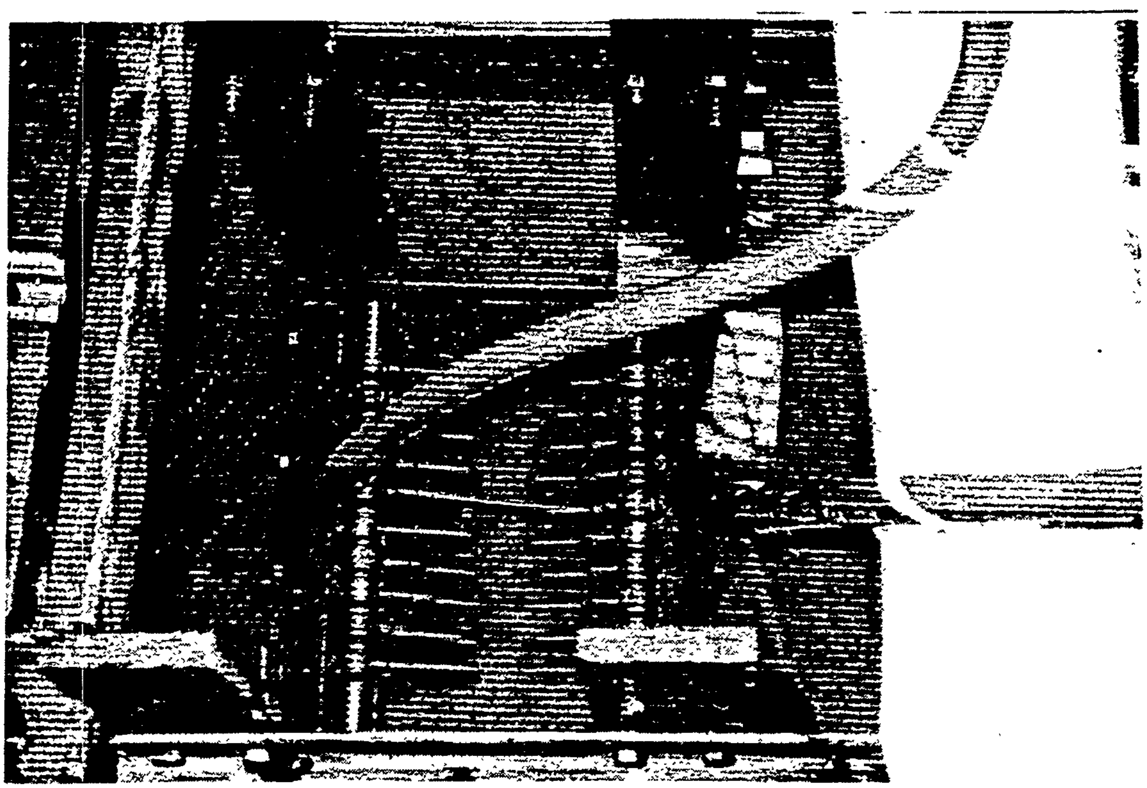


Figure 5-10 Multielectrode Scabbling Module (Latest Design)

TABLE 5-1

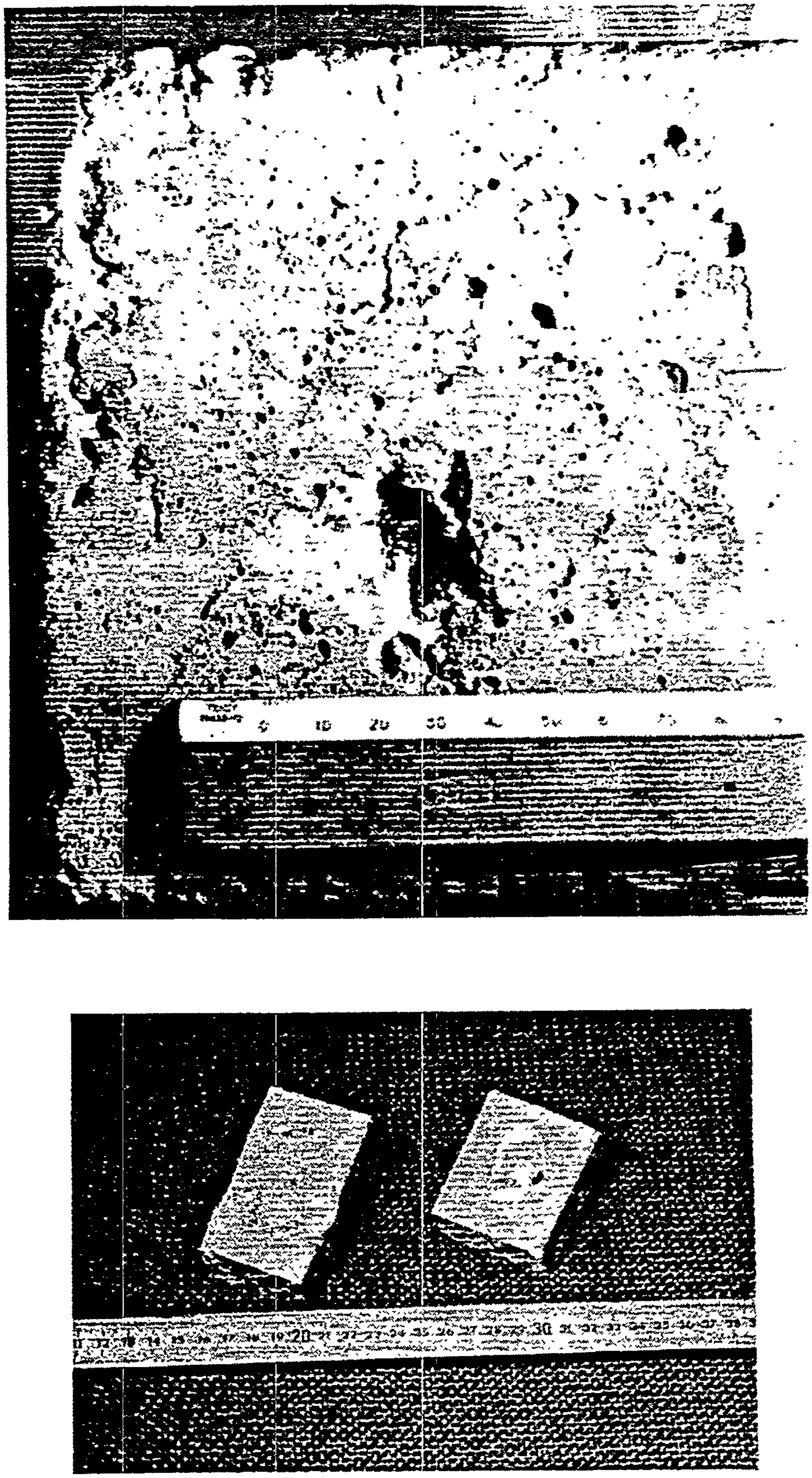
EXPERIMENTAL DATA FOR SINGLE CAVITY FORMATION

TAB.1.

1 N	2 samp. number	3 N.N	4 U kV	5 Wc	6 V cm^3	7 Q J/sm^3	8 W 1/4	9 W 1/2	10 W1/4/Wc	11 W1/2	12 Umax kV	13 R 1/4	14 D*L	15 D	16 W1/4/V	14 TAY mksek	18 water	19 discharge length, L mm
1	2	1.1	160	640	6.6	97.0												15
2	2	2.1	160	640	1.3	492.3												15
3	2	3.1	160	640	.5	1280												15
4	2	4.1	160	640	6.1	104.9												15
5	2	5.1	160	640	.9	711.1												15
6	2	6.1	160	640	.7	914.3												15
7	3	1.1	160	640	.5	1280											old	15
8	3	2.1	160	640	3.1	206.5											new	15
9	3	3.1	160	640	1.3	492.3											old	15
10	4	1.1	160	640	1	640											new	15
11	4	2.1	160	640	2.6	246.2											new	15
12	4	3.1	160	640	1.5	426.7											old	15
13	4	4.1	160	640	7.9	81.0											new	15
14	4	5.1	160	640	1.6	400											new	15
15	4	6.1	160	640	2.6	246.2											old	15
16	5	1.1	160	640	2.4	266.7											new	15
17	5	2.1	160	640	1.6	400											old	15
18	5	3.1	160	640	2.5	256											new	15
19	5	4.1	160	640	1.1	581.8											old	15
20	5	5.1	160	640	11.2	57.1											new	15
21	6	1.1	160	640	3.9	164.1											new	15
22	6	2.1	160	640	9.2	69.6											new	15
23	6	3.1	160	640	1.7	376.5											new	15
24	6	4.1	160	640	4.5	142.2											new	15
25	6	5.1	160	640	9.4	68.1											new	15
26	7	1.1	160	640	2	320											new	15
27	7	3.1	160	640	.7	914.3											new	15
28	7	4.1	160	640	1.6	400											new	15
29	7	5.1	160	640	1	640											new	15
30	8	1.1	200	1000	2.9	344.8											new	15
31	8	4.1	200	1000	.6	1666.7											new	15
32	8	5.1	200	1000	.4	2500											old	15
33	9	1.1	200	1000	3	333.3											new	20
34	9	2.1	200	1000	2.1	476.2											new	20
35	9	3.1	200	1000	1.4	714.3											new	20
36	9	4.1	200	1000	5	200											new	20
37	9	5.1	200	1000	8	125											new	20
38	17	2.5	160	640	.1	6400	323		.50		205	1.9	19.7	875.6	3230	.15	new	15
39	17	2.4	170	722.5	.3	2408.3	272		.38		219	1.2	23.7	1053.3	906.7	.38	new	15
40	17	2.7	180	810	.1	8100	257		.32		182	1.1	13.3	591.1	2570	3.07	new	15
41	17	2.2	190	902.5	.9	1002.8	148	283	.16	.31	182	1.7	13.9	618.2	164.4	.31	new	15
42	17	2.8	200	1000	.9	1111.1	206	341	.21	.34	215	1.3	17.4	773.3	228.9	.19	new	15
43	20	1.1	120	360			144				132	7.9	15.8			.77	new	15
44	20	1.2	140	490			138				165	1.5	10.1			.35	new	15
45	20	1.3	150	562.5	1	562.5	94		.17		190	.5	6.8	300.4	94.2	.77	new	15
46	20	1.4	160	640	16.7	38.3	217		.34		165	1.2	11.8	522.2	13.0	.27	new	15
47	20	1.5	180	810	2.4	337.5	258		.32		207	1.6	13.8	613.3	107.5	.27	new	15
48	21	1.1	150	562.5	1	562.5	188		.33		112	.8	8.1	361.8	188	.15	new	15
49	21	1.4	160	640	.6	1066.7	205	299	.32	.47	132	1.8	15.0	666.2	340.8		new	15
50	21	1.2	170	722.5	.4	1806.3	128		.18		157	1.2	9.0	401.3	320	.15	new	15
51	21	1.3	190	902.5	.5	1805	250	403	.28	.45	82	1.7	16	711.1	500		new	15
52	21	2.4	150	562.5	1	562.5											new	15
53	21	2.3	160	640	2.4	266.7											new	15
54	21	2.2	170	722.5	.4	1806.3											new	15
55	21	2.1	190	902.5	1	902.5											new	15
56	21	3.4	150	562.5	1	562.5											new	15
57	21	3.3	160	640	1	640											new	15
58	21	3.2	170	722.5	1.4	516.1											new	15
59	21	3.1	190	902.5	2	451.3											new	15
64	22	1.4	150	562.5	.3	1875	181	263	.32		173	2.6	15.9	705.3	603.3	.19	new	15
63	22	1.3	160	640	3	213.3	221	327	.35		71	2.4	14.1	624.9	73.7		new	15
62	22	1.2	170	722.5	1.9	380.3	632										new	15
61	22	1.1	190	902.5	.6	1504.2	250	420	.23		59	2.1	16.1	715.6	350		new	15
70	22	2.6	120	360			148				132	2.7	16.3			.38	new	15
69	22	2.5	130	422.5			337				165	3.1	11.3			.69	new	15
68	22	2.4	150	562.5			253	300			152	1.5	13.7				new	15
67	22	2.3	160	640			232				165	1.4	11.8			2.69	new	15
66	22	2.2	170	722.5			141				173	.6	8.0			.23	new	15
65	22	2.1	190	902.5			144	.266			192	1.4	9.4			.19	new	15

TABLE 5-1 (continued)

1 N	2 samp. number	3 N.N	TAB.2. 4 U kV	5 Wc	6 V cm^3	7 Q J/sm^3	8 W 1/4	9 W 1/2	10 W1/4/W	11 W1/2/W	12 Umax kV	13 D 1/4	14 D*L	15 D	16 W1/4/V	17 aks	18 water	19 discharge length, L mm
1	20	1.1	120	360			144				132	7.93	15.80			.77	new	15
2	22	2.6	120	360			148				132	2.70	16.26			.38	new	15
3	22	2.5	130	422.5			337				165	3.10	11.34			.69	new	15
4	20	1.2	140	490			138				165	1.54	10.06			.35	new	15
5	20	1.3	150	562.5	1	562.5	94.2		.17		190	.54	6.76	300.4	94.2	.77	new	15
6	21	1.1	150	562.5	1	562.5	188		.33		112	.75	8.14	361.8	188	.15	new	15
7	21	2.4	150	562.5	1	562.5											new	15
8	21	3.4	150	562.5	1	562.5											new	15
9	22	1.4	150	562.5	.3	1875	181	263	.32	.47	173	2.60	15.87	705.3	603.3	.19	new	15
10	22	2.4	150	562.5			253	300		.53	152	1.53	13.68				new	15
11	2	1.1	160	640	6.6	97.0												15
12	2	2.1	160	640	1.3	492.3												15
13	2	3.1	160	640	.5	1280												15
14	2	4.1	160	640	6.1	104.9												15
15	2	5.1	160	640	.9	711.1												15
16	2	6.1	160	640	.7	914.3												15
17	3	1.1	160	640	.5	1280											old	15
18	3	2.1	160	640	3.1	206.5											new	15
19	3	3.1	160	640	1.3	492.3											old	15
20	4	1.1	160	640	1	640											new	15
21	4	2.1	160	640	2.6	246.2											new	15
22	4	3.1	160	640	1.5	426.7											old	15
23	4	4.1	160	640	7.9	81.0											new	15
24	4	5.1	160	640	1.6	400											new	15
25	4	6.1	160	640	2.6	246.2											old	15
26	5	1.1	160	640	2.4	266.7											new	15
27	5	2.1	160	640	1.6	400											old	15
28	5	3.1	160	640	2.5	256											new	15
29	5	4.1	160	640	1.1	581.8											old	15
30	5	5.1	160	640	11.2	57.1											new	15
31	6	1.1	160	640	3.9	164.1											new	15
32	6	2.1	160	640	9.2	69.6											new	15
33	6	3.1	160	640	1.7	376.5											new	15
34	6	4.1	160	640	4.5	142.2											new	15
35	6	5.1	160	640	9.4	68.1											new	15
36	7	1.1	160	640	2	320											new	15
37	7	3.1	160	640	.7	914.3											new	15
38	7	4.1	160	640	1.6	400											new	15
39	7	5.1	160	640	1	640											new	15
40	17	2.5	160	640	.1	6400	323		.50		205	1.89	19.70	875.6	3230	.15	new	15
41	20	1.4	160	640	16.7	38.3	217		.34		165	1.22	11.75	522.2	13.0	.27	new	15
42	21	1.4	160	640	.6	1066.7	204.5	295	.32	.47	132	1.81	14.99	666.2	340.8		new	15
43	21	2.3	160	640	2.4	266.7											new	15
44	21	3.3	160	640	1	640											new	15
45	22	1.3	160	640	3	213.3	221	327	.35	.51	71	2.35	14.06	624.9	73.7		new	15
46	22	2.3	160	640			232				165	1.35	11.75			2.69	new	15
47	17	2.4	170	722.50	.3	2408.3	272		.38		219	1.24	23.70	1053.3	906.7	.38	new	15
48	21	1.2	170	722.5	.4	1806.3	128		.18		157	1.24	9.03	401.3	320	.15	new	15
50	21	2.2	170	722.5	.4	1806.3											new	15
51	21	3.2	170	722.5	1.4	516.1											new	15
52	22	1.2	170	722.5	1.9	380.3	632										new	15
53	22	2.2	170	722.5			141				173	.61	7.97			.23	new	15
54	17	2.7	180	810	.1	8100	257		.32		182	1.13	13.30	591.1	2570	3.07	new	15
55	20	1.5	180	810	2.4	337.5	258		.32		207	1.58	13.80	613.3	107.5	.27	new	15
56	17	2.2	190	902.50	.9	1002.8	148	283	.16		182	1.69	13.91	618.2	164.4	.31	new	15
57	21	1.3	190	902.5	.5	1805	250	403	.28		82	1.73	16	711.1	500		new	15
58	21	2.1	190	902.5	1	902.5											new	15
59	21	3.1	190	902.5	2	451.3											new	15
60	22	1.1	190	902.5	.6	1504.2	210	420	.23		59	2.05	16.10	715.6	350		new	15
61	22	2.1	190	902.5			144	266			192	1.42	9.44			.19	new	15
62	8	1.1	200	1000	2.9	344.8											new	15
63	8	4.1	200	1000	.6	1666.7											new	15
64	8	5.1	200	1000	.4	2500											old	15
65	9	1.1	200	1000	3	333.3											new	20
66	9	2.1	200	1000	2.1	476.2											new	20
67	9	3.1	200	1000	1.4	714.3											new	20
68	9	4.1	200	1000	5	200											new	20
69	9	5.1	200	1000	8	125											new	20
70	17	2.8	200	1000	.9	1111.1	206	341	.21		215	1.27	17.40	773.3	228.9	.19	new	15



(a)

(b)

Figure 5-11 a) Concrete Cavity Formed by Single 640 J pulse (at U = 160 kV)
b) Concrete Block Cutouts with Maximum (11.2 cm^3, at left) and average (2.6 cm^3, at right) Cavities Formed by Single Pulses

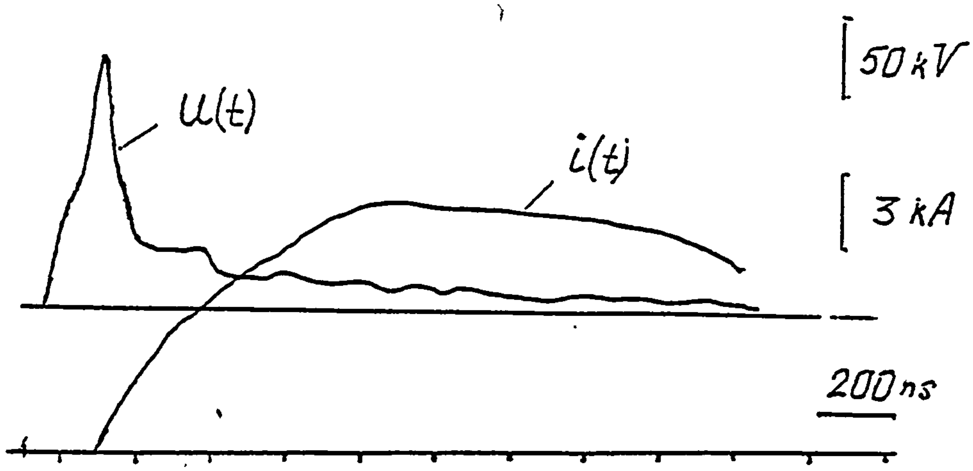


Figure 5-12 Current and Voltage Scans of Fast Discharge through Concrete (Fast Discharge)

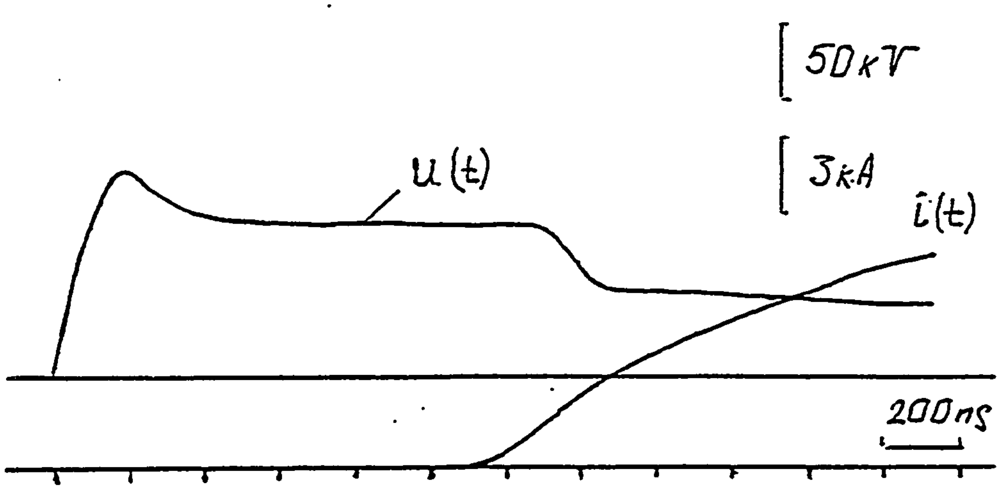


Figure 5-13 Current and Voltage Scans of Slow Discharge through Water Layer

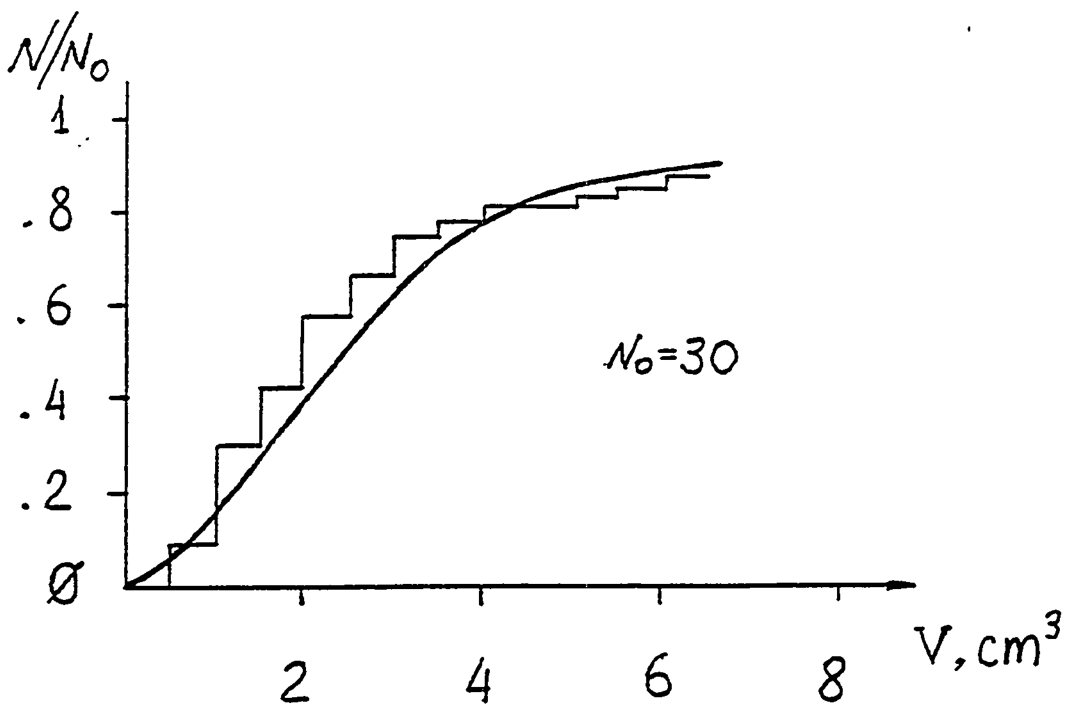


Figure 5-14 Concrete Cavity Volume vs. Energy Distribution Function

From the current and voltage oscillograms, energy released during T/4 and T/2, and efficiency η (discharge energy release-to-stored energy ratio) were calculated. The efficiency is rather high: for optimized voltages $\eta = 40\%$.

Scatter in E and η values is much smaller than in cavity volumes; this indicates that inhomogeneous structure of concrete and statistics of brittle fracture are the main causes of the scatter.

Besides the energy, instantaneous channel resistance and product function $f(t) = R (\int i^2 dt)^{0.5} \sim L_c \cdot D$ where L_c is channel length and D is Weitzel-Rompe parameter.

With average experimental value $L_c D \sim 13.5$ and $l_c = 1.5$ l, we obtain $D_{av} = 600$ V $sec^{0.5}$ in good agreement with other studies. These results indicate that measured efficiency and channel energy values correspond to calculations made on the basis of the Weitzel-Rompe model; accordingly, we conclude that this model can be used for practical purposes pulse generator optimization.

5.3.2.2 Multiple Cavities - Area Scabbling

In Table 5-2, data are presented for concrete scabbling by 9 series of 8 to 50 discharges. Scabbled areas from 39 to 96 cm^2 were formed by discrete traverses of a single electrode pair in two orthogonal (X,Y) directions. Surface area, volume, and depth of processing were calculated. The processing depth is nonuniform mainly because the treatment depth is comparable with the size of gravel. The depth distribution is presented in Figure 5-15, while the sample surface appearance (in comparison with single cavity) is shown in Figure 5-16. The average depth is in 7.6 to 10.7 mm for concrete samples processed.

The average value of the specific scabbling energy in these experiments was 303 J/cm^3 which is close to results obtained for single cavity processing.

5.3.2.3 EDS with Multiple Electrode Module

In the third series of scabbling trials a multitip electrode module (see Figure 5-9) has been used to provide broad area, shallow scabbling. The pulse generator was modified - a Marx circuit (Figure 5-17) capable of delivering 200 kV pulses has been assembled.

The same type of concrete samples was processed. Width of the total 100 cm^2 processed area was defined by the number of electrode tips (7 in these experiments, with 15 mm interelectrode distance). A series of 8-20 electric pulses was delivered to the electrode gaps which were firing randomly in accordance with the changes of inter-tip concrete resistance resulting from cavity formation. After the end of each series (when a row of cavities formed a single groove, the device was moved stepwise at a distance equal to the inter-tip gap length. By this procedure, the 100 mm long distance was traveled in 7-8 steps. In Figure 5-18, the surface of one processed sample is shown.

Results of these trials are summarized in Table 5-3. The average energy consumption was 300-500 J/cm^3 which is comparable with single discharge consumption. Scabbling depth is 4-8 mm and correlated with concrete strength and gravel size (less for larger gravel). The depth can be varied by changing inter-tip gap and voltage.

The last series of experiments was conducted using a modified electrode configuration, shown in Figure 5-10. A larger sample area was processed at scabbling rate and efficiency similar to those in Table 5-3.

TABLE 5-2

EXPERIMENTAL DATA FOR AREA SCABBLING

Tab.3

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
N	N.N	V area sm^3	U kV	W J	n dis	Wtn/S J/sm^2	hav mm	Wud J/sm^3	V/dis	S sm^2	hmax mm	St acr. mm	N.	along mm	N.
1	1.1	19.3	160	640	8	131.3	4.9	265.3	2.4	39		10	5	15	2
2	10.1	77.7	165	680.6	22	174.1	9.0	192.7	3.5	86		10	8	15	3
3	14	64.7	180	810	30	253.1	6.7	375	2.2	96	14.1	5	10	15	3
4	15	80.5	180	810	36	343.1	9.5	361.6	2.2	85	20.8	3	12	15	3
5	16	84.5	180	810	30	307.6	10.7	287.2	2.8	79	29.7	4	15	15	2
6	17	85	180	810	50	500	10.5	476.5	1.7	81	22.6	2	25	15	2
7	18	39.4	180	810	8	124.6	7.6	164.3	4.9	52	16	20	4	15	2
8	18.1	38.4	180	810	7	116.9	7.4	147.7	5.5	48.5	16	20	4	15	2
9	19	14.1	180	810	16	316.1	3.4	920.5	.9	41	9.8	10	8	15	2

TABLE 5-3

EXPERIMENTAL DATA FOR SHALLOW MULTIELECTRODE SCABBLING

Concrete	C μkF	T μks	U_o kV	W_o kJ	Number of Discharges n	W_o*n kJ	V cm^3	W kJ/cm^3	Sh cm^2	h mm
M220	.05	1.2	134	.45	40	18	55	.33	72	7.6
M220	.05	1.2	134	.45	60	27	75	.36	110	6.8
M350*	.125	2.0	130	1.05	25	26	43	.61	90	4.8
M270**	.05	1.2	134	.45	60	27	52	.52	132	4.0
M270	.05	1.2	134	.45	50	22	50	.45	100	5.0
M270	.05	1.2	134	.45	60	27	93	.29	110	8.5

