United States
Environmental Protection
Agency

Office of Exploratory
Research
Washington DC 20460

Research and Development

EPA/600/9-86/005 Feb. 1986

EPA

Abstracts of Phase I and Phase II Awards

Small Business Innovation Research Program 1983-1985

SBIR

EPA/600/9-86/005
February 1986

Abstracts of Phase I and Phase II Awards

Small Business Innovation Research Program 1983-1985

OFFICE OF EXPLORATORY RESEARCH
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
WASHINGTON, DC 20460

Disclaimer

This document has been reviewed in accordance with U.S. Environmental Protection Agency policy and approved for publication. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Contents

Contents (cont'd)

Contents (cont'd)

Contents (cont'd)

Contents (cont'd)

U.S. Environmental Protection Agency
Small Business Innovation Research Program

The Small Business Innovation Research (SBIR) Program represents a new approach to funding Federal R&D. Although government funds are spent for research on Federal agency R&D needs, the SBIR program also provides an incentive for the conversion of this research into potential commercial applications and technological innovations. At no additional cost to the government, SBIR increases the return on investment from Federal R&D.

Under the Small Business Innovation Development Act of 1982 (P.L. 97-219), Federal agencies solicit proposals on R&D research from small science- and technology-based firms with up to 500 employees. In Phase I of this three-phase program, the Environmental Protection Agency (EPA) makes awards of up to $50,000 for six months to determine whether the research idea, often on high-risk advanced concepts, is technically feasible, whether the firm can do high quality research, and whether sufficient progress has been made to justify a larger Phase II effort. Phase II is the principal research effort. At EPA these projects now average $150,000 for up to two years.

Conducted in 11 Federal R&D agencies, SBIR is one of the most competitive R&D programs in government. Only one proposal out of ten on the average is funded in Phase I. Less than half of these receive support in Phase II.

The SBIR design involves a third phase to pursue potential commercial applications of the research funded under the first two phases. Phase III, however, is supported solely by non-Federal funding, usually from third party, venture capital or larger industrial firms.

This report contains abstracts of the 51 Phase I and Phase II awards made by EPA from the period 1983 to 1985. The Phase I and II abstracts are listed by year awarded, and a description of the potential commercial applications of the research is provided. This report also describes how the follow-on funding commitment works and gives information on rights in data development under SBIR and on copyright and patent policy.

EPA receives advanced research proposals from small science- and technology-based firms across essentially all fields of environmental engineering, with emphasis on industrially relevant research. Phase I proposals are reviewed by EPA scientists and engineers who are experts in the specific research areas. Phase II proposals are peer reviewed principally by consultants from universities and private companies. The best proposals receive full EPA research support. Awards are based primarily on EPA evaluation of technical merit.

The SBIR program is highly competitive. In 1983, the first year of the program, EPA received 214 Phase I proposals which resulted in 10 awards. Phase I provided up to $25,000 for six months to determine, as much as possible within these limitations, whether the research idea appeared technically feasible, whether the small firm could do high quality research, and if the project had achieved sufficient progress to justify larger government support. The Phase I report also serves as a base for follow-on funding commitment discussions. The Phase I abstracts are described on pages 1 through 12 and 18 through 30 of this report.

In 1984, EPA received 136 Phase I proposals which resulted in ten (10) awards. Phase I awards this year were made for up to $35,620 for six months.

From the ten 1983 Phase I awards, five Phase II awards were made in 1984 for up to $100,000. Phase II is the principal research effort for those projects that appear most promising after the first phase and averaged $100,000 for 1-2 years. The 1984 Phase I and II abstracts are described on pages 7 through 17.

During 1985, 20 Phase I awards were made by the EPA Small Business Innovation Research Program. One hundred and fifty-four Phase I proposals were received for evaluation and the 20 successful awardees were given up to $48,667 for six months. From among the ten 1984 Phase I contractors that qualified for Phase II awards, 6 awards were made, and the awards averaged $150,000 for 1-2 years. Descriptions of Phase I and Phase II awards for 1985 can be found on pages 18 through 35.

This document provides information on EPA's Phase I and Phase II awards made since 1983 and on potential commercial applications as described by the awardee. When there is interest in possible licensing, investment or in a joint venture by a third party, we encourage direct contact with the business officials of the company whose names, addresses, and telephone numbers are listed on pages of this publication.

If there are questions on the program, please contact Walter H. Preston, Program Manager, or Donald F. Carey, Science Advisor, Small Business Innovation Research Program, U.S. Environmental Protection Agency, Office of Exploratory Research (RD-675), Washington, DC 20460, Telephone (202) 382-7445.

I. Abstracts of Phase I Awards SBIR—1983

Topic I—Multimedia (Solid, Liquid, Gaseous) Pollution Control Processes

1. Production of an Industrial Thermosetting Resin from Whey and Whey By-Products

Chemical Process Corporation
4435 Cherokee Drive
Brookfield, WI 53005

Tito Viswanathan, Ph.D., Principal Investigator
Donald Westerman, President
Region V
Amount: $24,375

The advent of ultrafiltration processes has allowed the cheese industry to produce high-quality, whey-protein concentrates for use as food ingredients. At the same time, however, more than two-thirds of the whey volume collected is essentially unusable whey permeate containing 5% lactose and accompanying salts. About 20% by volume of the whey remains associated with the cheese curd and is expelled under pressure after the curd particles are salted, then pressed together. This whey is necessarily high in sodium chloride and, consequently, represents a particularly difficult disposal problem. Since the whey proteins (1% w/v) are retained in the "salt whey," they may contribute to cross-linking in the resins, resulting in stronger adhesive properties. Thus, it appears that whey permeate and "salt whey" can be concentrated using conventional processing techniques available to any cheese plant in order to provide raw materials for the manufacture of resins. This proposal seeks to produce a valuable product from waste whey and reduce pollution by redistributing the resin in other products now using resin based in formaldehyde, a known source of indoor air pollution.

2. Research on Slag Steam Generators

Richard Jablin and Associates, Inc.
2500 West Club Boulevard
Durham, NC 27705

Richard Jablin, Principal Investigator
Richard Jablin, President
Region IV
Amount: $25,000

The Slag Steam Generator (SSG) has been demonstrated to cool molten slag without emission to air, discharges to surface water, or leaching to ground water, and to recover the sensible heat as useful energy. Additional research is

proposed in order to improve its reliability so that it may be accepted for use under production situations. Such research includes investigations into cooling plate metallurgy, the physical configuration of the SSG, heat transfer requirements, and operator safety devices. There will also be research into the production of high pressure steam as the desired form of useful energy.

3. Sludge Reclamation Using Coupled-Transport Membranes

Bend Research, Inc.
64550 Research Road
Bend, OR 97701-8599

Walter C. Babcock, Principal Investigator
Stephen L. Matson, Director of Research
Region X
Amount: $24,778

In 1980 the metals and electronics industries generated over seven million tons of hazardous waste at a cost of $100 to $400/ton. These sludges, which contain substantial amounts of mixed heavy metals, present a serious disposal problem and represent a waste of natural resources. The intrinsic value of metal such as nickel, chromium, and tantalum contained in these sludges is high, providing a significant incentive for their recovery.

It is the objective of the proposed project to develop an economical, energy-efficient process for the recovery of certain metal values in a usable form from these industrial sludges, thereby conserving valuable resources and controlling the amount of waste ultimately generated.

Since a clean separation of the various metals is the critical step in achieving this objective, the bulk of Phase I research will be directed toward evaluating a new membrane-separation process known as "coupled transport" for the continuous separation of metals from waste sludges. Once effective separation has been demonstrated, the coupled-transport process can be combined with existing, well-established recovery techniques to produce a cost-effective system capable of converting certain waste sludges into usable materials.

4. Recycling of Dust from Electric Arc Furnaces

PEDCo Environmental, Inc.
11499 Chester Road
Cincinnati, OH 45246-0100

William F. Kemner, Principal Investigator
George A. Jutze, President
Region V
Amount: $25,000

The major shortcomings of the various processes suggested by recycling metallurgical dust have been the high capital cost of the equipment and the need for large quantities of dust for the processes to be economical. Electric arc

furnace dust is not amenable to these processes because it is generated in small quantities and at a number of locations, distant from industrial centers where regional recycling might occur. Furthermore, EPA lists electric arc furnace dust as a hazardous waste because of the leachability of heavy metals. Samples of dust will be obtained from electric arc furnaces representative of carbon and low alloy steel. These samples will cover a matrix of high and low lime content and high and low zinc and lead content. The research objectives are to: evaluate processes for agglomerating the dust for recycle to the furnace; investigate the partition of metal components between the slag, steel, and dust upon recycling; and determine the effectiveness of stabilization techniques for the prevention of leaching of heavy metals for the concentrated dust discarded from the recycle circuit. Recovery of dusts from stainless steel production will not be a subject of this research, as stainless steel constitutes less than 10 percent of the total steel produced.

Topic II—Drinking Water and Wastewater Disinfection Alternatives to Chlorine

5. Ozone-Hydrogen Peroxide System An Alternate Disinfectant: A Model for Ozone Disinfection Through Free Radical Mechanism

Bollyky Associates
83 Oakwood Avenue
Norwalk, CT 06850

L. Joseph Bollyky, Principal Investigator
L. Joseph Bollyky, President
Region I
Amount: $25,000

Ozone is a valuable alternative to chlorine for the disinfection of wastewater and water. It generates no chlorinated organics and leaves no residuals harmful to human health or toxic to marine life. Ozone alone reacts through a free radical mechanism under alkaline conditions and free radical and polar mechanisms under neutral conditions.

The ozone-hydrogen peroxide system is a powerful oxidizing medium that has been shown to remove refractory dissolved organics from deionized water and from industrial wastewater much more effectively than ozone alone. It is believed to generate hydroxyl radicals and operates through a free radical mechanism. The disinfection effect of a chemical usually parallels its oxidation potential. The hydroxyl radical, the active agent of the ozone-hydrogen peroxide system, is a substantially stronger oxidant than ozone or chlorine.

