WHC-MR-0528

FOSTER WHEELER ENVIRONMENTAL CORPORATION

Feasibility Study of High Performance Pulsed Power Technology for Supporting Hanford Site Single-Shell Tank Waste Retrieval

March 29, 1996

Prepared for

Westinghouse Hanford Company
Tank Waste Remediation System
Task 019 of Order No. MGK-SVV-186918

Prepared by

Foster Wheeler Environmental Corporation
1981 Snyder Road, Suite 3
Richland, WA 99352

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FOSTER WHEELER ENVIRONMENTAL CORPORATION

March 29, 1996
FWRD-WHC/4344-L-96-043

Mr. David Ramsower
Westinghouse Hanford Company
P.O. Box 1970 MSIN H5-61
Richland, WA 99352

SUBJECT: WHC ORDER NO MGK-SVV-186918
TASK ORDER NO. 19
HP3T FEASIBILITY STUDY - FINAL REPORT

Dear Mr. Ramsower:

Foster Wheeler Environmental is please to provide the attached HP3T Feasibility Study. The report has incorporated both WHC comments and additional information from the technology vendor TZN. If you have any questions please call me at 372-5814.

Sincerely,

Brian Peters

Brian Peters, P.E.
Project Manager
Foster Wheeler Environmental Corporation

cc: R. Treat
R. Cameron
B. Peters
C. Blankingship (X0-17)
G. Carter (X5-53)
C. Davis (X5-53)
File: UST-ID 2.2/4.2

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1.0 INTRODUCTION AND OBJECTIVE

The U.S. Department of Energy (DOE) has established the Tank Waste Remediation System (TWRS) to safely manage and dispose of the wastes in single-shell tanks (SSTs) and double-shell tanks (DSTs) at the Hanford Site. The TWRS program has begun to assemble information on potentially applicable methods of retrieving wastes from SSTs in support of milestones under the *Hanford Federal Facility Agreement and Consent Order* (Tri-Party Agreement).

Westinghouse Hanford Company (WHC) has developed databases on retrieval methods that include more than 155 companies that have technologies potentially applicable to SST waste retrieval, including the High Performance Pulsed Power Technology (HP^3T). (Vendor information on the HP^3T system including responses to specific questions are provided in Appendix A.) This report summarizes the feasibility of the technology for supporting retrieval of SST waste. Other potential applications such as unblocking plugs in waste transfer pipelines are described in Appendix C. The feasibility study addresses issues of implementation, operation, and safety with a focus on strengths, weaknesses, and potential pitfalls of the technology. The feasibility study was based on information acquired from TZN GmbH, a German company that developed and manufactures HP^3T systems for a wide range of applications. Marketing partners of TZN for this technology are the German company Telerob and R.J. International, the U.S. representative of both companies.

2.0 DESCRIPTION OF HP^3T

An HP^3T system is capable of fracturing brittle materials into 100-μm particles using electrothermally-generated shock waves. Until now, the technology has been used only to separate glass, metal, ceramic, and plastic components. One primary application of the technology has been in foundries for removing ceramic molds from metal castings. Metals (except for those that are very brittle) are not impacted by the shock wave. The HP^3T system is highly effective in fracturing and mobilizing ceramic mold materials contained in the crevices of castings that are normally difficult to remove. The HP^3T system has also been shown to be effective in separating (1) glass in windshields from their protective layers of plastic; (2) concrete from reinforcing rods; (3) ceramic, plastic, and metal materials in computer chips; and (4) ceramic insulation from spark plugs and high-voltage insulators. The HP^3T system has been used successfully to bore a 7-in. (175-mm) diameter hole into hard rock at a rate of 33 ft/hr (10 m/hr). The HP^3T system has also been demonstrated successfully in mining applications. The HP^3T process is described in the following paragraphs.

An electric arc is generated by the discharge of the Pulsed Power Supply System into an energy converter, which consists of two electrodes spaced less than 2 in. (50 mm) apart. Individual arcs pulses are created with a repetition rate of every second (1 Hz) up to every 10 seconds (0.1 Hz). The repetition rate is matched to the application and to the conversion rate; the repetition rate can be adjusted by the Pulsed Power Supply System controls. The Pulsed Power Supply System consists of a small capacitor bank with an energy content of 760 to 9,500 Btu (0.8 to 10 kJ), depending on the application. Discharging the capacitor bank

bank into the energy converting system generates currents of 60,000 to 200,000 A. The charging voltage of the capacitor bank varies from 20,000 to 40,000 V, depending on the application.

The creation of an arc discharge between the electrodes of the energy converter generates a shock wave with an initial pressure that can be adjusted up to 174,000 lb/in^2 (1.2 x 10^9 Pa). The electrodes are immersed in at least 4 in. (100 mm) of water, which serves as a medium for transmitting the shock wave to the target or work piece. The electrical conductivity of the water directly influences the effectiveness of the electrical discharge. The maximum recommended salinity of the water surrounding the electrodes is 0.1%.

The energy of the shock wave is dissipated in the water and target media as a function of $1/\underline{r}^2$, where $\underline{r}$ is the distance from the arc zone. Thus, the ability of the shock wave to fracture brittle materials decreases rapidly with distance from the arc. This behavior can be used for the adjustment of the strength of the treatment. The effective distance is about 1 ft (300 mm).

Figure 1depicts the operation of HP^{3}T. Figure 2 shows the equipment included in an HP^{3}T system. The system is powered with three-phase alternating current (ac) at a nominal voltage of 230/400 V. By transforming and rectifying devices, the capacitor bank is charged to high voltage. A high voltage switch triggered by the control system introduces the discharge of the bank into the energy converter. The energy converter is connected to the capacitor bank by a coaxial cable. The maximum length of the cable is directly proportional to its ohmic resistance. In principal, this can be overcome be increasing the energy content of the capacitor bank. Unlimited cable lengths would then be possible; however, the efficiency of the entire system becomes unacceptably low. The recommendation is to limit the cable length to a maximum of 165 ft (50 m). The electrodes of the energy converter are made from stainless steel. Each electrode tip is made from high current resistive metal (alloy from copper and tungsten) and is designed for screw-off/screw-on replacement. The weight of the electrode system with its connector for the coaxial cable is approximately 45 lb (20 kg). This weight is for a system to disintegrate reinforced concrete, weights for other configurations may vary.

The following effectiveness data were obtained from the application of the HP^{3}T system for the fragmentation of 4-in. (100-mm) sized mineral blocks into powder. With an electrical energy level of 5,700 Btu (6 kJ) per pulse and a repetition rate of 1 Hz, approximately 20 pulses were necessary to convert 2.2 lb (1 kg) of mineral blocks into a sand-like consistency. The electrode tip lifetime is greater than 1 million pulses. On the basis of continuous operation of the system, the electrode tips will have to be replaced every 300 hours. With one set of electrode tips, 50 tons of mineral blocks can be disintegrated within 300 hours.