*Oil-Saturated Sample

**Very Coarse Gravel

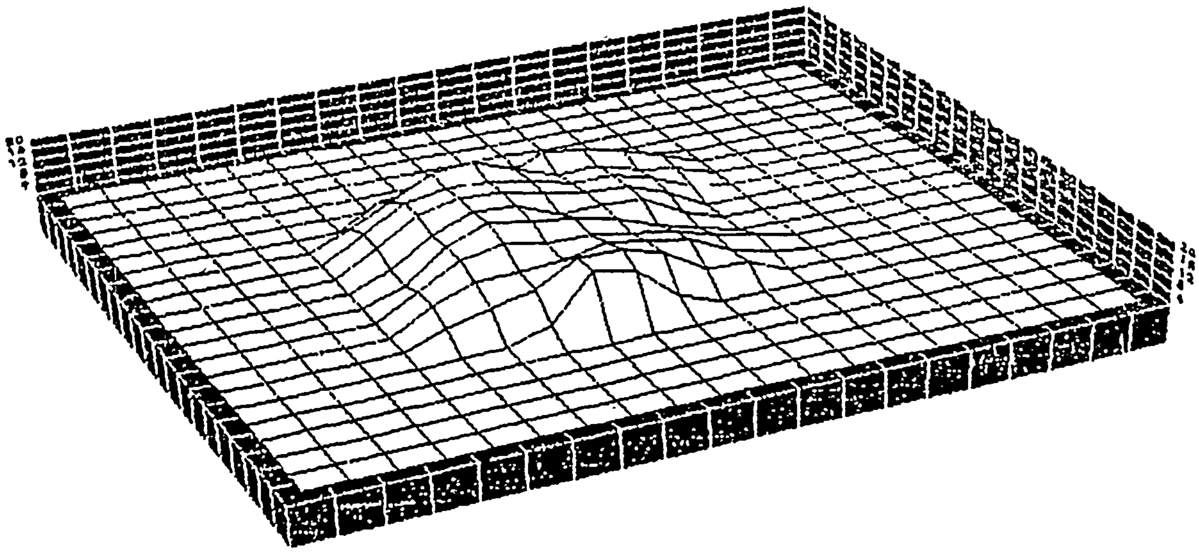


Figure 5-15 Scabbling Depth Distribution over Processed Concrete Area

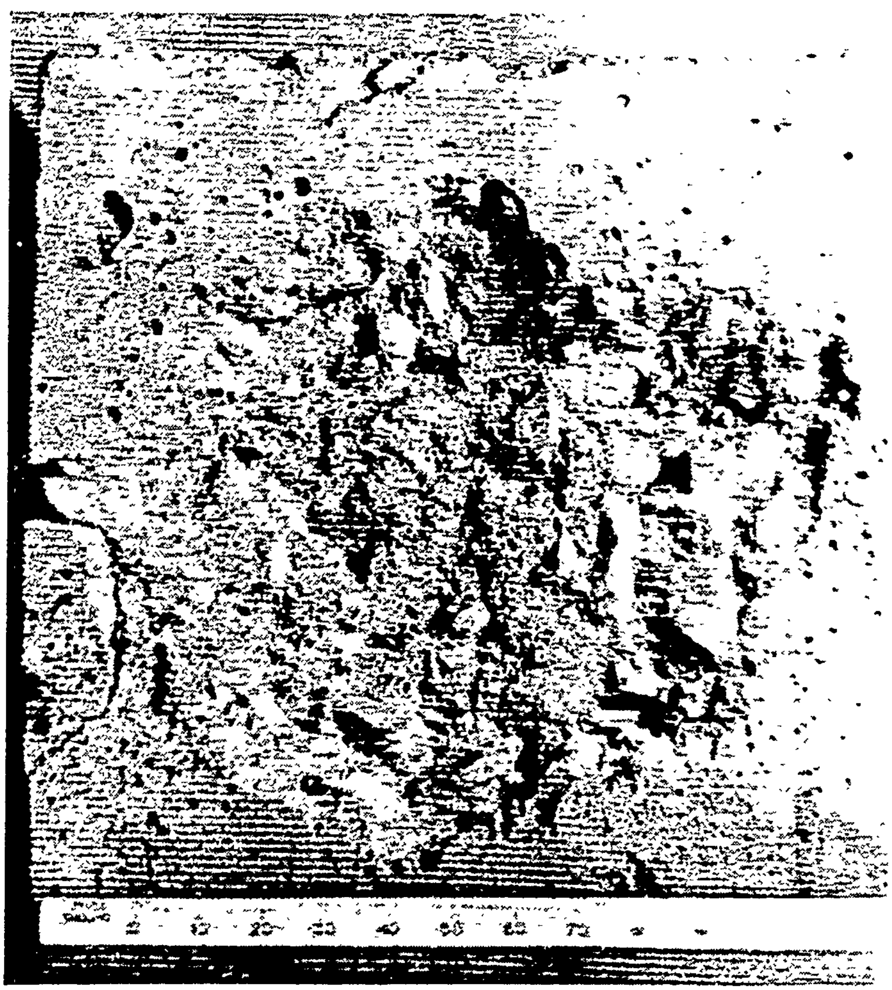


Figure 5-16 Appearance of Concrete Block Surface after Area Scabbling

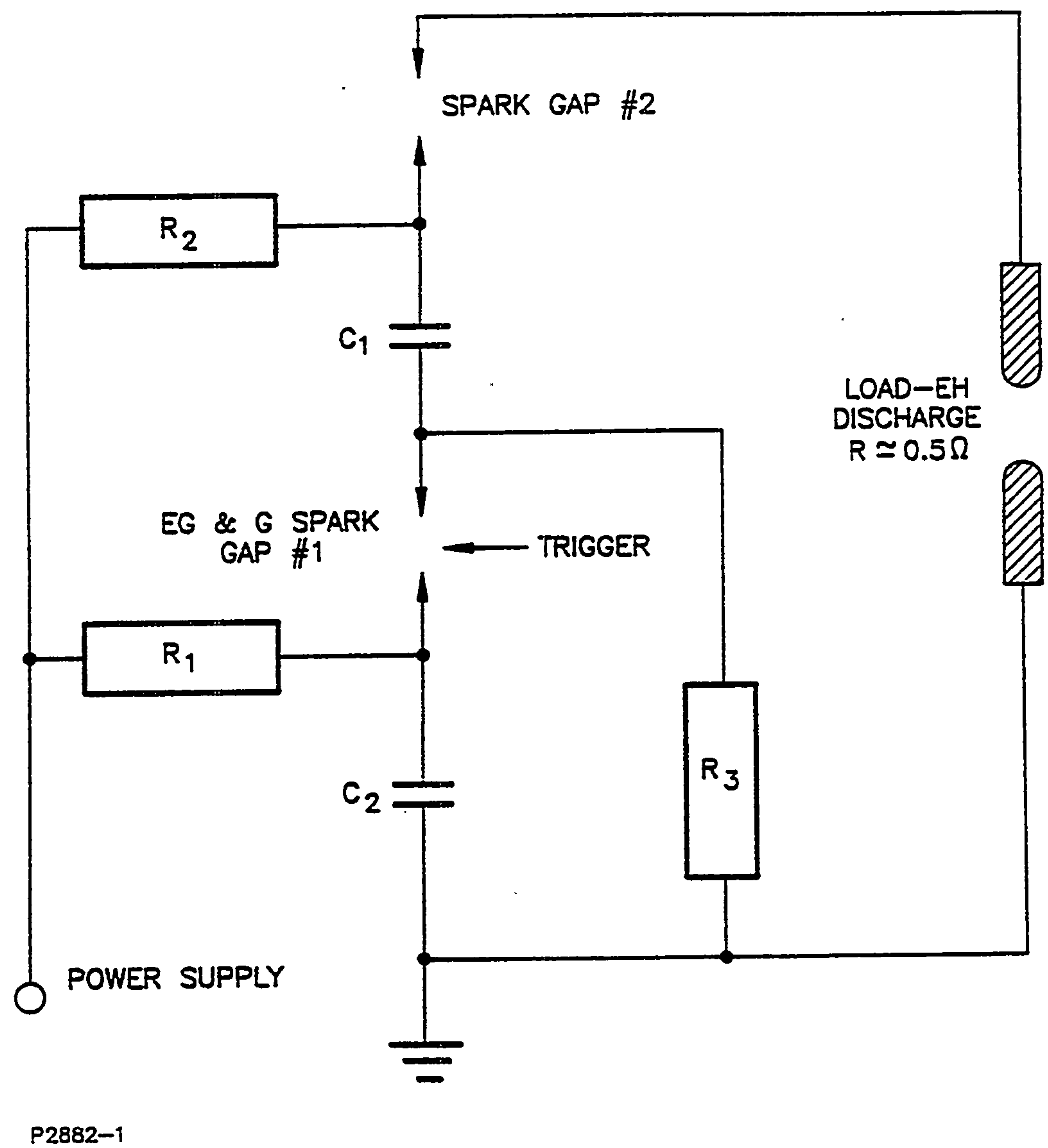


Figure 5-17 Electric Circuit of Modified Marx Generator for 120-200 kV Single Pulses

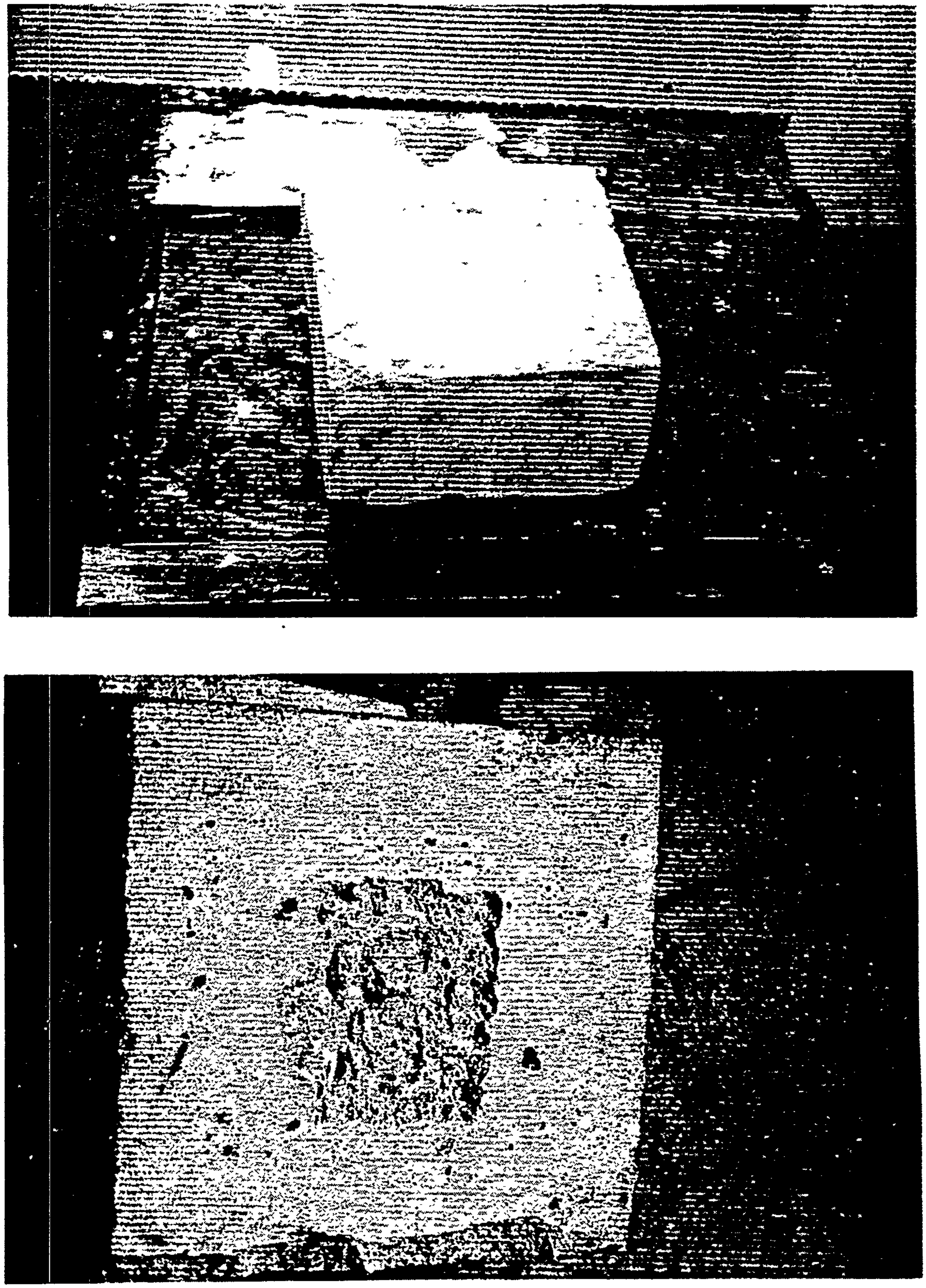


Figure 5-18 Surface of Concrete Block Processed by Multielectrode Module

5.3.3 Conclusions

We consider the results of these tests as quite positive. It has been shown that:

- EDS of concrete based on short, super-high voltage pulses has energy efficiency which is 3-4 times higher than provided by lower voltage/longer pulses EHS. Energy consumption about 0.1 kWh/ft^2 is projected.
- Depth of scabbling is controllable, shallow scabbling is feasible.
- Due to higher energy efficiency, a pulser of lower power can be used; alternatively a higher scabbling rate can be achieved.
- Cost of the pulser and scabbling module should be lower due to simpler circuitry needed for a multitip electrode device.
- Lower power consumption results in lower electrode erosion and longer lifetime of electric components.

Preliminary estimates made on the basis of the selected pulser's circuitry indicate that a lifetime of main pulser components corresponds to 10^8 pulses, which is sufficient for scabbling of about 100,000 ft^2.

While these data are encouraging, further longer duration/larger scabbling area tests are needed to prove reliability of the electrical and mechanical systems comprising the EDS system.

6.0 SCABBLING OF CONCRETE WITH SIMULATED CONTAMINANTS

The objective of this effort (Task 1.5 of the program) is to provide proof that concrete removal by EH scabbling is accompanied by the removal of contaminants, which could be separated for subsequent disposal. For this purpose, some chemicals simulating typical concrete contamination had to be incorporated in the surface concrete layer, and their behavior/ distribution traced during and after scabbling.

Due to safety/environmental limitations, either nontoxic materials or materials with very low radioactivity (allowed for nonrestrictive use) could only be used for the simulation.

6.1 GENERAL FEATURES OF CONCRETE CONTAMINATION BY RADIO-NUCLIDES

Contamination of concrete by radionuclides has been chosen as currently the most important case. According to a literature survey (see listing in Appendix D), two groups of the radionuclear contaminants can be distinguished:

A. For reactor buildings (facilities, power stations), concrete contamination by ^{137}Cs, ^{60}Co, ^{90}Sr isotopes prevails.

B. For formerly used uranium enrichment facilities, such as gaseous diffusion plants, ^{238}U, ^{235}U, transuranic elements and their fission products like ^{99}Tc, ^{237}Np are main sources of radioactivity.

Results of concrete contamination studies can be briefly summarized for our purposes as follows:

- Concrete contamination in reactor buildings penetrates rather deeply (a few cm, as shown in Figure 6-1).
- For uranium enrichment facilities, reported contamination depth is usually smaller - from 1 to 10 mm.
- Concrete floors comprise a most significant portion (80 to 90% by area) of the contaminated surfaces.
- In both types of sites, contamination is highly nonuniform, while average surface activity may be rather low; at selected "hot spots" activity may be one-two orders of magnitude higher. The "hot spots" are associated either with local penetration of radionuclides from certain equipment/operation (spills, accidental releases) or with surface defects such as concrete cracks, expansion joints, and worn paint coating.
- As could be expected, penetration depth is correlated with element/compound solubility in the aqueous media, especially in the alkaline concrete pore water (pH ~ 12) and with the compounds mobility (diffusivity).

Several specific examples of concrete contamination are given in Table 6-1.

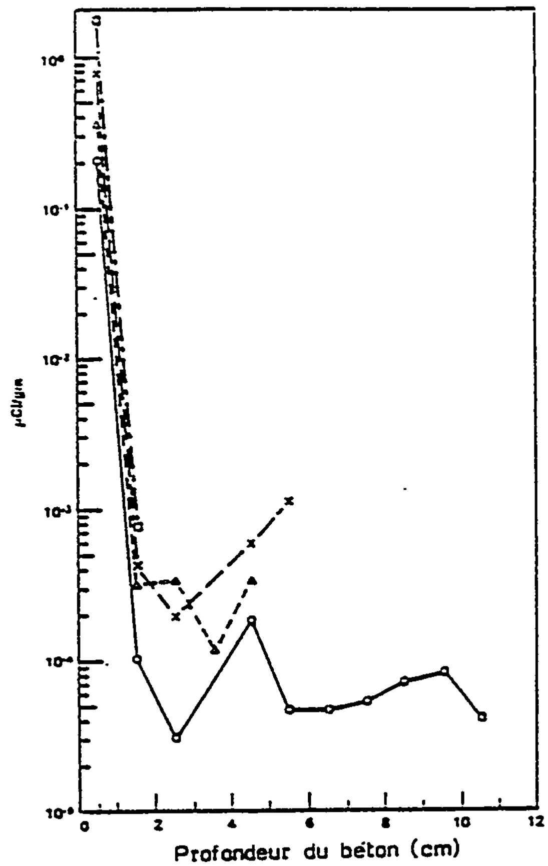


Figure 6-1 Distribution of ^{137}Cs in Concrete (Indian Point-1 Reactor, May 1982)

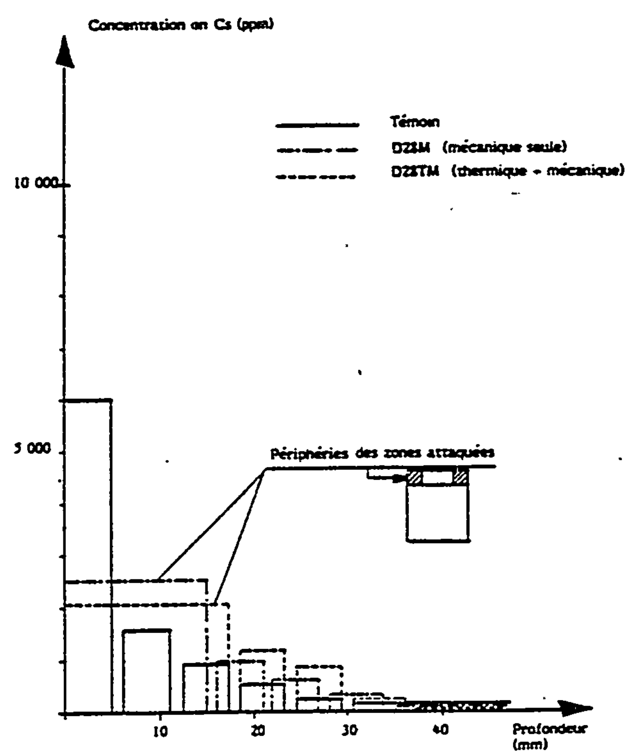


Figure 6-2 Concentration Profile of CsCl Doped by Solution (after 28-hour contact)

TABLE 6-1

EXAMPLES OF CONCRETE CONTAMINATION BY NUCLIDES AT VARIOUS SITES (from Refs. 51-61)

Site	Location	Main Contaminant	Radioactivity
Indian Point	Reactor	^{137}Cs	10^{-3}-1 μCi/g
Shipping-port US	Refuel Channel	^{60}Co	10^{-2} μCi/g (0.05 mR/hr at the surface)
Elza Gate Oak Ridge, US	Concrete Pad Floor	U	$2 \cdot 10^{4}$ dpm/100 cm^2 (at the surface)
JPDR Japan	Reactor Building	^{60}Co	10^{-2}-1 Bq/g
Three Mile Island US	TMI-2 Reactor	^{137}Cs ^{60}Co	2,000-60,000 μCi
Conviber, PA US	Production Facility (soil, concrete)	U	Up to 0.02 Ci/g (concrete and soil)
Oak Ridge US	K-25 Site	U, ^{99}Tc	1,000-10,000 dpm

6.2 LABORATORY SCABBLING OF CONCRETE WITH SIMULATED CONTAMINATION

6.2.1 Water-Soluble Contaminants: Evaluation for Concrete "Contaminated" by Alkali Salts

6.2.1.1 Experimental Technique

To simulate contamination of concrete in reactor buildings by Cs salts containing ^{137}Cs isotope or by other water-soluble radionuclides, we prepared concrete samples precipitated by alkali halides.

In the first few experiments, we followed a technique used in Ref. 51 to investigate/ simulate behavior of ^{137}Cs in a surface concrete layer subject to decontamination by a combined plasma/fuel torch. In Figure 6-2, concentration profiles of Cs in the doped concrete before and after torch treatment obtained in Ref. 51 is shown.

In our typical experiments, 18-30% water solution of "natural" (nonradioactive) CsF or CsCl was either deposited on one face of 2"x 2"x2" concrete cubes (see Figure 6-3), or the whole cubes were submerged into the salt solution for a few hours. Concrete samples taken at different distances from the "contaminated" faces by the diamond saw slicing or drilling were sent for spectrochemical analysis to determine Cs concentration vs. location. Analysis performed at a commercial laboratory (Luvak Inc., Boylston, MA) confirmed the possibility of generating certain isotope concentration gradients by the solution precipitation (see Table 6-2).

While the spectrochemical analysis for Cs is not complicated, it was desirable to find an even simpler and express method to measure alkali "isotope" concentration in the solutions and concrete debris. For this purpose we substituted sodium salts - chlorides or carbonates - for cesium salts; their chemical purposes and solubilities are not too different. Sodium tracing is rather simple because its concentration can be measured using a Na^+ ion-selective electrochemical sensor. Specifically, a simple miniature Na^+ detector by Horiba Co. was used. Determination requires only a drop of solution (or suspension), takes less than a minute, and has 10 to 20% data scatter, which is acceptable for this evaluation.

The following features were investigated in the auxiliary tests:

- Rate of NaCl penetration in concrete
- NaCl distribution in concrete
- Rate of leaching of concrete and concrete debris

After these tests, final experiments - EH scabbling of NaCl - impregnated concrete were performed.

6.2.1.2 Auxiliary Experiments

These experiments provided the following results:

1) Penetration of salt solution into concrete forms "contaminated" layer with 0.2 to 1.5% NaCl concentration (depending on NaCl concentration in the water solution).

2) Penetration rate is in 2 to 6 mg/cm^2 min range. At this rate, Na^+ concentration reaches 1/e of the surface value in about one hour at one inch depth.

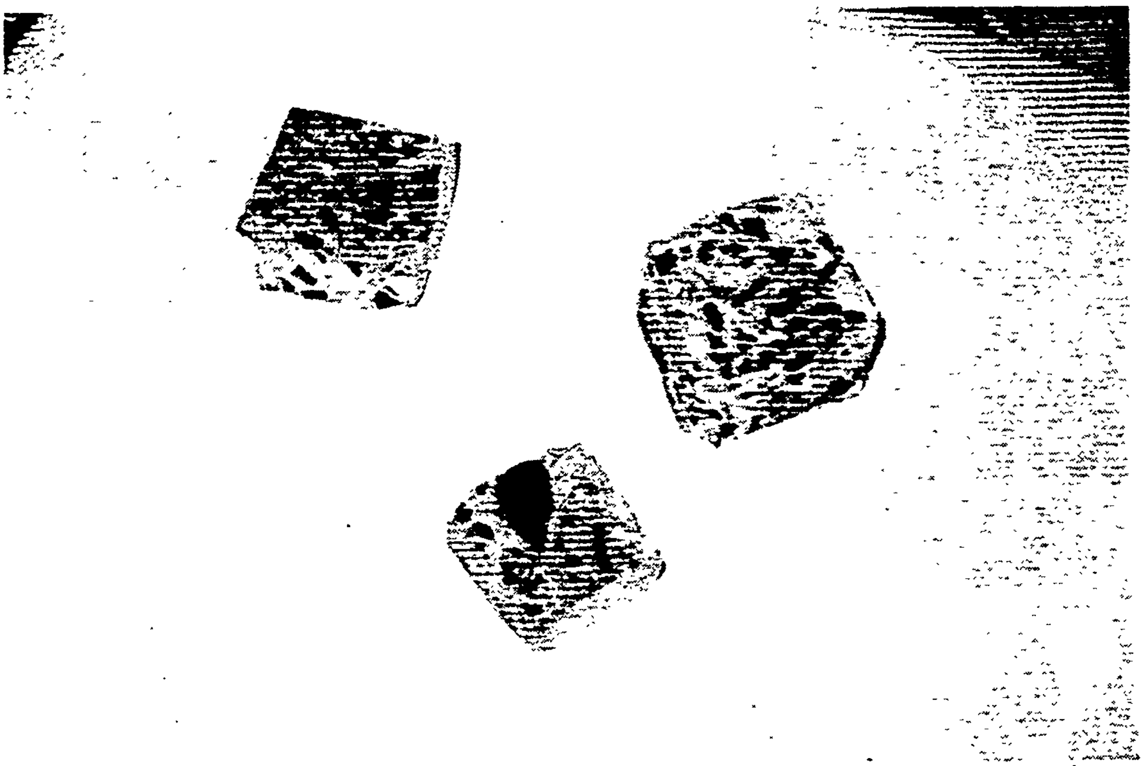


Figure 6-3 Concrete Cubes and Slices Used in Experiments with Water-Soluble "Contaminants"

TABLE 6-2

Cs CONCENTRATION IN THE CONCRETE SAMPLE 30% CsF SOLUTION IN WATER COVERED THE SURFACE FOR 12 HOURS

Concrete Sample Taken from Layers	Cs Wt %
Depth 0 to 1/4"	2.06
Depth 1/4 to 1/2"	0.52
Depth 1 to 1 1/2"	0.11

TABLE 6-3

CONCRETE DEBRIS PARTICLE SIZE DISTRIBUTION

95%	under	12.0 mm
50%	under	3.8 mm
22%	under	1.0 mm
10%	under	0.5 mm
2.5%	under	0.15 mm
0.3%	under	0.05 mm

3) Rate of Na^+ leaching of NaCl precipitated concrete depends, as expected, on the concrete surface area:

   a) Na^+ concentration in a fresh water layer over the bulk concrete surface increases parabolically at an average rate 1.5 10^{-2} mg/cm^2 min.

   b) Leaching of the concrete rubble is a much faster process.

Specifically, rubble with the following particle size distribution, shown in Table 6-3, was used in these experiments.

By measuring Na^+ content in water, the following leaching rates were found for this rubble:

After	1 minute,	20% Na removed
	5 minutes,	50% Na removed
	10 minutes,	65% Na removed

In other words, a substantial part of Na^+ is leached out the rubble in a few minutes. Extrapolation to the concrete debris consisting of small (hundreds of microns) particles predicts only a few seconds leaching time.

Because the leaching rate is high, leaching process is not a limiting step in Na^+ exchange between the contaminated rubble and bulk concrete. The exchange is limited by the penetration/diffusion rate; near-complete equilibrium is established in 10 to 60 minutes, depending on the properties of specific salt and on the location (depth) in concrete.

6.2.1.3 Scabbling of "Salty" Concrete

The following procedure was used in these tests:

1) Clean concrete blocks, with 170 cm^2 top surface area, epoxy-painted except central 100 cm^2, are covered by a 3 mm layer of salt water (18% NaCl), dried in air for one hour (time sufficient for surface to appear dry) and, finally, in a MW oven. Total NaCl content in the sample is obtained by weighing before and after precipitation.

2) Concrete samples are taken from the surface by sanding and drilling at 6 and 12 mm depths; 1 g samples are leached in 5 ml of water.

3) Concrete is covered by 30 mm fresh water layer, 100 cm^2 area is scabbled to 12 mm depth in the enclosure containing 500 cm^3 of fresh water; about 300 g of concrete rubble is generated.

4) Measurements of Na^+ content in the water/concrete slurry are made.

5) Measurements of concrete Na^+ content are made by drilling exposed surface.

Data obtained in one scabbling experiment are presented in Table 6-4. Results agree well with the main conclusions following from the auxiliary experiments, namely that leaching of concrete rubble is basically accomplished in 10 minutes, and that concrete recontamination begins with some (depth dependent) delay and reaches equilibrium with the surface-covering slurry in about an hour. Consequently, to avoid recontamination the slurry generated by EHS must be removed from the "fresh" and clean concrete surface in a matter of minutes.

TABLE 6-4

CONCENTRATION OF NA+ (IN PPM) IN WATER/CONCRETE SLURRY AND IN SOLID CONCRETE MEASURED IN A "SALTY" CONCRETE SCABBLING EXPERIMENT

Sample/Conditions	Concrete (depth, mm) 1(surface)	6	12	Water/Slurry
Clean Concrete	220	-	-	
Clean Water				170
Concrete after Precipitation	1900	1250	480	
Water Layer before Scabbling				350
2 Minutes after Scabbling	430	300	270	800
10	1100	660	270	1850
20	1300	-	-	1900
40	1400	900	380	1600

TABLE 6-5

PENETRATION OF URANIUM SOLUTION THROUGH CONCRETE

Type of Test	Location, Condition	Activity, dpm Sample I (Rapid Drying)	Sample II Pool-Slow Drying
Penetration of Uranium-Solution through 4 mm Thick Concrete Layer	Front Side: Wet Deposit	720	2470
	Dried Deposit	1054	3530
	Wiped	950	2805
	Back Side: After 6 hrs.	70	86
	After 72 hrs.	78	94

6.2.2 Water- Insoluble Contaminants: Evaluation for Concrete Contaminated by ^{238}U

6.2.2.2 Introductory Remarks and Methodology

Development of uranium contaminated concrete scabbling is the main objective of this program. Low solubility of uranium and related isotopes in aqueous solutions makes this case different from the one considered in the previous section. For the wet scabbling process, low solubility is a positive factor reducing danger of cross-contamination of the adjacent floor areas and recontamination of a "fresh" concrete surface by the rubble/water slurry generated by scabbling. If uranium compounds remain contained within the solid particulates and rapid recontamination by concrete-penetrating water solution does not take place, the slurry may be allowed to remain over the concrete surface for a relatively long time, and scabbling and rubble removal stages could be separated in time, if necessary.

It should be proven though that recontamination is not enhanced

a) by penetration of U-containing suspension through the cracks which could be generated by shock waves, and

b) by difficult-to-remove small particles settled on the concrete surfaces.

6.2.2.3 Experimental Results

A limited experimental task has been conducted with concrete samples contaminated by a low activity solution of depleted uranium (i.e., ^{238}U). Concentration of solution itself - 10,000 µg of U_3O_8 in 5% HNO_3 (spectroanalytical ICP standard, by Johnson-Matthey) - which corresponds to total activity of $1 \cdot 10^{-6}$ Ci, total content of U in a concrete layer (estimated on a basis of 25% porosity and penetration depth), and number of decays (counts) measured immediately over the surface - all were kept below the DOE-regulated levels (5000 dpm/100 cm^2 average over 1 m^2, and 15,000 dpm/100 cm^2 local maximum). The surface activity was measured by a survey meter (Ludlum Model 3) equipped with a scaling digital readout (Figure 6-4 a). Ludlum Model 44-88 pancake detector with 3300 dpm/mR/hr efficiency and 15.5 cm^2 window area has been used. No special calibration has been made because our interest was mainly in a surface activity change resulting from scabbling.

The following techniques were used to prepare U-contaminated concrete specimens:

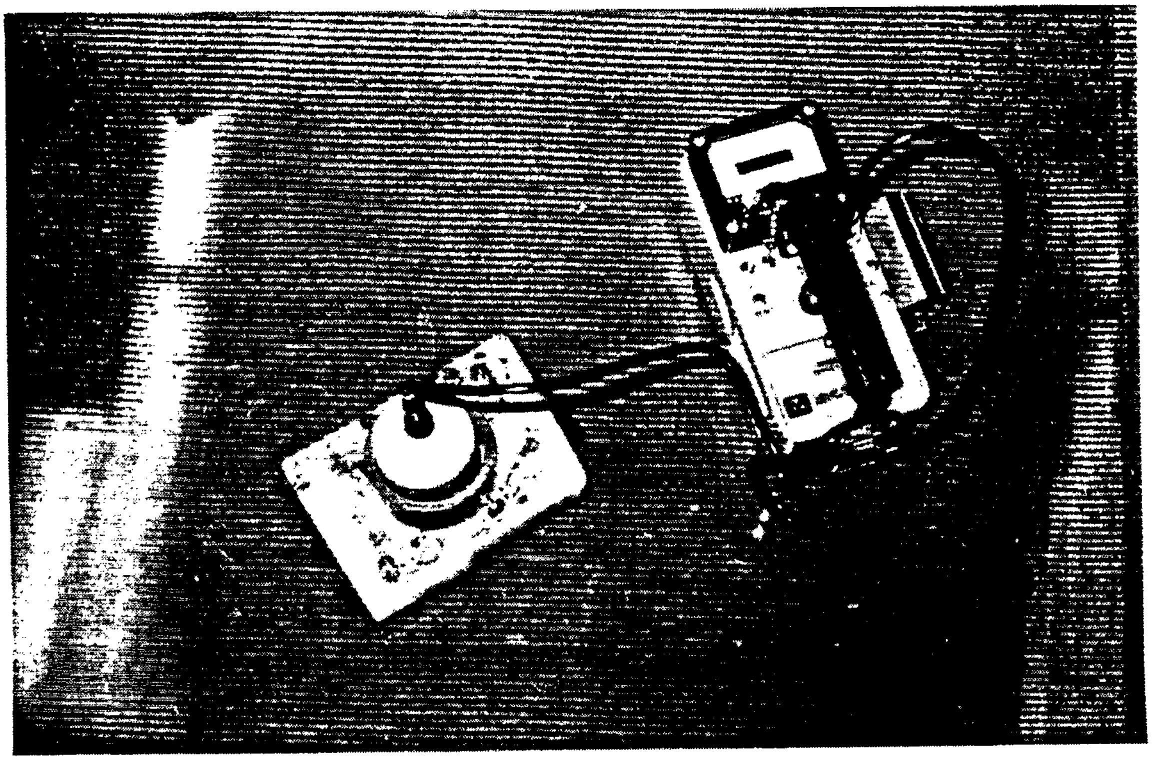
- A few milliters of U-solution (primary or diluted by HNO_3 to increase liquid volume and penetration depth) are deposited over the 100 cm^2 area of a 5"x5"x5" concrete cube (diamond saw-cut from a larger concrete block) or on the surfaces of the 5-6 mm thick concrete "slices" (see Figure 6-4 b).

  The volume of solution between 10 and 100 ml/cm^2 is selected to provide surface activity of the order of 1000 dpm. Deposits are easily recognizable by yellowing of the concrete surface.

- U-solution is deposited into narrow, deep slots cut into the concrete surface in order to simulate uranium contamination remaining in the concrete cracks and joints.

- U- solution is injected (by a syringe) into the surface layer of a "green" (uncured) concrete sample. The concrete is cured, incorporating the contaminant.

Activity of solution-covered, partially dried (wet), dried for 6 hours, and for 72 hours is then measured.



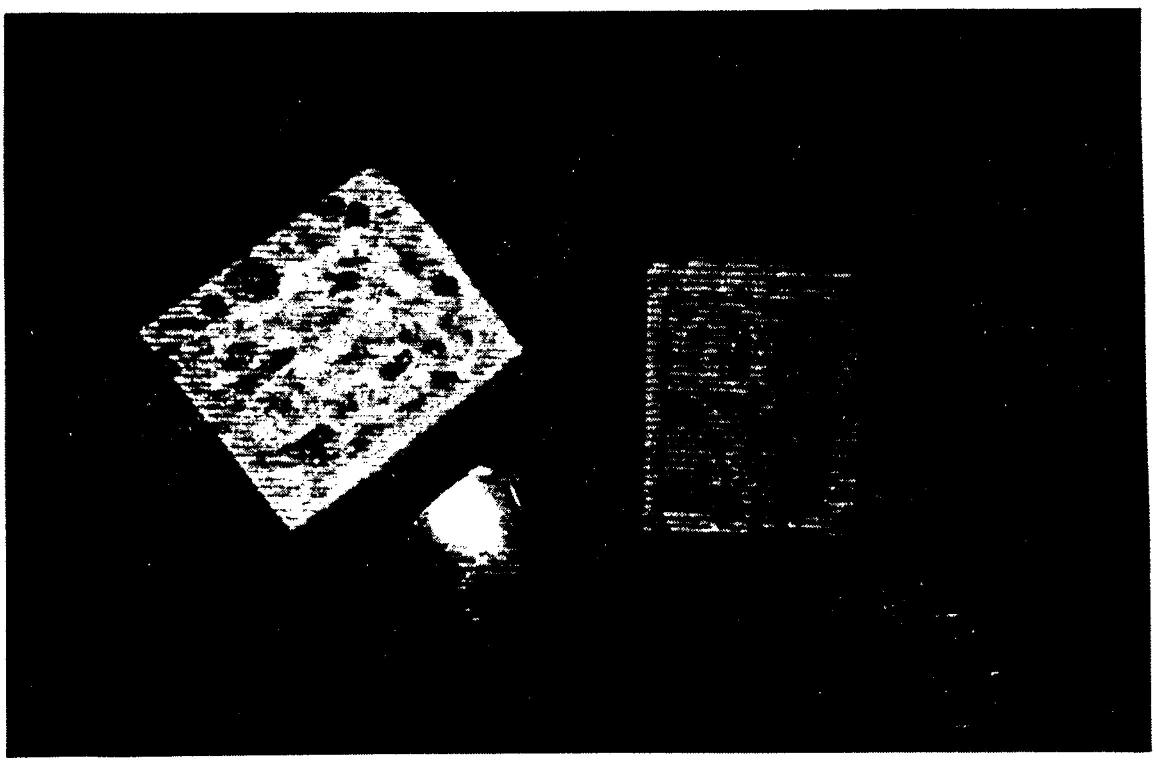


Figure 6-4 Surface-contaminated Concrete Samples with Depleted Uranium Contaminated Surface (a) and Radioactivity Measurements with Ludlum Survey Instrument(b)

Two types of experiments were performed. In a first series of preliminary tests

a) Penetration of uranium into concrete was evaluated.