This project would be the first feasibility evaluation of the ozone-hydrogen peroxide system as a disinfectant. Furthermore, the results should indicate whether the free radical or polar reaction of ozone is more important for disinfection.

Topic III—Compatibility of Soils and Various Liners with Organic Chemical Wastes

6. Compatibility of Soil Liners with Organic Chemical Wastes

Matrecon, Inc.
P.O. Box 24075
Oakland, CA 94623

Henry E. Haxo, Jr., Principal Investigator
Henry E. Haxo, Jr., President
Region IX
Amount: $24,987

The research presented in this proposal focuses on the development of simple, rapid test procedures to predict the transport of waste liquids that contain organic compounds through clayey soil liners over extended time periods. These procedures reflect bulk porosity and pore-size distribution characteristics of specific organic compound clay pairs. The project will assess the feasibility of performing and interpreting the following tests as they relate to permeability of soils to waste liquids containing organic solvents and other chemicals:

1. The effect of organic compounds on the settling characteristics and porosity of clayey soils. This test follows the technique for determining particle size distribution. Use is made of the effect of different organic compounds on the state of flocculation of the clay.
2. The effect of organic compounds on the strength characteristics of a clayey soil, expressed as plastic properties. This test identifies clay structural changes due to organic compound contamination by monitoring the strength of a wet clay.
3. The effect of organic compounds on compressibility of clayey soils. This test assesses structural changes of a clay by comparing the compression curves for contaminated and uncontaminated samples.

Topic IV—Stability of Hazardous Waste Containment Mechanisms

7. Experimental Studies of Erosion from Slopes Protected by Rock Mulch

Water Engineering and Technology, Inc.
P.O. Box 1946
Fort Collins, CO 80522

Chester C. Watson, P.E., Principal Investigator
Chester C. Watson, President
Region VIII
Amount: $23,254

Stabilization of hazardous waste sites and radioactive uranium mill tailings requires that methods be developed to prevent erosion of the protective covering applied at each site to contain the wastes. In the case of uranium mill

tailings a clay cap up to six feet thick is applied to prevent escape of radioactive radon gas. In arid areas where vegetation is difficult to establish, a rock mulch or gravel armor may be placed on the clay to prevent erosion by wind and rain. Natural talus slopes provide an excellent physical analog to this arrangement of materials, and studies show that the hydrological and erosional response of talus may depend upon the nature and distribution of fine material beneath the rock cover. The results (Sosedov, 1974; Yair and Lavee, 1976) indicate that talus can be either very stable or highly erodible due to removal of fine material by subsurface flow. It is suggested that this flow can occur along the interface between the rock cover and the underlying fine material.

The proposed research is designed to investigate experimentally the nature of subsurface runoff generation and erosion processes on rock mulch and underlying surfaces. During Phase I, laboratory experiments will determine which characteristics of rock mulch are important in runoff generation and subsurface erosion. Phase II will extend the study to a field site, located on uranium mill tailings in western Colorado, where test plots of the best and worst cases, as determined by Phase I, will be examined using a portable rainfall simulator. The results will be directly applicable by those involved in stabilization of hazardous waste and uranium mill tailings sites.

Topic V—Decontamination of Soils and Aquifers Exposed to Hazardous Solid Wastes

8. Dioxin Clean-Up Method

Kenterprise Research, Inc.
23 South Harlan Street
York, PA 17402

James Keane, Principal Investigator
James Keane, President
Region III
Amount: $25,000

A technology known as the *Hydrosunder Process*, invented by the proposer, removes oily substances from substrate materials by an entirely new method. It was developed as an oil sand process for Oil Mining projects. The method replaces the oily layer in contact with the substrate with a hydration layer that is essentially complete, thus isolating the oily compounds from the substrate. The process is known to strip oil from sand clay.

Topic VI—Volatile Organic Compound Conversion to Non-Reactive, Non-Toxic Compounds

9. Novel Processes for Control of Volatile Organic Compound Emissions

Merix Corporation
192 Worcester Street
Wellesley, MA 02181

Thomas W. Mix, Principal Investigator
Thomas W. Mix, President
Region I
Amount: $25,000

Four novel processes for the control of volatile organic emissions are proposed for investigation. The first of these is based on scrubbing the volatile organics with an oxidation resistant liquid which is regenerated by aqueous phase oxidation using a strong oxidant. A second process is based on use of a novel oxidation catalyst which will enable the low temperature conversion of volatile organics to non-reactive, non-toxic compounds. The third is based on use of solubility parameters and hard and soft acid and base considerations to enable optimal absorbent selection for recovery of volatile organics. The fourth is based on fuel oil scrubbing to control the volatile organic emissions and enable recovery of their heating value. A combination of experimental and analytic work is proposed to enable evaluation of the relative merits of these processes.

10. Ultraviolet Light Process for Treatment of Trichloroethylene in Groundwater

Photox International
5606 Long Creek
Houston, TX 77088

Robert W. Legan, Principal Investigator
Robert W. Legan, President
Region VI
Amount: $25,000

Contamination of groundwater by trichloroethylene and other volatile halogenated solvents represents a serious threat to the nation's drinking water. Current treatment techniques for controlling such contamination are limited to aeration, adsorption, and linking. A promising alternative is photochemical oxidation, but this process is as yet unoptimized, poorly understood, and largely limited. Photox International has developed a new ultraviolet (UV) light source which will emit short wavelength UV efficiently. This lamp can impart much greater energy to destroy chemical bonds than commercially available lamps and possibly eliminate the need for a chemical oxidant. This proposal discusses the research opportunity to use the new UV lamp to develop an economical process for oxidizing halogenated organic contaminants, specifically trichloroethylene, in water. The research goal is to determine the feasibility and scale-up factors for a novel photochemical process to oxidize trichloroethylene in groundwater. An economic analysis will be performed to evaluate its cost competitiveness with existing treatment technology.

II. Abstracts of Phase I Awards SBIR—1984

Topic I—Multimedia (Solid, Liquid, Gaseous) Pollution Control Processes

11. Combustion of Coal in a Fast Rotary Reactor

PEI Associates, Inc.
11499 Chester Road
Cincinnati, OH 45246

E. Radha Krishnan, P.E., Principal Investigator
Richard W. Gerstle, P.E., Vice-President
Region V
Amount: $35,620

The increased reliance of the power industry on U.S. coal reserves is threatened by an overall decline in the demand for power, the high cost of financing new plants, more stringent regulatory requirements, and inefficient energy recovery and pollution control. Conventional and established emerging coal-fired power generation technologies do not appear to offer the design technology breakthrough needed to alleviate this situation. PEI Associates has developed an innovative coal combustion technology based on the fast rotary reactor concept. The Fast Rotary Reactor coal combustor "fluidizes" the coal in a high speed rotary kiln, permitting high energy recovery. The injection of limestone and the control of combustion conditions permit *in-situ* control of sulfur dioxide and nitrogen oxide emissions. Research to date has extended through the bench-scale development stage. The Phase I research is intended to continue development through an intensive pilot plant test program in order to generate reliable performance and engineering data for scale-up.

12. Laser Induced Destruction of Aromatic Chlorinated Organics in Waste Waters

Energy and Environmental Engineering, Inc.
P.O. Box 215
1B Monsignor O'Brien Highway
E. Cambridge, MA 02141

James H. Porter, Principal Investigator
James H. Porter, President
Region I
Amount: $35,620

Chlorinated aromatic hydrocarbons (CAH's) make up a large fraction of the organic chemicals designated as toxic. They form the basis for the production of pesticides, fungicides, and herbicides; usually end up in dilute concentrations

in waste water streams resulting from the manufacture and/or use of the materials; persist in the biosphere as a result of their slow biodegradability; and concentrate in the biosphere as a result of their entrance into the food chain and their high solubility in animal fats and lipids.

The proposed research is designed to determine the effectiveness of a monochromatic laser light source in energizing the oxidation or polymerization of CAH's in dilute concentrations in water. If successful, this research could serve as a basis for the development of a control technology to destroy extremely toxic species existing in dilute concentrations in waste water, replacing current energy and cost intensive technologies designed to concentrate and destroy these species.

13. A Novel Fixed-Bed Adsorption, Solvent Regeneration Process

Merix Corporation
192 Worcester Street
Wellesley, MA 02181

Thomas W. Mix, Principal Investigator
Thomas W. Mix, President
Region I
Amount: $35,620

A novel process for fixed-bed adsorption using activated carbon and solvent regeneration is proposed for investigation. The process offers easier and less costly solvent regeneration, reduced adsorber bed-length requirements, reduced concentrations of adsorbed water, and lower process energy requirements and capital and operating costs. The process will have application to the recovery of specific impurities such as phenol from wastewater and has the potential to broaden significantly the range of application of activated carbon adsorption with solvent regeneration to the general treatment of wastewater and ground waters.

Topic II—Drinking Water and Wastewater Disinfection Alternative to Chlorine

14. Investigation of a New Approach Towards an Efficient Electrochemical Generator for Ozone

Electrochimica Corporation
2485 Charleston Road
Mountain View, CA 94040

M. Eisenberg, Principal Investigator
Jack Bitter, Corporate Official
Region IX
Amount: $35,600

An investigation of the concept of a new approach towards a highly efficient electrochemical ozone generator is proposed. This approach is based on the utilization of an oxygen reduction cathode instead of a hydrogen evolution electrode, resulting in a significant lowering of required cell voltage. This

approach also significantly simplifies the mass balance in the electrolyzer. An energy requirement of 7.8KWH/Kg of ozone is projected for the new electrochemical method compared to 16.5-22 KWH/Kg for commercial Corona discharge generators. In addition, the new approach will permit the reduction of concentrated streams of ozone (15-25% concentration compared with 2-3% for conventional generators). This will enable the design of more economical processes and equipment for disinfective treatment of water.