The HP^{3}T system is relatively compact, occupying a volume of 35 ft^3 (1 m^3) without the energy converter. The system is entirely air-cooled and involves the use of one coaxial cable approximately 0.8 in. (20 mm) in diameter (including insulation). The capital investment for a basic system that includes a 9,500-Btu (10-kJ) maximum energy content, the

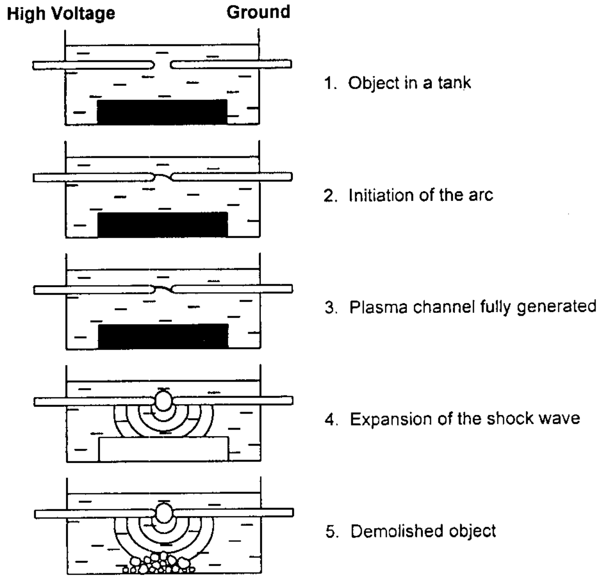

Figure 1. Schematic Principle of High Performance Pulsed Power Technology.

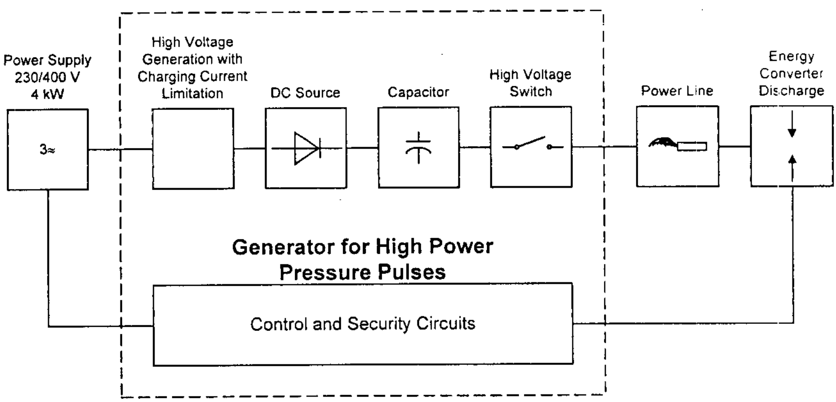

Figure 2. Schematic of the Power Supply for Creation of High Power Pulses.

electrode system, and a adjustable repetition rate of 0.1 Hz to 1 Hz is approximately $250,000. This cost does not include a deployment system.

3.0 FEASIBILITY FOR SST WASTE RETRIEVAL

The implementation, operations and maintenance, effectiveness, and safety of a conceptual HP^{3}T system for retrieving SST waste is evaluated in this section. Strengths, weaknesses, and pitfalls are summarized.

3.1 IMPLEMENTATION

The HP^{3}T system, including the energy converter, must be modified and combined with a deployment system to precisely position the electrodes directly on top of, or within inches of hardened tank waste. The deployment system should be capable of positioning the electrodes within about 8 in. (200 mm) of any target location in a tank to ensure that adequate overlap of the 1-ft (300-mm) diameter areas of influence of each position setting occurs. The deployment system must be sufficiently strong and robust or flexible enough to absorb the thrusts created by the shock waves. The deployment system must place the electrodes sufficiently far from the tank wall to prevent cracking and disintegration of the tank concrete when the shock wave passes through the steel wall.

The sensitivity of the arc discharge to the water conductivity will likely require that the electrodes be isolated from the tank liquid waste. A proposed modification to the HP^{3}T system to provide this would include an energy converter consisting of the two electrodes arranged in the focus of the inner parabolic shape of the metal housing. An elastomer or metal diaphragm would cover and seal the opening of the housing. A conceptual design is shown in Figure 3. Water would be pumped into the sealed housing to immerse the electrodes. The sealed energy converter would then be lowered into a liquid layer maintained over hardened waste. The water in the sealed energy converter and in the liquid layer over the heel would provide the medium for transmitting the shock wave from the arc-discharge to the heel. The diaphragm would flex and absorb any volumetric expansion that may occur within the sealed system during arcing.

3.2 OPERATIONS AND MAINTENANCE

A possible scenario for operations and maintenance of the HP^{3}T system at the Hanford Site is described in this section. Operations would begin by placing the energy converter over the hardened waste at a predefined location in the tank using an appropriate deployment system. The HP^{3}T system would be energized for continuous operation with the appropriate energy level and the desired repetition rate would be initiated. During operation of the HP^{3}T system, the deployment system would move the energy converter along a predefined course over the surface of the hardened waste in order to disintegrate the first waste layer. The travel velocity of the movement, the energy content of the HP^{3}T system, and the repetition rate would be adjusted to achieve maximum disintegration effectiveness

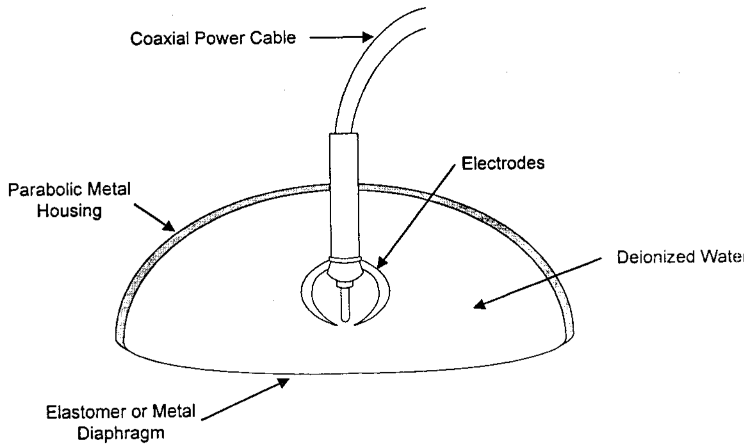

Figure 3. Proposed HP^{3}T System for SST Waste Retrieval.

according to the waste consistency. After the first hardened layer was disintegrated, a separate rubble conveyance system would be deployed to remove the waste from the tank. The rubble could be removed by sluicing, pumping, air-conveyance, or other suitable conveyance system. The HP^{3}T operations would resume after terminating rubble conveyance operations until the desired level of cleanup was achieved.

Maintenance on the electrode system would be required after about 300 hours of service because the energy converter electrode tip life is typically 1×10^6 shots. This replacement could be accomplished by raising the energy converter into a shielded work area. The energy converter could be washed, removed, and replaced using a remotely operated hoist and manipulators.

The shock wave created by the HP^{3}T system may be damaging to the deployment system, potentially resulting in high maintenance, depending on the type of deployment system utilized. The insulation on sections of the electrical cables that extend into the tank would be subject to radiation damage and may require replacement. The life of an elastomer or metal diaphragm would be low due to radiation and mechanical damage although this may not be a problem because the entire energy converter would likely be replaced every 300 hours. Maintenance of surface equipment would be expected to be routine because it would be conducted in a largely nonradioactive area off of the tank using direct human contact.

3.3 EFFECTIVENESS

The effectiveness of HP^3T systems were evaluated based on the following assumptions:

- The manufacturer's nominal disintegration rate of 400 lb/hr (180 kg/hr) for a 1-Hz repetitive system were arbitrarily reduced by half because of the likely need to achieve smaller particle sizes to ensure mobilization. Testing would be necessary to establish the power input necessary to generate particle sizes which could be reliably retrieved.