   4 mm thick slices (thinnest possible) of concrete were hewn from the block; activity at the back surface of the slices barely exceeded the initial level even after 72 hours allowed for penetration (see Table 6-5). This test was modified by maintaining liquid U-solution pool over the slice face; the result was similar.

   Evidently, characteristic diffusion/mobility time for the acidic U-solution is quite long. Higher activity at the location of deep (almost-through) holes or cracks was an exception.

   In other tests the same U-contaminated concrete slices were sanded mechanically. Surface activity and activity of the dust generated were measured. Results presented in Table 6-6 indicate that penetration depth does not exceed several tens of mm (e-times drop in activity corresponds to approximately 0.5 mm depth).

b) Recontamination of concrete surface by U-containing slurry was studied.

   In these experiments, water slurry made of grinded U-contaminated concrete (1:1 solid-to-water weight ratio) was poured into a 10x10 cm x 1 cm cavity made over the concrete surface, and left there for some time. Activity of slurry and concrete surface was measured. Data shown in Table 6-7 indicate that the surface recontamination remaining after wet vacuuming is low, and that recontamination does not correlate with slurry/surface contact time.

In the second test series, EH scabbling of the 5x5x5" U-contaminated concrete blocks was performed, and possible surface recontamination studied under more realistic conditions.

Grooves 1.5" wide and 1" deep were made on the faces of each of three sample blocks. These grooves were filled with concrete mix contaminated by some depth by injection of U-solution. After concrete was (partially) cured, activity of the filled grooves was measured at free surfaces and at half depth. To avoid spread of contaminated material and water, EH scabbling was performed using a plastic enclosure with tight cover-supporting electrodes. A schematic and photos of the device are shown in Figure 6-5. The blocks were scabbled by applying 15 -20 1000 J pulses. Due to incomplete curing of the filling concrete, this energy was sufficient for 1/2"-deep scabbling.

Activity of concrete surface was measured after processing and after several hours in contact with contaminated debris-water slurry (0.3 to 0.6 solid-to-water ratio). From the data in Table 6-8, we conclude that:

1) activity of the scabbled concrete surface is low - 1 to 2% of the initial surface activity, and

2) even long contact with scabbling-generated slurry does not result in the surface recontamination.

While considering these results, it should be taken into account a limited scale and small number of experiments, and semiquantitative character of measurements. Also, activity level of slurries involved was rather low due to a small amount of debris and its dilution by water.

TABLE 6-6

PENETRATION OF URANIUM SOLUTION INTO SURFACE CONCRETE LAYER

Type of Test	Sample	Activity, dpm Sample I	Sample II
Uranium-Contaminated Layer Removed by Sanding	Surface Sanded 30 µm Deep (A)	638	2380
	Debris (A)	400	920
	Surface Sanded 60 µm Deep (B)	575	2020
	Debris (B)	260	370

TABLE 6-7

RECONTAMINATION OF CONCRETE SURFACE BY U-SLURRY (1:1 WEIGHT RATIO)

Location and Condition	Initial	Activity, dpm After 15 Min. Exposure	After 70 Min. Exposure
Bottom of 100 cm^2 Concrete Cavity	62	-	-
Slurry-Filter Deposit	380	-	-
Bottom of Cavity:			
Slurry Poured	210	-	-
Slurry Removed	-	230	210
Wet Vacuumed and Dried	-	73	76

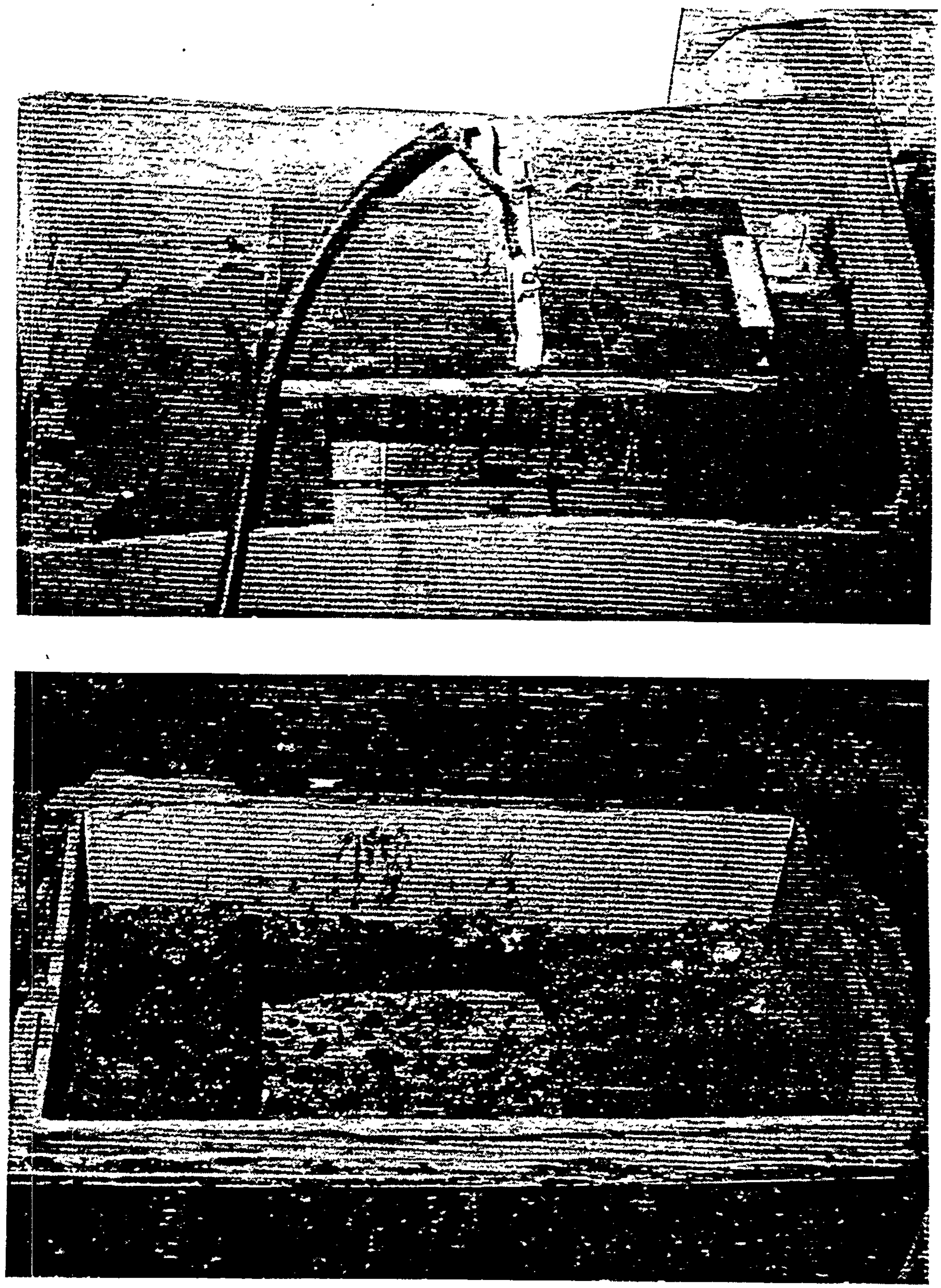


Figure 6-5 Device for Scabbling of U-contaminated Concrete and for Rubble/Surface Interaction Study

TABLE 6-8

SCABBLING OF U-CONTAMINATED CONCRETE

Location and Condition	Activity, dpm Sample I	Sample II*
Clean Concrete Surface	50	50
Concrete in Groove:		
Surface	2900	2500
At 1/4" Depth	360	280
Slurry Filter Deposit	420	370
Groove Bottom (1/2" Depth):		
Immediately after Scabbling	80	90
After 12 hrs. in contact with slurry and wet vacuuming	72	68

*More U-contaminated debris added into container.

One more scabbling experiment was conducted to check the ability of the technique to remove contaminant from concrete cracks. Dried U-solution in a 6" long, 3/32" wide, 1/2" deep slot provided 1100 dpm (surface-measured) average activity count. EH scabbling by sixty 2000 J pulses at 6"/min speed formed a 1.5" wide, 1/2" (max) groove along the slot length. Activity along the groove was reduced to 150 dpm. This test demonstrates EHS capability for removing deep contamination associated with the local concrete surface defects.

7.0 CONCEPTUAL DESIGN AND EVALUATION OF A PROTOTYPE INDUSTRIAL EH SCABBLER

In this section we describe the Task 6 effort involving conceptual design of a EHS prototype unit and prognosis of its performance and economics.

7.1 CONCEPTUAL DESIGN

7.1.1 Design Requirements and Approach

Conceptual design of a prototype EHS unit is evolving from data and experience with a laboratory scabbler. The following factors had to be taken into account in designing the main components of the EHS system

7.1.1.1 Electric Power Supply (Pulser)

- Efficient impact of EH discharge on concrete resulting in scabbling requires a certain minimum energy for each pulse. For a discharge channel located in water, this minimum corresponds to stored energy close to 1000 J (or about 500 J delivered to the discharge proper). On the other hand, too powerful discharges (> 3000 J) may result in the formation of unnecessary deep local cavities and through cracks in concrete.

- About 2000 J pulses provide a good compromise. These pulses may be obtained from various combinations of storage capacitance and charging voltage. Having in mind commercially available equipment and voltage minimum required for practical electrode gap about 1 cm, we obtain a desirable voltage range of 15 to 30 kV and corresponding capacitance in 20 to 5 μF range. A different approach, where a super-high voltage/low capacitance combination is used, was described in Section 6.

- To maximize energy efficiency of the pulser, capacitance, inductance, and resistivity of the circuit components should be selected to operate the system close to the "critical" mode, i.e., without excessive "damping" or "ringing." According to our experiments, the EH discharge efficiency is not very sensitive to deviations from "criticality" and, besides, the circuit "load" (water gap) may vary considerably (its resistance is usually in the 0.1 - 0.5 ohm, range). Nevertheless, optimizing circuit design calculation and "rough" tuning should be made.

- The rate of scabbling - surface area processed per unit time - depends firstly on the specific energy, e.g., energy deposited per unit length of a scabbling trail (sensitivity towards depths and width of the trail is weaker); the specific energy used in our experiments varied from 5 to 40 kJ/inch. At a given (optimized for scabbling depth and concrete strength) pulse energy, the specific energy can be most conveniently varied either by changing the scabbling tool travel velocity or by varying pulse repetition rate (frequency). To provide desirable processing flexibility, it should be possible to vary these two parameters, correspondingly, in 2"-20 "/min and 1 to 5 Hz ranges.

- Pulse energy and pulse frequency define required average power of the DC power supply - capacitor charger. For instance, to operate 2000 J, 4 Hz scabbling unit an 8 kW power supply is needed. Ten to twenty percent energy losses are anticipated even for a well-designed power supply; therefore, 10 kW nominal power can be recommended in this case.

- The simplest possible pulser would operate in the "overvoltage mode," i.e., allowing EH discharge to take place after the capacitor is charged over the water gap breakdown voltage. In this case, regularity of discharging can not be good because of inevitable changes in the breakdown voltage (due to variable gap length and conductivity, electrode shape and surface conditions). To make the discharge sequence and energy regular, a spark gap or other switch (e.g., thyratron) should be used. For our circuit parameters, sealed-off switches are adequate - they are simple to operate and have a satisfactory lifetime.

- Attention should be paid to the auxiliary circuit components - low power generator controlling pulse frequency, high voltage trigger operating spark gap, connecting HV cables, and (optional) instrumentation to measure/adjust pulse characteristics.

  Two factors are of importance:

  1) EH discharge is a source of a strong EM field and voltage surges in the electric circuits. To avoid damaging the pulser components, they should be protected from these phenomena. Shielding and proper grounding and AC side filters/ isolating transformers should be used.

  2) In most cases, shorter EH pulses benefit scabbling efficiency; therefore, circuit components and connectors should have low inductance. The length of HV cables between the pulser and discharge chamber should not be longer than necessary from the system integration and operating considerations.

  An option should be considered to place capacitors and switches on the same carriage as the discharge chamber.

- To increase the processing rate and efficiency (see below), a multielectrode EHS system should be used. The simplest multielectrode scabbler would have a separate pulser for each electrode pair. More sophisticated and less expensive circuits employing a smaller number of chargers, switches, and triggers and controls can be designed (see, for instance, circuit described in Section 6).

  An electric circuit meeting most of these considerations and requirements shall resemble the electric circuit we have used in the process characterization laboratory experiments.

7.1.1.2 <u>EHS Processing (Discharge) Chamber and Electrode System</u>

- A laboratory study of the EH phenomena shows that:

  1) To impose strong shock and crashing action onto concrete, the discharge should take place between electrode tips located very near the concrete surface.

  2) To prevent breakdown between electrodes above the water, the electrodes should be submerged into water at least 2 cm deep; a distance between the electrode or electrode holder parts not covered by water (or reliably insulated) should be more than 12 - 15 cm (a breakdown distance for water aerosol at 25 kV).

3) Intense formation of water droplets, splashes, and turbulent water motion accompany the EH discharge. Water and concrete debris spreads several feet from the discharge zone.

- Due to these factors, the electrodes and discharge zone should be confined within some chamber. The chamber should limit the spread of water and debris, allow to generate (by reducing air pressure) a water level well above the one over surrounding floor areas, and protect a secondary enclosure (see below) from being damaged by sound waves and water jets.

- Walls of the discharge chamber are subject to strong repetitive forces; on the other hand, use of metal is undesirable due to the possibility of electric breakdown. Mechanically strong isolators, especially fiberglass-reinforced plastics (e.g., G-10), are best suited chamber materials. To increase the chamber strength, exterior metal reinforcement of the chamber body may be recommended. An all-metal chamber with an inside isolating layer of flexible rubber-like plastic is another option; mechanically-strong insulating feed-throughs of sufficient standoff dimensions should be used for electrode holders.

  Distance between chamber walls and the discharge gap should be more than 2"-3"; for shorter distances, spalling of fiberglass takes place.

- Discharge electrodes can be either single-piece or have electrode tips welded/brazed to a holding rod (bolt). The electrode unit should be strong enough to withstand both electric discharge and friction forces due to surface "scratching" taking place when the chamber traverse over concrete. Low carbon steel is an acceptable material. While more "exotic" steels or alloys can be tried, we did not observe any serious advantages for their use. Some are brittle or sensitive to pulse stresses, others are expensive, and most do not provide substantial reduction of electric erosion. Due to intense electrode cooling, the electrode erosion rate is moderate.

- The electrode support structure should satisfy the following conditions:

  - It should be possible to maintain distance between electrodes continuously or periodically by motorized drive in a predetermined range (with ± 1/8" precision).

  - It should be possible to provide continuous contact between electrode tips and the (initial) concrete surface, applying certain vertical pressure; mechanical (spring), hydraulic or pneumatic support can be used for this purpose. A clearance between the electrode tip and concrete can be left, but to maintain it very narrow (< 1.5 mm) is difficult.

  - Each electrode should have individual adjustable, preferably shock-absorbing, support.

- The electrode system of various configurations can be suggested to form a single wide scabbling trail. A multielectrode unit has an important advantage: it has been shown that width of the trail formed by several electrode pairs is larger than the sum of individual trail widths. Evidently, EH pulses result in formation of cracks beyond each visible groove, therefore scabbling also occurs in between the neighboring trails.

- The multielectrode system can have a common chamber or a chamber subdivided in sections. In case single chamber is employed, a single strip may be used as a grounded electrode. In a preferred "compromise" solution, few electrodes within a single chamber form a single module with its own power supply (pulser).

  Further increase of the number of electrodes (and width of the processed strip) is achieved by installing two or more electrically-independent modules on the same carriage. This modular design offers flexibility in choosing the needed scabbling rate, and to select the width of the strip vs. scabbling velocity for a given electric power.

7.1.1.3 Water and Slurry Flow System

This subsystem performs several interrelated process water and concrete slurry flow management functions. Main requirements for the flow system are considered below.

- Air pressure in the discharge chamber should be reduced to raise the water level sufficiently for electrodes that are always being submerged (despite water level pulsations due to electric discharges) to avoid inter-electrode breakdown. For a horizontal concrete surface (floor), a 1" to 3" inch water depth should be established. A wet vacuum unit providing sufficient head (2-3 kW motor is required) is suggested. Besides air, some water splashed by EH discharge and fine concrete debris is removed by suction; water in the chamber is replenished either by recirculation or by suction (together with some air) through the unavoidable gap between the chamber walls and the concrete surface.

- To prevent spread of water and concrete debris over the surrounding floor, use of a second, lighter enclosure is suggested. It has been shown that without the enclosure it is difficult to maintain the necessary water depth in the discharge chamber without at least a 3/8" deep water pool over the floor. An alternative used in our experiments - isolation of the area under treatment with a light floor-sticking water barrier - is more acceptable for a limited time (about an hour) than "flooding" (a few square meters floor area or low scabbling rates) and water-insoluble contaminants. The moving enclosure concept is more general; sliding gasket or perimeter water suction might prevent water slurry spread beyond a 1-2 m^2 area.

- Concrete removed by scabbling and consisting mostly of 1 to 15 mm size rubble forms water slurry. The slurry should be removed by a second wet vacuum unit with a scoop trailing the discharge chamber. The scoop is positioned within an exterior enclosure. Its height over the scabbling trail and vacuum suction capacity control slurry flow rate and water/solid ratio.

  It should be possible to have one vacuuming system for both discharge chamber and enclosure, but two separate systems appear to be more flexible.

- Slurry is transferred to a container which should have capacity correlated with scabbling rate, and schedule and technique of the contaminated rubble removal. For 1/4" deep, 5 m^2/hr scabbling, 1:1 slurry solid/water weight ratio, and 90% water separation/recirculation rate, about 10 gal (80 kg) of wet rubble is generated per hour. This makes a standard 55 gallon barrel appropriate for a full-day (net 5-6 scabbling hours) operation.

- Treatment of water after at least coarse rubble is separated (filtered out) depends on the water solubility of the contaminant. If its solubility is low (as in the case of most uranium compounds, and only this case is considered below), then as much process water as possible could be recirculated without the danger of concrete recontamination. The return water, plus water added to make up for the loss to rubble, can be directed either into the discharge chamber or into the enclosure. The return line pump should be able to handle up to 120 l/hr (about 2 gal/min) water flow.

- There are two options for placing flow system equipment. For a moderate scabbling rate considered for this subscale system, all components, including the container, can be arranged within the carriage. On the other hand, this may not be necessary, because an electric power connection between the carriage and the control station is present anyway in most of the envisioned system configurations.

- Concrete rubble separated from water will certainly contain some (probably 10-20% by weight) water. To reduce weight and volume of the waste material, the container could be placed in a vacuuming drying chamber. The drying can proceed until carry-over of a fine fraction is still insignificant.

7.1.1.4 Carriage Positioner and Process Control Station

- An EHS module (or group of modules) is placed on a carriage. By traveling over the concrete surface (concrete floor is only considered here), locations to be decontaminated are selected. In a simplest case, when a large rectangular area is to be processed, this can be accomplished by a sequence of carriage transfers (in two perpendicular (x- and y-) directions.

  A certain ability to move in z-direction should also be provided. It is required to set the electrode position over concrete, and also for the convenience of inspection, maintenance, and adjustment.

- The carriage should be able to transfer the scabbling chamber over the wet floor and even over the floor covered with a 1/4" deep water "pool." While most of the concrete debris will be removed by a "wet vacuum" type system, some debris may be left over the process area (especially in the scabbling chamber "wake").

  Also, despite the presence of an enclosure (second chamber), some water droplets/splashes may be present; protection of the carriage components (drive, etc.) against water may be necessary.

- The carriage should be able to move the EH scabbler along one (x) axis with a step- or continuously controllable velocity in a 2"/min to 24"/min range. In each "scan," a concrete scabbling groove, 1/4" to 3/4" deep and 5" to 20 " wide (depending on the number of modules), is formed. To cover a wider area, the cart has to be moved in a lateral (y) direction; this movement may be manual or motorized (using, for instance, auxiliary wheels). The scabbling chamber can be of "symmetrical" design so that, if desirable, the floor processing can be exercised in both - forward and reverse - travel directions. At this time, we suggest to not consider more complicated carriage trajectories.

- Positioning of the discharge electrodes vs. floor surface deserves special attention. The electrode tips should be touching the surface. Increase of the distance between electrode tips and the floor surface over about 1/16" results in reduced scabbling efficiency. On the other hand, too tight contact between electrode tips and the floor is also undesirable: surface "scratching" results in additional mechanical loads, misalignment, and erosion. While this issue is also addressed by using individually "floating" electrodes (i.e., by using adjustable springs or pneumatic supports), it is desirable to maintain the height of the scabbling chamber vs. floor surface within a reasonably tight tolerance. These factors should be taken into account while choosing between a "free running" wheeled carriage and carriage running on a mobile runway. If some kind of runway is used, the choice should be made between a runway arranged over the contaminated floor to be processed with a scabbling chamber positioned at the cart midline, or a runway arranged along the edge of a contaminated area with a console-mounted scabbling chamber.

- Another carriage option, which resembles elevated, i.e., overhead runways or gantry cranes, should be attractive for scabbling large floor areas. The carriage itself moves on two elevated over the floor rails or on a monorail supported by columns which can be located outside the contaminated area. The scabbling module(s) is suspended on a variable-height (electrically or hydraulically controlled) column. The column base has lateral (y) motor drive; for larger y-travels, the whole gantry can be rolled over the floor.

  The elevated runway option has several advantages:

  - There is less contact between rails, wheels, hoses, cables with the contaminated floor.

  - The carriage hardware is less affected by water splashes and droplets.

  - Processed floor area is more visible.

  - Access to EHS module(s) is easier.

  - There is more flexibility with respect to the system integration: for instance, some electric and/or flow system components can be arranged on auxiliary carriages (tenders) hooked to the main one.

- Whatever type of carriage is used, it is connected to the process control station located out of the processed area by hoses, HV, motor drive and control cables, and water, slurry, and vacuum hoses.

  For extended process areas (in x-direction), the chassis will be moved (by a simple on/off motor drive) along the area borderline to shorten hoses and cables. A battery-powered drive and wireless remote control may also be provided, but, bearing in mind the inevitable presence of hoses and HV cables, this arrangement seems to be unnecessary. On the other hand, use of fiber-optic process control lines may be useful to isolate the process control system from EM noise.

- Controls (local and remote, tethered or wireless) should be available for the following positions and process parameters:

  - EHSM x-position

  - EHSM y-position

  - EHSM z-position

  - electrode/concrete surface clearance

- interelectrode gaps
- x-traverse speed
- DC charger voltage
- pulse frequency
- water flow rate (in collection and return lines)
- discharge chamber water level (or air pressure)
- volume (or weight) of collected concrete rubble

• It would be beneficial to measure and record some of these parameters, at least during shakedown trials. A real time data acquisition system can be used for this purpose with appropriate sensors installed. The number of position/process parameters to be controlled during routine EHS operation should be minimized.

7.1.2 Conceptual Design of Integrated System and Projected Performance Data

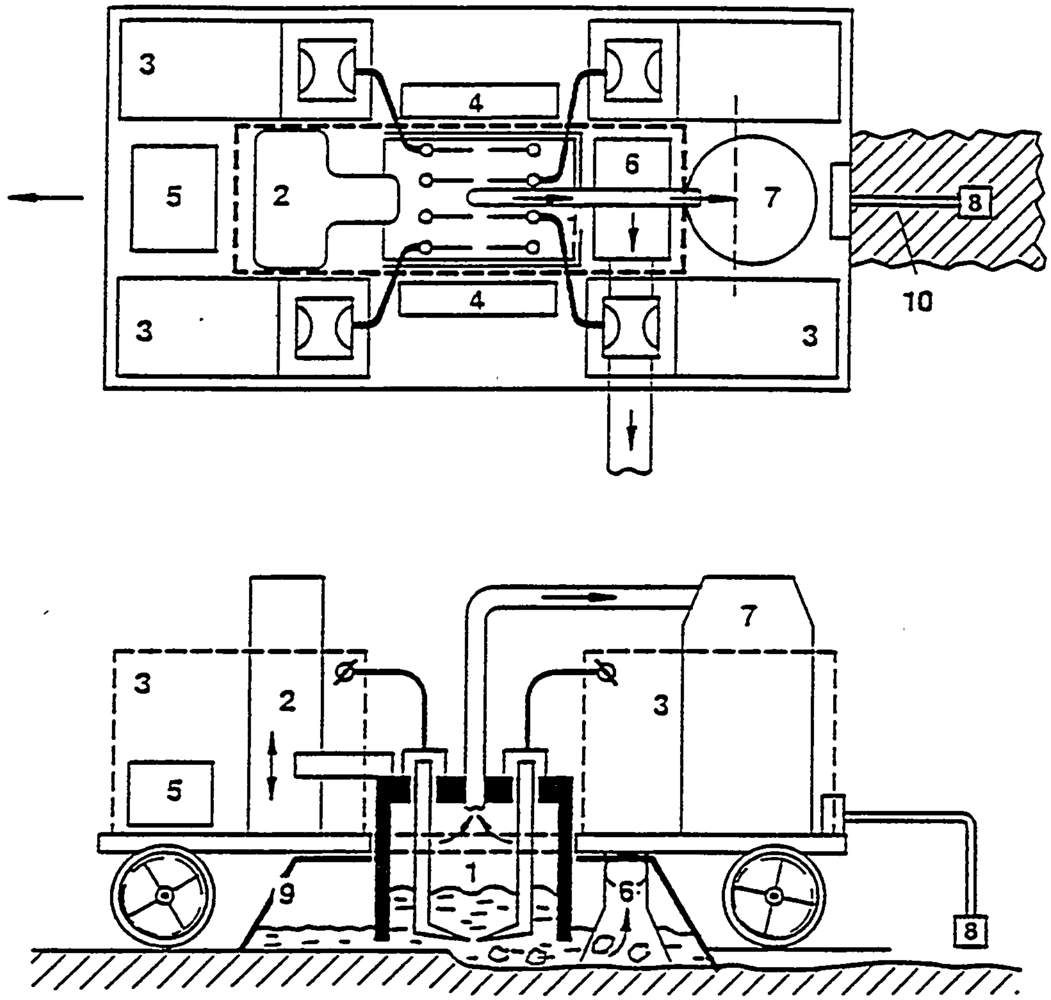
Schematics of two options for the integrated single-module EHS systems are shown in Figures 7-1 and 7-2. The first figure illustrates wheeled carriage (chassis) optional concept with some power supply components arranged within the carriage. The carriage could be similar to the ones used for dry scabbling (i.e., made by Pentek). In the second figure, a system mounted on a carriage moving over the elevated runway is shown. The central component - EHS module with four electrode pairs - is similar for both systems; it is shown in more detail in Figure 7-3. Specification of the power supply (pulser) and electrode system is given in Table 7-1. Finally, a flow diagram of the unit is outlined in Figure 7-4.

7.2 PROJECTIONS OF EHS PERFORMANCE AND ECONOMICS

7.2.1 Introduction

The main parameters entering calculations of EHS economics are the area scabbling rate (i.e., square meters per hour), energy efficiency, and cost of installed equipment (EHS system). In fact, other less tangible factors such as time required for equipment setup, operation convenience/automation, system reliability, frequency and simplicity of scheduled equipment adjustments, repair and part replacement is not less important. In addition, technology independent, site- and decontamination program-specific requirements and circumstances can greatly affect the economics of decontamination. Among these are:

- depth and character of contamination
- area size and configuration
- time schedule and safety procedures (which define net- vs. gross-processing time)
- technique used to evaluate completion of the decontamination
- efficiency and duration of equipment use at the site
- direct and indirect labor costs.