Topic III—Applied Biotechnology for Aerobic and Anaerobic Wastewater

15. An Activated Sludge Modification to Eliminate Bulking, Minimize Reactor Volume and Enhance Nutrient Removal

Aware, Inc.
201 Summit View Drive, Suite 300
Brentwood, TN 37207

Sam E. Shelby, Principal Investigator
James H. Clarke, President
Region IV
Amount: $33,768

A modification of the activated sludge process has been developed to eliminate sludge bulking, minimize reactor volumes, and enhance nutrient removals. The flow sheet utilizes two segments in series. The first employs a 10-minute mixed liquor contactor to adsorb 50-60% of the soluble carbon substrate. Contactor mixed liquor is flotation separated and discharged to a separate aeration reactor for metabolism of the adsorbed substrate.

After oxidation, mixed liquor is returned to the contactor. Flotation effluent is discharged to a separate activated sludge reactor served by a final clarifier and sludge recirculation. The contactor and oxidation reactor operate under anoxic conditions to minimize power consumption for aeration. Oxidation reactor temperature may be varied by variation of the solids concentration of the float. This results from the exothermic character of bio-oxidation. High concentrations of separated solids in the oxidation reactor minimizes its volume. Contactor operation eliminates the generation of filamentous organisms in the subsequent activated sludge reactor, thus eliminating sludge bulking and deterioration of effluent quality. Substrate-rich waste solids may be obtained by wasting upstream of the oxidation reactor, thus enhancing gas production from anaerobic digestion. Separate organism populations are maintained in each flow sheet segment. The contactor segment has operated successfully up to an F/M of 35 lb BOD/lb MLVSS/day, and the activated sludge segment, up to an F/M of 2.0 day^{-1}. Sludge age is thus minimized in both segments at less than 1-2 days. Recent research verifies the relationships between sludge age and nutrient content of waste biological solids. The capability to operate at minimum sludge age without bulking thus provides for maximum content of nitrogen and phosphorus in system waste sludge.

Topic IV—Biotechnology Applications for Control of Selected Hazardous Wastes

16. Application of Mold/Yeast in the Treatment of Leachate from Hazardous Waste Disposal Sites

Chesner Engineering, P.C.
2171 Jericho Turnpike
Commack, NY 11725

Warren H. Chesner, Principal Investigator
Warren H. Chesner, President
Region II
Amount: $35,535

This study describes the research conducted to identify the variety of mold or yeast which degrades leachate from hazardous waste landfills in a completely mixed, aerobic reactor. The research also examines alternative pretreatment steps which may be necessary to overcome the limitations in biological degradation due to the presence of toxic substances or nutrient deficiencies. Further, the research compares the effectiveness of mold and yeast relative to conventional microbes to utilize refractory organics, typically found in leachates, for cell growth and synthesis. The laboratory results are used for the conceptual design of a continuous, flow-through pilot plant needed to confirm the findings in Phase I in an anticipated Phase II program.

Topic V—Advanced Thermal, Chemical, and Physical Methods for Hazardous Solid Waste Destruction

17. Segregation for Thermal Destruction of Hazardous Waste in Contaminated Soil

International Hydronics Corporation
5 Crescent Avenue, Box 243
Rocky Hill, NJ 08553

A. B. Mindler, Principal Investigator
Robert B. Bruns, President
Region II
Amount: $35,419

Thermal destruction of hazardous waste in contaminated soil is the only known method of permanently managing this threat to ground water and the environment. However, the costs are so high that temporary storage has been selected for those sites where clean-up has been performed.

This proposal is for the development of pretreatment techniques to markedly reduce the amount of contaminated soil which requires treatment by thermal destruction. This is to be accomplished by separation of the clay, fine silt, and organic matter which are the soil constituents expected to contain most of the hazardous waste contamination.

In Phase I, determination will be made of the portion of hazardous waste carried by the finer constituents and organic matter. Techniques will be

developed for the removal of soil constituents which adhere to the larger particle size constituents by "scrubbing" with fine mesh adsorbents. Preliminary engineering approaches and costs for segregation will be established.

If this approach proves promising, Phase II will be an engineering study and appropriate trials of means to effect separation of the contaminated portion of the soil. This will be followed by trial burns or thermal destruction of the segregated portion of the soil.

Topic VI—Decontamination of Soils and Aquifers Exposed to Hazardous Solid Wastes

18. Feasibility of *In-situ* Biodegradation of Chlorinated Ethenes in Contaminated Aquifers

Cambridge Analytical Associates, Inc.
1106 Commonwealth Avenue
Boston, MA 02215

Samuel Fogel, Principal Investigator
Martin H. Wolf, President
Region I
Amount: $35,620

The chlorinated ethenes, vinyl chloride, vinylidine chloride, trichloroethylene, and tetrachloroethylene have been detected in ground water throughout the United States. Vinyl chloride and vinylidine chloride originate from industrial waste disposal sites as waste products of plastic manufacturing, and trichloroethylene is widely used as an industrial solvent. Since these compounds are highly toxic, it is necessary to develop methods for their removal from contaminated drinking water aquifers. The contamination caused by these compounds is frequently extensive and therefore not able to be treated cost-effectively by existing technologies. The investigators propose to evaluate the feasibility of *in-situ* biological treatment of these contaminated aquifers. They have identified three microbiological processes which have a high probability of achieving the complete biodegradation of chlorinated ethenes and propose to demonstrate this using 14^C labeled vinyl chloride and 14^C trichloroethylene. Two types of microorganisms, aerobic and anaerobic, will be isolated from sediments taken from a discharge area of a contaminated aquifer. Test compounds at concentrations from 10 to 1000 $\mu g/l$ will be incubated individually with aerobic and anaerobic organisms and with a sequential combination of those cultures. Chemical intermediates will be identified by GC and GC/MS, and $^{14}CH_4$ and $^{14}CO_2$ will be measured by liquid scintillation counting. The results should enable the design of specific aquifer restoration plans in which the subsurface environment is modified to create a microbiological barrier across the path of an approaching contaminant plume.

Topic VII—Detoxification, Solidification, or Other Methods for Fixing Organic Chemical Wastes

19. Controlled Solidification of Hazardous Organic Wastes with Recovery of Recyclable Components

Chemical and Metal Industries, Inc.
4701 Dahlia Street
Denver, CO 80216

David E. Hyatt, Principal Investigator
Richard L. Angstadt, President
Region VIII
Amount: $34,634

Present technology for solvent recovery and recycle or for the solidification of hazardous liquid organic waste cannot be applied to all waste streams. Materials containing corrosive, highly reactive, or acidic components are not compatible with the distillation/separation equipment of solvent recovery operations. Nor are these materials or those with highly toxic and/or corrosive vapor constituents (chlorocarbons, hydrogen fluoride, metal halides) suited to open trench mixing with solidifying reagent or to direct incineration.

The proposed research (Phase I) investigates the technical feasibility of neutralizing, detoxifying, and solidifying hazardous liquid organic waste in a closed containment system. The key component of the operating system is a twin screw, continuous mixer-extruder. This unit performs high shear mixing of liquid waste with neutralizing/solidifying reagents under temperature controlled and vapor contained conditions allowing recovery of volatile components for recycle.

A screening matrix will be developed to determine the amount of reagents and the conditions to be employed for each waste candidate. Testing will generate data on the chemical and physical aspects of solidification, on the safety aspects of hazardous component handling during processing, on the chemical and physical properties of the solidified waste, on recovery of volatile organic components, and on other pertinent scale-up factors for the definition of the Phase II effort.

20. Composting as a Waste Management Alternative for Organic Chemical Waste

Cal Recovery Systems, Inc.
160 Broadway, Suite 200
Richmond, CA 94804

Clarence G. Golueke, Principal Investigator
George M. Savage, Vice President
Region IX
Amount: $35,620

The research will investigate the technical, economic, and environmental feasibility of utilizing composting as an alternative waste management practice for treating, detoxifying, and biostabilizing organic chemical wastes. Selected biodegradable hazardous wastes will be subjected to the compost process to

ascertain the degree of detoxification and the responsible microorganism. Conceptual design of representative hazardous waste composting operations will be prepared based upon the results of the research. Lifecycle economics will be prepared in order to establish the competitive position of composting with contemporary treatment and disposal methods, i.e., landfill, incineration, and on-site dedicated containment.

III. Abstracts of Phase II Awards SBIR—1984

Topic I—Multimedia (Solid, Liquid, Gaseous) Pollution Control Processes

21. Production of an Industrial Thermosetting Resin from Whey and Whey By-Products

Chemical Process Corporation
1741 South 14th Street
Milwaukee, WI 53304

Tito Viswanathan, Principal Investigator
Donald H. Westerman, President
Region V
Amount: $100,000

In Phase I of this project, Maillard and Carmelization reactions associated with the thermal polymerization of lactose in whey were exploited to convert the solids in whey permeate (deproteinized whey) into a thermosetting resin which proved to be an excellent adhesive for binding wood particles. By the addition of condensing agents such as urea and phenol, concentrated (65 to 75% solids) resin solutions of variable viscosity and pH could be obtained. A mixture of wood particles with resin and low concentrations of a polyfunctional cross linker gave quality boards in the 55-60 lbs/ft^3 range when subjected to a press temperature of 185°C and 500 psi and press time of seven minutes.

The confirmed limited involvement of hydroxymethyl furfural (HMF) and levulinic acid in the reaction mechanism allowed the research effort to be directed toward other areas. The preliminary effective use and documentation of directed Maillard reactions along with urea and phenol-condensing agents without formaldehyde prompted additional research in selecting more effective catalysts and cross linking agents.

Relating the quantitative properties of the adhesive to its specific chemical composition and process for manufacture will constitute a major portion of the early research in Phase II. The impact of additional poly-functional cross linking agents or physical properties of finished boards and resins will be evaluated.

Reaction kinetics will be measured to optimize the production of the desired polymer while simultaneously minimizing the undesirable byproducts. Appropriately compounded resin will be dried and used in the production of board with limited evaluation as a molding resin.