- A hypothetical 75-ft (22.7-m) diameter tank contains 18 in. (450 mm) of heel material. It was assumed that 12 in. (300 mm) must be retrieved. It was also assumed that 6 in. (150 mm) of the heel must remain in the tank, to avoid applying shock waves within 6 in. (150 mm) of the tank steel (which may be weakened by stress corrosion and subject to cracking).

- The density of the heel material is 125 lb/ft^3.

- The energy converter must be replaced every 300 hours of operating service. The integrated waste retrieval system is designed to facilitate this and other maintenance activities, resulting in 70% total operating efficiency.

- Operations will be continuous seven days per week.

Based on these assumptions, the tank would contain 550,000 lb (250,000 kg) of retrievable heel material. Approximately 3,000 hours of pure operating time would be required to remove all of the heel material. If only 12 in. (300 mm) will be removed, 2,000 hours of pure operations will be needed to remove the material. At a 70% total operating efficiency, the removal of 12 in. (300 mm) of waste would require approximately four months and 10 energy converter change-outs.

3.4 SAFETY

Specific safety concerns associated with using the HP^3T system to remove the hardened heel from Hanford Site waste tanks include the following:

- **Structural damage to the tanks**. The potential for causing structural damage to the tank concrete and steel shell is a serious concern with this technology. Proper adjustment of the output power of the HP^3T system would be required to avoid opening cracks in the tank, which would cause rapid leakage of the liquid that overlies the hardened waste. Further damage to the tank concrete should be avoided so that the tank dome will not collapse under the weight of soil above it.

- **Electrical hazards**. High voltage precautions will be necessary. The pulse power generating equipment located next to the tank must be well-isolated from human contact when the system is operating. All in-tank equipment must also be well-grounded to avoid high-voltage risks to operating, maintenance, and monitoring crews.

- **Radiation exposure to workers**. The level of maintenance projected for this system may lead to radiation exposures to maintenance workers.

- **Combustion or explosion hazards**. The presence of electrical arcs inside the tank also provides a means for initiating combustion if separated organic materials are present, or an explosion if sufficient concentrations of explosive gas mixtures or ferrocyanides are present.

3.5 SUMMARY OF STRENGTHS, WEAKNESSES, AND PITFALLS OF HP^{3}T IN SST WASTE RETRIEVAL APPLICATIONS

The greatest strength of the HP^{3}T is its proven ability to degrade the physical integrity of materials similar to the hardened sludge heel that exists in some SSTs. This strength is related to one of its most significant weaknesses; i.e., a 6-in. (150-mm) or greater buffer layer of material on the tank walls and floor may be required to protect the integrity of the tanks from the damaging effects of shock waves. The protective buffer layer is equivalent to 2 to 5% of the waste currently in many tanks and may exceed the allowable residual waste requirements for closure of tanks as landfills. However, the protective layer may be found unnecessary as a result of future quantitative analyses of the tank structures. This may allow for more efficient recovery of tank heel materials. The integrity of the tank for containing liquid must be retained, as the water layer over the waste is essential for this technology to function.

A deployment system for the technology would likely be complex, expensive, and maintenance-prone, especially when the maintenance requirements for HP^{3}T are considered. Maintenance worker radiation exposures are possible. Waste retrieval rates may be unacceptably slow, even when the HP^{3}T system is set to a repetition rate of 1 Hz.

4.0 CONCLUSIONS

The feasibility of HP^{3}T for supporting retrieval of hardened SST waste appears doubtful based on low efficiency, worker risks, and the potential for damaging the tank structure. The technology was not compared to competing technologies for serving this difficult function. Therefore the technology cannot be ruled out as infeasible at this time.

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APPENDIX A
VENDOR INFORMATION

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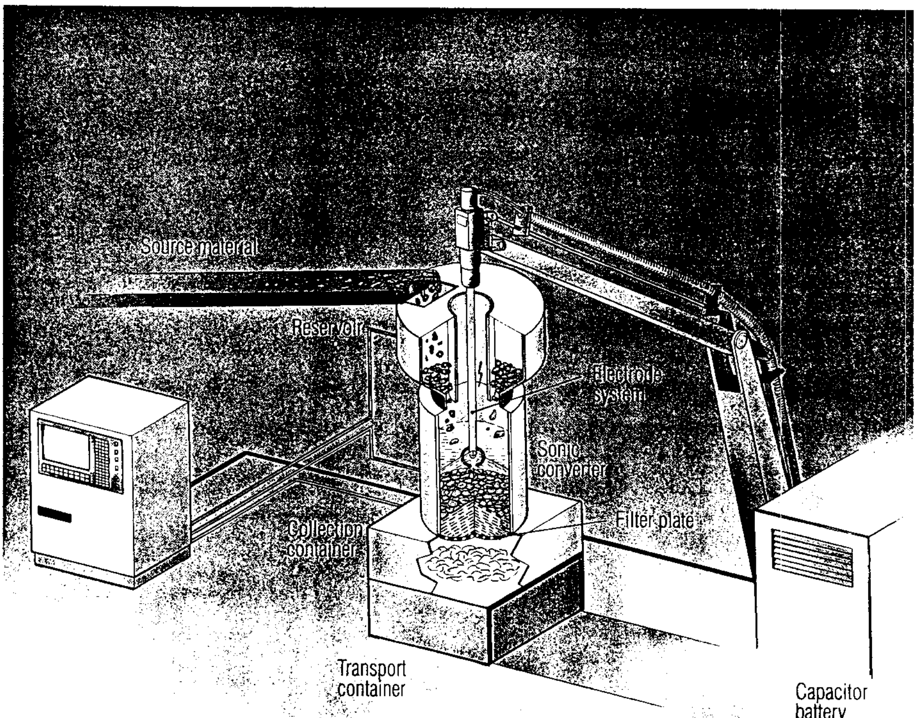
TZN

High Performance Pulsed Power Technology (HP^{3}T)

Contactless desintegration of compound materials



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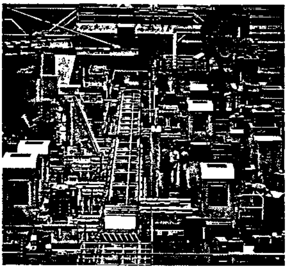

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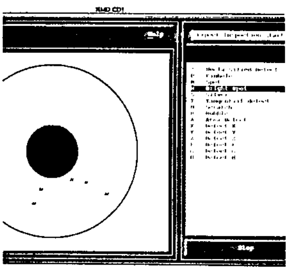

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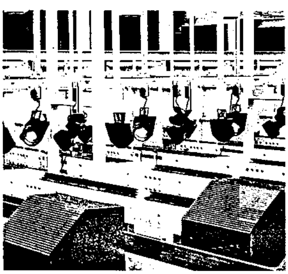

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Falckensteiner Straße 2 24159 Kiel

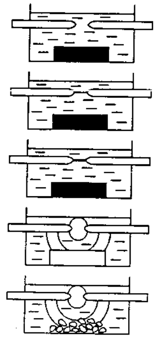
HP^{3}T technology (high performance pulsed power technology) provides economical solutions for recycling. This mainly applies where compound materials cannot be broken down into their component parts by means of traditional methods of disintegration such as chopping and grinding.