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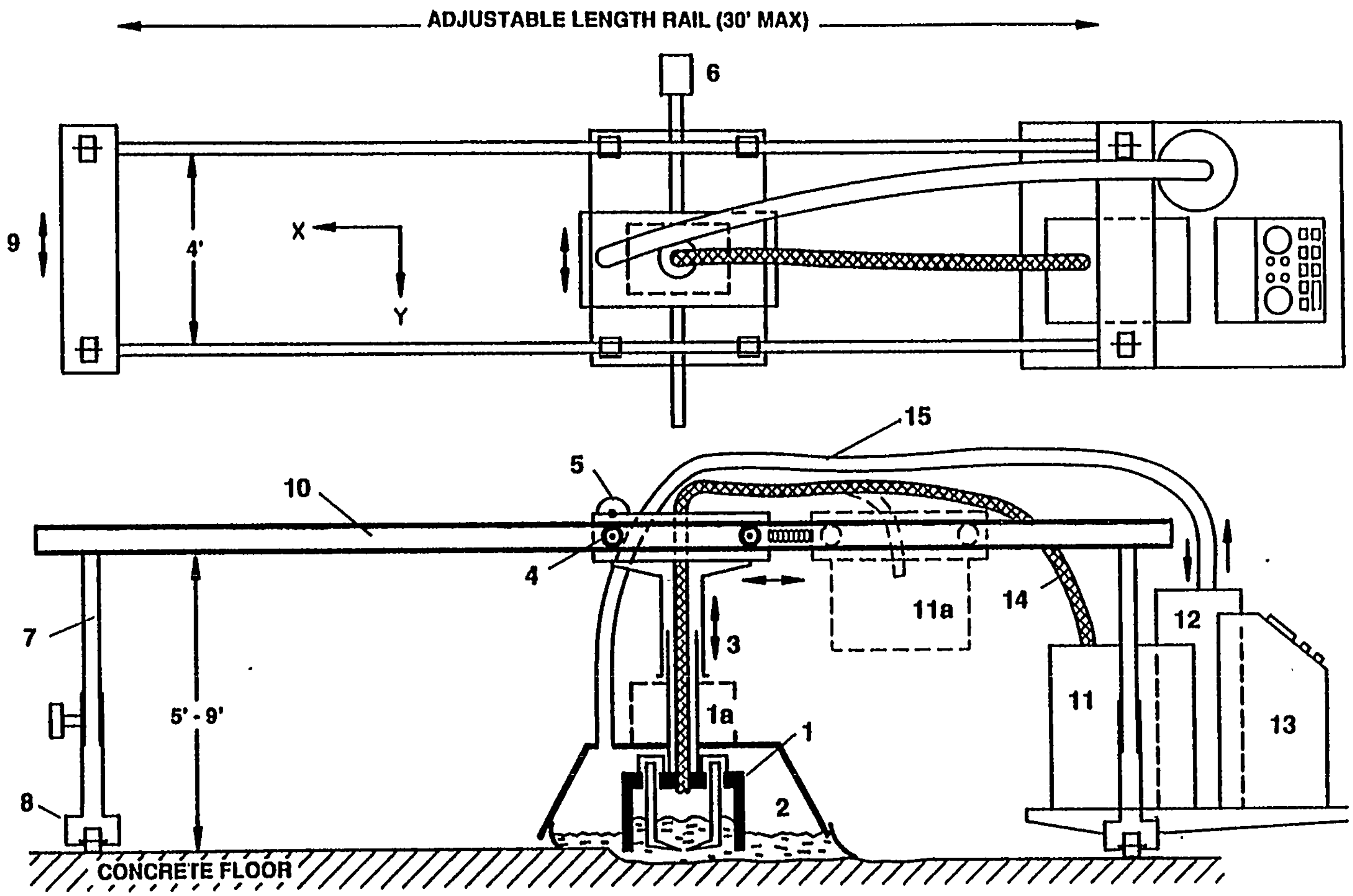
1	DISCHARGE/PROCESSING CHAMBER	6	WET VAC SYSTEM 2
2	CHAMBER HOLDER/POSITIONER	7	WET VAC SYSTEM 1
3	CAPACITORS AND SWITCHES	8	SURVEY METER
4.	MOTOR DRIVES	9	ENCLOSURE
5	CART DRIVE	10	SCABBLING TRAIL

Figure 7-1 EHS System Components Mounted on a Self-Propelled Carriage



1	DISCHARGE CHAMBER	6	MOTOR DRIVE y	11a	OPTIONAL POSITION OF POWER SUPPLY COMPONENTS ON A TENDER CARRIAGE
1a	SAME IN MAINTENANCE POSITION	7	GANTRY COLUMNS	12	WET VACUUM SYSTEMS AND PUMPS
2	ENCLOSURE	8	GANTRY WHEELS	13	CONTROL STATION
3	SUPPORT HYDRAULIC COLUMN	9	MANUAL TRAVERSE	14	CABLES
4	CARRIAGE	10	ELEVATED RUNWAY	15	HOSES
5	MOTOR DRIVE x	11	POWER SUPPLY		

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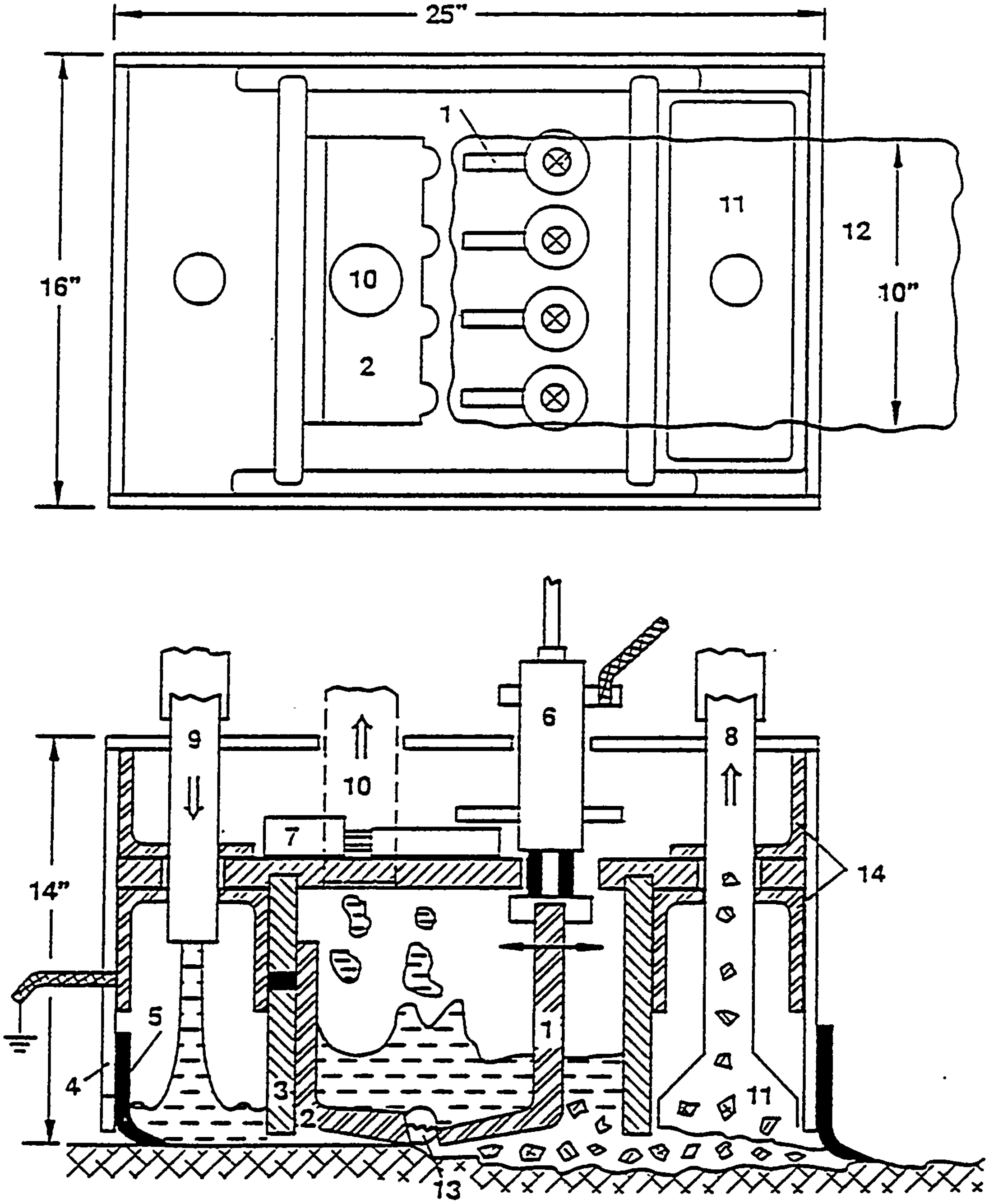
Figure 7-2 EHS System Components Mounted on an Elevated Runway



1. HV (+) ELECTRODE
2. GROUND ELECTRODE
3. DISCHARGE CHAMBER
4. ENCLOSURE
5. SLIDING GASKET
6. PNEUMATIC CYLINDER (SHOCK ABSORBER AND CLEARANCE ADJUSTMENT)
7. MOTOR DRIVE FOR DISCHARGE GAP ADJUSTMENT
8. SLURRY PIPE TO WET VACUUM
9. PROCESS WATER RETURN
10. WET VACUUM FOR CHAMBER PRESSURE/WATER LEVEL ADJUSTMENT
11. RUBBLE SCOOP
12. SCABBLING TRAIL
13. DISCHARGE GAP
14. RE-ENFORGING METAL PARTS

Figure 7-3 EHS Module with Four Electrode Pairs

TABLE 7-1

SPECIFICATION OF INDUSTRIAL PROTOTYPE EHS MODULE

Parameter	Option A (HV)	Option B (SHV)
Electric Power Installed, kW		
main (discharge)	20	8
auxiliary (drives)	5	5
Operating Voltage, kV	18-30	120-150
Capacitance, μF (per electrode)	5-10	0.1-0.3
Discharge Current, max, kA	60	10
Pulse Energy, J	1000-3500	500-1000
Discharge Duration T/2, μs	5-15	1-3
Repetition Rate, Hz (per electrode)	1-5	0.5-3
Number of Electrodes (electrode pairs) per Module	4	10
Electrode Gap, cm	0.5-1.5	1-3
Water Layer Depth, min, cm	2	4

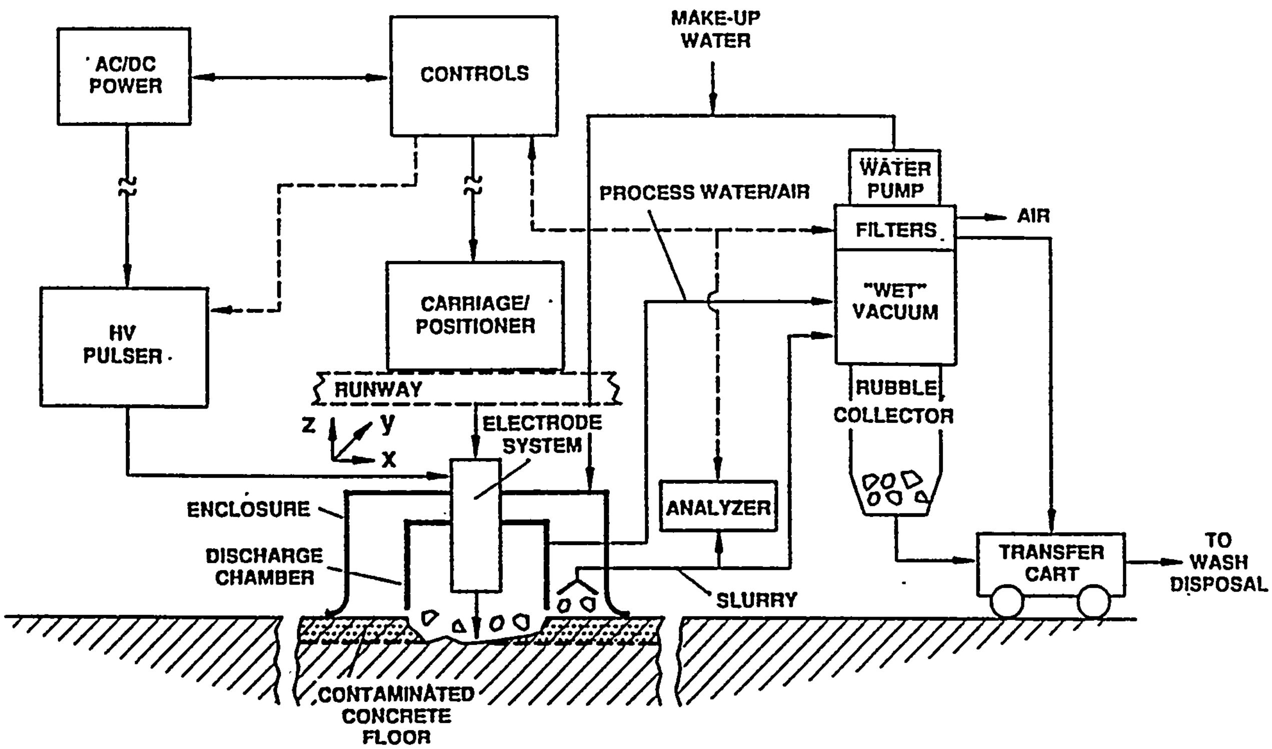


Figure 7-4 Integrated EHS System with Power and Flow Lines Shown

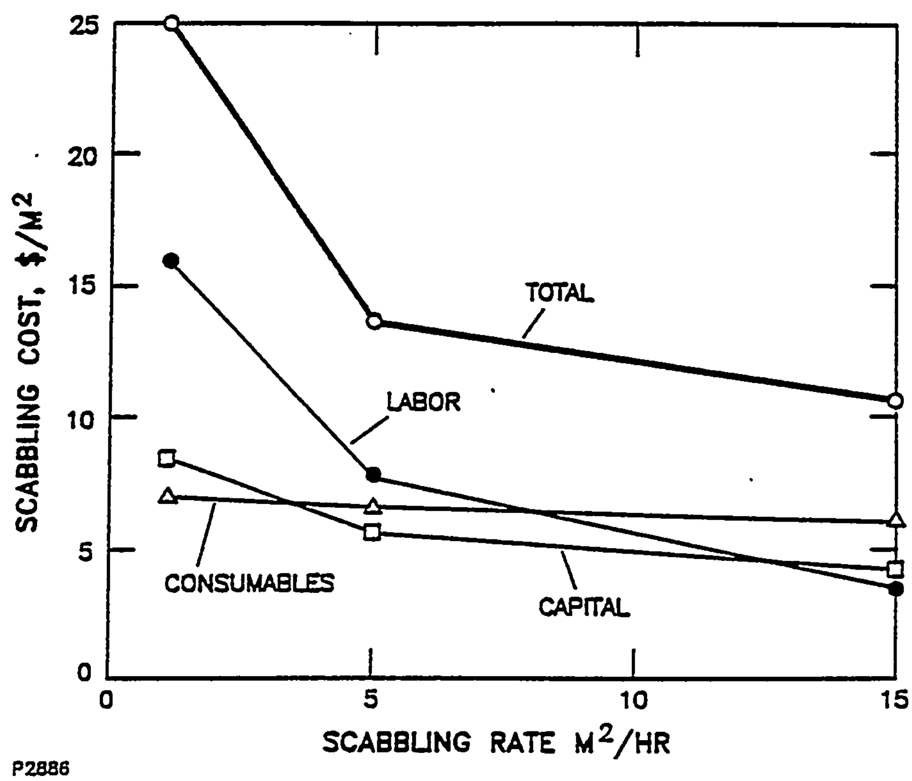


Figure 7-5 Concrete Scabbling Cost (total) vs. Scabbling Rate Equipment Size

Due to these factors - many of them unknown until the decontamination site and program are specified - even nominal processing cost estimates could be only approximate.

7.2.2 EHS Performance Parameters and Assumptions used in Economic Estimates

Decontamination cost estimates are made in this section for two EHS systems:

A. Subscale, single -module unit proposed for Phase II program.

B. Full-scale, three-module unit proposed for Phase III demonstration and, if successful, for future DOE and/or commercial uses.

In addition to the main high voltage option (A), data are presented for a still less well-characterized super-high voltage concept (B).

In Table 7-2, single module unit (option A) performance data are listed for two typical - minimum and maximum - scabbling depths. Performance projections for A and B design options (for 1 cm deep scabbling) are compared in Table 7-3. Preliminary estimates of decontamination cost are presented in Table 7-4 for single module (industrial prototype) and three module (full-scale) EHS systems. Here the scabbling rate and consumption data were averaged between two design options.

A more detailed comparison of HV and SHV design options indicates that the SHV option would have a two to four times higher energy efficiency which, for equal scabbling rate, would also require a smaller electric power supply. As a result, SHV system equipment cost should be about 15% lower; it is reflected in Table 7-5 for a single module unit. The same difference is to be expected for a full-scale unit, resulting in a total system cost of 296 K$ and 343 K$ for SHV and HV versions, respectively. These positive factors could be partially offset by somewhat higher initial and maintenance costs for equipment operating at higher voltages. Levels of complexity and longevity of an SHV electrode unit are less established than those for the HV option; one of the complications is a requirement for stepwise (alternate X and Z) movement for the tested electrode unit. Lastly, advantages of the SHV unit could be made less significant after other processing expenses common for both versions are added. According to our preliminary estimates, the SHV version would provide a 15 to 25% cost savings, which is a substantial but not a decisive advantage.

Physical differences between electric breakdown mechanisms (through water for HV vs. through concrete for SHV) may result in more significant differences in system engineering and decontamination efficiencies than the ones related to equipment/operation costs. This is the main reason for extending comparative testing of both approaches.

Main assumptions used for the cost estimates in Tables 7-4 and 7-5 are as follows:

- Electric energy cost: 0.1 $/kWh.
- Makeup water cost: 0.015 $/cu. ft.
- Capital cost of major equipment components and their assembly/integration costs are given in Table 7-5. Most data in the table are obtained from purchasing costs or quotes for commercially-available or custom-made components and materials.
- Lifetime of major short-life components (capacitors, spark gap switches, cables) or expendable components (such as some discharge chamber parts, electrodes, hoses) is

TABLE 7-2

PROJECTED PERFORMANCE OF A PROTOTYPE EHS MODULE VS. CONCRETE SCABBLING DEPTH

	Scabbling Depth, cm	
	0.5	1.5
Scabbling Rate, Area, max m^2/hr	4	3
Scabbling Rate, Volume (weight), m^3/hr (kg/hr)	0.02 (48)	0.045 (110)
Electric Energy Consumption, kWh/m^2	4	7
kJ/kg	300	230
Water Consumption, ℓ/m^2		
water-soluble contaminant	20	60
water-insoluble contaminant	10	20

TABLE 7-3

PROJECTED PERFORMANCE OF INDUSTRIAL PROTOTYPE EHS MODULES OF TWO DIFFERENT DESIGNS

Parameter	Option A (HV)	Option B (SHV)
Scabbling Depth, cm	0.5-2.5	0.4-1.5
Width of Scabbling Trail, cm		
per electrode	4-6	2.0-4.0
per module	20-30	20-40
Scabbling Rate*, m^2/hr (ft^2/hr)	5 (54)	5 (54)
Scabbling Rate*, kg/hr	125	125
Electric Energy Consumption, kWh/m^2	5	2.6
Water Consumption, gal/m^2	3	3
Electrode (steel) Consumption per electrode, cm/m^2	2	0.2
Decontamination (as surface uranium activity, counts/min/100 cm^2)		
initial	1000-10,000	1000-10,000
final	100-500	100-500

*for 1 cm (~ 3/8") scabbling depth

TABLE 7-4

PRELIMINARY ESTIMATE OF EHS DECONTAMINATION COST[1]

Item	Single Module	Three Modules
Processing Rate	10,000 m^2/year 5 m^2/hr	30,000 m^2/year 15 m^2/hr
Consumables		
Electricity[2]	0.48	0.43
Water	0.04	0.04
Electrodes, Other	0.12	0.12
Subtotal	**0.64**	**0.59**
Capital Cost[3]	5.4	3.8
Labor Cost[4]	7.9	3.2
Total[5]	**14 (1.3 $/ft^2)**	**7.6 (0.7 $/ft^2)**

Main Assumptions and Remarks:

(1) $/$m^2$. Numbers are for 1/4" scabbling, averaged between design options A (HV) and B (SHV).

(2) At 0.1 $/kWh rate.

(3) For 2000 net operating hours per year, five years service life, one year lifetime for some components. Engineering/design expenses not included.

(4) 2000 hrs/year operators time plus 500-1000 hrs/year setup and maintenance time; 75 $/hr labor cost, including overhead and management expenses, but not including health physics services.

(5) Waste disposal is not included.

TABLE 7-5

PRELIMINARY ESTIMATE OF EHS CAPITAL (EQUIPMENT) COST (K$)

Item	1-Module Prototype A(HV)	1-Module Prototype B(SHV)	3-Module Full-scale A
1. Electric Pulser			
DC charger	18	11	46
Capacitors	5	2	14
Sparkgap Switches	5	3	14
Pulsers/Triggers	3	2	8
Cables, Cabinet, Resistors, etc.	4	4	10
Subtotal	35	22	92
Assembly, Testing (labor)	20	15	40
TOTAL	55	37	132
2. EHS Module			
(Fabrication and Assembly of Mechanical Components)	7	6	20
Discharge Chamber (with vertical positioner)			
Electrode Systems (with supports and gap controls)	8	8	22
Exterior Chamber/Enclosure	2	2	5
Subtotal	17	16	47
Integration, Testing (labor)	8	8	20
TOTAL	25	24	67
3. Slurry Management System			
Wet Vacuum Units (2)	10	10	17
Rubble Collector/Separator	5	5	9
Recirculation Water Pump	3	3	5
Auxiliaries (flow/pressure controls, hoses, filters)	4	4	7
Subtotal	22	22	38
Assembly, Testing (labor)	10	10	20
TOTAL	32	32	58

TABLE 7-5 (continued)

PRELIMINARY ESTIMATE OF EHS CAPITAL (EQUIPMENT) COST (K$)

Capital Cost (k$)	1-Module Prototype A(HV)	1-Module Prototype B(SHV)	3-Module Full-scale A
4. Carriage/Positioner with Controls			
Self-propelled Chassis (cart)	10	10	10
Elevated Runway	5	5	5
Controls	5	5	8
Subtotal	20	20	23
Assembly, Testing (labor)	7	7	14
TOTAL	27	27	37
5. EHS System Integration, Testing (labor)	15	15	25
TOTAL EHS SYSTEM COST	**154**	**135**	**319**
Including:			
Components	94	80	200
Labor	60	55	119
Cost of One-Year Lifetime Components	17	10	35
Cost of Five-Year Lifetime Components	77	70	165

averaged, and defined as 2000 hours (one year of service) which corresponds to ~ $5x10^7$ pulses. It is estimated that about 20% of equipment belongs to this category.

- The lifetime of other system components is assumed to be 5000 hours or 5 years of service. It is also assumed that salvage value of the equipment (approximately) equals a cost of money.

- Net 2000 hrs/year (one man-year) processing time is assumed.

- One technician is handling the EHS unit during net operating hours.

- Another 500 to 1000 hours (depending on equipment size) are spent for the unit setup, scheduled maintenance, repairs, and parts replacement (by technician of similar qualification).

- 25 $/hr direct labor cost is assumed for the above technicians.

- Total labor cost is $25 x 3 = 75 $/hr. The "overhead" (indirect) 50 $/hr cost covers engineering, administrative, and other site expenses. Health physics (safety, evaluation of decontamination quality) are not included.

It follows from Table 7-4 that labor cost is a major item for a moderate processing rate (single module unit); its decrease is following the increase in scabbling rate and for a three-module unit, capital cost item prevails. While this can be achieved by increasing equipment size/power, there are at least two limitations:

a) rate-independent cost components are present, and

b) under conditions of limited time use and/or surface area due for decontamination, capital (initial) cost of equipment becomes most important.

7.2.3 Cost Comparison: EHS vs. Other Decontamination Techniques

To make a viable comparison between various decontamination techniques, all assumptions should be clearly spelled out.

Cost data for several other scabbling/decontamination techniques are shown in Table 7-6. Here, data compiled by Martin Marietta cost estimates for SHP water jet decontamination from Ref. 4.

Dry scabbling by shot blasting (e.g., Nelco scabblers) or by surface grinding ("Squirrel" and "Moose" units by Pentek) are, operation-wise, most similar to the EHS.

Processing costs claimed by manufacturers of these systems vary in a wide range. Lowest cost is quoted by Nelco: for dry scabbling of epoxy-painted concrete by 16" - wide shot blaster it is 8.6 $/m^2. Lowest cost quoted by Pentek for "Moose" unit is about 3 $/ft^2 for 1/4" deep scabbling in two passes.

Bearing in mind many uncertainties involved in all these estimates, as well as incomplete listing of assumptions made in the calculations, we conclude that dry and wet (EH) scabbling have comparable processing costs.

This result should not be surprising, because labor cost is the major factor. If a scabbling unit of higher productivity can still be one-man operated, it always will be less expensive. We

TABLE 7-6

COMPARATIVE COST DATA FOR CONCRETE DECONTAMINATION TECHNIQUES

Equipment/Process	Cost \$/(sq. ft. x 1/4")
(1)Manual Hand Tools*	82
(1)Needle Gun/Power Tools*	13
(2)Squirrel III (Dry Scabbling)	5.4
(2)Moose	2.7
(3)Shot Blaster A*	3.4
(3)Shot Blaster B**	0.8
(4)SHP Water Jet	94
EHS (Single Module, 10")	1.3
EHS (Three Module, 30")	0.7

*(10", Epoxy Paint)
**(16", Epoxy Paint)
(1)Martin Marietta Data
(2)Pentek Data
(3)Nelco Data
(4)Ref.

should keep in mind, though, that increasing net scabbling rates above certain levels will not provide a cost advantage, because at some point equipment setup and other weakly rate-dependent stages of the decontamination procedure become decisive components of the total cost. This tendency is illustrated semiquantitatively by Figure 7-5 (see page 127).

There are no process economics data for microwave scabbling. According to Ref. 61, the scabbling rate is comparable to that for EHS at similar tool travel speed and scabbling trail width. Capital cost of the MW equipment is expected to be higher. Other line items should be compared on the basis of generic differences between dry and wet scabbling techniques.

Information which is currently available and can be used for the EHS cost analysis is based on our laboratory trial data and, to some extent, on the extrapolation of generic results obtained from other technical applications of electro-hydraulic technology. This information is sufficient to make EHS prognostication which is, in our opinion, reliable within a factor of two. It does not, though, warrant much more detailed predictive calculations. Major sources of uncertainties belong to two main categories:

A. EHS equipment and operation: equipment lifetime and maintenance costs, and labor cost under a contaminated site environment carry the largest part of the uncertainty.

B. Site-related items: cost will depend on

- level, type, and depth of the contamination
- Size, configuration, and accessibility of the contaminated area
- schedule and logistics of operation and associated safety assurance/ decontamination control costs.

While some of these factors are general for competing decontamination technologies, others could be EHS technique-specific and still not fully understood at this time. Many of the uncertainties belonging to categories A and B shall be removed or narrowed as a result of larger-scale Phase II trials conducted at more realistic conditions.

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9.0 ADDENDUM

A. SCABBLING OF VERTICAL SURFACES

During Phase I of the project, feasibility of the EHS technique was demonstrated for horizontal surfaces (concrete floors and slabs) only. There were no major obstacles for implementing scabbling of vertical surfaces (walls). Nevertheless, additional effort is required to develop a static or dynamic (continuously traveling) enclosure holding the water pool against the wall. One possible approach is sketched in Figure 1. Here, the enclosure having a foamy perimeter gasket is tightened by reducing air pressure. The EHS head is traveling within the enclosure in the X direction, together with the enclosure in Z direction. After this "batch mode" scabbling is accomplished, process water and concrete rubble is removed, air pressure returned back to atmospheric, and enclosure transferred (by the carriage) to a new position where the batch scabbling is resumed. While there could be some technical problem with this or other possible approaches, they can certainly be resolved. The simplest case would be scabbling of vertical walls of trenches, tanks, etc. No water/rubble containing enclosure is required for these vertical surfaces, as well as surfaces having arbitrary angle with respect to horizon.

B. SAFETY RISK ANALYSIS

Safety concerns specific for the EHS decontamination technique are related mostly to the use of high-voltage electric power in combination with a wet environment (water droplets, splashes, films).

High voltage equipment and short current pulses used for EH scabbling are involved in many specialized applications. Among them are such widely used applications as X-ray industrial and medical installations, lasers (including those used in surgery), electric discharge machining, electrostatic filters, etc. Safety measures and features in these fields are well developed. The EHS operator at the control station located outside a contaminated zone will have a working environment common with the ones mentioned above. The station will have interlocks/warning/signal/emergency shutdown systems generic for many other HV power supplies.

Specifics of a wet environment are relevant only to contacts with and approaches to the self-propelled, tether-controlled carriage. Many "anti-HV" safety measures, in fact, overlap with measures taken routinely to limit or prevent access of personnel into contaminated areas. For instance, an operator or other personnel will be out of the contaminated floor area during the concrete scabbling, notwithstanding the presence of high voltage. Specific safety precautions will include, but are not limited to:

- Grounding of carriage equipment (overhead), HV cables, and tethers.
- Cutoff of high voltage when operator or maintenance personnel enters a dangerous HV/wet zone.
- Safeguards/switches at the enclosure containing storage capacitors, spark gaps, and a discharge chamber mounted on the carriage.
- Automatic discharge of storage capacitors immediately after pulsing/processing cycle terminates.
- Visual and/or audio signals indicating the start and end of the scabbling operation.

A full list and description of safety devices and measures will be completed before the demonstration trials at TDS and DOE sites begin.

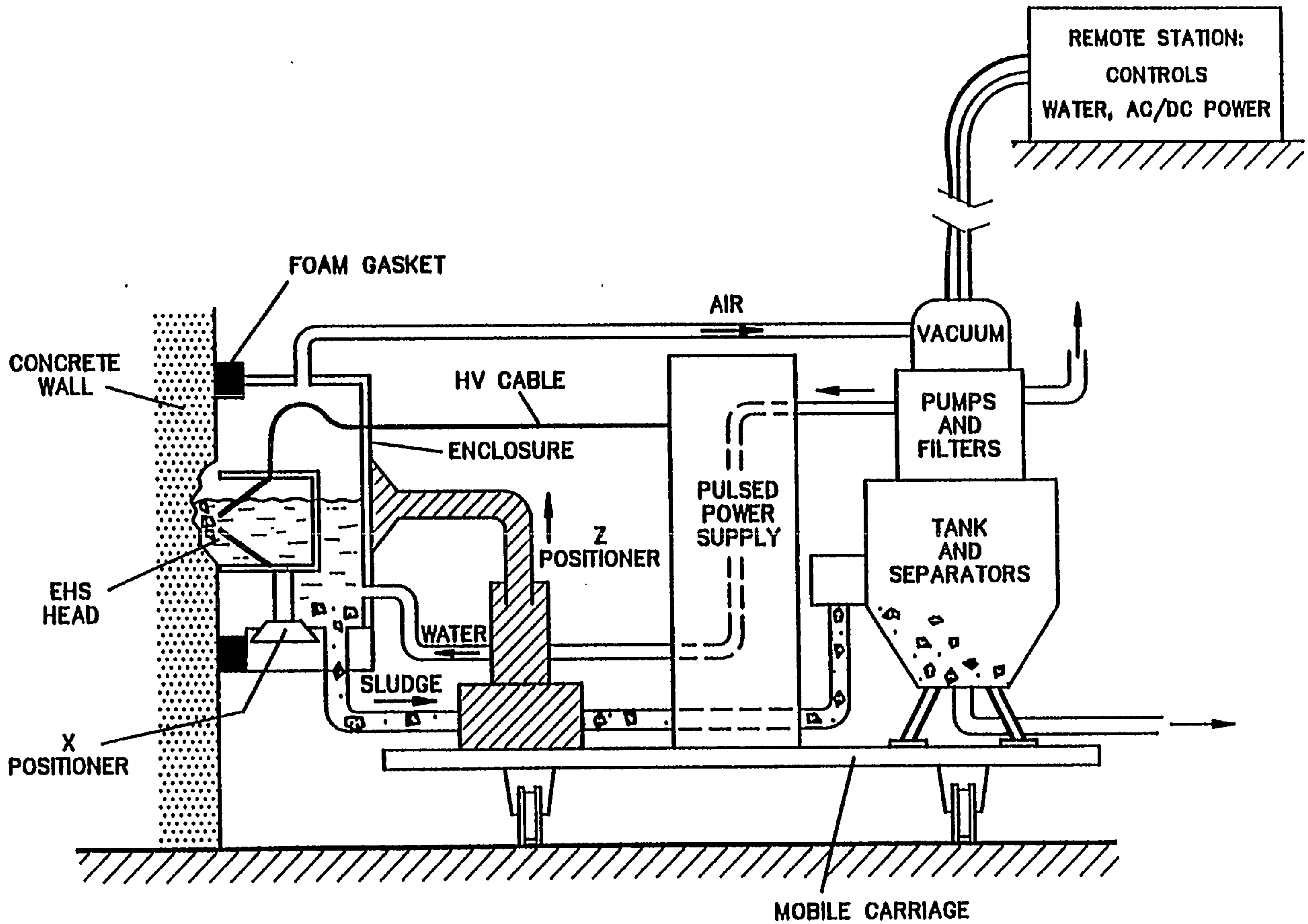

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Figure 1 Conceptual Drawing of EH System for Wall Scabbling

APPENDIX A

COMMERCIAL TEAM DEVELOPMENT

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APPENDIX A

COMMERCIAL TEAM DEVELOPMENT

As was indicated in the offer and commercialization plan of the initial proposal, TDS plans to collaborate with equipment suppliers and user/operators already active in decontaminating and decommissioning nuclear facilities. It is the TDS plan to design, construct, and assemble the EHS scabbling module and to integrate it with positioning controls and rubble handling equipment on a carriage designed and provided by a commercial equipment supplier. Advice and direction on the constraints and requirements of D and D operations will be obtained from facility operators and service providers already involved in D and D activities.

On this basis, team building, with the goal of developing a commercial EHS scabbling device was initiated parallel with Phase I, and it is projected to have completed the selection process and to have business agreements in place within the first three months of Phase II. Exchanges of information regarding EHS operating principles, test results, design concepts, comparative costs, and business strategies were initiated and are continuing with the following companies:

International Technology Corp.
BNFL, Inc.
AWD Technologies, Inc.
Stone and Webster Engineering Co.
SEG, Inc.
ENSR
Pentek, Inc.*
Nelco Manufacturing Co.
North American Industries

Each of the above companies has been apprised of the project progress and has been invited to TDS for an EHS demonstration.

It is the TDS plan to negotiate a business agreement with an equipment supplier, such as Pentek, Nelco, or North American Industries. Together we will design and build an EHS system, self-contained with regards to rubble handling and water recycle and collection, and mounted on a remotely controlled carriage. As envisioned, the system would appear not too different from ones currently sold by Nelco and Pentek. An optional type of carriage, e.g., a gantry suspended on guide rails, can be designed on the basis of commercial components manufactured by North American Industries. At present, confidentiality agreements between TDS and Pentek have been signed, and it is anticipated that Pentek will participate in Phase II of the project.

As part of Phase II, a potential user company, such as BNFL, Stone and Webster, Martin Marietta, or Fermco, will be engaged as a consulting firm to advise on the requirements and constraints of using the EHS system in specific D and D applications. Stone and Webster engineers, who have viewed a demonstration of EHS as well as BNFL, AWD, and SEG, have stated their interest in being involved in the project. On the other hand, the involvement of Martin Marietta or Fermco would have the advantage of providing access to a host site. Fermco, after viewing the demonstration of the EHS unit, has indicated, in writing, to DOE and TDS their

*Confidentiality Agreements signed.

interest in the development of EHS as well as their willingness to act as the host site for the Phase II demonstration.

In further exploration of the potential commercial market for EHS scabbling, a presentation (see Appendix B) was made at EPRI's Conference on Low Level Radioactive Waste Management. Although considerable interest was expressed by the attendees from the utility industry, definition of the need for advanced scabbling devices at nuclear power plants remains very speculative.