22. Research on Slag Steam Generator

Richard Jablin & Associates, Inc.
2500 West Club Boulevard
Durham, NC 27705

Richard Jablin, Principal Investigator
Richard Jablin, President
Region IV
Amount: $100,000

A Slag Steam Generator (SSG) has operated continuously for four months on molten slag from an ironmaking cupola. It proved that it can recover the thermal energy in the slag and do so with a minimum emission to air and water. It eventually failed due to thermal fatigue of the cooling surface.

The Phase I research study, which attempted to overcome the fatigue problem, was successfully completed, indicating that future units of the SSG may be build without incurring fatigue. The study presented an engineering analysis of the thermal stress conditions and the construction details which are required to deal with them. It also covered the safety features which would automatically guard against equipment failure that might result from an upset in operating conditions.

Estimates were made of installation costs for equipment as well as for operating revenues resulting from its operation. An analysis of these costs and revenues indicated that, in addition to eliminating air and water pollution, the SSG can provide a rapid return on investment as a result of the recovery of thermal energy, the production of an improved slag product, and the improvement of handling of the slag.

The first step in Phase II is to perform laboratory experiments on the most critical element of the process, which is the cooling drum. Technical computation and data have determined that this component will operate satisfactorily in the full-scale unit. However, in order to provide additional assurance, testing it in the laboratory is proposed.

The next step is to conduct market research into the application of the SSG in five steel companies. This investigation will determine the capacity of the SSG, the current environmental problems resulting from slag emissions, the value of the steam, and the value of the slag. Subsequently, a preliminary analysis will be made using the data obtained to determine which of the potential candidates would profit most in terms of reductions in environmental pollution and improvement in operating revenues. Additional engineering analysis will be conducted for the two most promising candidates. This analysis will determine details of the operating site and will involve the preparation of drawings and cost estimates for providing and installing the process.

The final step will be the preparation of a cash flow analysis for presentation to the operating companies, with the intention of selling them full-scale operating units.

23. Sludge Reclamation Using Coupled-Transport Membranes

Bend Research, Inc.
64550 Research Road
Bend, OR 97701-8599

David R. Kamperman, Principal Investigator
Harold K. Lonsdale, President
Region X
Amount: $99,761

In 1980 the metals and electronics industries generated over 7 million tons of hazardous waste at a cost of $100 to $400/ton. These sludges, which contain substantial amounts of mixed heavy metals, present a serious disposal problem and represent a waste of natural resources. The intrinsic value of metals such as nickel, chromium, and copper contained in these sludges is high, providing a significant incentive for their recovery.

During the Phase I program, actual sludge samples from a large chrome-plating shop were used to successfully demonstrate the use of coupled-transport membranes for the separation of chromium and copper. After dissolving the sludge, a copper-selective membrane was used to separate copper in the form of a copper sulfate concentrate. Copper having a purity of 99.99% was obtained from this concentrate by electrolysis. Trivalent chromium was electrolytically oxidized to hexavalent chromium, and a coupled-transport membrane was used to produce a pure sodium chromate concentrate. A synthetic sludge solution was used to demonstrate the electrolytic recovery of nickel following the removal of zinc impurities using coupled-transport membranes.

Based on these preliminary studies, process economics appear favorable, with an estimated return on investment in capital equipment of 27% based on the value of the metals recovered and the decreased sludge disposal costs.

Efforts during the Phase II program will focus on increasing metal-ion fluxes through the coupled-transport membrane and increasing the current efficiency of the chromium oxidation process. An integrated, bench-scale unit will be constructed that will allow the various recovery steps to operate simultaneously. A detailed economic analysis will be performed from data collected from the operation of this system.

24. Recycling of Dust from Electric Arc Furnaces

PEI Associates, Inc.
11499 Chester Road
Cincinnati, OH 45246

William F. Kemner, Principal Investigator
George A. Jutze, President
Region V
Amount: $100,000

The major shortcomings of the various processes suggested for recycling metallurgical dust have been the high capital cost of the equipment and the need for large quantities of dust for the processes to be economical. Electric arc furnace dust is not amenable to these processes because it is generated in small quantities at a large number of locations, distant from industrial centers where regional recycling might occur. Furthermore, electric arc furnace dust is

listed as a hazardous waste by the Environmental Protection Agency because of the leachability of heavy metals.

A trial of greenballing and recycling of the dust at a commercial steel plant will be conducted to investigate the three critical issues identified in the Phase I research. These issues are the fate of zinc and other volatile elements in the dust, the electrical energy consumption in the furnace during recycling, and the economics of recycling.

Topic II—Volatile Organic Compound Conversion to Non-Reactive, Non-Toxic Compounds

25. Novel Processes for Control of Volatile Organic Compound Emissions

Merix Corporation
192 Worcester Street
Wellesley, MA 02181

Thomas W. Mix, Principal Investigator
Thomas W. Mix, President
Region I
Amount: $100,000

A new scrubbing process with application to volatile organic compound (VOC) and odor control and acid gas scrubbing, the feasibility of which gas demonstrated in Phase I, is proposed for further development in a Phase II follow-on leading to its commercialization. The process enables an order-of-magnitude increase in the rate of liquid phase mass transfer for absoprtion of reactive VOC and odorous compounds such as vinyl monomers, mercaptans, sulfides, phenols, and amines. The process offers many other potential advantages as well and has promise for many other applications, including H_2S scrubbing and flue gas desulfurization.

IV. Abstracts of Phase I Awards SBIR—1985

Topic I—Drinking Water Treatment, Disinfection, and Distribution Contamination Control

26. Chemical/Radiation Well Treatment

George Alford and Bill Rogers
Ground Water Consultants
2301 Bryant Drive
East Point, GA 30344

George Alford, Principal Investigator
Bill Rogers, P.E., Associate
Region IV
Amount: $48,667

Iron and sulfur bacteria are principal causes of biofouling of well screens, pumps, treatment and processing equipment, and, in extreme cases, distribution systems. Associated problems are high-pumping cost, rapid pump and valve deterioration, corrosion of all ferrous material in contact with the water, increased disease risk (shielding, nurturing media), and bad taste, odor, and color.

The problem ranges from being merely a nuisance to eliminating the only reasonable source of water in some areas. It is world-wide but follows some patterns of intensive contamination.

Treatment has been attempted for several hundred years, with varying degrees of success. Generally, the common methods (chemical and mechanical) are only effective for short periods when contamination is severe and covers the area. Continuously trickling chlorine into the well or dosing each pump cycle with chlorine tends to prolong the effective period of treatment but is still not permanent in most severe cases.

A means is needed to sterilize the well and surrounding aquifer and to retard bacterial growth or maintain the kill. Radiation offers the opportunity to achieve both objectives safely. Sterilization can be accomplished at lower doses than commonly used to preserve potatoes, fish, and grains. Existing techniques will allow triple encapsulation of active materials, insuring no leaks, no contact with the water or aquifer, and therefore, no radioactive matter outside the shielded rod.

Lab facilities are in place at Georgia Tech for a test of sterilizing sewage sludge.

Topic II—Municipal and Industrial Wastewater Treatment and Pollution Control

27. A Substitute for Chromic Acid Etching of Plastics for Plating

J. P. Laboratories, Inc.
212 Durham Avenue
P.O. Box 636
Metuchen, NJ 08840

G. N. Patel, Principal Investigator
G. N. Patel, President
Region II
Amount: $48,500

Chromic acid is used for etching plastics for electroplating and electromagnetic interference (EMI) shielding. More than a million pounds of chromic acid is used every year in the United States for etching plastics. Hexavalent chromium is highly toxic, requires expensive equipment for its recovery from the wastewater and the sludge requires proper disposal. Plastic platers are seeking a less hazardous and less expensive substitute for chromic acid.

A number of etching systems have been proposed in the literature but none of them are being used because of their toxicity, flammability, and high cost. A new system is proposed for etching of plastics for plating. The system is the least toxic possible and less expensive than others.

28. Biological Sequencing Batch Reactor Treatment of a Mixed Municipal and Industrial Wastewater in an Egg-Shaped Reactor

SBR Technologies, Inc.
15631 Springmill Drive
Mishawaka, IN 46545

Lloyd H. Ketchum, Jr., Principal Investigator
Robert L. Irving, Corporate Official
Region V
Amount: $48,500

Operating strategies have been developed for biological Sequencing Batch Reactor (SBR) treatment of both municipal wastes (i.e., low-strength wastes) and industrial wastes (i.e., high-strength wastes containing difficult to degrade organics). SBR systems should also offer advantages for biological treatment of mixed municipal and industrial wastewaters that are relatively low strength, but contain inorganics and hard to degrade hazardous organics. Engineering a reactor to accomplish biological treatment of such wastewaters is important and is the focus of the proposed studies. Low-strength wastewater treatment typically requires maintaining small quantities of sludge in the reactor to facilitate removal of treated effluent, and to hold hydraulic retention times low (i.e., small reactor size). However, when biological treatment of hard-to-degrade and toxic organics is attempted, quantities of sludge held in the reactor must be large enough to maintain sufficient numbers of organisms acclimated to biological degradation of those organics. The egg-shaped reactor, which has been widely used in Germany and recently introduced in the United States for

anaerobic sludge digestion, appears to be well suited for biological SBR treatment of these mixed wastewaters. The proposed studies are directed at the process development and engineering design of an egg-shaped SBR system for treatment of mixed municipal and industrial wastewaters.

29. Pulsed Air Biological Fixed Film Treatment

Process Dynamics Incorporated
119 West 8th Street
P.O. Box 3007
Jacksonville, FL 32206

Harry Pepper III, Principal Investigator/President
Harry Pepper, Jr., Co-Principal Investigator/Vice President
Region IV
Amount: $48,219

A high rate downflow sparged biological fixed film reactor design has been proposed. This system offers an improvement over previous designs in that instead of constant air sparging, the air sparging to the packed seed is pulsed to offer more efficient oxygen utilization. Another improvement is that because of the pulsing air, the air header supply can be located below the media to permit full use of the media capacity for biological oxidation and filtration. This automated high rate system provides secondary treatment at loading at least five times that of activated sludge, and no clarifiers are necessary.