HP^{3}T exposes workpieces to the pressure pulse of a charge of electrical current. In the material this pressure pulse then has the following effects:

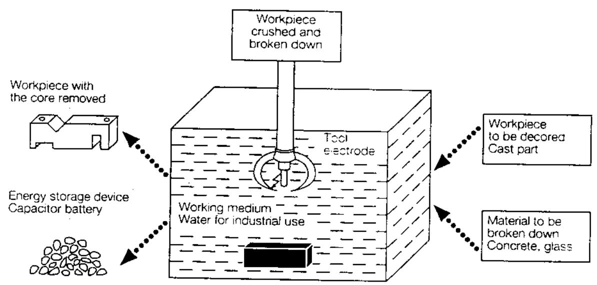
- Pressure and strain
- Reversal of bonding processes at particle boundaries
- Destruction of material at points of discontinuity

HP^{3}T is applied either in a water bath or by using encapsulated energy converters and can be exceptionally well integrated into automated processes.

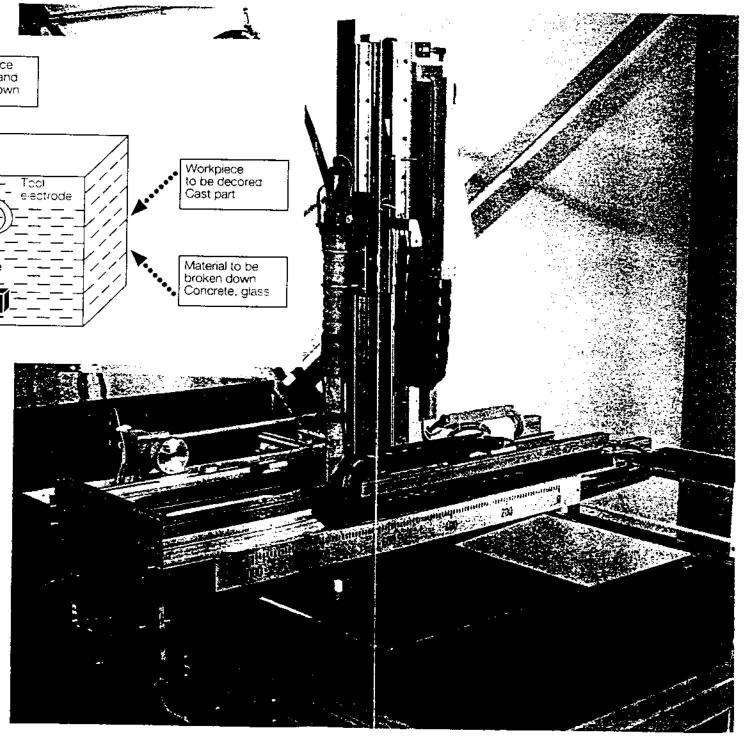
HP^{3}T produces end products of superior purity, while being a method which is practically free of wear and tear and causing only very low energy costs.



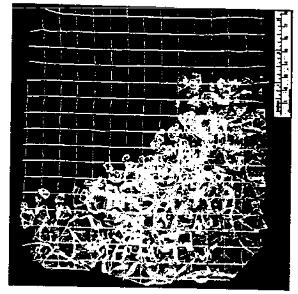
1. Material block in water bath
2. Formation of the electric arc
3. Fully formed plasma channel
4. Dissemination of the pressure waves
5. Broken-down material



The breakdown of electronic components to separate metal, plastic and ceramic materials

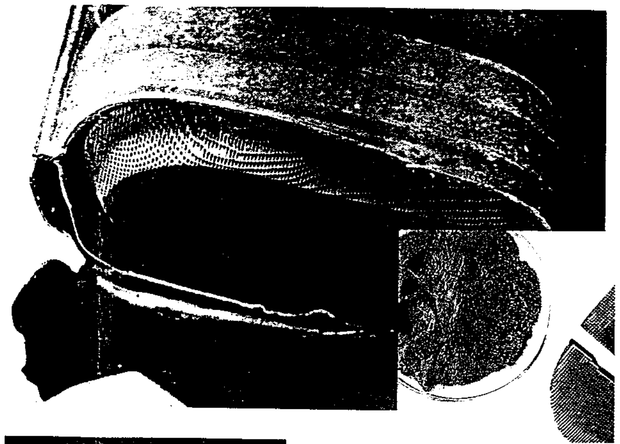


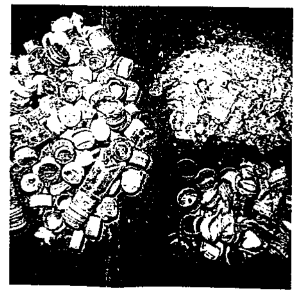
HP^{3}T technical equipment for examining disintegration processes



Breaking down laminated glass in order to separate glass and wire meshing without destroying the structure of the wire

Crushing the ceramic part of a vehicle's catalytic converter





Separated components after the second pulse

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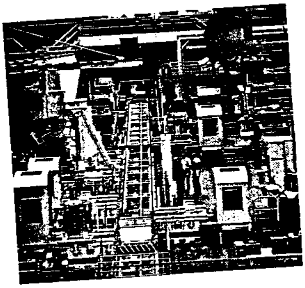

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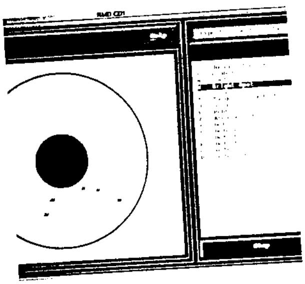

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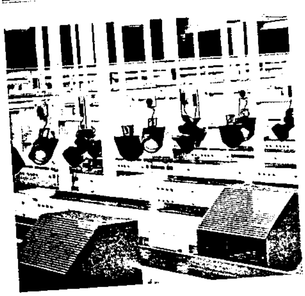

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FAX

From: John W. Riddington

Fax: (509) 375-3391

To: Richard J Cameron, FWEC

Fax: 372-5801

Pages: 1 + 6

Date: 27 February 1996

Ref: Arrangements for telerob GmbH Meeting at Richland Foster Wheeler Environmental Company Offices, 29 February 1996

Rick,

This confirms our conversation this afternoon on the subject meeting arrangements:

1. Mr Bernd Schott and you will meet on Thursday 29 February in the lobby of the Richland Red Lion at approximately 1.30 pm, in order to drive Bernd to the 2.00 meeting.

2. After the meeting you will return Bernd to the Red Lion.

I would appreciate if you would explain to Bernd the role of FWEC in the ACTR technology selection process, and what the likely follow-on events and timing is likely to be.

I am attaching for your information, the english translation of the November Hannover Colloquium technical paper describing the HP3T. If you could arrange it, it might be helpful to have copies available for the attendees (?). Whem I get back, (07 March), I can make copies of the presentation materials as a hand-out for the attendees.

I hope David Ramsower or Jim Yount from the ACTR program can attend. As I mentioned I have contacted Steve Pulsford of Bechtel Hanford and passed on your invitation to attend. Steve is associated with the "C" Reactor D&D Demonstration program in which Bechtel has a lead role I understand.

Thank you for your kind assistance in this matter. I will contact you on my return to the office on 07 March. Again I aplolgise for not attending the meeting.

Best regards

John

John Riddington for telerob GmbH

IV Stillegungskolloquium Hannover

An Approach for Remote Controlled Retrieval of Solidified Constituents of Radioactive Liquid Waste.

Dr. B. Birkicht, Kai Tscheschlok

Introduction

Operation and shut-down of nuclear sites often produces radioactive liquid waste which is temporarily stored until final processing and storage.