APPENDIX B

EPRI CONFERENCE PRESENTATION

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CONCRETE DECONTAMINATION BY ELECTRO-HYDRAULIC SCABBLING

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Abstract

TDS is developing an Electro-Hydraulic device that has the potential of 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. Control of the pulse energy, frequency and traverse speed control the depth of the scabbling action. Performance thus far, has demonstrated the capability of the bench scale unit with a single pair of electrodes to scabble a swath 3" wide, up to 1" deep at a rate of up to 12" per minute. A unit with multiple electrodes will increase the width of the swath.

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.

Textron Defense Systems (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 a strong pulsed electric discharge and propagated through water between the discharge and the concrete. The high impulse pressure, developed at the liquid-solid interface, results in stresses which can controllably deform, crack, or break a whole solid body or peel off the surface layer. Accordingly, EH has found previous technical applications for crushing and grinding of minerals, drilling of rocks, forming of metals, cleaning of surfaces, and demolition of foundations.

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 mechanically fed electrodes. Shock waves propagating through the water deliver strong pressure pulses to a localized wall and result in concrete scabbling. Water provides an efficient transfer of discharge energy and also acts as a debris retainer. Unlike high-pressure water jets, miniscule water flow rates are adequate for EHS, since the scabbling stresses are created by the discharge and not water flow momentum. In addition, no orifices are involved, so that a large amount of solids loading can be tolerated in the water.

To achieve the desired scabbling depth and rate, process parameters (pulse energy, duration and frequency, and electrode configuration), should be optimized on the basis of laboratory tests and process modeling.

It is projected that EHS technology will provide sizable improvement over other available technologies for concrete decontamination. Reduced energy consumption, water consumption, and dust generation, plus rapid processing of the concrete surface, should result in a faster, less expensive and less hazardous cleaning procedure.

The Electro-Hydraulic Effect

The term Electro-Hydraulic effect summarizes several physical and chemical phenomena which accompany high voltage spark discharges in water (or other liquid). Below, we consider briefly the most important of these phenomena, how they affect bordering solids, and what are (or can be) their practical uses.

A strong and short (pulsed) spark-like electric discharge in liquid is accompanied by:

- Generation and propagation of an extremely intense shock wave (pressures of up to 100,000 atm).
- Generation and pulsation of gaseous/vapor discharge cavity, filled by liquid vapors (cavitation).
- Radiation of electromagnetic (including optical) waves by the discharge channel.

Depending on specific conditions, electric energy can be transformed by means of any or all of the effects described above, i.e., by means of shock waves, cavitation, or radiation. Any or all of these effects produce strong forces at the interfaces between liquid and solid bodies submerged into or bordering with the liquid, and, under certain conditions, may result in their disintegration by crushing, grinding, or dispersion. By varying the parameters of the electric discharge, e.g., energy, duration, repetition rate, etc., conditions favorable for certain effects can be generated. Thus, because the interaction of shock waves has been found to be most effective in material crushing applications, parameters that maximize the generation of shock waves should be selected.

It has been shown by many researchers(1-6) that breaking of materials by shock wave impingement is due to formation of radial cracks generated by a compression wave. Growth rate of these cracks can reach 7,000 m/sec. Even more effective are tensile stresses which are developed after reflection of compression waves from free surfaces of solids or from boundaries of body components with different acoustic toughness (r.a = density times sonic velocity). For comminution of materials, e.g., fine grinding, and quite probably for scabbling of thin surface layers, after-discharge phenomena, especially cavitation and explosive boiling of liquid leading to high stress gradients, are of major importance.

The qualitative understanding of EH phenomena may be sufficient for some practical applications, but development of efficient equipment, process optimization, and control requires development of at least semiquantitative theory. This development, initiated by pioneering works of Yutkin(7) in the 50's and 60's, was conducted mainly by Russian researchers(8-12) and borrowed ideas and approaches from several fields of physics and mechanics, specifically physics of electric discharges, theory of explosions and shock waves, and knowledge of mechanical properties and strength of solids, especially rock, minerals, and building materials.

On the basis of electric discharge physics, approximate theories describing expansion of the discharge channels in liquid have been developed. The theories allow estimates of (i) transfer of electric energy into mechanical energy, (ii) total and partial hydrodynamic efficiencies vs. discharge geometry and electrical parameters, and (iii) pressure at the shock wave front vs. distance.

Results of theoretical calculations(8) show that shock wave pressures can reach values as high as 60,000 atmospheres at the origin of the wave and still maintain pressures on the order of tens of atmospheres, even at 1 m from the discharge.

Several technical applications of EH effect have been developed and some of them have found rather broad industrial applications. We present these to illustrate that, while EH use for decontamination is a new concept, there is a solid body of work for other applications. These applications include:

- (i) Comminution (coarse and fine grinding) of minerals and other brittle materials(11,15,18-21);
- (ii) Demolition of concrete structures;(13,14)
- (iii) Pulsed liquid pumping;(15)
- (iv) Drilling and mining operations;(16,17,18)
- (v) Cleaning of castings and scaled tanks.(11, 16)

Design of EHS System

A block flow diagram of an EHS system is shown in Figure 2. Design considerations relevant to several of the system components follow.

The electric power supply consists of two units. The first, which can be remote, includes AC supply for motor drives and other system uses, and DC supply for the electric pulser. The second unit - electric pulser proper - should be located close to the EHS head; low inductance of the connecting cables is required to generate short pulses with steep fronts. The DC power supply will operate at 30 to 50 kV, providing pulses of 20 to 2,000 J energy; a thyratron or spark-gap switch with a function generator will control the repetition rate.

The EH processing head is the central component of the system. It carries single or multiple electrodes. Optimization and selection of the electrode configuration for specific conditions is one of the major design considerations.

To achieve high energy efficiency, it is important to maximize pressure transfer to the concrete surface. Interelectrode gap, distance between electrodes and concrete surface, electrode shape and size are among the variables to be optimized. Material selection to minimize the effects of erosion of the electrodes and insulation must be exercised.

In all designs, a small amount of water needs to be supplied in the space between electrodes and concrete to provide effective pressure transfer. It can be done by low-pressure flow. The use of low pressure and flow rate is beneficial as compared to high pressure jets, due to reduced water consumption and less probable spread of contamination.

The rubble removal subsystem can be based either on hydraulic or on pneumatic transfer of concrete rubble. The first type of system is similar to that used for rock rubble removal from bore holes or in dredges. An erosion resistant pump must be used. The system has the advantage that no gas exhaust is involved. Disadvantages include the possibility of contaminated sludge loss from the boot, and possible problems with pump operation may occur due to irregular sludge flow. Use of pneumatic transfer with vacuum sufficient to suck in the rubble from the surface and to prevent sludge loss from the boot seems to be more reliable. With this system, proper cleaning of the exhaust air should be readily achieved. Rubble system instrumentation will include pressure and flow rate meters, sludge level (or weight) indicators, and, in some cases, exhaust gas composition sensors.

The robotic/positioning subsystem should provide comparatively fine (precision ~ a few mm) positioning of the EHS head within the working envelope: over the concrete surface (in X-Y directions), and adjust distance between electrode(s) and concrete surface (along Z -direction). Less precise transfer over longer distances can be implemented using a remotely-controlled cart (carriage), which may also serve as a platform for the electric pulser and, possibly, for some components of the sludge system and characterization equipment.

Design of the positioner should be customized with respect to type, surface area, and surface orientation (exterior, interior, vertical, horizontal, etc.). Many commercial robotic systems (for instance, those used for welding, drilling, water jet machining) can be employed with some modification.

The characterization of contaminant before, during, and after processing is an important task to guide and monitor the scabbling operation. The feasibility of on-line, real-time control based on analysis of the process sludge will be explored. A small part of the sludge stream will be sucked from the main line, filtered and directed to a spectro-analytical instrument - Inductively Coupled Plasma-Emission Spectroscopy (ICP-ES) unit conventionally used for analysis of solutions and suspensions. The data obtained on elemental composition will characterize the removed contaminated material. Periodic fresh (makeup) water from the same line will be analyzed to estimated upper level of contamination still remaining on the concrete surface. Analysis for metals, especially radio nuclides, total carbon, and total chromium will be performed. The characterization unit will be tested in the laboratory, and later, if successful, integrated with general process controls.

It is not expected that spectrometric analysis will be sufficient for complete characterization, therefore other sensors, for instance, counters measuring radioactivity level, should be installed as part of the device.

The process control unit should, in most cases, operate remotely. Using a pre-programmed operation schedule, in combination with real-time signals from positioning, characterization, sludge flow, sensors, etc., it will control the pulsed power, supply and position of electrodes, and water supply, i.e., effectively the whole scabbling process.

Test Performance
Two test units were assembled 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 concrete slab immersed in a tank of water. The second unit is an extension of the first, but as Figure 4 shows, it is designed to study EHS of concrete floors.

Both test units used a common power supply and control system. This consisted of a high voltage, 16 to 25 Kv generator which delivered 800 to 2200 joule pulses of 5 to 15 microsecond duration at a frequency of 0.5 to 3 hertz. About 50% of the stored energy is released in a 6 to 12mm discharge gap.

Several designs of the processing chamber varying from entirely open to completely enclosed, as well as a variety of electrode arrangements were tested. Problems with the electrode and insulating materials which had to withstand the impact of repetitive "electric explosions" were addressed. Although improvements can still be envisioned in electrode configurations and "boot" design, etc. the design of the components for the two test units proved to be satisfactory for the purpose of generating preliminary engineering data.

In test unit #1 using a single electrode pair, slabs of 2500 lbs/sq. in. concrete, 4" to 6" thick, and 400 to 700 sq. in. in an area were scabbled. The range of operating conditions and a summary of the results are listed in Table I. Typically, at 10"/min surface traverse rate, 2000 joules at $2H_Z$, the scabbling action forms a swath 0.45" in the concrete surface. This corresponds to a scabbling rate of 10sq. ft./hour with energy consumption of 1.400 kJ or 0.4 kWh per sq. foot. The energy consumption per unit mass of concrete removed is thus 560/J/g. The energy consumption of course is more for deeper scabbling and less for thin layer scabbling. Figure 5 (a and b) shows two surfaces being treated by the EHS process.

Test unit #2 was designed to explore EHS in a configuration applicable to concrete floor decontamination. As Figure 4 illustrates, the water tank in which the concrete slabs had been immersed was replaced by a shallow pool, 0.5 to 1.0" deep, containment arrangement. In this particular set up the containment barriers define a floor area of about 12 sq. ft. the partially enclosed discharge chamber or "scabbling head" is mounted on a controlled traverse suspension arm over the pool. All of the device controls and suspension arm mounts etc., are located outside of the pool barriers.

Results similar to those shown in Table I were obtained using Test Unit #2 to scabble sections of a concrete floor. Operation of the unit indicated that is should be possible with certain modifications in the boot enclosure to reduce the depth of the pool to about 1/8". this will, of course, reduce the quantity of contaminated recycle water even further. Tests with the new configuration after modification of the enclosure are planned. A schematic of the projected device for concrete wall scabbling is shown in Figure 6.

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.

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TABLE I

RANGE OF OPERATING CONDITIONS AND RESULTS

Operating Voltage	18 - 25 kV
Storage Capacitance	3.7 - 7.4 mF
Pulse Energy	800 - 2200J
Operating Frequency	0.5 - 3.0 Hz
Average DC power	1.5 - 4 kW
Electrode Transfer Velocity	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< > 0.75 inches
Concrete Area Processed	10 - 30 sq in./sq./min
Energy Consumption	400 - 1500 J/g

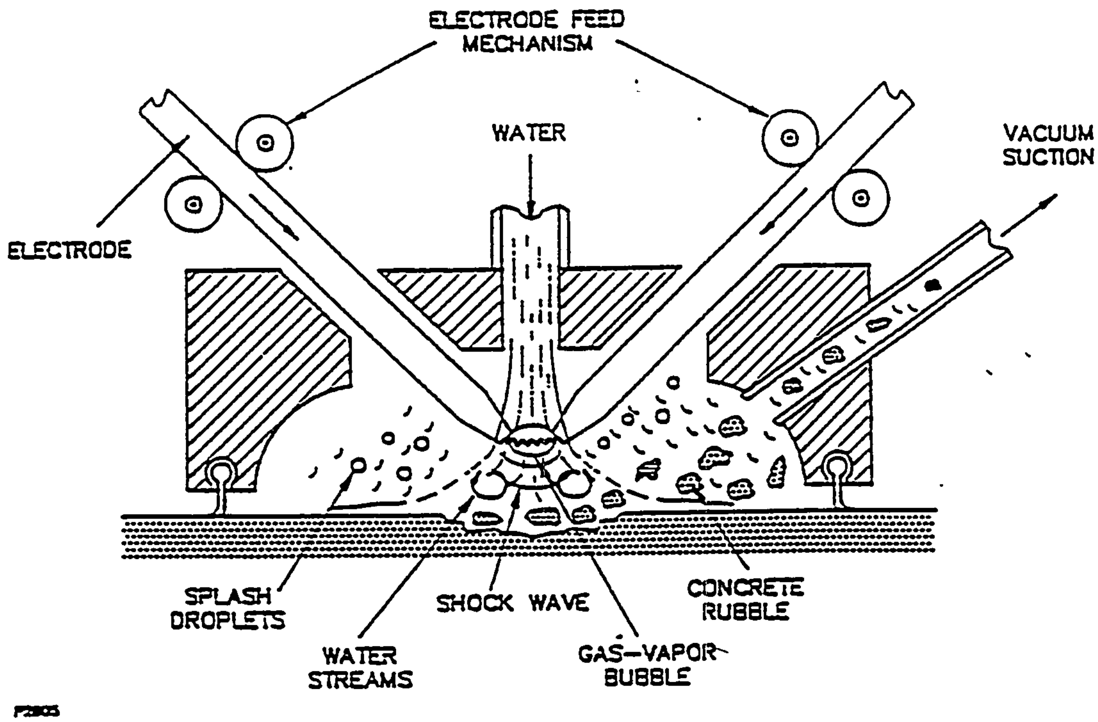


Figure 1 Electro-Hydraulic Scabbling System for Concrete Decontamination

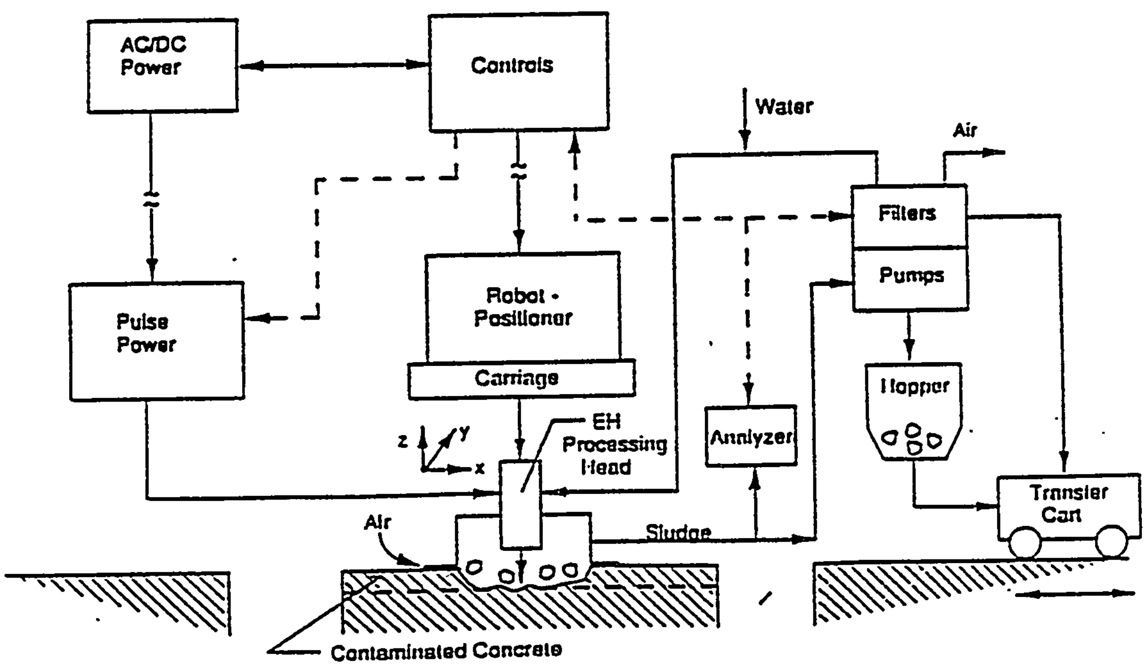


Figure 2 Block Flow Diagram of EHS System

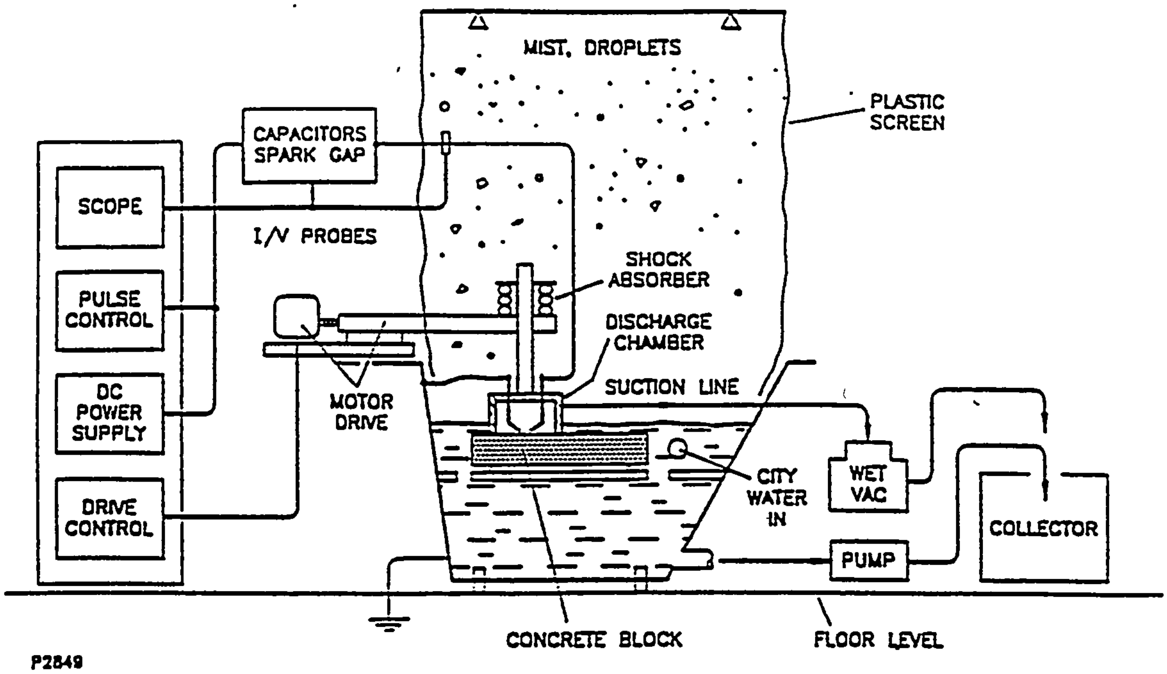


Figure 3 EHS Test Unit #1 for Concrete Slabs

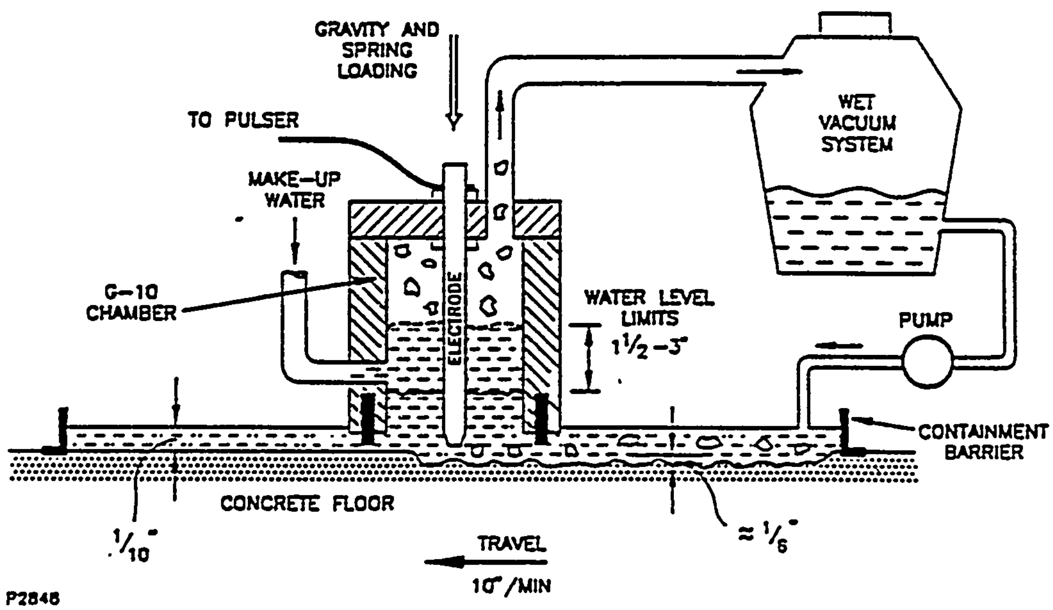
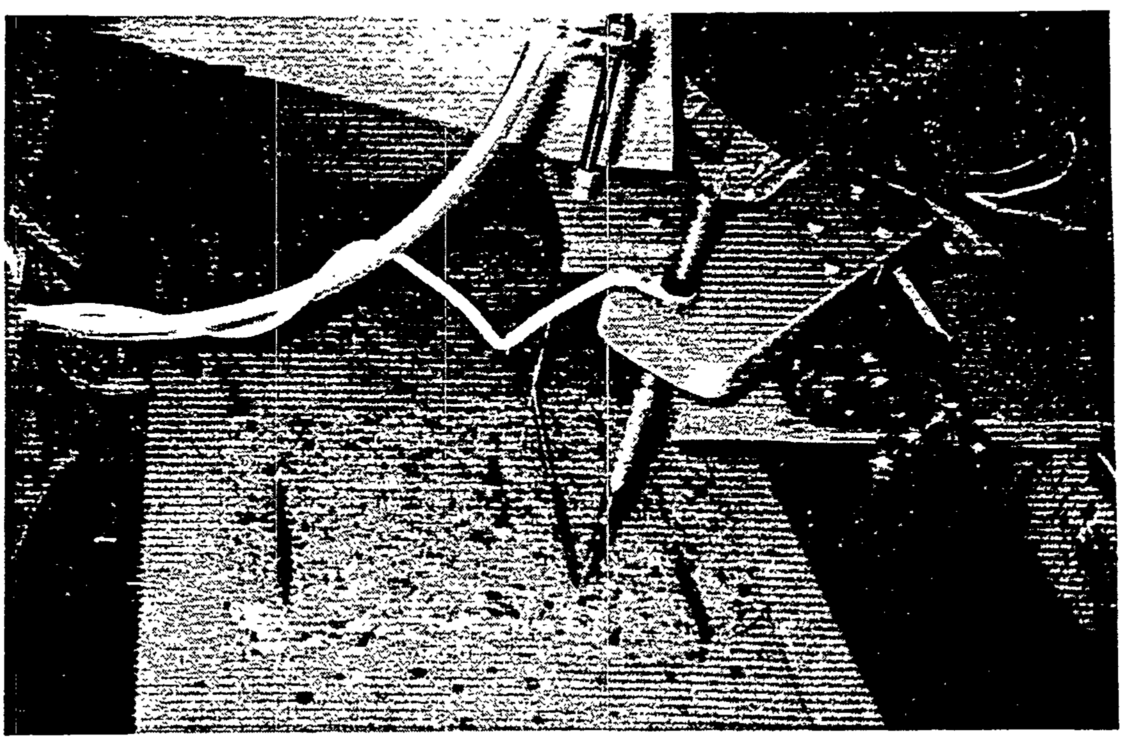


Figure 4 EHS Test Unit #2 for Concrete Floors

(a)



(b)

Figure 5 Photographs of EHS in Progress
(a) Showing Flash of Electric Discharge
(b) Showing Partly Scabbled Surface

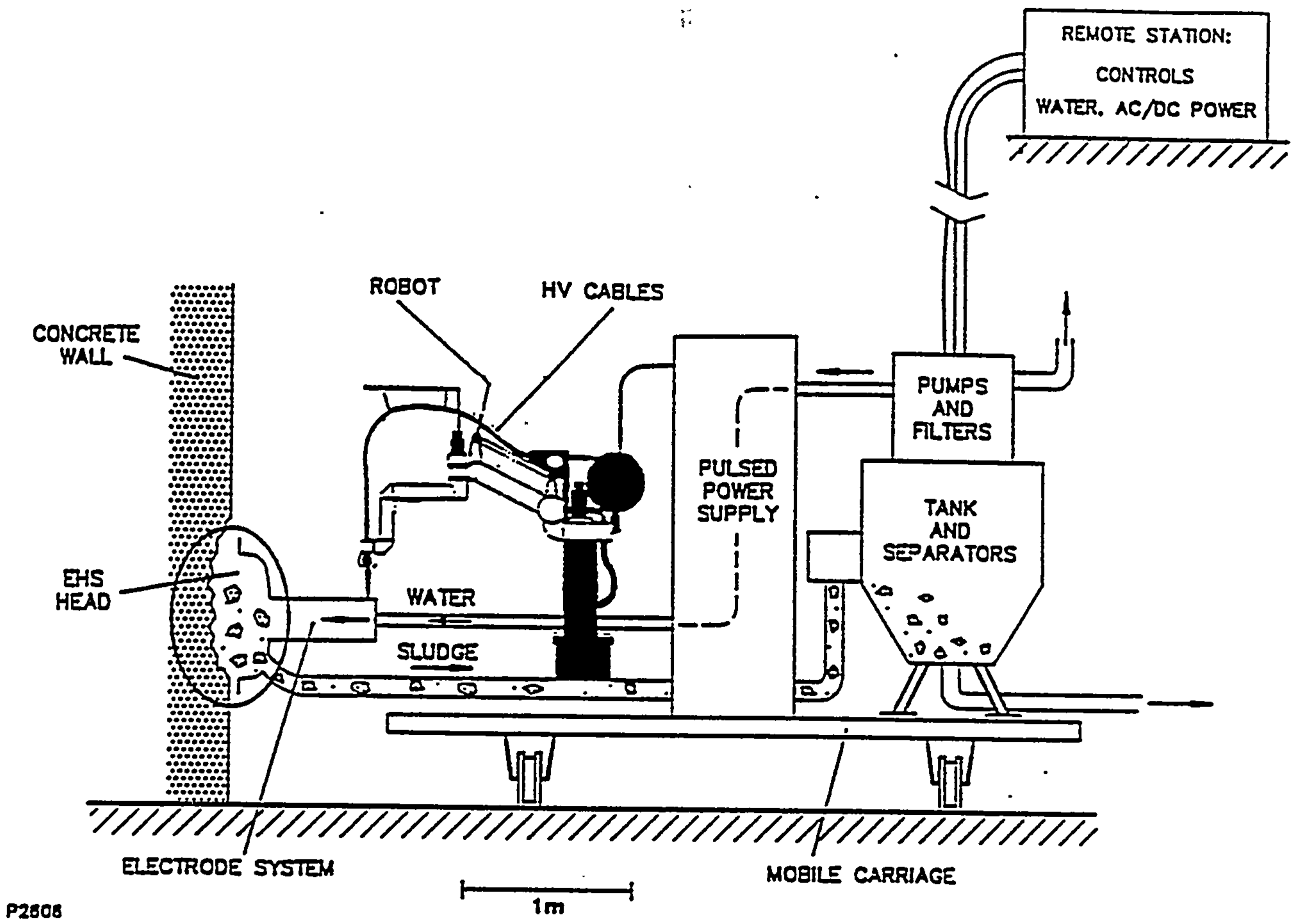


Figure 6 Design of EHS Device for Wall Scabbling

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APPENDIX C

DISCLOSURE OF INVENTION

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TEXTRON DEFENSE SYSTEMS

DISCLOSURE OF INVENTION

PREPARE IN TRIPLICATE. USING AS MANY PAGES AS NECESSARY.

INVENTOR NAME(S)	DEPT.	INVENTOR SIGNATURE(S)	DATE
Goldfarb, V.	ET	V. Goldfarb	Feb. 25, 1994
Woodroffe, J.A.	ET	[signature]	2/25/94
PROJECT OR CONTRACT NO., IF ANY: DE-AC21-93MC30164		DEPT. MGR. SIGNATURE	
DATE OF CONCEPTION: July 1992		WHERE DOCUMENTED (SEE INSTRUCTION 10): Proposal TDS No. B929	
DATE REDUCED TO PRACTICE, IF ANY: October-November 1993		WHERE DOCUMENTED (SEE INSTRUCTION 10)	

TITLE

Concrete Decontamination by Electro-Hydraulic Scabbling

SEE INSTRUCTIONS ON REVERSE SIDE

SEE ATTACHED.

Date Read and Understood by Me	Signature of Witness
2/25/94 P. Kotidis	[signature]
Date Read and Understood by Me 2/25/94	Signature of Witness [signature]

There is a recognized need for controllable removal of surface layers of natural or artificial materials, such as rocks or building materials. Removal of a surface layer of concrete structures - e.g., floors or walls - contaminated by radionuclides, hazardous metals and organic substances is an important example. At many nuclear technology related sites, the contaminants penetrate into the concrete to a significant depth (up to 1-2 inches).

The purpose of this invention is to provide a new concrete decontamination/scabbling technique which combines high productivity, cost effectiveness, environmental/health safety, process controllability, and low volume of secondary waste. Other concrete decontamination methods - mechanical, hydraulic, explosive, thermal, and electric - which are at various stages of development and implementation do not provide the full spectrum of these advantages.

The proposed method is based on the Electro-Hydraulic effect - several phenomena accompanying fast, high-current, spark-like electric discharges in water. A shock wave propagating through water, as well as cavitation generated by turbulent water movement, results in volumetric and surface stressed in the solid contiguous to water. These stresses are able to deform, crack, or break a whole solid body or peel off the surface layer. In the case of concrete, removal of the surface layer (scabbling) occurs.

To achieve the desired scabbling depth and rate, process parameters - pulse energy, duration and frequency, electrode configuration, water layer depth - can be varied and optimized. The concrete rubble (sludge) - contaminated concrete particles of various sizes suspended in water - should be removed by an appropriate sludge transfer/separation/collection system and directed to a waste disposal site. The processing depth should be selected to provide a predetermined level of concrete decontamination that should be appropriate for treatment as a general, nonhazardous waste or reuse.

As should be evident from the description, the whole concrete electro-hydraulic scabbling (EHS) process should be implemented by integration of electric, flow/mechanical, and robotic/controls subsystems in a single unit.

While Electro-Hydraulic effect has found several industrial applications, including complete demolition of building structures, its feasibility for controlled surface scabbling had to be demonstrated. The demonstration experiments were conducted at the TDS laboratory in October-December 1993 under DOE Contract No. DE-AC21-93MC30164.

A simplified schematic of the laboratory scabbling unit is shown in Figure 1, and one of the electrode configurations used to scabble the surface of a 20" x 30" x 4"block is presented in Figure 2. The main process parameters and typical experimental results are listed in Table 1.

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TABLE 1

Operating Voltage	20-23 kV
Storage Capacitance	3.7-7.4 μF
Pulse Energy	2000-3000 J
Operating Frequency	0.8-1.5 Hz
Average DC Power	1.5-3 kW
Electrode Transfer Velocity	0.8-1.3 inch/min
Scabbling Depth	0.5"-1.0"
Scabbling Trace Width	2"-3"
Depth of Water Layer	0.5"-1.0"
Time of Continuous Operation	15 min.
Concrete Removed:	
Volume/Pulse	0.4-1.2 cm^3
Weight/Pulse	0.8-2.5 g
Concrete Area Processed	2-7 in. sq./min
Energy Consumption	0.8-1.5 g/kJ

Thus, the experiments confirmed technical feasibility of the EH scabbling of concrete.