An 8-10 gpm automated pilot plant has been fabricated to test the air fixed film design. The pilot plant contains two cells. One cell will contain a volcanic ash media and the other activated carbon. The media effective size is about 3.5 mm. Activated carbon will be investigated because of its potential for use in the biological degradation of industrial or hazardous wastes. The treatment performance and oxygen utilization efficiency will be compared for the two media.

The system performance and oxygen transfer efficiency will be evaluated by treating primary effluent wastewater at a municipal facility. The air sparge rate and pulsing time interval will be varied and the level of improvement in oxygen transfer efficiency and effect on treatment performance will be observed. Influent and effluent, TCOD, SCOD, TSS and turbidity measurements will be used to define treatment performance. Reactor dissolved oxygen measurements and off-gas analyses will be made to evaluate the oxygen transfer efficiency at each air rate and pulse interval.

Topic III—Biological Sludge Treatment for Improved Handling and Disposal

30. Detoxification of Sludge Using Aerobic Thermophilic Digestion with Air Aeration: Pilot Plant Analysis

Microgen Corporation
218 Cayuga Heights Road
Ithaca, NY 14850

William J. Jewell, Principal Investigator
William J. Jewell, President
Region II
Amount: $48,667

Pathogens, toxic metals, and toxic organics occur at low concentrations in municipal wastewaters, but many of these materials are concentrated thousands of times in the resulting primary and secondary biological sludges. A review of the Environmental Protection Agency's (EPA's) "safe sludge" designation for use in food production shows that nearly half of all sludges generated cannot be defined as "safe," thus eliminating the cost-effective ultimate disposal alternative of land application. A process that could eliminate the toxic constituents of sludge would be of benefit to many municipalities and industries.

Previous research has developed a process that promises to be capable of detoxifying sewage sludge in a cost-effective manner. This project outlines the next phase that is needed to bridge research information with commercial application.

Aerobic digestion with unique highly efficient self-aspirating aerators was shown to be capable of autoheating sludges to pasteurization temperatures (50°C+) by Jewell in a full scale facility in 1979. Further development showed that modifications to the process have the potential of removing pathogens, toxic metals, and possibly toxic organics in a cost-effective, simple process.

Autoheating slurry temperatures can easily achieve 60°C with most sludges without heat energy additions (higher temperatures would be possible with heat exchangers), thus killing all pathogens. Manipulation of the pH in these hot aerobic slurries showed that greater than 80% of most toxic metals could be rapidly solubilized (in less than 3 hours). Although not tested, aeration at these temperatures would be likely to result in volatilization of some toxic organics. Finally, it was shown that the process could also be applied to anaerobically digested sludge. This latter application is important not only because of the large installed digestion capacity, but short term aeration (6 hours) of anaerobically digested sludge results in rapid temperature increases, and significantly increased settleability and dewatering characteristics, thus achieving up to 50% volume reduction. Thus a hypothetical system with hydraulic retention time of less than 24 hours should be capable not only of substantially reducing sludge volumes but also of producing sludge that would meet EPA's "safe" designation for virtually all organic sludges either as an add-on process or as a new installation.

This study will examine the impact of the unique self-aspirating aerators on the settleability, dewaterability, autoheating, and metal removal characteristics of anaerobically digested sewage sludge in a 28 m^3 full scale unit located at the Binghamton, New York, sewage treatment facility (a 190 million l/d capacity plant). Three other sludges representing a wide range of contaminants, will be

trucked to this facility and used in short term batch tests. The results of these trials will be used to estimate design requirements and to estimate the feasibility of the process.

31. Development of Chemical Fixation Process to PFRP Classification for Municipal Sludge Treatment—Enabling the Reuse of the Resulting Product

Chemfix Technologies, Inc.
1675 Airline Highway
P.O. Box 1572
Kenner, LA 70063

Peter P. Meehan, Jr., Principal Investigator
D. N. Silverman, III, President
Region VI
Amount: $48,667

Safe treatment and utilization of municipal wastewater sludges is a topic of significant concern. There is definite need for the development of a treatment process which does all of the following:

- Conforms to U.S. Environmental Protection Agency requirements for a "Process to Further Reduce Pathogens."
- Creates a product not subject to reinfection.
- Produces a material suitable for beneficial use.
- Is economical to utilize.
- Produces a non-toxic product.

This research will afford such a treatment. It is based on the patented CHEMFIX® process and utilized and expands upon the chemistry intrinsic to the process.

Pathogenic organisms will be inactivated by high pH and ammonia disinfection. Metals will be immobilized through chemical reduction or soil absorption.

Chemical tests will compare the product with agricultural lime and fertilizer parameters to establish the economic value of the product in agriculture. Physical testing will indicate viability of the product for landfill cover, road base material or building, soil amender, or slope stabilizer.

32. Improved Performance of Anaerobic Digesters

Engineering Resources
1400 Kings Drive
Fayetteville, AR 72701

James L. Gaddy, Principal Investigator
Stephen S. Adams, Vice President
Region VI
Amount: $48,609

The objectives of this research are threefold: (1) to develop techniques for rapid start-up of anaerobic digesters; (2) to develop procedures for rapid recovery of upset digesters which have been shocked by overloading, toxic substances, or pH depression problems; and (3) to increase the overall kinetics

of anaerobic digestion. Reaction kinetics may be improved by enhancing the growth of methanogenic bacteria in the culture. This is accomplished through the addition of selected organic nutrients and by making nutrients more available to the methanogens in the digesters by the addition of chelating agents. Start-up and recovery times may be shortened by the addition of large numbers of pure culture methanogens. This method reduces the time spent waiting for sufficient methanogenic growth to develop and permits steady high rate digestion.

The commercial impact of smoother start-ups, quick response to upsets, and improved overall kinetics will be manifested in improved economics for anaerobic digestion. Improved economics will stimulate the interest of the private sector in utilizing anaerobic digestion as both a waste treatment process and a technique for energy recovery from waste materials.

33. Effect of Mobile Dewatering of Septage Sludges on STP Outflows as Well as on Residential Septic System Leaching Fields

Waste Process Technology
50 Fairmount Street
Marlborough, MA 01752

Kenneth J. MacLean, Principal Investigator
Kenneth J. MacLean, Executive Director
Region I
Amount: $48,470

Studies indicate that straight septage introduction to activated sludge plants causes shock loading and subsequent violation of effluent permit standards.

This project intends to evaluate dewatering of sludge by the use of wire cloth screening to determine if the dewatered sludge meets landfill acceptability standards. It intends also to determine if the return of the filtrate to the septic tank of origin or another septic tank impairs the function of leaching fields or if potential pathogen transfer from one tank to another creates a public health risk.

This study will pilot test filtration of septage with a subsequent physical and chemical analysis of the sludge and filtrate. Existing data will be evaluated to assess the impact of filtrate on the function of the leaching field in addition to the reduction of the resting period. Various chemicals and polymers will be evaluated for effectiveness in the straining of septage. The technologies in question are (1) mobile vacuum filters and (2) mobile micro screens. This will also include an economic analysis. It is expected that this technology will improve the outflow characteristics of STP's of design flows <5 mgd by removing the shock load to septage from the headworks. Vacuum filtration at the plants should improve, and filtrate should contain lower BOD, TSS, and VSS. In addition, it is expected that this technology will have no adverse impact on the leaching characteristics of residential septic systems and will actually increase the pumping frequency due to the cost savings to the homeowner.

Topic IV—Solid and Hazardous Waste Disposal and Pollution Control

34. Recovery of Arsenic, Antimony, Chlorocarbons from Spent Fluorocarbon Catalyst

Chemical and Metal Industries, Inc.
4701 Dahlia Street
Denver, CO 80216

David E. Hyatt, Principal Investigator
Richard L. Angstadt, President
Region VIII
Amount: $46,984

In November of 1984 the President signed into law a set of far-reaching amendments to the Resource Conservation and Recovery Act of 1976. Under the new law, land disposal of all hazardous wastes is to be banned over the next five years. Waste reduction, recycle, and incineration are emphasized. Particularly targeted are waste streams containing halogenated solvents and arsenic due to the threats these materials pose to human health and to the environment. Present technology for recovery and recycle or for the incineration of hazardous halogenated organic wastes cannot be applied to all such materials. Streams which contain complex azeotropic mixtures or are corrosive, highly reactive, or acidic are not compatible with current distillation/separation or incineration equipment.

The spent catalyst from fluorocarbon manufacturing processes is an excellent example of a hazardous and toxic waste stream which will be targeted early by the new Act and for which current disposal technology is inadequate. The proposed research (Phase I) investigates the technical feasibility of recovering arsenic, antimony, and chlorocarbons from spent fluorocarbon catalyst with almost total recycle or reuse of the metal values and recycle or incineration of the halocarbons. Final solid waste products of the process will be minimal and nonhazardous.

35. Reclamation and Reuse of Chemical Values from Municipal Sludge Solids

John Brown Associates, Inc.
P.O. Box 145
Berkeley Heights, NJ 07922

Herbert S. Skovronek, Principal Investigator
John A. Brown, President
Region II
Amount: $42,034

Municipal waste treatment produces sludges rich in complex organic chemicals that should be considered as a chemical raw material and resource analogous to wood pulp, agricultural wastes, or petroleum. Current disposal practices of landfilling, ocean disposal and even incineration disregard these values and at best recover energy (and possibly metals).

It is proposed to carry out several classical chemical operations, such as acetylation, carboxymethylation, nitration, etc., on samples of municipal

sludges, emphasizing the cellulosic nature of the sludges. The goal will be to produce and isolate derivatives that can be compared to existing products now manufactured from virgin materials (e.g., cellulose acetate, carboxymethyl cellulose, nitrocellulose). In addition, recognizing that sludge is a complex mixture, solubilization processes, such as xanthatin or treatment with cuprammonium hydroxide, will be explored as a means of isolating a pure cellulose. Product evaluation will be carried out to the extent of demonstrating that usable fibers, films, etc., can be produced.

