Industrial Waste Reduction Program

Annual Report

FY 1993

**Office of Industrial Technologies
Assistant Secretary, Energy Efficiency and Renewable Energy
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TABLE OF CONTENTS

EXECUTIVE SUMMARY	1
INTRODUCTION	3
Program Objectives	4
Waste Characterization	5
Opportunity Assessments	6
Institutional Analysis	6
Technology R&D Projects	6
Technology and Information Transfer	7
Program Management	7
Impacts	8
SUCCESSFULLY COMMERCIALIZED PROJECTS	13
Reclaim and Reuse Waste Water: Water-based Paint	13
Methanol Recovery From Hydrogen Peroxide Production	14
Evaluation of a No-Clean Soldering Process	16
Dual Cure Coatings	17
WASTE CHARACTERIZATION	19
Identify/Evaluate Data	19
Simultaneous Waste and Energy-Environmental Economic Tabulations (SWEEET)	19
Application of Results to R&D & Life Cycle Analysis	20
Lifecycle Computer Aided Data (L-CAD) Project	20
OPPORTUNITY ASSESSMENTS	21
Identify Industry Needs	21
Report on Critical Technologies and Industrial Waste Reduction	21
Workshop on Waste Reduction R&D Priorities for Industrial Manufacturers	22
Energy Policy Act Section 2108 Report to Congress	23
TECHNOLOGY RESEARCH & DEVELOPMENT	25
General	25
National Industrial Competitiveness Through Efficiency: Energy, Environment, and Economics (NICE ³)	25
Operational Efficiencies	26
Collection of Vapor-Liquid Equilibrium (VLE) Data for Acid Gas - Mixed Amine Systems Using Fourier Transform Infrared Spectroscopy	26
In-Process Recycle	27
Membrane Vapor Recovery Systems	27
Recycled Paper in Freight Pallet Production	28
On-site Aluminum Recycling: Automobile Wheels	29
Development of Superior Asphalt Recycling Agents	30
Process Redesign	31

Silicon Oxide Utilization	31
Hydrogen Sulfide Utilization	32
VOC Control Strategies: Recycle and Recover Technologies	33
Ultraviolet Curing: Pressure Sensitive Labels	34
Electric Tundish (Holding Furnace): Continuous Copper Alloy Casting	34
Ultrasonic Dishwashing	35
Ultrasonic Tank Cleaning: Pharmaceutical Industry	36
Solicitation, Waste Reduction in the Petroleum Industry	37
Solvent Waste Minimization by Supercritical Carbon Dioxide Cleaning	37
Electroplating Waste Minimization	38
Revitalize the U.S. Silicon/Ferrosilicon Industry, Silicon Technology Competitive Cooperative (STCC)	40
Biological/Chemical Caprolactam Production Process	41
Novel Selective Surface Flow (SSF) Membranes For Recovery of Hydrogen From Waste Gas Streams	41
Solicitation: Waste Reduction in the Metals and Pulp and Paper Industries	42
TECHNOLOGY TRANSFER	45
Technology Exchange	45
Waste Stream Minimization/Utilization Technologies Showcased	45
Information Exchange	46
IWRP Technical Program Plan Section Update	46
Program Evaluation	46
IWRP Annual Program Review	46
Proposal Evaluation - OTEA/NIST Technology Evaluation Services for The U.S. Department of Energy (DOE)	47
DOE HEADQUARTERS POINTS OF CONTACT	49
ACRONYMS AND ABBREVIATIONS	51
INDEX	53

EXECUTIVE SUMMARY

The Department of Energy's Industrial Waste Reduction Program (IWRP) sponsors the development, demonstration, and deployment of technologies that offer a significant opportunity to reduce waste generation, improve productivity, and enhance environmental performance in U.S. industry. The program emphasizes technology-driven solutions that are economically beneficial and environmentally sound. Its goal is to *improve the energy efficiency and competitiveness of private industry by cost-effectively reducing waste*. Industry, universities, national laboratories and other government agencies are working cooperatively to meet this goal.

The IWRP emphasizes the timely commercialization of new technologies that can produce measurable energy, environmental, and economic benefits. All projects are substantially cost-shared with private companies to foster the commercialization process. The program is proud to claim four successfully commercialized technologies that have begun generating benefits:

- Reclaim and Reuse Waste Water (PPG Industries)
- Methanol Recovery from Hydrogen Peroxide Production (FMC Corp.)
- Solvent Reduction through Use of a No-Clean Soldering Process (Motorola Inc., Sandia National Laboratories, and Los Alamos National Laboratory)
- Dual Cure Coatings (3M Company)

The current IWRP portfolio boasts 32 projects in progress. Assuming a 10-percent commercial success rate, these projects have the potential in the year 2010 to:

- Reduce energy consumption by 0.89 quadrillion Btu (with a Federal expenditure of \$0.35 for each barrel of oil saved).
- Reduce waste by over 71 million tons, excluding waste waters (with a Federal expenditure of \$0.75 per ton of waste reduced).
- Improve industrial competitiveness by lowering the cost of waste management (by at least \$1 billion per year) and improving the productivity of manufacturing.
- Leverage \$35 million in industrial R&D funds from 20 companies with \$24 million in Federal funds (in 1993 dollars).