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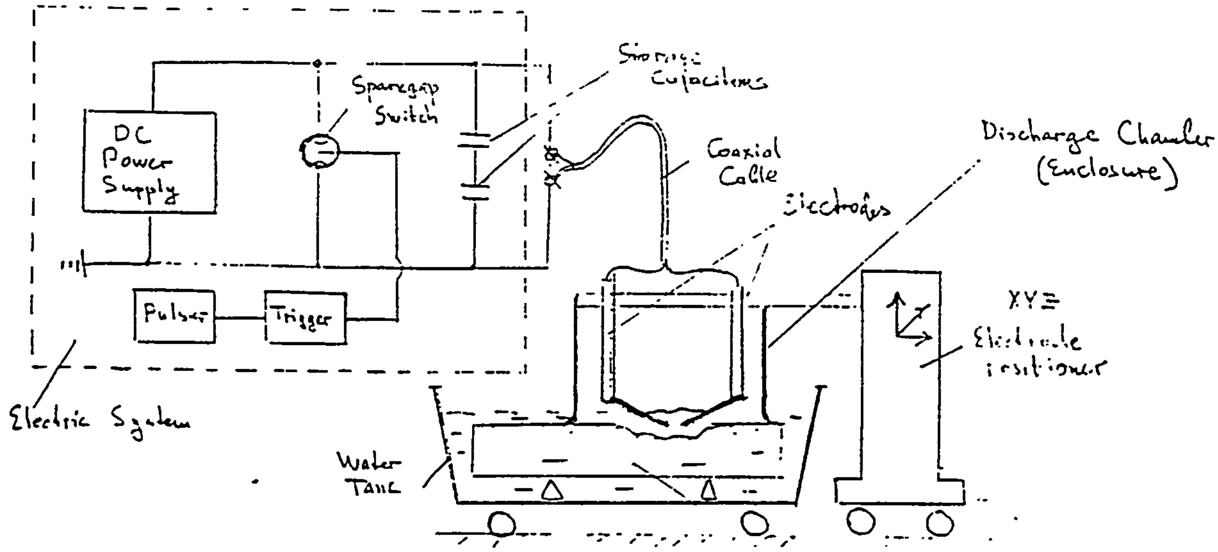
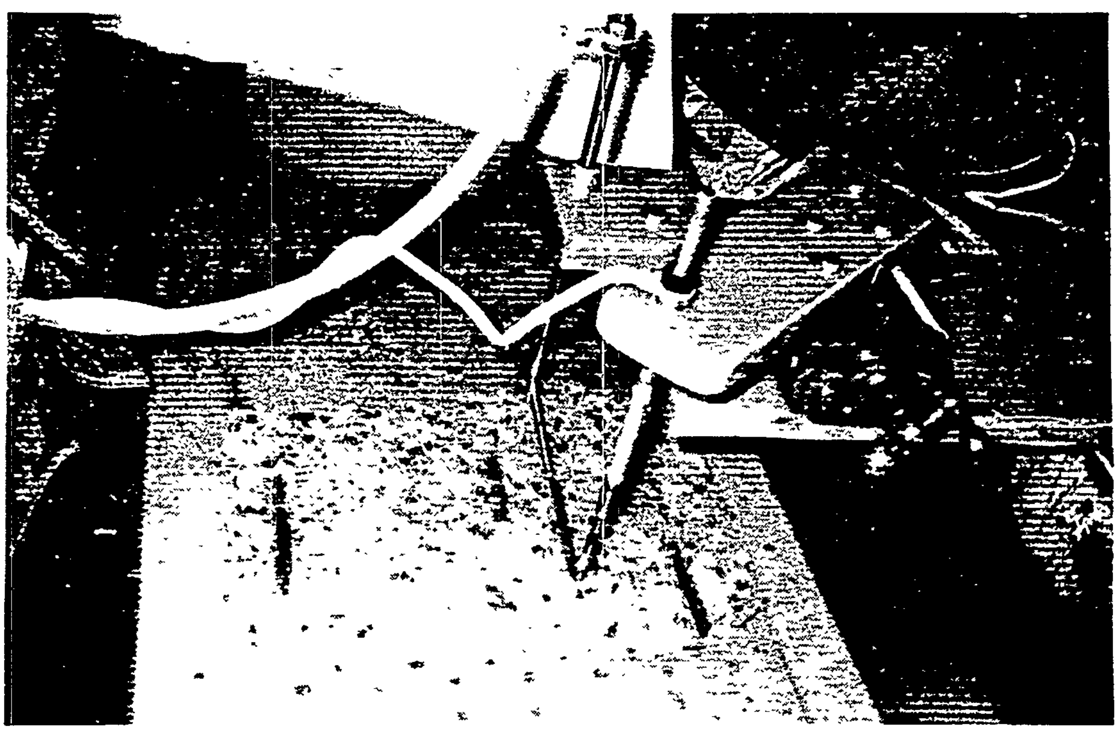


Figure. 1.



(b)

Figure 2

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APPENDIX D

EXCERPTS FROM LITERATURE SURVEY

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9. Radionuclide characterization of reactor decommissioning waste and neutron-activated metals - EDB 93-17 93:104202 93001004398

Robertson, D. E.; Thomas, C. W.; Wynhoff, N. L.; Haggard, D. L.(M)

1993-06 76 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Pacific Northwest Lab., Richland, WA (United States) LOCATION OF WORK- US SPONSORING AGENCY- Nuclear Regulatory Commission, Washington, DC (United States) LITERARY INDICATOR(S)- Numerical Data CONTRACT/GRANT NUMBER- DOEAC06-76RLO1830 REPORT NUMBER(S)- NUREG/CR--5894; PNL--8106 SUBFILE CODE- IMS PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS Document Order Number- TI93016280 SPONSORING ORGANIZATION CODE(S)- NRC CORPORATE ENTRY CODE- 9512268 INCOMING TAPE SERIAL NUMBER- AHC29304%%2 ANNOUNCEMENT IDENTIFICATION- EDB-93:104202 LANGUAGE- English NDN- 108-0581-4470-9

This study is providing the NRC and licensees with a more comprehensive data base for regulatory assessment of the radiological factors associated with reactor decommissioning and disposal of wastes generated during these activities. The objectives of this study are being accomplished during the actual decommissioning of Shippingport Station and the detailed analysis of neutron-activated materials from commercial reactors. The radiological characterization studies of Shippingport decommissioning materials have now been completed, and analyses of dismantled piping and scabbled concrete have shown that neutron activation products, dominated by Co-60, comprised the residual radionuclide inventory. Waste classification assessment have shown that all decommissioning materials (except reactor pressure vessel internals) could be disposed of as Class A waste. Spent fuel disassembly hardware from the Shippingport Core-3 was analyzed for long-lived activation products. Nb-94 and Ni-63 concentrations in Inconel-X750 and stainless steel components exceeded their Class C limits. Measurements and assessments of C-14 in spent fuel disassembly hardware from three commercial nuclear power stations showed that this radionuclide never exceeded the Class C limit for al components. However, the Ni-63 and Nb-94 concentrations in some of these materials did exceed the Class C limits. These measurements are providing the basis for an assessment of the disposal options for these types of highly radioactive materials. Work is continuing on radiological characterization of spent PWR and BWR control rod assemblies. Three control rods, including a BWR cruciform control rod blade, a PWR control rod cluster assembly, and a PWR burnable poison rod assembly, have been characterized for their long-lived activation product concentrations and distribution by direct assay methods. These spent control rods could all be classified as Class C low-level waste. These rods are presently being sampled.

DESCRIPTOR(S)- *BWR TYPE REACTORS --Decommissioning; *LWBR TYPE REACTORS --Decommissioning; *PWR TYPE REACTORS --Decommissioning; *RADIOACTIVE WASTE DISPOSAL --Planning; *SHIPPINGPORT REACTOR --Decommissioning CALVERT CLIFFS-1 REACTOR; CARBON 14; COBALT 60; CONCRETES; CONTAMINATION REGULATIONS; CONTROL ELEMENTS; COOPER REACTOR; EXPERIMENTAL DATA; GAMMA SPECTROSCOPY; INCONEL ALLOYS; IRON 53; LOW-LEVEL RADIOACTIVE WASTES; NICKEL 63; NIOBIUM 94; PIPES; POINT BEACH-1 REACTOR; QUALITATIVE CHEMICAL ANALYSIS; RADIOACTIVE WASTES; RADIOASSAY; SAMPLING; SILVER 108; SILVER 110; SPENT FUELS; STAINLESS STEELS; US NRC IDENTIFIER(S)- ALLOYS; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BETA-PLUS DECAY RADIOISOTOPES; BREEDER REACTORS; BUILDING MATERIALS; BWR TYPE REACTORS; CARBON ISOTOPES; CHEMICAL ANALYSIS; COBALT ISOTOPES; DATA; DAYS LIVING RADIOISOTOPES; ELECTRON CAPTURE RADIOISOTOPES; ENERGY SOURCES; ENRICHED URANIUM REACTORS; EVEN-EVEN NUCLEI; EVEN-ODD NUCLEI; FUELS; HIGH ALLOY STEELS; INFORMATION; INTERMEDIATE MASS NUCLEI; INTERNAL CONVERSION RADIOISOTOPES; IRON ALLOYS; IRON BASE ALLOYS; IRON ISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPES; LIGHT NUCLEI; MANAGEMENT; MATERIALS; MINUTES LIVING RADIOISOTOPES; NATIONAL ORGANIZATIONS; NICKEL ALLOYS; NICKEL BASE ALLOYS; NICKEL ISOTOPES; NIOBIUM ISOTOPES; NUCLEAR FUELS; NUCLEI; NUMERICAL DATA; ODD-ODD NUCLEI; POLLUTION REGULATIONS; POWER REACTORS; PWR TYPE REACTORS; RADIOACTIVE MATERIALS; RADIOACTIVE WASTE MANAGEMENT; RADIOACTIVE WASTES; RADIOISOTOPES; REACTOR COMPONENTS; REACTOR MATERIALS; REACTORS; REGULATIONS; SECONDS LIVING RADIOISOTOPES; SILVER ISOT; SILVER ISOTOPES; SPECTROSCOPY; STEELS; THERMAL REACTORS; US ORGANIZATIONS; WASTE DISPOSAL; WASTE MANAGEMENT; WASTES; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISO; YEARS LIVING RADIOISOT; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 220900.

11. **Electroosmotic decontamination of concrete - EDB 93-18 93:096061 93000957039**

Bostick, W. D.; Bush, S. A.; Marsh, G. C.; Henson, H. M., (Oak Ridge K-25 Site, TN (United States)); Box, W. D.; Morgan, I. L., (Oak Ridge National Lab., TN (United States))(M)

1993-03 73 page(s) DOCUMENT TYPE- Report AUTHOR AFFILIATION- Oak Ridge K-25 Site, TN (United States); Oak Ridge National Lab., TN (United States) CORPORATE AUTHOR- Oak Ridge K-25 Site, TN (United States) LOCATION OF WORK- US SPONSORING AGENCY- USDOE, Washington, DC (United States) CONTRACT/GRANT NUMBER- DOEAC05-84OT21400 REPORT NUMBER(S)- K/TCD--1054 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE93010258 SPONSORING ORGANIZATION CODE(S)- DOE CORPORATE ENTRY CODE- 9528600 ANNOUNCEMENT IDENTIFICATION- EDB-93:096061 LANGUAGE- English NDN- 108-0580-6548-2

A method is described for the electroosmotic decontamination of concrete surfaces, in which an electrical field is used to induce migration of ionic contaminants from porous concrete into an electrolyte solution that may be disposed of as a low-level liquid radioactive waste (LLRW); alternately, the contaminants from the solution can be sorbed onto anion exchange media in order to prevent contaminant buildup in the solution and to minimize the amount of LLRW generated. We have confirmed the removal of uranium (and infer the removal of sup 99 Tc) from previously contaminated concrete surfaces. In a typical experimental configuration, a stainless steel mesh is placed in an electrolyte solution contained within a diked cell to serve as the negative electrode (cathode) and contaminant collection medium, respectively, and an existing metal penetration (e.g., piping, conduit, or rebar reinforcement within the concrete surface) serves as the positive electrode (anode) to complete the cell. Typically we have achieved 70 to >90% reductions in surface activity by applying <400 V and <1 A for 1--3 h (energy consumption of 0.4--12 kWh/ft sup 2).

DESCRIPTOR(S)- *CONCRETES --Decontamination ELECTRIC FIELDS; ELECTRODES; ELECTRODYNAMICS; LOW-LEVEL RADIOACTIVE WASTES; ORGDP; TECHNETIUM 99; URANIUM IDENTIFIER(S)- ACTINIDES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; CLEANING; ELEMENTS; GASEOUS DIFFUSION PLANTS; HOURS LIVING RADIOISOTOPES; INDUSTRIAL PLANTS; INTERMEDIATE MASS NUCLEI; INTERNAL CONVERSION RADIOISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPE SEPARATION PLANTS; ISOTOPES; MATERIALS; METALS; NATIONAL ORGANIZATIONS; NUCLEAR FACILITIES; NUCLEI; ODD-EVEN NUCLEI; RADIOACTIVE MATERIALS; RADIOACTIVE WASTES; RADIOISOTOPES; TECHNETIUM ISOTOPES; US DOE; US ERDA; US ORGANIZATIONS; WASTES; YEARS LIVING RADIOI SECTIONAL CLASSIFICATION CODE- 052001.

18. **Final report of the decontamination and decommissioning of the BORAX-V facility turbine building - EDB 93-12. 93:069136 93000972079**

Arave, A. E.; Rodman, G. R.(M)

1992-12 45 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- EG and G Idaho, Inc., Idaho Falls, ID (United States) LOCATION OF WORK- US SPONSORING AGENCY- USDOE, Washington, DC (United States) LITERARY INDICATOR(S)- Progress Report CONTRACT/GRANT NUMBER- DOEAC07-76ID01570 REPORT NUMBER(S)- EGG--2683 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE93012142 SPONSORING ORGANIZATION CODE(S)- DOE CORPORATE ENTRY CODE- 9507781 ANNOUNCEMENT IDENTIFICATION- EDB-93:069136 LANGUAGE- English NDN- 108-0577-7305-5

The Boiling Water Reactor Experiment (BORAX)-V Facility Turbine Building Decontamination and Decommissioning (D&D) Project is described in this report. The BORAX series of five National Reactor Testing Station (NRTS) reactors pioneered intensive work on boiling water reactor (BWR) experiments conducted between 1953 and 1964. Facility characterization, decision analyses, and D&D plans for the turbine building were prepared from 1979 through 1990. D&D activities of the turbine building systems were initiated in November of 1988 and completed with the demolition and backfill of the concrete foundation in March 1992. Due to the low levels of radioactivity and the absence of loose contamination, the D&D activities were completed with no radiation exposure to the workers. The D&D activities were performed in a manner that no radiological health or safety hazard to the public or to personnel at the Idaho National Engineering Laboratory (INEL) remain.

DESCRIPTOR(S)- *BORAX-5 REACTOR --Decommissioning; *BUILDINGS --Demolition BACKFILLING; CONCRETES; DECONTAMINATION; PROGRESS REPORT; RADIATION MONITORING; REACTOR SAFETY; TURBINES IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; DOCUMENT TYPES; ENRICHED URANIUM REACTORS; EQUIPMENT; MACHINERY; MATERIALS; MONITORING; POWER REACTORS; REACTORS; RESEARCH AND TEST REACTORS; SAFETY; TANK TYPE REACTORS; TEST REACTORS; THERMAL REACTORS; TURBOMACHINERY; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

28. **Migration of uranium in old mine concretes: implications for the behaviour of cementitious barriers in a radioactive waste repository** - EDB 92-20 92:152138 92000840320

Rougeau, P.; Menager, M. T.; Thomassin, J. H.; Pineau, F.

JOURNAL NAME- Geochronique (France) ABBREVIATED JOURNAL TITLE- Geochronique NO. 42 1992-05 PP. 89 DOCUMENT TYPE- Journal Article ISSN- 0292-8477 CODEN- GECHD LOCATION OF WORK- FR LITERARY INDICATOR(S)- Conference; Short Communication REPORT NUMBER(S)- CONF-9208126-- SUBFILE CODE- FRN PUBLICATION COUNTRY- FR CONFERENCE DATE- 24 Aug - 3 Sep 1992 CONFERENCE TITLE- 29. Geological International Congress CONFERENCE LOCATION- Kyoto (Japan) ANNOUNCEMENT CODE- EDB; ETD INCOMING TAPE SERIAL NUMBER- FR9203359 ANNOUNCEMENT IDENTIFICATION- FRD-92:003359; EDB-92:152138 LANGUAGE- English NDN- 108-0567-1669-6

Short communication.

DESCRIPTOR(S)- *CONCRETES --Adsorption; *CONCRETES --Comparative evaluations; *CONCRETES --Radioactive waste disposal; *CONCRETES --Uranium mines; *NATURAL URANIUM --Leaching; *NATURAL URANIUM --Radionuclide migration GEOCHEMISTRY; GROUND WATER; ROCK-FLUID INTERACTIONS IDENTIFIER(S)- ACTINIDES; BUILDING MATERIALS; CHEMISTRY; DISSOLUTION; ELEMENTS; ENVIRONMENTAL TRANSPORT; EVALUATION; HYDROGEN COMPOUNDS; MANAGEMENT; MASS TRANSFER; MATERIALS; METALS; MINES; OXYGEN COMPOUNDS; RADIOACTIVE WASTE MANAGEMENT; SEPARATION PROCESSES; SORPTION; UNDERGROUND FACILITIES; URANIUM; WASTE DISPOSAL; WASTE MANAGEMENT; WATER SECTIONAL CLASSIFICATION CODE- 540230.

41. **Wash-off effects in urban areas** - EDB 92-04 92:021323 92000846802

Mueck, K.; Steger, F., (Oesterreichisches Forschungszentrum Seibersdorf GmbH (Austria))

JOURNAL NAME- Radiation Protection Dosimetry (United Kingdom) ABBREVIATED JOURNAL TITLE- Radiat. Prot. Dosim. VOL. 37 NO. 3 1991 PP. 189-194 DOCUMENT TYPE- Journal Article ISSN- 0144-8420 CODEN- RPDOD AUTHOR AFFILIATION- Oesterreichisches Forschungszentrum Seibersdorf GmbH (Austria) LOCATION OF WORK- AT SUBFILE CODE- GBN PUBLICATION COUNTRY- GB ANNOUNCEMENT CODE- EDB; ETD INCOMING TAPE SERIAL NUMBER- GB9105183014481 ANNOUNCEMENT IDENTIFICATION- AIX-23:014481; EDB-92:021323 LANGUAGE- English NDN- 108-0554-2874-9

The reduction of the activity distributed in urban areas in three Austrian cities after a radioactive fall-out, by run-off and wash-off effects from stabilised surfaces and the resulting dose reduction to the population were investigated four years after the Chernobyl fall-out to predict the long term external exposure of the population. The measurements were performed in cities with different fractions of dry and wet deposition after the Chernobyl accident in order to determine whether any differences in radionuclide removal with regard to wet and dry fall-out was observable. High resolution in situ gamma spectroscopy was employed to measure the gamma flux from sup 137 Cs and sup 134 Cs at points over stabilised surfaces, which was then compared with undisturbed grass surfaces. The average reduction of the place activity on stabilised surfaces amounted to a factor of 10 +- 5 compared to the original deposition after the fall-out. Asphalt showed the highest reduction factor (11.4), concrete less (8.1), stone slabs and cobblestone only about 4.5 and gravel virtually no reduction (1.1). Only very little variation of this reduction with dry or wet deposition was observed. (author).

DESCRIPTOR(S)- *GLOBAL FALLOUT --Surface contamination; *GLOBAL FALLOUT --Urban areas; *SURFACE CONTAMINATION --Global fallout; *SURFACE CONTAMINATION --Urban areas ASPHALTS; AUSTRIA; CESIUM 137; CHERNOBYLSK-4 REACTOR; CONCRETES; DEPOSITION; FALLOUT DEPOSITS; RADIATION DOSES; REACTOR ACCIDENTS; SOILS IDENTIFIER(S)- ACCIDENTS; ALKALI METAL ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BITUMENS; BUILDING MATERIALS; CESIUM ISOTOPES; CONTAMINATION; DEVELOPED COUNTRIES; DOSES; ENRICHED URANIUM REACTORS; EUROPE; FALLOUT; GRAPHITE MODERATED REACTORS; INTERMEDIATE MASS NUCLEI; ISOTOPES; LWGR TYPE REACTORS; MATERIALS; NUCLEI; ODD-EVEN NUCLEI; ORGANIC COMPOUNDS; OTHER ORGANIC COMPOUNDS; POWER REACTORS; RADIOISOTOPES; REACTORS; TAR; THERMAL REACTORS; WATER COOLED REACTORS; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 070602.

42. **Results of the Radiological Survey at Conviber, Inc., 844 Garfield Street, Springdale, Pennsylvania (CVP001) - EDB 92-04 92:021276 92000822389**

Foley, R. D.; Cottrell, W. D.; Crutcher, J. W.(M)

1991-10 19 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Oak Ridge National Lab., TN (United States). Health and Safety Research Div. LOCATION OF WORK- US SPONSORING AGENCY- USDOE, Washington, DC (United States) CONTRACT/GRANT NUMBER- DOEAC05-84OR21400 REPORT NUMBER(S)- ORNL/RASA--89/18 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE92004589 SPONSORING ORGANIZATION CODE(S)- DOE CORPORATE ENTRY CODE- 9501950 ANNOUNCEMENT IDENTIFICATION- EDB-92:021276 LANGUAGE- English NDN- 108-0554-2827-0

As part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), the US Department of Energy (DOE) is implementing a radiological survey program to determine the radiological conditions at sites that were used by the department's predecessor agencies. During the mid-1940s, and possibly continuing until 1951, the Conviber site in Springdale, Pennsylvania, was used to machine extruded uranium in support of government efforts. In 1980 a radiological scanning survey of this site was conducted by DOE and Argonne National Laboratory (ANL) staffs. Their report noted one anomaly: elevated radiation levels over a small area inside the building where uranium had been machined. Because much of the floor was inaccessible, for surveying and because of the lack of definitive records documenting use of this site, a comprehensive radiological assessment was recommended. The radiological survey discussed in this report for the site of Conviber, Inc., Springdale, Pennsylvania, was conducted by members of the Measurement Applications and Development Group of Oak Ridge National Laboratory in June of 1989. The survey included a surface gamma scan, collection of concrete and soil samples, and measurement of direct and removable alpha and beta-gamma contamination. One indoor location with a gamma measurement of 20 mu R/h was found. In June of 1990 ORNL staff returned to investigate the location with elevated gamma. A hole was drilled through the concrete, gamma measurements were taken, and soil samples were obtained for analyses. In these eight indoor soil samples, concentrations of sup 238 U ranged from 90 to 20,000 pCi/g. However, under current site use, residual uranium covered by concrete does not pose a health risk.

DESCRIPTOR(S)- *BUILDINGS --Contamination; *URANIUM 238 --Radiation monitoring CONCRETES; GAMMA RADIATION; PENNSYLVANIA; REMEDIAL ACTION; SAMPLING; SOILS; THORIUM IDENTIFIER(S)- ACTINIDE ISOTOPES; ACTINIDE NUCLEI; ACTINIDES; ALPHA DECAY RADIOISOTOPES; BUILDING MATERIALS; DEVELOPED COUNTRIES; ELECTROMAGNETIC RADIATION; ELEMENTS; EVEN-EVEN NUCLEI; FEDERAL REGION III; HEAVY NUCLEI; IONIZING RADIATIONS; ISOTOPES; MATERIALS; METALS; MONITORING; NORTH AMERICA; NUCLEI; RADIATIONS; RADIOISOTOPES; SPONTANEOUS FISSION RADIOISOTOPES; URANIUM ISOTOPES; USA; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 054000.

54. Engineering evaluation/cost analysis for the proposed removal of contaminated materials from pad 1 at the Elza Gate site, Oak Ridge, Tennessee - EDB 91-05 91:026770 91000391068

NO-AUTHOR

1990-09 38 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Argonne National Lab., IL (USA) LOCATION OF WORK- US CONTRACT/GRANT NUMBER- DOEW-31109-ENG-38 REPORT NUMBER(S)- DOE/OR--23701-37.2 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE91006014 SPONSORING ORGANIZATION CODE(S)- DOE/NE CORPORATE ENTRY CODE- 0448000 ANNOUNCEMENT IDENTIFICATION- EDB-91:026770; NTS-91:008802; INS-91:004700; ERA-91:009767 LANGUAGE- English NDN- 108-0538-3653-8

This engineering evaluation/cost analysis (EE/CA) has been prepared in support of the proposed removal action for cleanup of radioactively contaminated concrete and soil beneath a building on privately owned commercial property in Oak Ridge, Tennessee. The property, known as the Elza Gate site, became contaminated with uranium-238, radium-226, thorium-232, thorium-230, and decay products as a result of the Manhattan Engineer District storing uranium ore and ore processing residues at the site in the early 1940s. The US Department of Energy (DOE) has responsibility for cleanup of the property under its Formerly Utilized Sites Remedial Action Program (FUSRAP). The DOE plans to remove the cracked and worn concrete pad and contaminated subsoil beneath the pad, after which the property owner/tenant will provide clean backfill and new concrete. Portions of the pad and subsoil are contaminated and, if stored or disposed of improperly, may represent a potential threat to public health or welfare and the environment. The EE/CA report is the appropriate documentation for the proposed removal action, as identified in guidance from the US Environmental Protection Agency. The objective of the EE/CA report, in addition to identifying the planned removal action, is to document the selection of response activities that will mitigate the potential for release of contaminants from the property into the environment and minimize the related threats to public health or welfare and the environment. 7 refs., 2 figs., 3 tabs.

DESCRIPTOR(S)- *CONCRETES --Decontamination; *OAK RIDGE RESERVATION --Remedial action; *SOILS --Decontamination COST ESTIMATION; CRACKS; DOCUMENTATION; ENVIRONMENTAL IMPACTS; MANHATTAN PROJECT; PUBLIC HEALTH; RADIATION HAZARDS; RADIOACTIVE WASTES; RADIUM 226; THORIUM 230; THORIUM 232; URANIUM 238; URANIUM ORES; US DOE; US EPA IDENTIFIER(S)- ACTINIDE ISOTOPES; ACTINIDE NUCLEI; ALKALINE EARTH ISOTOPES; ALPHA DECAY RADIOISOTOPES; BUILDING MATERIALS; CARBON 14 DECAY RADIOISOTOPES; CLEANING; EVEN-EVEN NUCLEI; HAZARDS; HEALTH HAZARDS; HEAVY ION DECAY RADIOISOTOPES; HEAVY NUCLEI; ISOTOPES; MATERIALS; NATIONAL ORGANIZATIONS; NEON 24 DECAY RADIOISOTOPES; NUCLEI; ORES; RADIOACTIVE MATERIALS; RADIOISOTOPES; RADIUM ISOTOPES; THORIUM ISOTOPES; URANIUM ISOTOPES; US DOE; US ERDA; US ORGANIZATIONS; WASTES; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 054000.

57. Engineering evaluation/cost analysis for the proposed removal of contaminated materials from Pad 1 at the Elza Gate site, Oak Ridge, Tennessee - EDB 90-15 90:107038 90000276825

NO-AUTHOR

1990-06 36 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Argonne National Lab., IL (USA). Environmental Assessment and Information Sciences Div. LOCATION OF WORK- US CONTRACT/GRANT NUMBER- DOEW-31109-ENG-38 REPORT NUMBER(S)- DOE/OR--23701-37.1 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE90013535 SPONSORING ORGANIZATION CODE(S)- DOE/NE CORPORATE ENTRY CODE- 9526936 ANNOUNCEMENT IDENTIFICATION- INS-90:021676; NTS-90:018449; EDB-90:107038; ERA-15:038692 LANGUAGE- English NDN- 108-0528-0313-6

This engineering evaluation/cost analysis (EE/CA) has been prepared in support of the proposed removal action for cleanup of radioactively contaminated concrete and soil beneath a building on privately owned commercial property in Oak Ridge, Tennessee. The property, known as the Elza Gate site, became contaminated with uranium-238, radium-226, thorium-232, thorium-230, and decay products as a result of the Manhattan Engineer District storing uranium ore and ore processing residues at the site in the early 1940s. The US Department of Energy (DOE) has responsibility for cleanup of the property under its Formerly Utilized Sites Remedial Action Program (FUSRAP). The DOE plans to remove the cracked and worn concrete pad and contaminated subsoil beneath the pad, after which the property owner/tenant will provide clean backfill and new concrete. Portions of the pad and subsoil are contaminated and, if stored or disposed of improperly, may represent a potential threat to public health or welfare and the environment. The EE/CA report is the appropriate documentation for the proposed removal action, as identified in guidance from the US Environmental Protection Agency. the objective of the EE/CA report, in addition to identifying the planned removal action, is to document the selection of response activities that will mitigate the potential for release of contaminants from the property into the environment and minimize the related threats to public health or welfare and the environment. 7 refs., 2 figs., 3 tabs.

DESCRIPTOR(S)- *ABANDONED SITES --Remedial action; *CONCRETES --Contamination; *RADIOACTIVE MATERIALS --Removal; *RADIUM 226 --Radioecological concentration; *SOILS --Contamination; *THORIUM 230 --Radioecological concentration; *THORIUM 232 --Radioecological concentration; *URANIUM 238 --Radioecological concentration CLEANING; COST BENEFIT ANALYSIS; DAUGHTER PRODUCTS; EVALUATION; HEALTH HAZARDS; OAK RIDGE IDENTIFIER(S)- ACTINIDE ISOTOPES; ACTINIDE NUCLEI; ALKALINE EARTH ISOTOPES; ALPHA DECAY RADIOISOTOPES; BUILDING MATERIALS; CARBON 14 DECAY RADIOISOTOPES; ECOLOGICAL CONCENTRATION; EVEN-EVEN NUCLEI; FEDERAL REGION IV; HAZARDS; HEAVY ION DECAY RADIOISOTOPES; HEAVY NUCLEI; ISOTOPES; MATERIALS; NEON 24 DECAY RADIOISOTOPES; NORTH AMERICA; NUCLEI; RADIOISOTOPES; RADIUM ISOTOPES; TENNESSEE; THORIUM ISOTOPES; URANIUM ISOTOPES; USA; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 054000.

58. Evaluation of contamination on concrete of JPDR building - EDB 90-12 90:085613 90000252857

Yasunaka, H.; Hatakeyama, M.; Sukegawa, T.; Kozaki, T.; Yamashita, S.; Hoshi, T., (Japan Atomic Energy Research Inst., Naka, Ibaraki (Japan))(A); Feizollahi, F.; Kohout, R.; Suzuki, A(M)

1989 PP. 183-188 658 page(s) DOCUMENT TYPE- Book Analytic MONOGRAPH TITLE- Low and intermediate level radioactive waste management AUTHOR AFFILIATION- Japan Atomic Energy Research Inst., Naka, Ibaraki (Japan) LOCATION OF WORK- JP LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-891006-- SUBFILE CODE- NOV PUBLISHER- American Society of Mechanical Engineers PUBLICATION PLACE- New York, NY (USA) PUBLICATION COUNTRY- US CONFERENCE DATE- 23-28 Oct 1989 CONFERENCE TITLE- Joint international waste management conference CONFERENCE LOCATION- Kyoto (Japan) ANNOUNCEMENT CODE- EDB; ETD; INS INCOMING TAPE SERIAL NUMBER- 90:011414 ANNOUNCEMENT IDENTIFICATION- NOV-90:011414; INS-90:016075; EDB-90:085613 LANGUAGE- English NDN- 108-0525-8894-8

Decontamination of radioactive contaminated concrete in a nuclear facility is indispensable for reducing the amount of radioactive concrete waste and also for treating its building without any regulatory restriction when it is decommissioned. It is, therefore, necessary to estimate exactly the situation of radioactive contamination such as distribution and penetration depth of contamination of concrete floors and walls in the buildings before demolition. In the Japan power demonstration reactor (JPDR), the situation of the contamination of the buildings was estimated by radioactivity measurement of concrete samples from the buildings before demolition. The results of the measurement are presented.