In addition, an integral part of the project will be an evaluation of the new wastes that would be generated and a preliminary judgment of whether such processing offers environmental benefits.

36. Photolytic Detoxification Concept

W. J. Schafer Associates, Inc.
Corporate Place 128, Building 2, Suite 300
Wakefield, MA 01880

Douglas G. Youmans, Principal Investigator
Patricia A. Buckley, Contract Administrator
Region I
Amount: $48,601

Use of a pulsed ultraviolet radiation is proposed as a means to detoxify equipment used in the preparation of toxic chemical compounds. The radiation will serve to both vaporize material adhering to the surface as well as to bring about photolytic destruction. This combination of effect is projected to provide a dry cleaning concept where the toxic material and its byproducts (potentially toxic) can be concentrated in a chemical trap rather than being diluted in a liquid phase solvent. This concentration feature thus provides a small volume of material for further processing (e.g., thermal decomposition) or storage. The technology appears to offer a practical detoxification device which can be used to detoxify equipment *in situ* or buildings and equipment that have been contaminated by accident.

37. Landfill Leachate Control Treatment Via *In Situ* Flow Modification

ENG, Inc.
1430 Massachusetts Avenue
Cambridge, MA 02138

Trevor P. Castor, Principal Investigator
Trevor P. Castor, President
Region I
Amount: $48,667

Recent promising developments in the petroleum industry "Profile Modification Technology" (PMT) will be evaluated for their application to leaking landfill sites. Profile flow modification treatments are used to increase flow resistance in high permeability areas 75 feet to as much as 1000 feet from the injection wellbore. These treatments can withstand formation pressures and temperatures up to 200°F. The treatment materials readily attach to reservoir rock surfaces and then cross-link to plug the pores in permeable formations. The prospect of sealing off large, highly permeable (leaking) areas in the bases

of landfills is very appealing. However, several fundamental concerns must be addressed before this process can be field tested and commercialized.

The most common concern with this technique is whether the material will be resistant to the wastes stored in landfills. Other concerns include whether the treatment can physically penetrate and then seal the leaking areas and can be applied efficiently enough to be an economic alternative to competing remedial measures.

These issues will be evaluated to determine possible application of existing *in-situ* gel materials considering their compatibility with representative hazardous wastes. The mechanisms responsible for unsatisfactory *in-situ* gel performance will be identified and improvement recommended. Also the flow behavior of these materials will be examined in a simulated landfill environment to determine whether this new geological setting poses significant problems for the application of PMT to landfill leachate control.

38. Enhanced Thermal Destruction of Hazardous Wastes Utilizing Microwave Techniques

Fossil Energy Research Corporation
23342 South Point, Suite C
Laguna Hills, CA 92653

Richard E. Thompson, Principal Investigator
Richard E. Thompson, Corporate Official
Region IX
Amount: $48,667

The project will examine the technical feasibility of enhancing the thermal destruction of hazardous waste sludges, tars, and watery wastes by improving the dispersion and burnout of these materials in incinerators and other combustion equipment. The primary focus will be on the evaluation of proprietary microwave techniques, singly or potentially in combination with proprietary additive materials. The objectives are to achieve increased thermal destruction efficiency, improved combustion stability, reduced auxiliary fuel use (if any), and an ability to destroy a wider range of hazardous wastes. Preliminary performance and cost comparisons will be made with conventional techniques including an evaluation of recent European technology.

39. Development of an Automated Geophysical Ground Water Quality Monitoring System for Use at Toxic and Hazardous Waste Disposal Sites or Other Sites Where There Are Contaminants

IEG Limited
2340 Kohler Drive
Boulder, CO 80303

Scott E. Hulse, Principal Engineer
Scott E. Hulse, President
Region VIII
Amount: $48,624

A permanently installed ground-water quality monitoring system that uses several kinds of electrical geophysical measurements and advanced analytical

procedures to sense contaminant escape and ground-water contamination has been designed for use in conjunction with observation wells at industrial and municipal solid and liquid waste disposal sites, brine ponds near oil fields, industrial process water containment facilities, mineral processing and leaching facilities and mines where there is acid drainage. The system will be useful for detecting effects of some inorganic and possibly some organic substances; however, site-specific physical property characteristics must be used to optimize system operation at a particular facility. The automated system will include instrumentation and software that controls data acquisition, data processing, archival function, data communications and preparation of periodic data reports. The system will provide site managers with information that can be used in conjunction with data from complementary systems to assure compliance with environmental regulations and should make overall operation more cost-effective.

40. Metal Value Recovery from Alloy Chemical Milling Waste

Montana Environmet, Inc.
54 Apple Orchard Road
Butte, MT 59701

L. G. Twidwell, Principal Investigator
L. G. Twidwell, Corporate Official
Region VIII
Amount: $47,811

A proposal is presented outlining a research study directed toward treatment of chemical milling waste for recovery of cobalt, chromium, and nickel. The application of a new technology is proposed that is selective and cost effective for recovery of these three elements. The process is one of solution purification by selective phosphate precipitation. The precipitation is selective toward trivalent cations over divalent cations; and importantly, the solid product is readily filterable.

This proposed study is to be a continuation of present studies that have demonstrated selective recovery of iron and chromium from a number of divalent cations; Cu, Zn, Ni, and Cd. The emphasis of the study will be on the selective separation of cobalt and nickel. Preliminary testwork has demonstrated that cobaltic phosphate precipitation produces a Co/Ni ratio of over 10; whereas commercial precipitation processes presently produce Co/Ni ratios of 1.5-3. A feature of utmost importance is that the precipitated phosphate products are readily filterable. Preliminary experimental results and photomicrographs of precipitated phosphate products are presented in the Phase II proposal.

At present, chemical milling sludge waste materials are disposed of in hazardous waste landfills. If this new precipitation technology can be shown to be successful, then disposal of a toxic waste and recovery of critical and strategic metals may potentially be accomplished.

Topic V—Environmental Monitoring Instrumentation

41. Development of Commercially Available Instrumentation for Monitoring Indoor Radon Progeny

Sun Nuclear Corporation
415-C Pineda Court
Melbourne, FL 32940

Joel M. Siegel, Principal Investigator
Thomas L. Powers, President
Region IV
Amount $47,208

Radon daughters in indoor air represent a greater radiological hazard to the population than any other naturally occurring or man-made radiation source. A system to detect the alpha particles emitted by these radiologically active radon daughters is proposed. A key element of this work is to provide a suitable calibration between detected alpha energy and indoor radiological hazard. The instrumentation design and development effort will be directed so as to insure that the predicted accuracy will be achieved.

The ultimate goal of this proposal is to develop commercially available and easily used instrumentation for the monitoring of indoor working levels of radon. The scope of Phase I is to establish "breadboard" and working prototypes to prove the detector theory and define intensifier requirements. Several instruments would be produced in Phase II and field testing of both the instrumentation and the derived calibration algorithms would be undertaken. The entire project envisions two instruments, the first designed for ease of operation by governmental and institutional users, and the second, intended for permanent installation in high risk structures and dwellings.

42. An Optical Particle and Flux Monitor for Stack Emissions

Spectron Development Laboratories, Inc.
3303 Harbor Boulevard, Suite G3
Costa Mesa, CA 92626-1579

Cecil F. Hess, Principal Investigator
Chris W. Busch, President
Region IX
Amount: $48,665

The presence of solid particulates entrained in the air can be detected by measuring their scattered light and the overall light extinction. Very sensitive extinction measurements can be performed with transmissometry. Among the most promising and simple transmissometers are the Maximum Turbidity Method, the Dispersion Quotient Method, and the Two-Color Transmissometer. For reasonably clean air with slight dust contamination, more sensitivity can be obtained by looking at the characteristics of the scattered light. A more elaborate technique based on a pulse height analyzer combined with laser Doppler Velocimetry will provide the size and velocity distribution of the particulates entrained in the air.

It is the objective of this work to evaluate the above methods to establish their sensitivity to size and concentration, their insensitivity to variations in index of

refraction, their insensitivity to the shape of the particulates, and their potential with simple white light sources. A method for prototype implementation will be established.

43. Development of a Retrofit *In-Situ* Three Point Audit Device for Testing of Linearity and Calibration of Commercially Available In-Stack Transmissometers

Eastern Technical Associates
Box 58495
Raleigh, NC 27658

Thomas H. Rose, Principal Investigator
Thomas H. Rose, President
Region IV
Amount: $48,036

Commercially available in-stack transmissometers for opacity measurement presently have only the capability of a one point dynamic upscale check or no dynamic upscale check during operation. In order to perform necessary multi-point audits of linearity checks, the instrument must be removed from service or at the least be manually fitted with an external audit device. This requires access to the instrument often located at evaluated stack heights with poor safety provisions. Thus, routine audits that should be performed are often not performed, with the accompanying production of low quality data. This project proposes to develop a retrofit dynamic audit/calibration device that will fit most commercially available transmissometers capable of being remotely activated to produce three up-scale points for audit, calibration, and diagnostic purposes. The increased ease and safety in performing these audits will result in more and better quality data from opacity monitors.

44. Supercritical Fluid Chromatographic Methods for Non-Volatile Organic Compounds

Lee Scientific
379 North University, #104
Provo, UT 84601

Douglas Later, Principal Investigator
Lee R. Phillips, Contracts Officer/Legal Counsel
Region VIII
Amount: $48,639

Lee Scientific proposes to investigate and develop new and improved instrumental methods for the analysis of non-volatile organic compounds in complex environmental matrices by capillary column supercritical fluid chromatography (SFC). Non-volatile compounds of specific interest include heavy-molecular-weight, polar, and thermal-labile species which have proven to be difficult or impossible to analyze by conventional GC and/or HPLC methods. In Phase I of this work, the feasibility of analyzing selected non-volatile compounds, both as standard compounds and as those found in the presence of complex mixtures, by capillary column SFC will be demonstrated. Experimental aspects of this phase of the study will include the investigation of supercritical fluid mobile phase solubility effects and SFC detector sensitivity

limitations. Subsequent phases of the investigation will concentrate on the development of improved detection systems for SFC, binary pumping systems, and new capillary column coatings optimized for specific compound classes which are of interest to the Environmental Protection Agency (EPA).