During storage of liquid waste, time delayed crystallization processes or cementation of sediments can be created depending on the ingredients and in the solid deposits. Wetted surfaces of the equipment then become coated with the deposits. Conventional chemical/physical methods of decontamination can only partially remobilise the deposits.

This report describes an approach to remove by remobilization those sediments, using an innovative method that has been successfully applied for the de-coring of foundry castings. The effectiveness of this method is demonstrated by separating compound materials that were previously defined as inseparable.

Solidification process and characteristics of Sediments

Liquid waste solidification primarily depends on the solubility of its contents. If the solubility of a substance exceeds its solvent's capability, precipitation of solids takes place.

During the storage of nuclear liquid waste in system tanks, crystalline deposits often cause contamination problems, usually from substances of low solubility deposited as caking or as sediment. For this reason the solid deposits have a very poor resuspension and solubility quality.

Precipitation of solids can happen spontaneously or after some delay. It is caused primarily by crystal nucleation processes and by the crystal growth afterwards. By exceeding a substance's solubility in the liquid waste (over-satiation of solubility) the numbers of nucleus crystals increase. While storing liquid waste it is possible that local regions in the storage tanks appear as preferred regions of crystal growth due to local over-satiation.

Preferred regions are

- phase interface liquid waste/air
- contact surfaces providing heat exchange processes
- medium flow regions
- areas of sedimentation (bottom of tank, etc.)

Over-satiation may appear by water evaporation or by significant temperature gradients at the interface of liquid waste and air. This can lead to incrustation at the walls of the tank in this region due to an increased rate of nucleation.

The same effect occurs in the heat exchange-contact surfaces where incrustation can appear both in cooled and heated contact surfaces, which are contacted by the mediums.

If there are fluidic conditions in the region of nucleus crystallines which assure an optimal transportation of substances to the crystalline surface, a preferred structure of crustings will take place in those regions by growth of crystallines.

Many cakings in the storage tanks are caused by sedimentation of solids with solidification in advance. By mixing single charges of liquid waste of different composition, favorable conditions for solids deposit can be achieved. On appearance of a significant over-satiation of a substance a quick deposit of solids will take place by a chemical procedure of precipitation. In the course of this, fine-grained particles of solids arise which settle as deposits in preferred zones of sedimentation. Based on a fast growth, the sediments contain highly significant irregularities in their crystalline structure. The impurities will be bonded adsorbently, respectively included in the crystal grating by enlargement of the specific surface of solids. The solids in the liquid waste result in sedimentation together with precipitation products containing main parts of radioactive nuclides, for example corrosion products. After sedimentation gradual solidification will take place as a result of aging. The aging of sediments is based on slowly forming recristallization in which specific surfaces of solids of the product precipitation will be reduced significantly by formation of a regular crystal grating. Finally, the sediments transform into a solid conglomerate in which the insoluble radionuclides are confined.

Problem zones in the areas of tank internals

Many of the storage tanks include internals for cooling, sampling, ventilating as well devices for filling and removal. If the liquid level in the tank stays constant for a longer period, deposits of crystals appear on the surface level of the liquid at all the internals, respectively at the tank walls. Those "bathtub rings" are areas of most vigorous activity other than the deposits at the bottom of the tank.

Additional deposit spots can be observed in areas reached insufficiently by liquid flow, eddying occurs, for example at intersections of cooling tubes. Big crystalline lumps of concrete-like consistency can be found there.

While the cakings on the bottom of the tanks vary from muddy to pasty or amorphous or cemented, the "bathtub rings" and the crystalline lumps are totally solid. Often they cannot be removed satisfactorily even by mechanical methods.

Even coatinglike infiltrations into the tank wall material, caused by diffusion processes, can not be excluded. To decontaminate such coatings, they have to be separated at their intercrystalline boundarys.

However, overcoming the bonding forces in the crystalline structures, in the boundary areas to the tank material requires a very high energy flow. This cannot be achieved by common chemical-physical procedures. Mechanical abrasive procedures are successful in local areas only.

In the following explanation a treatment is described which assures a homogeneous distributed impact of a high potential of energy to a crystalline body. The treatment safely removes deposits and coatings by applying the principle of crystalline destruction.

Remobilisation with High Performance Pulsed Power Technology HP³T

The treatment called High Performance Pulsed Power Technology (HP³T) is suitable for liquid storage tanks made from impact resistant materials, i.e. steel. The method generates pressure pulses of several hundred bars within just a few µs. The pulses expand spherically in the fluid that is used as a transfer media (element) for the energy. On impact, the pressure pulse shock waves generate tension and shearing stress forces at the material boundary layers. This leads to mechanical destruction of the deposit material into small particles. Appropriate adjustment of the process parameters to the type of deposit material can produce fragmentation down to 100 µm particle size. The fragmented materials can be remobilised by means of the liquid work media, pumped, filtered and transferred for conditioning. After filtration the liquid is reused to minimize the amount of secondary waste generated.

Generation of electrical High Performance Power Pulses

To generate the electrical High Performance Power Pulses a capacitor battery is charged to store energy. This charged capacitor battery is discharged in a serial oscillator.

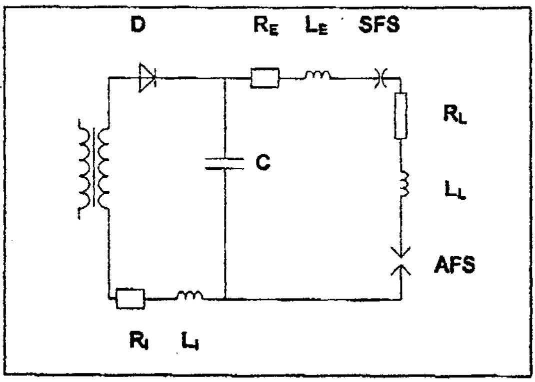

Fig. 1: electrical schematic of the power converter

C	power storage (condensator battery)
D	high voltage rectifier
R and L	electrical dimensions of the series oscillation circuit
SFS	power switch
AFS	discharge gap (i.e. electrode in work media for energy convertion

The electrical components of the discharger a shown in following schematic (see Fig. 2).

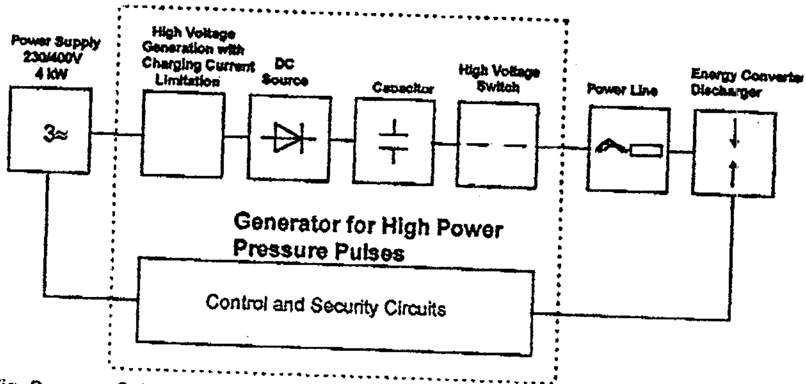

Fig. 2: Schematic of the power supply for creation of High Power Pulses

By use of a high voltage switch the stored energy of a capacitor battery is fed to the discharger via the power line.