DESCRIPTOR(S)- *CONCRETES --Cleaning; *JPDR REACTOR --Decontamination CUTTING TOOLS; DOSIMETRY; REACTOR DECOMMISSIONING IDENTIFIER(S)- BUILDING MATERIALS; BWR TYPE REACTORS; CLEANING; DECOMMISSIONING; ENRICHED URANIUM REACTORS; EXPERIMENTAL REACTORS; MATERIALS; POWER REACTORS; REACTORS; RESEARCH AND TEST REACTORS; THERMAL REACTORS; TOOLS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

59. Demonstration experience with an abrasive blasting technique for decontaminating concrete pads - EDB 90-11 90:076092 90000238157

Devgun, J. S., (Argonne National Lab., IL (USA)); Land, R. R., (Bechtel National, Inc., Oak Ridge, TN (USA)); Doane, R. W., (TMA/Eberline, Oak Ridge, TN (USA))(M)

8 page(s) DOCUMENT TYPE- Report AUTHOR AFFILIATION- Argonne National Lab., IL (USA); Bechtel National, Inc., Oak Ridge, TN (USA); TMA/Eberline, Oak Ridge, TN (USA) CORPORATE AUTHOR- Argonne National Lab., IL (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference CONTRACT/GRANT NUMBER- DOEW-31109-ENG-38 REPORT NUMBER(S)- CONF-900210--46 SUBFILE CODE- TIC PUBLICATION COUNTRY- US CONFERENCE DATE- 25 Feb - 1 Mar 1990 CONFERENCE TITLE- 16. annual waste management symposium: working towards a cleaner environment CONFERENCE LOCATION- Tucson, AZ (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE90010082 SPONSORING ORGANIZATION CODE(S)- DOE/NE CORPORATE ENTRY CODE- 0448000 ANNOUNCEMENT IDENTIFICATION- NTS-90:014538; INS-90:013925; EDB-90:076092; ERA-15:030163 LANGUAGE- English NDN- 108-0524-9374-3

A demonstration was performed for decontaminating a radioactivity contaminated concrete pad with a portable abrasive blasting system. The system utilizes a rotating blast wheel that scours the concrete surface with metal abrasive. The metal abrasive, pulverized concrete dust, and contaminants rebound into a separator chamber. The reusable metal abrasive is recycled, and the pulverized media are removed to an integral dust collection system. The exhaust is HEPA filtered to minimize release of airborne contaminants. However, the technique had limited success in reducing contamination around the cracks and seams in the concrete where the higher activity levels of contamination were detected during the radiological survey before the cleanup. The technique can be successful and cost-effective in decontaminating large areas of low contamination; however, careful characterization and planning are necessary. 3 refs., 3 figs., 1 tabs.

DESCRIPTOR(S)- *CONCRETES --Decontamination; *EXPLOSIVE FRACTURING --Demonstration programs ABRASIVES; DUST COLLECTORS; ENVIRONMENTAL EXPOSURE; GAMMA RADIATION; OAK RIDGE; PARTICULATES; PLANNING; PORTABLE EQUIPMENT; RADIUM 226; REMEDIAL ACTION; SEPARATION PROCESSES; SITE SURVEYS; SURFACE CONTAMINATION; THORIUM 230; THORIUM 232; URANIUM 238 IDENTIFIER(S)- ACTINIDE ISOTOPES; ACTINIDE NUCLEI; ALKALINE EARTH ISOTOPES; ALPHA DECAY RADIOISOTOPES; BUILDING MATERIALS; CARBON 14 DECAY RADIOISOTOPES; CLEANING; COMMINUTION; CONTAMINATION; ELECTROMAGNETIC RADIATION; EQUIPMENT; EVEN-EVEN NUCLEI; FEDERAL REGION IV; FRACTURING; HEAVY ION DECAY RADIOISOTOPES; HEAVY NUCLEI; IONIZING RADIATIONS; ISOTOPES; MATERIALS; NEON 24 DECAY RADIOISOTOPES; NORTH AMERICA; NUCLEI; PARTICLES; RADIATIONS; RADIOISOTOPES; RADIUM ISOTOPES; TENNESSEE; THORIUM ISOTOPES; URANIUM ISOTOPES; USA; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 054000.

83. Progress in the release of the Shippingport site and materials - EDB 90-03
90:016386 90000184098

Eger, K. J.; Galgoul, M. J.; Gardner, D. L.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 59 1989 PP. 66-67 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-890604-- SUBFILE CODE- UMT PUBLICATION COUNTRY- US CONFERENCE DATE- 4-8 Jun 1989 CONFERENCE TITLE- Annual meeting of the American Nuclear Society CONFERENCE LOCATION- Atlanta, GA (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT9001%%52 ANNOUNCEMENT IDENTIFICATION- EDB-90:016386; INS-90:004070; ERA-15:013479 LANGUAGE- English NDN- 108-0518-9695-7

The decommissioning of the Shippingport atomic power station involved not only the disassembly of the nuclear side of the plant, but also the disposition of the site structures and equipment by release or by disposal as radwaste. The simple burial of all of this material would have been prohibitively expensive. Furthermore, it would have been unnecessary, since the vast majority of the material had had little (if any) contact with radioactivity. To save these costs, as well as to protect the public, the materials had to be classified so that the clean materials could be released from the site (or with the site) for unrestricted use. Two separate programs were developed and implemented during the Shippingport Station Decommissioning Project (SSDP) to do just this. The purpose of the material release program was to verify that any material released from the site had met the requirements in Regulatory Guide 1.86. This program included the consideration of prior survey results and the use of the materials, an initial survey for release from radiologically controlled areas, and a documented release survey just prior to the removal of any material from the site. The US Department of Energy (DOE) criteria for the release of the site for unrestricted use required that the total dose to the maximum exposed individual not exceed 1 mSv/yr by the worst-case scenario, and in addition be as low as reasonably achievable (ALARA). The DOE also provided a manual for relating the amount of radioactive material in the soil to this annual dose.

DESCRIPTOR(S)- *REACTOR DECOMMISSIONING --Radioactive waste management; *REACTOR DECOMMISSIONING --Waste management; *REACTOR MATERIALS --Classification; *SHIPPINGPORT REACTOR --Reactor decommissioning ALARA; CONCRETES; DECONTAMINATION; DOCUMENTATION; ECONOMICS; OILS; RADIATION DOSES; RADIATION PROTECTION; REACTOR DISMANTLING; SAMPLING; SITE CHARACTERIZATION; US DOE; US NRC IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; DECOMMISSIONING; DEMOLITION; DOSES; ENRICHED URANIUM REACTORS; MANAGEMENT; MATERIALS; NATIONAL ORGANIZATIONS; ORGANIC COMPOUNDS; OTHER ORGANIC COMPOUNDS; POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; US ORGANIZATIONS; WASTE MANAGEMENT; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

84. Contaminated concrete scabbling at the Shippingport station decommissioning project - EDB 90-03 90:016381 90000164089

Bauer, R. G.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 59 1989 PP. 67 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-890604-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 4-8 Jun 1989 CONFERENCE TITLE- Annual meeting of the American Nuclear Society CONFERENCE LOCATION- Atlanta, GA (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT9001%%53 ANNOUNCEMENT IDENTIFICATION- EDB-90:016381; INS-90:004064; ERA-15:013460 LANGUAGE- English NDN- 108-0518-9690-8

The Shippingport atomic power station was the first commercial nuclear power plant in the United States, joining the Duquesne Light Company (DLC) grid in December 1957. The Shippingport station was shut down in October 1982 and defueled in preparation for dismantling. On September 6, 1984, the Shippingport Station Decommissioning Project (SSDP) office of the US Department of Energy (DOE) assumed responsibility for the site. At turnover, there were several areas in the plant where radioactive contamination was entrained in concrete surfaces. The removal of contaminated concrete at SSDP was an important part of the decontamination to meet site release criteria, which is a major consideration in the decommissioning of nuclear power reactors. The highlights of this activity include: (1) development and application of remote scabbling tools, which effectively removed the contaminated concrete surfaces, and (2) use of scabblers minimized the removal of noncontaminated concrete by removing shallow layers of the surface and contributed to waste control, since the waste form enabled good packaging efficiency.

DESCRIPTOR(S)- *CONCRETES --Removal; *DISCHARGE CANALS --Concretes; *SHIPPINGPORT REACTOR --Reactor decommissioning COBALT 60; DECONTAMINATION; EFFICIENCY; PACKAGING; RADIATION DOSES; REACTOR DISMANTLING; REACTOR FUELING; TOOLS; US DOE; USA IDENTIFIER(S)- BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; CLEANING; COBALT ISOTOPES; DECOMMISSIONING; DEMOLITION; DOSES; ENRICHED URANIUM REACTORS; INTERMEDIATE MASS NUCLEI; INTERNAL CONVERSION RADIOISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPES; MATERIALS; MINUTES LIVING RADIOISOTOPES; NATIONAL ORGANIZATIONS; NORTH AMERICA; NUCLEI; ODD-ODD NUCLEI; POWER REACTORS; PWR TYPE REACTORS; RADIOISOTOPES; REACTORS; THERMAL REACTORS; US ORGANIZATIONS; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISOT SECTIONAL CLASSIFICATION CODE- 220900.

86. **Surface decontamination utilizing mechanical vacuum blasting methods - EDB 89-22 89:152699 89000123248**

McKernan, M. L.; Schulmeister, A. R.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 56 1988 PP. 79-81 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-880601-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 12-16 Jun 1988 CONFERENCE TITLE- American Nuclear Society annual meeting CONFERENCE LOCATION- San Diego, CA (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT8925%%332-MH ANNOUNCEMENT IDENTIFICATION- EDB-89:152699; INS-89:027129 LANGUAGE- English NDN- 108-0515-2190-1

As part of the Shippingport Station Decommissioning Project (SSDP) surface decontamination effort, vacuum blasting techniques were utilized to remove fixed radioactive contamination entrained in steel and concrete painted surfaces to meet on-site and off-site release limits. Removal of contaminated paint by vacuum blasting was restricted to selected areas of the project. Specifically, this technique was applied only when it was determined to be cost-effective compared to other methods of paint removal or direct disposal of the bulk material as contaminated waste. As the lower portions of the reactor plant container painted steel surface was eligible for this surface decontamination technique. A performance summary of the results obtained using vacuum blasting is included. Based on these results, it is concluded that application of vacuum blasting techniques was effective in terms of removal rate, person-hours expended, and waste generated.

DESCRIPTOR(S)- *REACTOR DECOMMISSIONING --Decontamination; *SHIPPINGPORT REACTOR --Reactor decommissioning ABRASIVES; CONCRETES; PAINTS; PERFORMANCE; STEELS; SURFACE CONTAMINATION; TRAINING; VACUUM SYSTEMS IDENTIFIER(S)- ALLOYS; BUILDING MATERIALS; CLEANING; COATINGS; CONTAMINATION; DECOMMISSIONING; ENRICHED URANIUM REACTORS; IRON ALLOYS; IRON BASE ALLOYS; MATERIALS; POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

87. **Decontamination to achieve site-release criteria - EDB 89-22 89:152698 89000123247**

Schulmeister, A. R.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 56 1988 PP. 78-79 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-880601-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 12-16 Jun 1988 CONFERENCE TITLE- American Nuclear Society annual meeting CONFERENCE LOCATION- San Diego, CA (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT8925%%331-MH ANNOUNCEMENT IDENTIFICATION- EDB-89:152698; INS-89:027128 LANGUAGE- English NDN- 108-0515-2189-5

The Shippingport Station Decommissioning Project presented unique opportunities in the management and performance of component and area decontamination to meet established site-release criteria. Decontamination activities were performed to meet the following overall project objectives: (1) internal decontamination of radioactively contaminated components to meet low-specific-activity (LSA) shipping limits, (2) reduction of component radiation levels to as low as reasonably achievable (ALARA) for subsequent dismantlement, packaging, and off-site disposal, (3) reduction of surface contamination to qualify steel structurals for unrestricted off-site release, and (4) reduction of surface contamination to qualify concrete structurals for unrestricted on-site release. The paper discusses planning and scheduling decontamination activities, surface decontamination methods and techniques, and internal component decontamination methods and techniques. Successful completion of the decontamination activities at Shippingport has demonstrated that state-of-the-art technology can by applied cost-effectively to support a full-scale nuclear power plant decommissioning.

DESCRIPTOR(S)- *REACTOR DECOMMISSIONING --Activity levels; *REACTOR DECOMMISSIONING --Decontamination; *SHIPPINGPORT REACTOR --Reactor decommissioning ALARA; CONCRETES; PERFORMANCE; PLANNING; RADIATION PROTECTION; SCHEDULES; SURFACE CONTAMINATION IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; CONTAMINATION; DECOMMISSIONING; ENRICHED URANIUM REACTORS; MATERIALS; POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

89. TMI-2 [Three Mile Island Unit 2] reactor building basement concrete activity distribution - EDB 89-21 89:143485 89000095560

Babel, P. J.; Lancaster, R. E.; Distenfeld, C. H.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 460-461 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT0927##15 ANNOUNCEMENT IDENTIFICATION- EDB-89:143465; INS-89:027120 LANGUAGE- English NDN- 108-0514-2959-0

As a result of the March 1979 accident, the Three Mile Island Unit 2 (TMI-2) reactor building basement wall and floors were submerged in up to 2.6 m (8.5 ft) of water at an activity concentration of 4.8 BBq center-dot l sup minus 1 (0.13 mCi center-dot ml sup minus 1) of sup 137 Cs. This radioactivity penetrated the coated and uncoated concrete surfaces to various depths over a 2.5-yr period. After all the water had been removed, the general area exposure rates in the reactor building basement ranged from 0.14 to >43 mu Ci center-dot kg sup minus 1 center-dot s sup minus 1 (2 to 600 R/h). For decontamination and licensing purposes, it is necessary to determine the type, quantity, location, and penetration of radioactive materials in the reactor building basement concrete. The initial efforts to determine the contamination level in the reactor building basement was by thermoluminescent dosimeters (TLDs) attached to ropes at specific distances apart. The quantity of radioactive material in the concrete was initially estimated by using radiation shielding computer codes. To obtain more accurate information, the robot was used to obtain concrete core bore samples from the floors and walls of the various types of concrete at different elevations. Concrete core bore samples were sent to Idaho National Laboratory and Oak Ridge National Laboratory to determine the strontium content of the concrete and possibility of leaching to remove activity from the concrete for decontamination purposes. The results of the leach testing showed that the concrete can be passively leached to remove the radioactive material.

DESCRIPTOR(S)- *BASEMENTS --Concretes; *CONCRETES --Activity levels; *CONTAINMENT BUILDINGS --Basements; *THREE MILE ISLAND-2 REACTOR --Reactor accidents BOREHOLES; COMPUTER CODES; DECONTAMINATION; FLOORS; GAMMA SPECTROSCOPY; IDAHO NATIONAL ENGINEERING LABORATORY; LEACHING; MATHEMATICAL MODELS; MECHANICAL STRUCTURES; ORNL; RADIATION DOSES; ROBOTS; SAMPLING; STRONTIUM; SURFACE COATING; SURFACE CONTAMINATION; THERMOLUMINESCENT DOSEMETERS; WALLS IDENTIFIER(S)- ACCIDENTS; ALKALINE EARTH METALS; BUILDING MATERIALS; BUILDINGS; CAVITIES; CLEANING; CONTAINMENT; CONTAMINATION; DEPOSITION; DISSOLUTION; DOSEMETERS; DOSES; ELEMENTS; ENRICHED URANIUM REACTORS; LUMINESCENT DOSEMETERS; MATERIALS; MEASURING INSTRUMENTS; METALS; NATIONAL ORGANIZATIONS; POWER REACTORS; PWR TYPE REACTORS; REACTORS; SEPARATION PROCESSES; SPECTROSCOPY; THERMAL REACTORS; US AEC; US DOE; US ERDA; US ORGANIZATIONS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

70. A fast-sorting measurement technique to determine decontamination priority - EDB 89-21 89:143464 89000095558

Distenfeld, C. H.; Brosey, B.; Igarashi, H.

JOURNAL NAME- Transactions of the American Nuclear Society (USA) ABBREVIATED JOURNAL TITLE- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 458 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC (USA) ANNOUNCEMENT CODE- EDB; ERA; ETD; INS INCOMING TAPE SERIAL NUMBER- JT0927##11 ANNOUNCEMENT IDENTIFICATION- EDB-89:143464; INS-89:027119 LANGUAGE- English NDN- 108-0514-2958-9

Recovery of large contaminated buildings, such as the Three Mile Island Unit 2 (TMI-2) reactor building, are complicated by ceilings that can be 12 to 13 m high. Much of the overhead space is filled with conduits, pipes, cable trays, ventilation ducts, and steel structures. The total complex surface can greatly exceed the total surface of walls and floors. Concrete pedestals, heavy steel stands, embedded steel rails, refueling mechanisms, and other similar structures complicate normally accessible areas and impede exposure reduction efforts. Initial recovery of contaminated spaces tends to involve treatment of hot spots and accessible spaces such as floor and wall surfaces. Subsequent decontamination may be less efficient since untreated surfaces, such as in overhead spaces, may be beyond the reach of ordinary decontamination tools. To conserve radiation exposure of recovery personnel, it is important to prioritize the effort so that early work provides maximum exposure reduction. Subsequent exposure reduction can then be carried out with less total exposure to recovery personnel. This favorable scenario depends on identification of key surfaces that most affect the exposure rate. The quick-sort method that was developed is based on the Eberline HP 220A directional survey system.

DESCRIPTOR(S)- *CONTAINMENT BUILDINGS --Decontamination; *DECONTAMINATION --Program management; *RADIATION MONITORS --Performance; *THREE MILE ISLAND-2 REACTOR --Reactor accidents CABLES; CEILINGS; CONCRETES; EFFICIENCY; ELECTRICAL EQUIPMENT; FLOORS; MECHANICAL STRUCTURES; OCCUPATIONAL EXPOSURE; PIPES; RADIATION MONITORING; RADIATION PROTECTION; RADIOACTIVITY TRANSPORT; REACTOR CHARGING MACHINES; REACTOR CORE DISRUPTION; STEELS; SUPPORTS; SURVEILLANCE; VENTILATION SYSTEMS; WALLS IDENTIFIER(S)- ACCIDENTS; ALLOYS; BUILDING MATERIALS; BUILDINGS; CLEANING; CONTAINMENT; ENRICHED URANIUM REACTORS; EQUIPMENT; IRON ALLOYS; IRON BASE ALLOYS; MANAGEMENT; MATERIALS; MEASURING INSTRUMENTS; MECHANICAL STRUCTURES; MONITORING; MONITORS; POWER REACTORS; PWR TYPE REACTORS; REACTOR ACCIDENTS; REACTOR COMPONENTS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

72. **Conception, design, and development of the RRV [remote reconnaissance vehicle] and the RWV [remote work vehicle] - EDB 89-20 89:136522 89000095600**

Champeny, L.; Whittaker, W. L.

JOURNAL NAME- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 500-501 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC, USA ANNOUNCEMENT CODE- EDB; ERA; ETD; INS ANNOUNCEMENT IDENTIFICATION- EDB-89:136522 NDN- 108-0513-6017-6

Remote technology is sought for a variety of activities in the nuclear industry where radiation and other aspects of the work environment pose hazards to or preclude a human work force. Exposure-related costs and instances of necessity motivate the use and development of remote technology. The remote work vehicle (RWV) and the remote reconnaissance vehicle (RRV) are teleoperated systems developed for such uses. This paper considers design and development of these systems with emphasis on responding to a specific need: recovery of the Three Mile Island Unit 2 (TMI-2) containment basement.

DESCRIPTOR(S)- *ROBOTS --Design; *THREE MILE ISLAND-2 REACTOR --Reactor accidents BASEMENTS; BOREHOLES; CONCRETES; CONTAINMENT BUILDINGS; DECONTAMINATION; HYDRAULIC EQUIPMENT; MAINTENANCE; MAN-MACHINE SYSTEMS; MANIPULATORS; OPERATION; PERFORMANCE; REACTOR DISMANTLING; RELIABILITY; REMOTE HANDLING EQUIPMENT; REMOTE VIEWING EQUIPMENT; SAMPLING; TOOLS; TRANSPORT; USES IDENTIFIER(S)- ACCIDENTS; BUILDING MATERIALS; BUILDINGS; CAVITIES; CLEANING; CONTAINMENT; DEMOLITION; ENRICHED URANIUM REACTORS; EQUIPMENT; LABORATORY EQUIPMENT; MATERIALS; MATERIALS HANDLING EQUIPMENT; POWER REACTORS; PWR TYPE REACTORS; REACTORS; REMOTE HANDLING EQUIPMENT; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

73. **Criteria development of remotely controlled mobile devices for TMI-2 [Three Mile Island Unit 2] - EDB 89-20 89:136521 89000095589**

Fillnow, R.; Bengel, P.; Giefer, D.

JOURNAL NAME- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 500 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC, USA ANNOUNCEMENT CODE- EDB; ERA; ETD; INS ANNOUNCEMENT IDENTIFICATION- EDB-89:136521 NDN- 108-0513-6016-4

Since 1982, GPU Nuclear Corporation has used a series of remote mobile devices for data collection and cleanup of highly contaminated areas in the Three Mile Island Unit 2 (TMI-2) nuclear facilities. This paper describes these devices and the general criteria established for their design. Until 1984, the remote equipment used at TMI was obtained from industry sources. This included devices called SISI, FRED, and later LOUIE-1. Following 1984, the direction was to obtain custom-made devices to assure a design that would be more appropriate for the TMI-2 environment. Along with this approach came more detailed criteria and a need for a thorough understanding of the task to be accomplished by the devices. The following families of equipment resulted: (1) remote reconnaissance vehicles (RRVs), (2) the LOUIE family, and (3) remote working vehicle (RWV) family.

DESCRIPTOR(S)- *ROBOTS --Uses; *THREE MILE ISLAND-2 REACTOR --Reactor accidents BASEMENTS; BOREHOLES; CONCRETES; DECONTAMINATION; DEMINERALIZERS; DEPOSITION; DESIGN; FLOORS; MANIPULATORS; PERFORMANCE; RADIATION MONITORING; RADIATION PROTECTION; REACTOR DISMANTLING; REMOTE HANDLING EQUIPMENT; REMOTE VIEWING EQUIPMENT; REMOVAL; SEALS; SPECIFICATIONS; SURVEILLANCE IDENTIFIER(S)- ACCIDENTS; BUILDING MATERIALS; CAVITIES; CLEANING; DEMOLITION; ENRICHED URANIUM REACTORS; EQUIPMENT; LABORATORY EQUIPMENT; MATERIALS; MATERIALS HANDLING EQUIPMENT; MONITORING; POWER REACTORS; PWR TYPE REACTORS; REACTORS; REMOTE HANDLING EQUIPMENT; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

78. **Evaluation of radionuclide penetration of structural concrete surfaces in the Three Mile Island Unit 2 reactor building** - EDB 89-20 89:136490 89000095554

Davis, C. M.

JOURNAL NAME- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 456-457 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA AUTHOR AFFILIATION- Bechtel, Oak Ridge, TN (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC, USA ANNOUNCEMENT CODE- EDB; ERA; ETD; INS ANNOUNCEMENT IDENTIFICATION- EDB-89:136490 NDN- 108-0513-5985-0

The March 28, 1979 loss-of-coolant accident at Three Mile Island Unit 2 (TMI-2) resulted in the exposure of /approx/3000 m/sup 2/ of reactor building internal concrete surfaces to both liquid-and vapor-borne contaminants. The period of contact between the major structural concrete surfaces and the aqueous solutions of mixed fission products ranged from a few days to several years. Exclusive of the reactor building basement impingement walls above a height of 1.6 m, all concrete surfaces were protected with an epoxy-based coating. This coating provides a tough, easily decontaminated surface for the concrete during normal operation and maintenance cycles. At the completion of the gross decontamination of the accessible reactor building elevations in 1982, exposure rates remained elevated above expected levels as indicated by early decontamination factors. Exposure rate measurements and small-scale scarification samples of the reactor building surfaces demonstrated that the protective coatings and concrete in the reactor building had absorbed radionuclides, thereby creating a large fixed source. In September 1983, a concrete core sampling program was conducted in the TMI-2 reactor building to assess the depth of contaminant penetration into the coatings and concrete on elevations 93m and 106 m. Sampling of the reactor building basement concrete surfaces [elevation 86 m] was deferred until 1985 and 1986 to provide lead time for remote systems development.

DESCRIPTOR(S)- *COATINGS --Performance; *CONCRETES --Surface contamination; *CONTAINMENT BUILDINGS --Concretes; *THREE MILE ISLAND-2 REACTOR --Reactor accidents AEROSOLS; AQUEOUS SOLUTIONS; AUTORADIOGRAPHY; BASEMENTS; BOREHOLES; CORIUM; DECONTAMINATION; FISSION PRODUCTS; LOSS OF COOLANT; MELTDOWN; RADIATION PROTECTION; RADIOCHEMICAL ANALYSIS; RADIOISOTOPES; REACTOR CORE DISRUPTION; REMOTE HANDLING EQUIPMENT; SAMPLING; SPECTROPHOTOMETRY IDENTIFIER(S)- ACCIDENTS; BUILDING MATERIALS; BUILDINGS; CAVITIES; CHEMICAL ANALYSIS; CLEANING; COLLOIDS; CONTAINMENT; CONTAMINATION; DISPERSIONS; ENRICHED URANIUM REACTORS; EQUIPMENT; ISOTOPES; MATERIALS; MATERIALS HANDLING EQUIPMENT; MIXTURES; POWER REACTORS; PWR TYPE REACTORS; QUANTITATIVE CHEMICAL ANALYSIS; RADIOACTIVE MATERIALS; REACTOR ACCIDENTS; REACTORS; SOLS; SOLUTIONS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

79. **Surface activity characterization with TLD rings - EDB 89-19 89:131873 89000095555**

Vallem, R. J.; Distenfeld, C. H.; Peterson, H. K.

JOURNAL NAME- Trans. Am. Nucl. Soc. VOL. 57 1988 PP. 457 DOCUMENT TYPE- Journal Article ISSN- 0003-018X CODEN- TANSA LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-881011-- SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct - 4 Nov 1988 CONFERENCE TITLE- Joint meeting of the European Nuclear Society and the American Nuclear Society CONFERENCE LOCATION- Washington, DC, USA ANNOUNCEMENT CODE- EDB; ERA; ETD; INS ANNOUNCEMENT IDENTIFICATION- EDB-89:131873 NDN- 108-0513-1368-0

At Three Mile Island Unit 2 in the summer and fall of 1983, a major effort to reduce the reactor building exposure rates was evolving. A major data acquisition program was also evolving to provide the information that was needed to prioritize the dose reduction efforts. By the end of the year, there was enough information to know the major dose contributors and their relative contributions. The data that dealt with the floors indicated that their contribution was minor compared to other sources. It would not be long, however, before the major contributors to the exposure rates were mitigated and the minor contributors, like the floors, would become more important. At that point, the current data would be insufficient to effectively prioritize additional dose reduction work. A large part of that information gap would be filled because of the development and deployment of the thermoluminescent dosimeter rings.

DESCRIPTOR(S)- *CONTAINMENT BUILDINGS --Radiation monitoring; *THERMOLUMINESCENT DOSEMETERS --Performance; *THREE MILE ISLAND-2 REACTOR --Reactor accidents ACCURACY; ACTIVITY LEVELS; ALARA; BETA PARTICLES; CESIUM 137; COATINGS; CONCRETES; DATA ACQUISITION; DECONTAMINATION; FLOORS; PERSONNEL DOSIMETRY; PROGRAM MANAGEMENT; RADIATION DOSES; RADIATION PROTECTION; SAMPLING; SURFACE CONTAMINATION; USES IDENTIFIER(S)- ACCIDENTS; ALKALI METAL ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; BUILDINGS; CESIUM ISOTOPES; CHARGED PARTICLES; CLEANING; CONTAINMENT; CONTAMINATION; DOSEMETERS; DOSES; DOSIMETRY; ENRICHED URANIUM REACTORS; ISOTOPES; LUMINESCENT DOSEMETERS; MANAGEMENT; MATERIALS; MEASURING INSTRUMENTS; MONITORING; NUCLEI; ODD-EVEN NUCLEI; POWER REACTORS; PWR TYPE REACTORS; RADIOISOTOPES; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 220900.

80. **Contaminated concrete scabbling at the Shippingport Station Decommissioning Project - EDB 89-19 - 89:131127 89000089744**

Bauer, R. G. (M)

13 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Westinghouse Hanford Co., Shippingport, PA (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference CONTRACT/GRANT NUMBER- DOE AC06-87RL10930; AC06-84RL10421 REPORT NUMBER(S)- DOE/SSDP--0067; CONF-890604--19 SUPPLEMENTARY NOTE(S)- Portions of this document are illegible in microfiche products SUBFILE CODE- TIC PUBLICATION COUNTRY- US CONFERENCE DATE- 4-8 Jun 1989 CONFERENCE TITLE- Annual meeting of the American Nuclear Society CONFERENCE LOCATION- Atlanta, GA, USA ANNOUNCEMENT CODE- EDB; ERA; ETD; INS; NTS Document Order Number- DE89016830 CORPORATE ENTRY CODE- 9522926 ANNOUNCEMENT IDENTIFICATION- EDB-89:131127 NDN- 108-0513-0622-4

At turnover, there were several areas in the plant where radioactive contamination was entrained in concrete surfaces. The walls and floors of the refueling canal representing the primary source of contaminated concrete at the SSDP. The residual contamination levels in the refueling canal were low and it was not certain that concrete decontamination would be required, as the site release criteria had not been formally established. The primary isotope of concern was Co-60. The mean concentration of radioactivity entrained in the concrete surface was measured at 11,200 pCi/gm. Exposure rates adjacent to the walls averaged 3 mRem/hr. The technical specification for concrete decontamination was initially prepared as a contingency measure in parallel with the development of the site release criteria. The Decommissioning Operations Contractor (DOC) prepared this specification to be utilized if the final approved release criteria required it; or, to avoid future project delays in the absence of an approved site release criteria. With the receipt of DOE guidance for development of the site release criteria (100 mrem/yr to the maximum exposed individual), it was determined that the refueling canal did not meet the occupancy scenario requirements. The DOC subsequently issued the bid package and awarded the subcontract for the removal of contaminated concrete. This summary highlights some of the management decisions and engineering considerations for the removal of the contaminated concrete at the SSDP. The paper will give further background to the engineering decisions, concrete decontamination practices and experience. 2 refs.

DESCRIPTOR(S)- *FLOORS --Contamination; *RADIOACTIVE MATERIALS --Transport; *SHIPPINGPORT REACTOR --Decommissioning; *WALLS --Contamination CONCRETES; CONTAINMENT BUILDINGS; DECONTAMINATION; PACKAGING; REINFORCED MATERIALS IDENTIFIER(S)- BUILDING MATERIALS; BUILDINGS; CLEANING; CONTAINMENT; ENRICHED URANIUM REACTORS; MATERIALS; POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 054000.

84. **Nuclear power plant Niederaichbach - dismantling and concrete removal - EDB 89-12 89:077408 89000020885**

Loeschhorn, U.; Birkhold, U.; Obst, J.; Stasch, W. EDITOR- Pope, J. M.; Leonard, I. M.; Mayer, E. J.

1987-07 1495-1501 page(s) DOCUMENT TYPE- Report Analytic MONOGRAPH TITLE- Spectrum '86: Proceedings: Volume 2 AUTHOR AFFILIATION- Kernforschungszentrum Karlsruhe GmbH (West Germany) CORPORATE AUTHOR- American Nuclear Society (USA). Fuel Cycle and Waste Management Div.; American Nuclear Society (USA). Niagara-Finger Lakes Section LOCATION OF WORK- DE LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-860905--Vol.2 SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 14 Sep 1986 CONFERENCE TITLE- International meeting on low, intermediate and high level waste management - decontamination and decommissioning CONFERENCE LOCATION- Niagara Falls, NY, USA ANNOUNCEMENT CODE- ETD; INS; EDB; ERA Document Order Number- DE88015082 CORPORATE ENTRY CODE- 9524905; 9524906 ANNOUNCEMENT IDENTIFICATION- ERA-14:028408; EDB-89:077408 NDN- 108-0507-7107-7

The Niederaichbach Nuclear Power Plant was shut down for good in 1974 and brought into the state of safe enclosure. The followup decommissioning plan is divided into five steps: (1) Manual in-place dismantling of the nonradioactive systems within the safety containment; (2) Manual removal of the contaminated material; (3) Remote controlled dismantling of the activated material; (4) Removal of concrete of the biological shielding by explosives; and (5) Conventional demolishing of the buildings. The steel will be reused after melting or decontamination by scrap dealers or conditioned for final disposal. The rubbish can be reused for road design or disposed off on conventional storage areas.

DESCRIPTOR(S)- *CONCRETES --Removal; *NIEDERAICHBACH REACTOR --Decommissioning BIOLOGICAL SHIELDS; CUTTING; DECONTAMINATION; DEMOLITION; FEDERAL REPUBLIC OF GERMANY; PLANNING; RADIOACTIVE WASTE DISPOSAL; RECYCLING; REMOTE HANDLING; REMOTE HANDLING EQUIPMENT; STEELS IDENTIFIER(S)- ALLOYS; BUILDING MATERIALS; CARBON DIOXIDE COOLED REACTORS; CLEANING; ENRICHED URANIUM REACTORS; EQUIPMENT; EUROPE; GAS COOLED REACTORS; HEAVY WATER MODERATED REACTORS; HWGCR TYPE REACTORS; IRON ALLOYS; IRON BASE ALLOYS; MACHINING; MANAGEMENT; MATERIALS; MATERIALS HANDLING EQUIPMENT; POWER REACTORS; REACTORS; SHIELDS; THERMAL REACTORS; WASTE DISPOSAL; WASTE MANAGEMENT; WESTERN EUROPE SECTIONAL CLASSIFICATION CODE- 220900.