45. Development of a Highly Reliable Cost-Effective Continuous Emission Monitor

ADA Technologies, Inc.
6973 South Andes Circle
Aurora, CO 80016

Michael D. Durham, Principal Investigator
Judith A. Armstrong, President
Region VIII
Amount: $48,667

The purpose of the proposed project is to provide a proof of concept evaluation of an instrument capable of measuring NO, O_2, and SO_2 using UV absorption and a photodiode array spectrophotometer. If successful, this instrument would satisfy all the requirements of a continuous emission monitoring system required by the Environmental Protection Agency. Since all three gases would be measured with a single instrument with no moving parts, it is believed that it would be less costly and more reliable than commercially available instruments.

The Phase I testing will involve an evaluation of the concept in the laboratory under simulated flue gas conditions. A commercially available photodiode array spectrophotometer will be used in the initial phases of testing. The unit will be modified using a quartz prism and optics to produce the spectra of interest across the diode array. Testing will be performed to determine the response of the instrument to the primary gases of interest. Potential interference gases will then be introduced into the simulation gas stream. An algorithm will then be derived to isolate and determine the concentration of the three gases of interest and null out the effects of the interference gases.

V. Abstracts of Phase II Awards SBIR—1985

Topic I—Multimedia (Solid, Liquid, Gaseous) Pollution Control Processes

46. Determination of Reaction Pathways and Energy Requirements in Laser Induced Photolysis of Chloro-Aromatics

Energy and Environmental Engineering, Inc.
P. O. Box 215
1B Monsignor O'Brien Highway
East Cambridge, MA 02141

James E. Porter, Principal Investigator/President
Region I
Amount: $150,000

Among the chemical species often found contaminating our water bodies are the chlorinated aromatic compounds. These compounds have managed to contaminate natural water sources by several means including: the migration of leachates from dumpsites into groundwaters; the drainage of agricultural lands containing pesticides into surface waters; and through the chlorination for disinfection of drinking and waste waters containing natural humic acids. Chloroaromatics are relatively stable at ambient conditions and form a predominant class of compounds on the list of priority pollutants.

Past research has shown that laser generated electromagnetic radiation will stimulate the chemical reaction of chloroaromatics when contained in low concentrations in water. Further, the radiation is not absorbed by water molecules, thus making the energy source highly specific. The source interacts only with chloroaromatic molecules although one molecule in 100,000 may be a chloroaromatic. The reaction pathways and products of the reaction are not well defined, but preliminary results indicate dechlorination as a first reaction step when oxygen is dissolved in the aqueous phase and a water insoluble polymer is formed under anaerobic conditions. The proposed research is designed to determine reaction pathways, products of reaction, and energy requirements for several model compounds which may appear in reaction sequences. A model of the chemical kinetics and energy absorption physics is also proposed which will be validated experimentally during the course of this research. The successful completion of this project will lead to the development of criteria for the design of photochemical reaction systems for the detoxification and/or destruction of chloroaromatics contained in waste waters.

Topic II—Drinking Water and Wastewater Disinfection Alternative to Chlorine

47. Research and Development of an Efficient Electrochemical Generator for Ozone-Phase II

Electrochimica Corporation
20 Kelley Court
Menlo Park, CA 94025

Morris Eisenberg, Principal Investigator
Jack Bitter, Corporate Official
Region IX
Amount: $150,000

In Phase I, the value of a new approach towards electrochemical ozone generation was demonstrated experimentally, by employment of *oxygen-reduction cathodes*, to lower the overall operation cell voltage requirements by *1.0 - 1.8 v*. This provides a basis for substantial future increases of product yield per unit energy consumed. Furthermore, elimination of conventional hydrogen-producing cathodes is found to reduce some ozone product losses and to increase the safety of the equipment by eliminating or reducing the possibility of hydrogen-oxygen or hydrogen-ozone mixture.

After a review of the technical background and the key promising experimental results, a detailed experimental work plan is presented for Phase II covering a number of tasks such as optimization of the electrolyte, cell design and its integration with refrigeration and the flow system, development of the design for one domestic and one industrial ozone generator, and construction and testing of one prototype. Finally, a commercialization program including a market survey and an analysis task and business plan is presented.

Topic III—Applied Biotechnology for Aerobic and Anaerobic Wastewater

48. The Treatment of Selected Industrial Wastewaters with the Biosorption Process

Aware Incorporated
621 Mainstream Drive
Suite 200
Nashville, TN 37228

Gregory W. Pulliam, Principal Investigator
James H. Clark, President
Region IV
Amount: $149,489

The Phase I study has shown that the biosorption process can remove more than 90 percent of the soluble organics in a synthetic wastewater with a contact time of 10 minutes, a sludge regeneration time of 2 hours, and a floc loading of 100 mg COD/g VSS. It would be expected that different types of industrial wastes would exhibit different rates of biosorption relative to the composition of the waste.

The objective of Phase II will be to screen several representative industrial wastewaters using the methodology developed in Phase I. Industrial wastewaters to be investigated include dairy products, food processing, tannery, and organic chemicals. Bench-scale studies will be conducted to determine biosorption kinetics, minimum sludge regeneration time, process oxygen requirements, process performance vs. floc load, and aneraobic gas production from waste sludge digestion. Preliminary capital and operating costs for the biosorption process will be calculated for each industrial wastewater.

Topic IV—Decontamination of Soils and Aquifers Exposed to Hazardous Solid Wastes

49. Biodegradation of Chlorinated Ethenes in Ground Water and Wastewater by Methane-Utilizing Bacteria

Cambridge Analytical Associates, Inc.
1106 Commonwealth Avenue
Boston, MA 02215

Sam Fogel, Principal Investigator
Martin H. Wolf, President
Region I
Amount: $150,000

Chlorinated ethenes—vinyl chloride, vinylidene chloride, trichloroethylene, and tetrachloroethylene have been detected in drinking water aquifers throughout the United States. Their presence is of concern because they are carcinogens as well as being highly toxic. Because these substances have been disposed of for decades and are transported rapidly by ground water, the contaminant plumes extend over large areas. These characteristics make *in situ* biodegradation a potentially more cost-effective alternative than the pumping of contaminated ground water to above-ground treatment.

Although the chlorinated ethenes have long been considered non-biodegradable, the Phase I research demonstrated that methane-utilizing bacteria can readily degrade most of these substances. In Phase II, *in situ* biodegradation of chlorinated ethenes in ground water will be demonstrated by either naturally occurring or injected methane-utilizing bacteria. This will be accomplished by injecting methane, oxygen, mineral nutrients, and, if necessary, methane-utilizing bacteria into a carefully selected contaminated aquifer under controlled conditions. Since experimental verification of the concept of *in situ* biodegradation has not been published in peer-reviewed journals, this work will contribute to the understanding of this technique in general, as well as to the restoration of aquifers contaminated with chlorinated ethenes.

In order to prevent further contamination of aquifers by chlorinated ethenes, industrial waste streams containing these substances should be pre-treated. This project proposes to design and test a biological reactor implementing methane-utilizing organisms to degrade chlorinated hydrocarbons in these concentrated sources.

Topic V—Detoxification, Solidification, and Other Methods for Fixing Organic Chemical Wastes

50. Controlled Solidification of Hazardous Organic Waste with Recovery of Recyclable Components

Chemical and Metal Industries, Inc.
4701 Dahlia Street
Denver, CO 80216

David E. Hyatt, Principal Investigator
Richard L. Angstadt, Company Official
Region VIII
Amount: $150,000

Phase I research has demonstrated the feasibility of a process for the treatment of hazardous, acid-forming liquid organic wastes in a contained system that does not expose the workplace or the environment to toxic or carcinogenic emissions. In Phase I, spent antimony fluorocarbon catalyst was identified as an excellent example of an extremely hazardous, toxic, and corrosive waste stream, but one with a high potential for the recovery of valuable and recyclable chemicals. The process developed in Phase I coupled with a proprietary extraction process developed by Chemical and Metal Industries allows the recovery of antimony pentachloride for recycle to the fluorocarbon industry and the recovery of halocarbons for either recycle or destruction by incineration. The remaining waste, mostly arsenic trichloride, is neutralized, fixed, and solidified. The final waste to be disposed of by landfill would be only one-fifth of that using current disposal practice.

Value recovery (recycle of antimony pentachloride catalyst) made possible by the Phase I process is estimated to yield a gross profit margin of $750,000 annually for a facility treating 1,250,000 pounds of spent catalyst per year (present U.S. and Canadian generation rates). Current treatment and disposal costs, including burial, for the same amount of spent catalyst is about $525,000.

In Phase II, this project proposes to demonstrate the capability of operating the process on a continuous basis in a closed system with total containment of arsenic and carcinogenic halocarbons. Phase II will develop the engineering data needed to construct a commercial facility and demonstrate the process to the degree necessary to obtain outside support for such commercialization. The amendments to RCRA, signed into law by the President in November 1984, make this project both timely and urgent. The Environmental Protection Agency has been mandated by the Congress to identify appropriate alternatives to land disposal, including *treatment, recycling,* and *waste reduction,* within well-defined deadlines. The proposed process can be adapted to many of the more hazardous and troublesome waste streams, that is, those containing dissolved heavy metals and halocarbons.