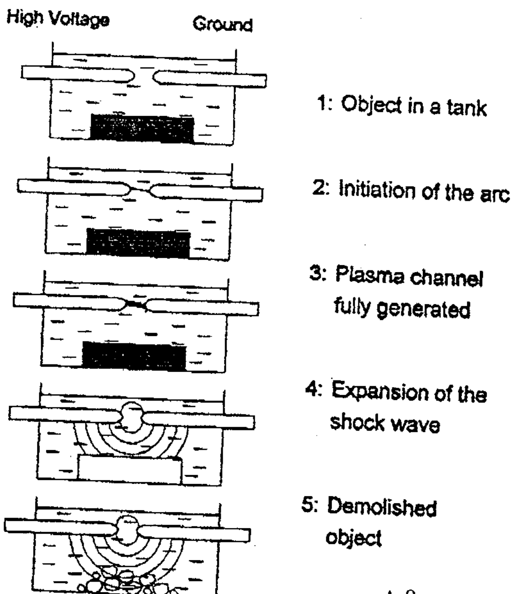

Fig. 3:

Schematic principle of the High Performance Pulsed Power Technology

The discharging process generates a plasma channel between the bipolar electrodes immersed in a liquid aqueous media. The energy of the capacitor battery is discharged within µs causing a rapid generation of pressure in the plasma channel. This leads to a rapid change of the pressure density at the plasma envelope. This pressure density change expands in the liquid in what is described as a High Performance Power Pulse. The energy is also accompanied by thermal and visual radiation effects. Specific applications of the treatment may require that the discharge circuit be designed to handle the amount of energy necessary to generate a high power pulse up to 1000 bar maximum pressure within only µs amount of time. [1,2]

Commercial Industry Applications of the Process

The castings are positioned by conveyors under an electrode in a water bath. The shock wave generated by the electrodes cracks the agglutenate in the sand core by eliminating its adhesive forces and removes the slagging from the workpiece. Areas difficult to reach like undercuts are cleaned out cleanly without physical contact. [3]

The treatment process effectiveness has been demonstrated in many commercial applications. These applications have included the separation of compound materials previously considered to be inseparable. Several examples are briefly discussed below:

Automobile Windshields

Using HP^3T car compound glass windshields can be separated into their component parts. Glass layers sticking to the base plastic foil are fragmented and separated at the boundary layer of glass/glue from the foil. The plastic foil with the glue sticking to it is not destroyed due to its high elasticity. [4]

Destruction of Reinforced Concrete

The disintegration of reinforced concrete has been proven successfully. Depending on the number of pulses given to the concrete the mass of concrete is removed from the reinforcing bars. The concrete can be separated into its original constituents, e. g. aggregate and cement particles.

Separation of Components with Compound Materials

Separation of commercial components such as computer chips, spark plugs and high voltage insulators comprising metal parts and brittle material parts has been demonstrated. In a typical application, a payload charge of 6 lbs weight is totally disintegrated within one minute.

Disintegration of Ore and Rock

The process (HP^3T) has been successfully used in the construction business for disintegration of ore or bore holes. For example, with a bore diameter of 7" the cutting velocity reached an average of 18'/hour. [6]

Summary

As described above, the High Performance Pulsed Power Technology (HP^{3}T) has already been proven as a mature process ready for use in other industries. The potential for the use of HP^{3}T in the nuclear industry is considered to be high, particularly in the pre-treatment of retrieved buried waste and decontamination and decommissioning of facilities. Plans are in preparation for the demonstration of HP^{3}T at a nuclear facility. The demonstration involves the decontamination of process vessels previously used for storage of liquid waste. Patents are pending for the remotely controlled application of the technology.

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[2] Winkler — Hochgeschwindigkeitsbearbeitung, Verlag Technik Berlin 1973

[3] Franz, Scheibe — Vortrag ISEM + Electromachining Magdeburg 1989 Machining and Working of Materials by Electrically Generated Power Sound Pulses

[4] Weise, Hofmann, Löffler — Fragmentation of Composite Materials by Electrothemacally Generated Pressure Pulses 10th IEEE-Conference Albuquerque 1995

[5] Weise, Hofmann, — Möglichkeiten der Anwendung von Hochleistungspulsen zum Aufschluß von elektronischen/elektrischen Komponenten Elektronik-Schrott-Workshop Hannover 1995

[6] N.N. — Verfahren und Anlage zur elektrodynamischen Fragmentierung von Feststoffen Forschungszentrum Karlsruhe, Technik und Umwelt, Stabsabteilung Technologietransfer und Marketing, Mai 1995

FAX

RJ International

Technologies, Resources, Consulting Services

From:	John W. Riddington	To:	Russ Treat, FWEC
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Pages:	1 + 7	Date:	March 27, 1996

Ref: tele*rob* GmbH Presentation of HP^{3}T to FWEC and Bechtel Hanford on February 29, 1996 - **Answers to Questions Raised**

Mr. Treat

Attached is a copy of the answers provided by Bernd Schott of tele*rob* and TZN to questions raised by the attendees at the above meeting.

Please note that questions raised at a similar meeting the following day at INEL, Idaho Falls, are also included.

I would like to confirm the hand delivery to you yesterday of the tele*rob* TZN comments to your draft report "Feasibility Study of High Performance Pulsed Power Technology for Supporting Tank Waste Retrieval and Pipeline Plug Removal" dated March 14, 1996.

On behalf of tele*rob*, I would like to express our thanks for the opportunity of making the HP^{3}T presentation. If you have any questions, please contact me at (509) 375-4788.

Best regards,

John Riddington

cc Bernd Schott

Answers to Questions raised at the telerob HP³T Presentation Meetings

29 Feb & 01 March at Hanford and Idaho Falls

Electrode

1. Provide a general description of the HP³T Process. (H and I)

A. The energy charge held in the capacitor is transferred to the electrode which is the energy convertor. The discharged pulsed power energy is converted at the electrode into kinetic or sound wave energy being in turn transmitted via the liquid medium (water) to the work piece to be treated. The work piece and electrode are both immersed in a water bath. The electrode discharge system comprises two electrodes forming a gap in which an arc is generated by the overvoltage applied. Note that to date this is the application mode and is used for recycling applications. (As will be discussed later there are other application configurations of electrode and water transfer medium)

2. What is the service life and wear rate of the electrode during continuous operation? Has the recycling industry experience provided any indication of what the electrode life might be for example? (H and I)

A. Several commercial HP³T installations are providing good operational data on the service life and wear rate of the electrode. For continuously operating systems an electrode tip life of approximately 1×10^6 shots is typical. Depending of course on the application, this could require the replacement of the weaker components once a week. In a typical application, working for 16 hours a day resulted in 200,000 pulses per day. The electrode was depleted (worn away) after four days and changed out after 12 days. Since the electrode system is a low cost item in general, it is usual to replace the complete sub-system.

3. What is dimension of the gap between electrodes? A typical value will suffice. (H and I)

A. Air gap with 30 kV, 2 cm (maximum 5 cm)

4. Can the electrode be automatically adjusted to compensate for erosion/wear? (H and I)

A. The support system for the electrodes is subject to stresses during the energy discharge mode. Because of the structural loads involved it was judged prudent to avoid mechanical complexity. Following this design philosophy, an automatic electrode gap adjustment system is not recommended. Replacement of such critical parts as electrodes is the recommended approach.