85. **Shippingport Station Decommissioning Project: Contaminated concrete removal: Topical report - EDB 89-12 89:076601 89000017973**

NO-AUTHOR

1989-05-15 40 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Westinghouse Hanford Co., Shippingport, PA (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Progress Report CONTRACT/GRANT NUMBER- DOE AC06-87RL10930 REPORT NUMBER(S)- DOE/SSDP--0047 SUPPLEMENTARY NOTE(S)- Portions of this document are illegible in microfiche products SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- ETD; INS; NTS; EDB; ERA Document Order Number- DE89012575 CORPORATE ENTRY CODE- 9522926 ANNOUNCEMENT IDENTIFICATION- ERA-14:028129; EDB-89:076601 NDN- 108-0507-6335-4

This Topical Report is a synopsis of the removal of contaminated concrete from the Shippingport Station Decommissioning Project (SSDP). The information is provided as a part of the Technology Transfer Program to document the decontamination activities in support of site release in the decommissioning of a nuclear power reactor. 4 refs., 8 figs., 2 tabs.
DESCRIPTOR(S)- *CONCRETES --Decontamination; *PROGRAM MANAGEMENT --Planning; *SHIPPINGPORT REACTOR --Decommissioning PROGRESS REPORT; TASK SCHEDULING; TECHNOLOGY TRANSFER IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; DATA PROCESSING; DOCUMENT TYPES; ENRICHED URANIUM REACTORS; MANAGEMENT; MATERIALS; POWER REACTORS; PROCESSING; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 054000.

87. **Decontamination of the Gentilly-1 fuel pool** - EDB 89-12 89:076379 89000020886

Le, H.; Denault, P. EDITOR- Pope, J. M.; Leonard, I. M.; Mayer, E. J.

1987-07 1701-1714 page(s) DOCUMENT TYPE- Report Analytic MONOGRAPH TITLE- Spectrum '86: Proceedings: Volume 2 AUTHOR AFFILIATION- Atomic Energy of Canada Ltd., Montreal, Quebec. CORPORATE AUTHOR- American Nuclear Society (USA). Fuel Cycle and Waste Management Div.; American Nuclear Society (USA). Niagara-Finger Lakes Section LOCATION OF WORK- CA LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-860905--Vol.2 SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 14 Sep 1986 CONFERENCE TITLE- International meeting on low, intermediate and high level waste management - decontamination and decommissioning CONFERENCE LOCATION- Niagara Falls, NY, USA ANNOUNCEMENT CODE- ETD; INS; EDB; ERA Document Order Number- DE88015082 CORPORATE ENTRY CODE- 9524905; 9524906 ANNOUNCEMENT IDENTIFICATION- ERA-14:027989; EDB-89:076379 NDN- 108-0507-6114-0

The decontamination program to support the decommissioning work for the 250 MWe Gentilly-1 Nuclear Station, performed by Atomic Energy of Canada Limited (AECL) included both in situ decontamination and removal with storage of equipment and systems. Of the major equipment and rooms decontaminated, which included the feedwater pump room, the sumps and floor drains, the ventilation systems, the decontamination center and various offices and workshops, the fuel pool and related systems provided the greatest challenge. Fuel pool decontamination included decontamination of both the storage pool and the shuffling bay, the purification system, the tools and equipment used in fuel manipulation and fuel storage, and the various rooms and areas associated with this equipment. This paper describes in detail, the procedure, the tools and equipment used, and the data obtained from the various decontamination techniques used in the decontamination of the fuel pool. The decontamination techniques include hydrolazing, scarifying, chipping, chemical cleaning and hand scrubbing.

DESCRIPTOR(S)- *FUEL POOLS --Decontamination; *GENTILLY REACTOR --Decommissioning ACTIVITY LEVELS; AUXILIARY SYSTEMS; CANADA; OPERATION; PERFORMANCE; REINFORCED CONCRETE; REMOTE HANDLING EQUIPMENT; REMOVAL; SEDIMENTS; SPENT FUEL STORAGE; SURFACE CLEANING; TOOLS IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; CONCRETES; EQUIPMENT; HEAVY WATER MODERATED REACTORS; HWLWR TYPE REACTORS; MATERIALS; MATERIALS HANDLING EQUIPMENT; NATURAL URANIUM REACTORS; NORTH AMERICA; POWER REACTORS; REACTORS; REINFORCED MATERIALS; STORAGE; SURFACE FINISHING; WATER COOLED REACTORS SECTIONAL CLASSIFICATION CODE- 052001.

88. Retention of /sup 134/Cs and /sup 137/Cs by roof tiles - EDB 89-09 89:054020
89748383001

Nicholson, K. W. EDITOR- Olast, M.; Sinnaeve, J.

1988 193-199 page(s) DOCUMENT TYPE- Report Analytic MONOGRAPH TITLE- Joint CEC/OECD(NEA) workshop on recent advances in reactor accident consequence assessment Proceedings of the Second part of the workshop AUTHOR AFFILIATION- UKAEA Harwell Lab. Environmental and Medical Science Div. CORPORATE AUTHOR- Commission of the European Communities, Luxembourg LOCATION OF WORK- XE LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- EUR--11408; CONF-8801124-- SUBFILE CODE- FRN PUBLICATION COUNTRY- FR CONFERENCE DATE- 25 Jan 1988 CONFERENCE TITLE- OECD-NEA/CEC workshop on recent trends in the evaluation of reactor accident consequences CONFERENCE LOCATION- Rome, Italy ANNOUNCEMENT CODE- ERA; ETD; EDB Document Order Number- TI88757197 CORPORATE ENTRY CODE- 1910850 ANNOUNCEMENT IDENTIFICATION- FRD-89:000988; EDB-89:054020 NDN- 108-0505-3851-6

Clay and concrete roof tiles have been collected from three buildings in southern England and analyzed for /sup 134/Cs and /sup 137/Cs surface activity. Collection took place a little over a year after the passage of a plume from the Chernobyl reactor accident and the execution of a similar study, in which the dry deposition velocity of particulate Cs was determined. Most tiles were taken from locations adjacent to those removed in the previous study and the weathering of Cs has been evaluated. The /sup 134/Cs on all of the tiles and the /sup 137/Cs on the concrete tiles could be ascribed to Chernobyl, however, substantial amounts of /sup 137/Cs on the clay tiles would be due to weapons fall-out also. The results indicate a limited amount of weathering for each Cs isotope, for the concrete tiles, with about 60-80% of the deposited material still remaining after a year. Retention by the clay tiles appeared to be even greater than for concrete but there was a wide variability in levels. Overall, for /sup 134/Cs, decay was found to be comparable to weathering for reducing activity on roofs, but the longer half-life of /sup 137/Cs means that weathering was correspondingly more important for this isotope. The low rate of weathering indicates that significant amounts of dry deposited material could remain on a roof for a number of years after a deposition episode.

DESCRIPTOR(S)- *BUILDINGS --Fallout deposits; *CESIUM 134 --Surface contamination; *CESIUM 137 --Surface contamination; *CHERNOBYLSK-4 REACTOR --Fallout deposits; *REACTOR ACCIDENTS --Environmental impacts; *ROOFS --Contamination CLAYS; CONCRETES; NUCLEAR EXPLOSIONS; PLUMES; UNITED KINGDOM; WEATHERING IDENTIFIER(S)- ACCIDENTS; ALKALI METAL ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; CESIUM ISOTOPES; CONTAMINATION; ENRICHED URANIUM REACTORS; EUROPE; EXPLOSIONS; FALLOUT; GRAPHITE MODERATED REACTORS; HOURS LIVING RADIOISOTOPES; INTERNAL CONVERSION RADIOISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPES; LWGR TYPE REACTORS; MATERIALS; NUCLEI; ODD-EVEN NUCLEI; ODD-ODD NUCLEI; POWER REACTORS; RADIOISOTOPES; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WESTERN EUROPE; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 220900.

95. **Analysis of data from leaching concrete samples taken from the TMI-2 reactor building basement - EDB 88-24 88:191818 88807748999**

Collins, E. D.; Box, W. D.; Godbee, H. W.; Scott, T. C.(M)

1988 33 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Oak Ridge National Lab., TN (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference; Numerical Data CONTRACT/GRANT NUMBER- DOE AC05-84OR21400 REPORT NUMBER(S)- CONF-881024--6 SUPPLEMENTARY NOTE(S)- Portions of this document are illegible in microfiche products SUBFILE CODE- TIC PUBLICATION COUNTRY- US CONFERENCE DATE- 30 Oct 1988 CONFERENCE TITLE- TMI-2 accident materials behavior, plant technology and recovery CONFERENCE LOCATION- Washington, DC, USA ANNOUNCEMENT CODE- ERA; ETD; INS; NTS; EDB Document Order Number- DE89002229 CORPORATE ENTRY CODE- 4832000 ANNOUNCEMENT IDENTIFICATION- EDB-88:191818 NDN- 108-0475-6875-0

Samples of contaminated concrete from the basement of the reactor building at the Three Mile Island Nuclear Power Station, Unit 2 were tested and analyzed at Oak Ridge National Laboratory to determine the potential for decontamination by diffusion-controlled leaching under conditions of full submergence and by forced flow-through leaching of porous concrete block walls. Pertinent physical characteristics of the concrete were measured, and leaching tests were performed. Data were analyzed by established mass transport principles, and predictions of leaching for several years were made. A numerical algorithm was used to model removal of sup 1 sup 3 sup 7 Cs and sup 9 sup 0 Sr by forced flow-through leaching. Results indicated that forced flow-through leaching would require only a few days, whereas complete decontamination by submerged, diffusion-only methods would require several years. 9 refs., 8 figs., 8 tabs.

DESCRIPTOR(S)- *CESIUM 137 --Leaching; *CONCRETES --Permeability; *STRONTIUM 90 --Leaching; *THREE MILE ISLAND-2 REACTOR --Concretes CONTAMINATION; DIFFUSION; EQUATIONS; MASS TRANSFER; MATHEMATICAL MODELS; NUMERICAL DATA; PAINTS; POROSITY IDENTIFIER(S)- ALKALI METAL ISOTOPES; ALKALINE EARTH ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; CESIUM ISOTOPES; COATINGS; DATA; DISSOLUTION; ENRICHED URANIUM REACTORS; EVEN-EVEN NUCLEI; INFORMATION; INTERMEDIATE MASS NUCLEI; ISOTOPES; MATERIALS; NUCLEI; ODD-EVEN NUCLEI; POWER REACTORS; PWR TYPE REACTORS; RADIOISOTOPES; REACTORS; SEPARATION PROCESSES; STRONTIUM ISOTOPES; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 220502.

98. Decommissioning with diamond - EDB 88-16 88:129878 8807502961

Jennings, M.

JOURNAL NAME- Ind. Diamond Rev. VOL. 48 NO. 525 1988 PP. 47-48 DOCUMENT TYPE- Journal Article ISSN- 0019-8145 CODEN- INDRA LOCATION OF WORK- GB SUBFILE CODE- GBN PUBLICATION COUNTRY- GB ANNOUNCEMENT CODE- EDB ANNOUNCEMENT IDENTIFICATION- GBN-88:002961; EDB-88:129878 NDN- 108-0469-5132-9

The decommissioning of the Windscale Advanced Gas-cooled Reactor is discussed. The decommissioning is carried out to stage 3, when the reactor core, including the thick reinforced concrete bioshield, is demolished. In particular, the use of diamond sawing and stitch-drilling in the demolition is discussed. New techniques have had to be developed and experiments made as to the best tools to tackle the problems. The problem of the thickness of the reinforced concrete can be overcome by diamond wire-sawing. The other main problem is contamination and activation of the materials used to build the reactors. (U.K.).

DESCRIPTOR(S)- *CUTTING TOOLS --Reactor decommissioning; *DIAMONDS --Cutting tools; *WAGR REACTOR --Reactor decommissioning ACTIVITY LEVELS; BIOLOGICAL SHIELDING; CONTAMINATION; REINFORCED CONCRETE; RESEARCH PROGRAMS IDENTIFIER(S)- AGR TYPE REACTORS; BUILDING MATERIALS; CARBON; CARBON DIOXIDE COOLED REACTORS; CONCRETES; DECOMMISSIONING; ELEMENTAL MINERALS; ELEMENTS; ENRICHED URANIUM REACTORS; GAS COOLED REACTORS; GCR TYPE REACTORS; GRAPHITE MODERATED REACTORS; MATERIALS; MINERALS; NONMETALS; POWER REACTORS; REACTORS; REINFORCED MATERIALS; SHIELDING; THERMAL REACTORS; TOOLS SECTIONAL CLASSIFICATION CODE- 220900.

102. Surface decontamination utilizing mechanical vacuum blasting methods - EDB 88-13 88:101484 88

McKernan, M. L.; Schulmeister, A. R.(M)

1988 6 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Westinghouse Hanford Co., Shippingport, PA (USA); General Electric Co., Shippingport, PA (USA) LOCATION OF WORK- US LITERARY INDICATOR(S)- Conference CONTRACT/GRANT NUMBER- DOE AC06-84RL10421; AC06-76RL01857 REPORT NUMBER(S)- DOE/SSDP--0035; CONF-880601--27 SUBFILE CODE- TIC PUBLICATION COUNTRY- US CONFERENCE DATE- 12 Jun 1988 CONFERENCE TITLE- American Nuclear Society annual meeting CONFERENCE LOCATION- San Diego, CA, USA ANNOUNCEMENT CODE- NTS; EDB; ERA; INS Document Order Number- DE88007299 CORPORATE ENTRY CODE- 9522926; 9523685 ANNOUNCEMENT IDENTIFICATION- INS-88:018921; ERA-13:033629; EDB-88:101484 NDN-108-0466-6808-5

As part of the Shippingport Decommissioning Project surface decontamination effort vacuum blasting techniques were utilized to remove fixed radioactive contamination entrained in steel and concrete painted surfaces to meet on-site and off-site release limits. Removal of contaminated paint by vacuum blasting was restricted to select areas of the project. Specifically, this technique was applied only when it was determined to be cost effective compared to other methods of paint removal or direct disposal of the bulk material as contaminated waste. As a result of pre-decontamination surveys it was determined that the lower portions of the Reactor Plant Container painted steel surface was eligible for this surface decontamination technique. 3 refs., 1 tab.

DESCRIPTOR(S)- *SHIPPINGPORT REACTOR --Reactor decommissioning; *SHIPPINGPORT REACTOR --Surfaces; *SURFACES --Decontamination; *SURFACES --Explosive fracturing BUILDING MATERIALS; COMPLIANCE; CONCRETES; CONTAINMENT; MATERIALS HANDLING; RADIOACTIVE WASTE MANAGEMENT; RADIOACTIVE WASTES; REACTOR DISMANTLING; REMOVAL; STEELS IDENTIFIER(S)- ALLOYS; BUILDING MATERIALS; CLEANING; COMMINUTION; DECOMMISSIONING; DEMOLITION; ENRICHED URANIUM REACTORS; FRACTURING; IRON ALLOYS; IRON BASE ALLOYS; MANAGEMENT; MATERIALS; POWER REACTORS; PWR TYPE REACTORS; RADIOACTIVE MATERIALS; REACTORS; THERMAL REACTORS; WASTE MANAGEMENT; WASTES; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

109. **Abrasive water jet cutting technique for biological shield concrete dismantlement - EDB 88-03 88:016679 8701525127**

Konno, T.; Narazaki, T.; Yokota, M.; Yoshida, H.; Miura, M.; Miyazaki, Y. EDITOR- Tarcza, G. A.

1987 IV.270-IV.284 page(s) DOCUMENT TYPE- Report Analytic MONOGRAPH TITLE- Proceedings of the 1987 international decommissioning symposium AUTHOR AFFILIATION- Japan Atomic Energy Research Institute, Ibaraki-ken CORPORATE AUTHOR- Westinghouse Hanford Co., Richland, WA (USA) LOCATION OF WORK- JP LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-871018--Vol.2 SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 4 Oct 1987 CONFERENCE TITLE- International decommissioning symposium CONFERENCE LOCATION- Pittsburgh, PA, USA ANNOUNCEMENT CODE- EDB; ERA; INS Document Order Number- DE87012822 CORPORATE ENTRY CODE- 9500104 ANNOUNCEMENT IDENTIFICATION- INS-88:001236; ERA-13:008880; EDB-88:016679 NDN- 108-0458-2249-2

The Japan Atomic Energy Research Institute (JAERI) is developing the abrasive-water jet cutting system to be applied to dismantling the biological shield walls of the JPDR as a part of the reactor dismantling technology development project. This is a total system for dismantling highly activated concrete. The concrete biological shield wall is cut into blocks by driving the abrasive-water jet nozzle, which is operated with a remote, automated control system. In this system, the concrete blocks are removed to a container, while the slurry and dust/mist which are generated during cutting are collected and treated, both automatically. It is a very practical method and will quite probably by used for actual dismantling of commercial power reactors in the future because it can minimize workers' exposure to radioactivity during dismantling, contributes to preventing diffusion of radiation, and reduces the volume of contaminated secondary waste.

DESCRIPTOR(S)- *BIOLOGICAL SHIELDS --Reactor dismantling; *JET DRILLS --Performance; *JPDR REACTOR --Reactor decommissioning; *REACTOR DECOMMISSIONING --Jet drills CONCRETES; DECONTAMINATION; WATER IDENTIFIER(S)- BUILDING MATERIALS; BWR TYPE REACTORS; CLEANING; DECOMMISSIONING; DEMOLITION; DRILLING EQUIPMENT; DRILLS; ENRICHED URANIUM REACTORS; EQUIPMENT; EXPERIMENTAL REACTORS; HYDROGEN COMPOUNDS; MATERIALS; OXYGEN COMPOUNDS; POWER REACTORS; REACTORS; RESEARCH AND TEST REACTORS; SHIELDS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

111. **Microwave decontaminator for concrete surface decontamination in JPDR - EDB 88-02 88:008871 8701525115**

Yasunaka, H.; Shibamoto, M.; Sukegawa, T.; Yamate, T.; Tanaka, M. EDITOR- Tarcza, G. A.

1987 IV.109-IV.116 page(s) DOCUMENT TYPE- Report Analytic MONOGRAPH TITLE- Proceedings of the 1987 international decommissioning symposium AUTHOR AFFILIATION- Japan Atomic Energy Research Institute, Ibaraki-ken CORPORATE AUTHOR- Westinghouse Hanford Co., Richland, WA (USA) LOCATION OF WORK- JP LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-871018--Vol.2 SUBFILE CODE- JMT PUBLICATION COUNTRY- US CONFERENCE DATE- 4 Oct 1987 CONFERENCE TITLE- International decommissioning symposium CONFERENCE LOCATION- Pittsburgh, PA, USA ANNOUNCEMENT CODE- EDB; ERA; INS Document Order Number- DE87012822 CORPORATE ENTRY CODE- 9500104 ANNOUNCEMENT IDENTIFICATION- INS-88:000202; ERA-13:007486; EDB-88:008871 NDN- 108-0457-4482-1

Radioactive contamination of nuclear facilities must be evaluated to determine appropriate decommissioning procedures which address both worker-exposure and waste management. The Japan Atomic Energy Research Institute (JAERI) measured concrete surface contamination prior to the dismantlement of the Japan Power Demonstration Reactor (JPDR). Measured penetration-depths of the contamination were with 2cm of the surface. JAERI has developed a microwave decontaminator for concrete surface removal. It can remove the surface of concrete to a depth of more than 1cm with a single-pass, and be used for walls as well as floors. Concrete surface contamination of the JPDR will be removed by both the microwave decontaminator and conventional machines to evaluate the usefulness of the microwave decontaminator.

DESCRIPTOR(S)- *CONCRETES --Decontamination; *DECONTAMINATION --Microwave equipment; *JPDR REACTOR --Decontamination; *JPDR REACTOR --Reactor decommissioning; *MICROWAVE EQUIPMENT --Performance SURFACES IDENTIFIER(S)- BUILDING MATERIALS; BWR TYPE REACTORS; CLEANING; DECOMMISSIONING; ELECTRONIC EQUIPMENT; ENRICHED URANIUM REACTORS; EQUIPMENT; EXPERIMENTAL REACTORS; MATERIALS; POWER REACTORS; REACTORS; RESEARCH AND TEST REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

114. **Examination of concrete samples from the TMI-2 reactor building basement - EDB 88-01 88:001167 8712093472**

Akers, D. W.; Roybal, G. S.(M)

1987-02 49 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- EG and G Idaho, Inc., Idaho Falls (USA) LOCATION OF WORK- US CONTRACT/GRANT NUMBER- DOE AC07-76ID01570 REPORT NUMBER(S)- GEND-INF--081 SUPPLEMENTARY NOTE(S)- Portions of this document are illegible in microfiche products SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- NTS; INS; EDB; ERA Document Order Number- DE88002201 CORPORATE ENTRY CODE- 9507781 ANNOUNCEMENT IDENTIFICATION- ERA-13:005814; EDB-88:001167 NDN- 108-0456-6804-1

Core samples were obtained from the concrete walls of the TMI-2 reactor building basement which had been submerged for up to three years in reactor coolant which leaked from the damaged reactor. The concrete samples were obtained in 1985 and 1986 using a Rover robot equipped with a drilling attachment. Three samples were sent to the Idaho National Engineering Laboratory (INEL) for examination to determine the leachability and total retention of fission products in the concrete. These data are to be used in the evaluation of methods for decontaminating the reactor building basement. It was determined that for some radionuclides (e.g., sup 9 sup 0 Sr) up to 90% of the total activity can be removed by leaching. 11 refs., 10 figs., 3 tabs.
DESCRIPTOR(S)- *THREE MILE ISLAND-2 REACTOR --Containment buildings; *THREE MILE ISLAND-2 REACTOR --Decontamination CONCRETES; COOLANTS; FISSION PRODUCTS; LEACHING IDENTIFIER(S)- BUILDING MATERIALS; BUILDINGS; CLEANING; CONTAINMENT; DISSOLUTION; ENRICHED URANIUM REACTORS; ISOTOPES; MATERIALS; POWER REACTORS; PWR TYPE REACTORS; RADIOACTIVE MATERIALS; REACTORS; SEPARATION PROCESSES; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.

120. **Contamination and decontamination experience with protective coatings at TMI-2 [Three Mile Island Unit 2]: Final report - EDB 87-15 87:108684 8707013828**

Schwartztrauber, K. E. (M)

1987-05 68 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Pentek, Inc., Coraopolis, PA (USA); Electric Power Research Inst., Palo Alto, CA (USA) LOCATION OF WORK- US REPORT NUMBER(S)- EPRI-NP--5206 SUBFILE CODE- TIC PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA; INS Document Order Number- TI87920433 CORPORATE ENTRY CODE- 9517562; 9500767 ANNOUNCEMENT IDENTIFICATION- INS-87:023383; ERA-12:034872; EDB-87:108684 NDN- 108-0448-9298-0

A review has been conducted of the use of protective coatings in the nuclear industry with emphasis on the performance of Three Mile Island Unit 2 (TMI-2) coating systems. TMI recovery experiences; lessons learned with coatings; and research related to contamination, decontamination, and radioactivity penetration into epoxy coatings (qualified per 10CFR50, Appendix B, for use in the TMI-2 containment building) have been summarized. Technical findings compiled, and the generic implications of the TMI-2 data analyzed.

DESCRIPTOR(S)- *THREE MILE ISLAND-2 REACTOR --Physical radiation effects; *THREE MILE ISLAND-2 REACTOR --Protective coatings CESIUM 134; CESIUM 137; CONCRETES; CONTAMINATION; DECONTAMINATION; LEACHING; PERFORMANCE; REACTOR ACCIDENTS; SPECIFICATIONS; STRONTIUM 89; STRONTIUM 90; SURFACE TREATMENTS IDENTIFIER(S)- ACCIDENTS; ALKALI METAL ISOTOPES; ALKALINE EARTH ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; CESIUM ISOTOPES; CLEANING; COATINGS; DAYS LIVING RADIOISOTOPES; DISSOLUTION; ENRICHED URANIUM REACTORS; EVEN-EVEN NUCLEI; EVEN-ODD NUCLEI; HOURS LIVING RADIOISOTOPES; INTERMEDIATE MASS NUCLEI; INTERNAL CONVERSION RADIOISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPES; MATERIALS; NUCLEI; ODD-EVEN NUCLEI; ODD-ODD NUCLEI; POWER REACTORS; PWR TYPE REACTORS; RADIATION EFFECTS; RADIOISOTOPES; REACTORS; SEPARATION PROCESSES; STRONTIUM ISOTOPES; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 220900.

132. **Remote handling equipment for the decommissioning of the Windscale Advanced Gas Cooled Reactor** - EDB 86-09 86:072402 8603504267

Barker, A.; Birss, I. R.; Fish, G.

1984 267-275 page(s) DOCUMENT TYPE- Book Analytic MONOGRAPH TITLE- International conference on robotics and remote handling in the nuclear industry AUTHOR AFFILIATION- United Kingdom Atomic Energy Authority, Charles II Street, London LOCATION OF WORK- GB LITERARY INDICATOR(S)- Conference REPORT NUMBER(S)- CONF-840916-- PUBLISHER- American Nuclear Society PUBLICATION PLACE- LaGrange Park, IL PUBLICATION COUNTRY- US CONFERENCE DATE- 23 Sep 1984 CONFERENCE TITLE- Robotics and remote handling in the nuclear industry conference CONFERENCE LOCATION- Toronto, Ontario, Canada ANNOUNCEMENT CODE- EDB; INS ANNOUNCEMENT IDENTIFICATION- INS-86:010879; EDB-86:072402 NDN- 108-0425-7881-8

A decision to decommission the Windscale Advanced Gas Cooled Reactor was taken shortly after reactor shutdown in 1981. The fuel has now been discharged and the decommissioning programme will last about 10-12 years. The paper describes the programme and objectives and deals with methods of handling and disposing of the radioactive waste material. The main new facility required is a Waste Packaging Building adjacent to the existing reactor in which the waste boxes will be filled, active waste encapsulated in concrete and the boxes cleaned, swabbed and monitored to comply with IAEA transport regulations. The handling machine concept and features are described. The assaying and packaging of the waste material, the control of box movement and the process of concrete encapsulation is described. The paper concludes with a description of the development programme to support the Project. The tasks include a study of cutting techniques, production and control of dust and smoke, viewing and lighting methods, filtration, decontamination and fixing of contamination.

DESCRIPTOR(S)- *RADIOACTIVE WASTE FACILITIES --Remote handling equipment; *RADIOACTIVE WASTE PROCESSING --Solidification; *WAGR REACTOR --Reactor decommissioning; *WAGR REACTOR --Remote handling equipment CLEANING; CONCRETES; DECONTAMINATION; IAEA; MONITORING; PACKAGING; RADIOACTIVE WASTE DISPOSAL; REACTOR SHUTDOWN; REGULATIONS; WASTE TRANSPORTATION IDENTIFIER(S)- AGR TYPE REACTORS; BUILDING MATERIALS; CARBON DIOXIDE COOLED REACTORS; CLEANING; DECOMMISSIONING; ENRICHED URANIUM REACTORS; EQUIPMENT; GAS COOLED REACTORS; GCR TYPE REACTORS; GRAPHITE MODERATED REACTORS; INTERNATIONAL ORGANIZATIONS; MANAGEMENT; MATERIALS; MATERIALS HANDLING EQUIPMENT; NUCLEAR FACILITIES; PHASE TRANSFORMATIONS; POWER REACTORS; PROCESSING; REACTORS; SHUTDOWNS; THERMAL REACTORS; TRANSPORT; WASTE DISPOSAL; WASTE MANAGEMENT; WASTE PROCESSING SECTIONAL CLASSIFICATION CODE- 220900.

135. **Decontamination of concrete surface with a blowpipe - EDB 86-04 86:024090 8510102147**

Ebeling, W.; Boedeker, B.; Rose, K.(M)

1984 57 page(s) DOCUMENT TYPE- Report ISBN- 92-825-4329-3 CORPORATE AUTHOR- Commission of the European Communities, Luxembourg LOCATION OF WORK- DE REPORT NUMBER(S)- EUR--8969 PUBLICATION COUNTRY- LU ANNOUNCEMENT CODE- ERA; EDB CORPORATE ENTRY CODE- 1910850 ANNOUNCEMENT IDENTIFICATION- FR-85:02147; EDB-86:024090 LANGUAGE- German NDN- 108-0420-9863-8

To optimize parameters of blowpipe flames, tests of erosion have been carried out on coated and non-coated inactivated concrete samples with a fan jet burner. It has been shown it is possible to control the separation of dusts and aerosols when flame descaling. For an aspiration distance having three filtering units, an efficiency situated between 99,991% and 99,999% has been obtained. In the stock of solid materials of the shut-down Gundremmingen KRB-A nuclear reactor, tests have been carried out on contaminated concrete surfaces. Contamination was essentially due to sup 1 sup 3 sup 7 Cs and sup 6 sup 0 Co, 90% coming from sup 1 sup 3 sup 7 Cs. To reach the limit value falling below the control limit for a future utilization, it has been necessary to eliminate 4 to 5 mm of concrete. Tests showed that activity accumulates in the combustion dross. By reason of the ascending convection current, an increase of the activity of aerosols, from the bottom to the top, has been noticed. The contamination of the surfaces of a room, during tests carried out, was neglected. The program of tests realized showed the aptitutde of flame descaling as concrete surface decontamination process.

DESCRIPTOR(S)- *CONCRETES --Decontamination AEROSOLS; CESIUM 137; COBALT 60; DUSTS; EFFICIENCY; EROSION; FLAMES; RWE-BAYERNWERK REACTOR IDENTIFIER(S)- ALKALI METAL ISOTOPES; BETA DECAY RADIOISOTOPES; BETA-MINUS DECAY RADIOISOTOPES; BUILDING MATERIALS; BWR TYPE REACTORS; CESIUM ISOTOPES; CLEANING; COBALT ISOTOPES; COLLOIDS; DISPERSIONS; ENRICHED URANIUM REACTORS; INTERMEDIATE MASS NUCLEI; INTERNAL CONVERSION RADIOISOTOPES; ISOMERIC TRANSITION ISOTOPES; ISOTOPES; MATERIALS; MINUTES LIVING RADIOISOTOPES; NUCLEI; ODD-EVEN NUCLEI; ODD-ODD NUCLEI; POWER REACTORS; RADIOISOTOPES; REACTORS; SOLS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS; YEARS LIVING RADIOISOTOPES SECTIONAL CLASSIFICATION CODE- 210100.

137. **Development of a remotely operated concrete decontamination vehicle. Final report - EDB 85-24 85:182373 8512072050**

Baker, H. G.; Cugini, A. V.; Lefkowitz, S.(M)

1985-10 61 page(s) DOCUMENT TYPE- Report CORPORATE AUTHOR- Pentek, Inc., Coraopolis, PA (USA) LOCATION OF WORK- US REPORT NUMBER(S)- EPRI-NP--4303 PUBLICATION COUNTRY- US ANNOUNCEMENT CODE- EDB; ERA Document Order Number- TI86920033 CORPORATE ENTRY CODE- 9517562 ANNOUNCEMENT IDENTIFICATION- ERA-11:002710; EDB-85:182373 NDN- 108-0418-0245-0

This document describes the design, fabrication, testing and demonstration of a remotely operated (tethered) concrete scabbling vehicle. This vehicle was designed to remotely decontaminate concrete floor surfaces in nuclear facilities, and thereby increase productivity and reduce operator radiation exposure. The completed unit consists of a tethered chassis, a portable remote control console, a seven cylinder scabbler head, and a vacuum system to collect and store the scabbled debris. The remote scabbler can decontaminate up to 400 ft sup 2 /h at a surface removal depth of 1/16 in.

DESCRIPTOR(S)- *CONCRETES --Decontamination; *THREE MILE ISLAND-2 REACTOR --Decontamination; *WEST VALLEY PROCESSING PLANT --Decontamination FLOORS; REMOTE CONTROL; SURFACE TREATMENTS IDENTIFIER(S)- BUILDING MATERIALS; CLEANING; CONTROL; ENRICHED URANIUM REACTORS; FUEL REPROCESSING PLANTS; MATERIALS; NUCLEAR FACILITIES; POWER REACTORS; PWR TYPE REACTORS; REACTORS; THERMAL REACTORS; WATER COOLED REACTORS; WATER MODERATED REACTORS SECTIONAL CLASSIFICATION CODE- 220900.