51. Pilot-Scale Oily Waste Composting Project

Cal Recovery Systems, Inc.
160 Broadway
Suite 200
Richmond, CA 94804

Clarence G. Golueke, Principal Investigator
George M. Savage, Corporate Official
Region IX
Amount: $149,969

The research will investigate the technical, economic, and environmental feasibility of utilizing composting as an alternative waste management practice for treating, detoxifying, and biostabilizing organic petroleum wastes. Refinery oily wastes will be subjected to the compost process in a pilot reactor unit to ascertain the degree of degradation of oil and grease. The performance of the pilot reactor will be monitored over the course of the experimental period. Various process parameters will be studied during the research, including loading rate, moisture content of the composting mixture, rate of aeration, and the use of inoculums isolated during the Phase I research effort. At the completion of the composting experiments, an analysis of the economics and of the environmental impacts of oily waste composting will be performed.

Follow-On Funding Commitment

The SBIR program, in addition to funding high quality research, is designed to provide incentives for the conversion of Federally sponsored research to technological innovation in the private sector for its economic benefits to the Nation. This research can serve as both a technical and pre-venture capital base for ideas which may have commercial potential. Proposers are asked to consider whether the research they are proposing to EPA also has commercial possibilities either for the proposed application or as a base for other applications. If it appears to have such potential, proposers are encouraged to obtain a contingent commitment for non-SBIR, preferably private, follow-on funding from a third party, to pursue further development after the government-funded research phases. Government funding pays for research on Federal objectives (Phases I and II); private funding pays for development on commercial objectives (Phase III).

The commitment for follow-on venture capital or other funding can be obtained from a third party of the proposer's choice. The commitment normally is contingent upon three factors: (1) the SBIR firm receiving a Phase II award; (2) the research achieving certain technical objectives mutually agreed upon between the small business and the provider of the follow-on capital; and (3) the research not being bypassed in the marketplace during Phase II. A few clearly defined and measurable objectives should be stated in the commitment agreement at the threshold level that would justify private investment if those technical objectives were achieved in Phase II. The objectives do not have to be the same as those stated in the proposal, but they must be able to be accomplished within the scope of the proposed government-funded research.

In order to be assured of an extra point of merit in the review process, a signed contingent commitment between the small business and a third party of its own choice is requested following submission of the Phase II proposal. The commitment is optional but will receive extra consideration in the evaluation process when other factors are of approximately equal merit which frequently is the case. The maximum value in Phase II evaluation will be given for a signed formal agreement with reasonable terms and funding equal to or in excess of the Federal investment in Phase II.

The commitment may be in the form of venture capital, contract R&D, a joint venture, and R&D limited partnership, or other agreement with a third party, or a combination thereof. No amortization, repayment, or repurchase of commitment funds may be included during the Phase II period of performance.

Phase III funding also may be advanced and invested during Phase II to accelerate the research and development process.

Source of Funding—The commitment agreement may be from a financial institution, such as a venture capital firm or a Small Business Investment Company (SBIC), if the small firm wishes to pursue commercialization of any resulting product itself. An alternative option is for the small business to obtain a commitment from a manufacturer already in the field. This coupling would utilize the small firm for the innovative R&D phase, and, through licensing or technology acquisition by the larger firm, the know-how and capabilities of the larger firm for production, marketing, and continuing financing in return for Phase III funding and a royalty agreement. This coupling to a larger firm already in the field may be one of the fastest, most capital-efficient, and lowest risk

ways to bring new and innovative technology to the market place. Other potential sources include joint ventures, R&D limited partnerships, a public offering in process, state finance programs, or existing investors where the probability of actual follow-on investment can be demonstrated.

Phase III also may involve Federal non-SBIR funded R&D or production commitments with another Federal agency for potential products or processes (resulting from the EPA funded research) intended for use by the United States government.

Objectives of Follow-on Funding—The use of the third party has a number of objectives. These include (1) providing a more objective opinion of the market potential of the research and technology because the third party must consider a substantial potential investment and (2) creating strong incentives for private investment in R&D, in technological innovation, and in small science/technology-based business. Each can be facilitated through the government front-end funding of the highest risk area (research) which, if successful, should lower the risk for follow-on private investors to pursue possible commercialization.

The approach also provides a number of incentives for small science and technology firms, and possibly for venture capital firms and large manufacturers interested in investment and technology acquisition as well. It encourages further development of EPA funded research, the obtaining and investing of venture capital, contract R&D, or equivalent funding and the coupling of Federally supported research to the needs of U.S. small and large industry. Where successful, the approach will increase the economic and social benefits to the nation from Federal R&D.

The Commitment—The Phase II follow-on funding commitment is due within four months following the end of Phase I period of performance. It should be submitted to the Program Manager, Small Business Innovation Research, Office of Exploratory Research (RD-675), 401 M Street, SW., Washington, DC 20460. This is to provide time for discussion with potential investors during Phase I and actual negotiation following the availability of the Phase I final report which can provide a better assessment of the technical feasibility of the concept. The commitment agreement should state, on a contingent basis, that the investor will provide venture capital or other funding for follow-on development of the project immediately following the EPA-funded Phase II so that the innovation process can continue without interruption toward commercialization.

The agreement should set forth the specific amount of Phase III funds that will be made available to the small firm contractor and indicate the dates the funds will be made available. It also should contain a few specific technical objectives, which, if achieved in Phase II, will make the commitment exercisable by the small business. The terms cannot be contingent upon the obtaining of a patent, due to the length of time this process requires. Further information will be provided to Phase I awardees.

Rights in Data Developed Under SBIR

The contractor may retain rights in technical data, including software developed under the EPA contract, except that the government shall have the right to use such data for governmental purposes. The final technical report delivered under the contract, including technical data, may be made available to the public by the government except for that portion of the report containing technical data properly identified and marked as set forth below. To the extent permitted by law, the government will not release properly identified and

marked technical data, such as data relating to an invention or software, outside the government except for evaluation purposes for a period of two years from the expiration of the contract without the approval of the contractor. The contractor must properly identify such data and set it off on a separate page in any submission to the Agency. Such data must be clearly labeled as proprietary and marked with a legend similar to the following:

> "The following is proprietary information which (name of contractor) requests not be released to persons outside the government except for purposes of evaluation, for a period of two years from the expiration of contract No. _____ ."

In addition to the rights vested in the government to use such technical data during the two-year period mentioned above, the government shall retain a royalty free, irrevocable, world-wide license to use the data after the conclusion of the two-year period whether or not the contractor has sought or obtained patent protection or claimed copyright protection.

Copyrights

The contractor normally may copyright and publish (consistent with appropriate security considerations, if any) material developed with EPA support. The U.S. Environmental Protection Agency obtains royalty-free license for the Federal government and requires that each publication contain an appropriate acknowledgement and disclaimer statement.

Patents

Small business firms normally may retain the principal worldwide patent rights to any invention made with EPA support. EPA receives a royalty-free license for Federal government use, reserves the right to require the patent holder to license others in certain circumstances, and requires that anyone exclusively licensed to sell the invention in the United States must normally manufacture it domestically. To the extent authorized by 35 U.S.C. 205, EPA will not make public any information disclosing an EPA-supported invention for a two-year period to allow the contractor a reasonable time to pursue a patent. Additional information may be obtained from the Office of the General Counsel, LE-130, U. S. Environmental Protection Agency.

Alphabetical List of Awardees

Chemical Process Corporation
Donald Westerman, President
4435 Cherokee Drive
Brookfield, WI 53005 ..... 1, 14

Chesner Engineering, P.C.
Warren H. Chesner, President
2171 Jericho Turnpike
Commack, NY 11725
(516) 499-1085 10

Eastern Technical Associates
Thomas H. Rose, President
P. O. Box 58495
Raleigh, NC 27658
(919) 834-2970 29

Electrochimica Corporation
Jack Bitter, Corporate Official
20 Kelly Court
Menlo Park, CA 94025
(415) 327-8600 ..... 8, 32

Energy and Environmental Engineering, Inc.
James H. Porter, President
P. O. Box 215
1B Monsignor O'Brien Highway
E. Cambridge, MA 02141
(617) 720-3800 ..... 7, 31

ENG, Inc.
Trevor P. Castor, President
1430 Massachusetts Avenue
Cambridge, MA 02138
(617) 547-0360 25

Engineering Resources
Stephen S. Adams, Vice President
1400 Kings Drive
Fayetteville, AR 72701
(501) 442-9448 22

Fossil Energy Research Corporation
Richard E. Thompson, Corporate Official
23342 South Point, Suite C
Laguna Hills, CA 92653
(714) 859-4466 26

George Alford and Bill Rogers
Ground Water Consultants
Bill Rogers, P.E. Associate
2301 Bryant Drive
East Point, GA 30344
(404) 349-2413/(904) 252-3573 18

IEG Limited
Scott E. Hulse, President
2340 Kohler Drive
Boulder, CO 80303
(303) 499-2693 26

International Hydronics Corporation
Robert B. Bruns, President
5 Crescent Avenue
P. O. Box 243
Rocky Hill, NJ 08553
(609) 921-9216 10

J. P. Laboratories, Inc.
G. N. Patel, President
212 Durham Avenue
P. O. Box 636
Metuchen, NJ 08840
(201) 549-5370 19

John Brown Associates, Inc.
John A. Brown, President
P. O. Box 145
Berkeley Heights, NJ 07922
(201) 647-6890/(919) 286-4693 24

Kenterprise Research, Inc.
James Keane, President
23 South Harlan Street
York, PA 17402 5

Lee Scientific
Lee R. Phillips, Contracts Officer
379 North University, #104
Provo, UT 84601
(801) 375-1119 29

Matrecon, Inc.
Henry E. Haxo, Jr., President
P. O. Box 24075
Oakland, CA 94623 4

Merix Corporation
Thomas W. Mix, President
192 Worcester Street
Wellesley, MA 02181 ..... 6, 8, 17

Microgen Corporation
William J. Jewell, President
218 Cayuga Heights Road
Ithaca, NY 14850
(607) 257-5560/256-4533 21

State Listing of Awardees

☆U. S. GOVERNMENT PRINTING OFFICE:1986/646-116/20771