5. Describe the system design parameters to be evaluated for any given application of the process to any selected workpiece/target material. (H and I)

A. The electrode set-up for the HP³T process needs to be custom matched to the particular target work piece. Different targets may require the adjustment of several parameters of the pulsed power supply system. Listed below are the key elements of the electrode system and the corresponding design parameters that will vary, depending on the target characteristics being considered.

electrode distance (gap)	:	power level
electrode shape	:	geometrical restrictions
electrode material	:	electrode life is function of energy level
auxiliary systems, ie parabolic mirror to direct the pressure wave	:	

Depending on the application, the above parameters are adjusted accordingly.

6. From what material is the electrode manufactured? (H)

A. Standard steel, 12 mm diameter, 10 cm long (also available with tungsten/nickel tip depending on application, more expensive and more complex.

7. How is the electrode connected with the cable? (H)

A. Screwed or plug connection depending on application.

8. What is the safe distance from electrode to operator? (H)

A. High voltage precautions necessary; operator can stand next to the bath or even touch container and pipeline. No hazards for the operator as long as he doesn't touch the electrode, no EMS.

9. Can the electrodes be designed as flat interlocked plates? (H)

A. Yes, depending on application

10. Could electrodes be designed as disks which can be adjusted by rotation? (H)

A. Yes, depending on application; however, may be difficult to readjust automatically.

Cable

11. Of what material is the cable connected with the electrode? (H and I)

A. Conventional co-axial high voltage cable, diameter 10 mm, 12 mm, minimum 5 mm.

12. Can you advise the relationship of the cable diameter and length with intensity of current? (H and I)

A. No experience, has to be tested

13. What are the resistance/line losses relative to length of cable? (Formula?) (H)

A. Has to be tested, no experience with more than 10 m.

14. What is the maximum length of cable that can be accommodated between electrode and capacitor? (H)

A. Theoretically 100 m but has to be tested (no experience with more than 10 m).

15. In the Hanford tank farms waste transfer lines, the typical pipe construction is an inside diameter of 75 mm (3") and outside diameter of 150 mm (6"), double walled configuration. The inside pipe and spacer is stainless steel with the outer pipe made of fiber glass. Would the fiber glass material be damaged by the application of the **HP³T** process? (H)

A. In order to assess the potential for damage to the outer fiber glass pipe in the typical double walled Hanford pipe assembly described, it is recommended that simulated waste blocked test samples be subjected to controlled testing in laboratory conditions. telerob/TZN would be happy to collaborate with setting up such tests.

The size of the electrode system with cable, would obviously be limited by the blocked pipe internal diameter. The lower limit of the electrode diameter will be influenced by the power level necessary to clear the blockage. Also the mechanical stiffness of the electrode system is an important parameter for this application. In general , very small systems can be successfully designed. Again, test rig electrode assemblies would be recommended to demonstrate performance.

It should be noted that any weld slag residues on the internal faces of welded joints will be removed by the process, and oxidation deposits will be cleaned off.

16. How small can the electrode be designed ? For example can pipes smaller than 100 mm diameter (4") be entered? (H)

A. Diameter 4 cm, 12 cm long, for maximum 2 kJ energy (depending on application).

17. What shape is the electrode, can it be adjusted? What is the service life? (H)

A. Shape of electrode as shown on the picture of the encapsulated power converter, (see technical bulletin).

18. Do weldments present potential dangers to use of the process? (H)

A. Yes, weldments can result in reduced wall thicknesses that present potential dangers of damage.

19. Are rusted parts particularly susceptible? How effective is the process in removing rust? (H)

A. Rust particles are removed completely, reduced wall thickness can cause potential danger.

Abrasive Procedure for Concrete Surfaces.

20. Is it feasible to remove concrete surfaces by means of a water bubble (encapsulated energy convertor) with an electrode inside, e.g. surface contamination removal. (H)

A. Questions regarding the surface cleaning of concrete surfaces and waste removal by means of encapsulated energy convertor end effectors and related matters such as costs would be best if addressed for a specific application. Cleaning of surfaces by use of a water bubble is theoretically possible; however, durable material for the enclosure has to be developed (during last tests, material broke after 10 shots). It does appear however that such an end effector would be helpful to some of the waste dislodging tasks at Hanford and preliminary tests are planned by telerob/TZN to determine the principles involved. telerob would be happy to collaborate on such an adaptation of the HP^3T proven principles.

21. Pumps and instrument assemblies installed in Hanford waste tanks will accumulate hard deposits of waste such that they cannot be removed from the tank riser because the resulting waste deposits are too large. This is known as the "lollipop effect". Is it feasible to design an encapsulated energy convertor (end effector) to be applied to these deposits to break them away from the assemblies, hence permitting their removal from the riser free of waste. This would require placement of the end effector by means of a manipulator inserted through a riser. (H)

A. Encapsulated energy converter has to be developed.

22. Can the electrode be activated beneath a "thin water film"? What water depth is necessary above the electrode. (H)

A. A minimum water level of 30 to 50 cm is necessary.

23. Is it possible to use sponge as a medium for transferring the energy? (H)

A. No, burned off after one shot.

24. The underground waste tanks at Hanford are reinforced concrete including the top dome. The floor of the tank and tank sides up to the start of the dome are steel lined. Most of them are of 1940's vintage and therefore there is great concern that any process used to remove or dislodge the waste does not in any way cause damage to the concrete walls and dome. What would be the recommended distance of the electrode from the tank inner surfaces to ensure that the tank wall and concrete dome integrity is not compromised? (H)

A. No answer possible without bench tests. The electrode could be placed close to the steel liner and with pulses adjusted accordingly, no damage to the concrete should occur.

Encapsulated Energy Convertor.
(This is of interest for externally clearing pipe blockages.)

25. Have there already been trials with stainless steel or aluminum membranes or diaphragms for this type of end effector? (H and I)

A. No, it is expected that the diaphragm, with repetitive pulses would fatigue at the edges.

26. What is the efficiency of the HP^3T in the encapsulated system when used outside of the pipe compared with an electrode inside a pipe or a bath? (H)

A. Comparison is not possible due to different forces and reactions. Due to the parabolic design, the encapsulated energy converter with 5 kJ will have the same results as the electrode in water with 10 kJ.

27. Is separate cooling necessary for this end effector? (H)

A. Cooling is not necessary. Water bath has filter system that cleans 5 litres of water per hour (50 litre filter), temperature will rise by 2° to 3°C per day.

Costs

28. What are the approximate costs per pulse, eg current consumption/material consumption? (H and I)

A. Operating experience with 10 kJ HP^3T System: Electricity 0.0004 DM per pulse. Costs for the electrode: 0.0006 DM per pulse.

29. What is the cost of an electrode? (H and I)

A. US $200.00 for a steel electrode, depending on application.

30. What is the expected life of the high voltage switch, replacement cost, and time to change out in the field? (H and I)

A. Replacement costs for high voltage switch and other electrical parts approx. US $650.00 per month.

31. What are the expected costs for cooling/cleaning? (H)

A. No cooling necessary.

Environment

32. What noise effects are caused during operation of both the encapsulated and water bath installations? (H and I)

A. 121 dB at the electrode, 60 dB outside.

33. What temperature is generated during operation of: water bath, capacitor, high voltage switch, power supply cable, and the electrode respectively. (H and I)

A. Temperature of the high voltage switch 80° to 90°C, cooled by a fan.

Comparison of HP^{3}T to Ultrasonic Energy Systems

34. What is the efficiency and productivity of HP^{3}T when compared with an ultrasonic energy source performing the same function? (H)

A. No comparison possible. An ultrasonic energy system is a permanent frequency with the same level (milli J) - HP^{3}T single repetitive pulses (kJ). Ultrasonic systems clean soft materials from brittle materials, HP^{3}T breaks brittle materials and has no effect on soft materials.

Effect of saline solution in the water bath

35. Up to what percentage of saline in the bath water will HP^{3}T maintain its effectiveness? (H)

A. Maximum 0.1% saline solution, higher saline percentage has to be tested.

36. Is it possible to arrange flushing of the electrode with fresh water in a saline solution? (H)

A. Flushing of the electrode would blow out the plasma channel - does not work.

Other Miscellaneous Questions

37. Effective Radius of HP^{3}T. What is the typical distance between electrode and work piece to be treated? (H and I)

A. Maximum effective radius is about 20 cm and a typical electrode to workpiece distance is approximately 4"/5".

38. Please explain the formula $P_{wirk} \nsim f(1/r^2)$. (H and I)

A. Formula was developed by experiment. The efficiency is reduced by (distance)^2.

39. How has the power of HP^3T pulse been measured, what device was used? (H and I)

A. Pulses were measured by Kistler pressure sensors.

40. Repression of volume during the pulse? (H and I)

A. There is no repression of volume. The pressure wave is transmitted via the water.

41. What are the consequences should the electrode touch a component or metal part, (safety concerns). (H)

A. If electrode touches a metal part, it could melt or result in a short circuit.

42. Please provide us with information on capacitance of the condensator battery. (I)

A. Capacitance of condensator battery: 2 kJ to 10 kJ depending on design, frequency current and resistance.

John W Riddington,
26 March, 1996

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APPENDIX B
OTHER POTENTIAL APPLICATIONS

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FEASIBILITY FOR OTHER POTENTIAL APPLICATIONS AT THE HANFORD SITE

The implementation, operations and maintenance, effectiveness, and safety of conceptual HP^{3}T systems other applications are evaluated in this appendix. The other applications include unblocking of pipeline plugs and decontamination of process equipment and concrete surfaces.

FEASIBILITY FOR UNBLOCKING PIPELINE PLUGS

The HP^{3}T system must be combined with other technologies to render it suitable for unblocking pipeline plugs. The HP^{3}T electrodes must be positioned within a few inches of a plug and be hydraulically connected to the plug to be effective. Pipelines used in the tank farms are encased in an outer pipe that provides protection against leakage to the environment. The annulus between the pipes allows any leakage from the transfer piping to drain under low pressure to a tank. Therefore, the annulus would be filled with chemically adjusted water that meets tank farm acceptance criteria to provide the required hydraulic connection. One option for accomplishing this would be to install a freeze valve around the outer pipe on the downsloping side of the plug and drip water in to the annulus on the upsloping side of the freeze valve. This would eventually create a 1-ft-long seal composed of ice in the annulus; the annulus would then be filled with water.

The electrodes would be hydraulically connected to the encasement pipe by immersing both the pipe and electrodes in a pool of water. This would be accomplished by (1) digging a hole in the ground to expose the pipe, (2) positioning the electrodes near the plug, and (3) filling the hole with water to immerse the electrodes. It was assumed that chemically adjusted water can be added to the transfer pipe on the upsloping side of the plug to create hydraulic connection with the plug. This water would also be pressurized to blow out the plug when shock waves have sufficiently weakened it.

The position of the plug in the pipeline should be identified within a few inches of its actual location, but practically it may be possible to identify its location within a few feet. If the location of the plug is known within a few feet, the electrodes may be moved along the pipe in successive settings spaced about six inches apart. Locating the plug is complicated by the presence of earthen cover over the piping and the presence of encasement piping. One candidate method of estimating location is by metering air into the pipe and measuring the pressure created. This method relies on (1) ability to seal off the draining end of the plugged pipe, e.g., at a pump, sluicer, or valve pit, (2) precise knowledge of the pipe design, and (3) assurance that the pipe contains no appreciable accumulation of liquid or solid wastes. Another method of locating a plug would require removal of some of the earthen cover at various locations to measure gamma radiation levels. An abrupt drop in radiation may exist on the downsloping side of a plug if waste containing sufficiently high levels of ^{137}Cs was being pumped at the time pluggage occurred.

The location of the plug would be identified using a suitable method, and then the earth around the pipe at the plug location would be exhumed. High radiation levels may be encountered during this activity, requiring special shielding and/or use of remote excavation techniques. The resulting hole would be filled with a clay-water slurry to create a seal in the soil to prevent water from percolating at an excessive rate. The annular freeze plug would be created and then the annulus would be filled with water. The electrodes would then be located at the first designated position along the pipe, the hole would be filled with water, and power would be applied to the system using a mobile HP^{3}T unit and electric generator. For this application it was assumed that a repetitive rate of 0.1 Hz would be effective. The electrodes would be moved in 6-in. (150-mm) steps and powered. The highest allowable hydraulic pressure would be maintained in the transfer pipe on the upsloping side of the plug. It was assumed that the shock waves would eventually be effective in breaking up the plug and restoring flow through the transfer line. After suitable flow conditions were established, the freeze plug would be thawed and the annular space drained the annular space would also be dried to reestablish the operating function of the leak detection system contained therein. No significant maintenance issues for this system were identified.

The effectiveness of HP^{3}T for unblocking pipeline plugs is unknown. The plug material may exhibit the characteristics of a compacted wet clay, which would be resistant to fracturing. The confined nature of a plug in a pipeline may also cause difficulty in dispersing any particles that are formed. This may prevent the creation of a channel necessary for liquid flow. The ability to precisely locate plugs is also unknown. The technology would not be applicable when fiber-reinforced piping is used for the encasement because the shock waves would crack the fiberglass.

In terms of safety of the system, workers may receive relatively high radiation exposures during activities associated with locating the plug, installing the freeze valve, excavating around the pipeline and positioning the electrodes. Workers may also encounter contaminated earth when excavating near the pipeline. However, similar exposures may occur with alternative methods for unblocking pipeline plugs. The potential for high voltage fields in the ground creates shock hazards to personnel working in the vicinity. The power generating equipment must also be properly isolated to protect workers.

The principal strength of the technology in this application is the potential for avoiding the need to penetrate into highly radioactive pipelines to remove a plug. However, the HP^{3}T technology is unproven for this application and may not be successful when non-brittle plugs have formed. The advantage of avoiding penetration into pipelines is partially offset by the need to excavate in the area of the plug and the need to install a freeze valve. Relatively high worker exposures will be incurred during both activities.

FEASIBILITY FOR DECONTAMINATION OF EQUIPMENT AND SURFACES

The application of HP^{3}T for decontamination of equipment would be similar to that described for retrieval of waste from tanks except that the process equipment could be brought to a decontamination facility. For example, the HP^{3}T system could be used in an open water-filled tank placed in the Hanford T Plant canyon. Process equipment could be placed in the bath and the HP^{3}T system used to remove encrusted internal and external contamination. This application is similar to the industrial application of HP^{3}T for removing slag from metal castings.

The application of HP^{3}T for decontamination of concrete surfaces would require an encapsulated energy convertor similar to that described in the main report. The concrete surface would be covered by several inches of water and the HP^{3}T system used to pulverize the concrete surface. Specific questions regarding this application were addressed as questions 20-24 in Appendix A.

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