Funding for the IWRP has grown from \$1.7 million in 1990 to \$13 million in 1994. New companies join the program each year, reaping the benefits of working cooperatively with government. New technologies are expected to reach commercial success in fiscal year (FY) 1994, further increasing the benefits already accrued. Future Annual Reports will also include projects from the Waste Utilization and Conversion Program.

Program activities are organized into five elements: Waste Characterization, Opportunity Assessments, Institutional Analysis, Technology Research and Development, and Technology and Information Transfer. Descriptions of the program's 32 active projects are organized in this report according to these elements. Each project description provides a brief background and the major accomplishments during FY 1993. If additional information is desired on any of the projects, the person listed at the end of the background description may be contacted directly.

INTRODUCTION

The industrial sector is vital to the economic strength of the United States. In 1988, the value added to the U.S. economy by the industrial sector was over one trillion dollars¹, and its 360,000 facilities employed nearly 30 million people.²

A strong industrial base is vital to the economic health and prosperity of the United States. To achieve the type of long-term economic growth that creates jobs and protects the environment will require new approaches to manufacturing. Modern production systems that use energy and materials more efficiently will edge out less competitive production practices and reduce environmental impacts in the process. Successful companies will consider the life-cycle impacts of industrial materials and products when making strategic production decisions. Since industrial wastes often signal inefficiencies in the use of energy and materials, advanced manufacturing technologies will almost always lower production costs and increase long-term profitability. As we move toward the next century, U.S. industry will need to find dynamic ways to address the technological challenges of modern manufacturing in order to maintain its economic strength and viability.

THE DIVERSE U.S. INDUSTRIAL COMPLEX

- Consumes hundreds of millions of tons of raw materials.
- Uses thousands of technologies.
- Uses tens of thousands of processes.
- Uses millions of pieces of equipment.
- Produces hundreds of thousands of products.
- Produces tens of thousands of waste streams.

Industry consumes 37 percent of all the energy used in the United States each year, or about 30 quadrillion British Thermal Units (Btu). The cost to industry for this energy is about \$130 billion per year (see Figure 1).³ Furthermore, nearly half of the petroleum that industry consumes (eight quadrillion Btu) is imported, which adds to the U.S. trade deficit.

Best estimates indicate that U.S. industry generates over 12 billion tons of waste each year, and approximately 750 million tons of it are hazardous (see Figure 2).⁴ The cost to industry of handling, cleaning, and disposing of these wastes is estimated at \$70 billion per year, and this figure is increasing. The production of waste also represents a significant amount of wasted energy, i.e., the energy used for its transportation, treatment, and disposal; energy used to produce and process raw

U.S. Energy Consumption 1992

Figure 1. U.S. Energy Consumption, 1992

materials that end up as waste; and the energy embodied in the agricultural and forest wastes that could be used as fuels.

Although U.S. industry is working to improve its environmental performance, much more needs to be done. The challenge is to find ways in which industry can become more efficient and produce less waste while contributing income and jobs to the economy.

Industrial Waste Streams

Total: 12.3 Billion Tons

Program Objectives

Figure 2. Waste Generated by Industry

The Office of Industrial Technologies (OIT) was established under the U.S. Department of Energy (DOE) Assistant Secretary for Energy Efficiency and Renewable Energy in 1974. Its primary mission is to work with industry to improve industrial energy efficiency, reduce environmental impacts, and strengthen economic competitiveness. Accordingly, OIT manages a rigorous program of technology research, development, demonstration, testing, and evaluation. Its specific goals are to:⁵

- Improve the energy efficiency and competitiveness of private industry through cost-effective reduction of waste.
- Work with private industry to identify the technologies needed to improve the productivity and fuel flexibility of industry.
- Negotiate working arrangements with private industry, universities, and government laboratories to develop these technologies.
- Disseminate information on emerging technologies to potential industrial users.

INDUSTRIAL WASTE FACTS - PER PERSON -

- 46 tons of wastes generated per year
- \$173 per year for treatment and disposal
- 110 gallons of gasoline could be saved

To focus specifically on the reduction of wastes from industrial processes, OIT supports the Industrial Waste Reduction Program (IWRP). The goal of the IWRP is to *improve the energy efficiency and competitiveness of private industry through cost-effective waste material reduction*. This goal is achieved through cost-shared projects with industry, states, universities, and other Federal agencies, and through the active involvement of representative stakeholders in planning and implementing the program. Additional program goals include increasing jobs and decreasing emissions of greenhouse gases. This Annual Report describes the activities of the IWRP.

The IWRP takes advantage of five basic waste reduction strategies to achieve its goals: improved housekeeping, process changes, product changes, feedstock changes, and in-plant recycling. All of these are useful waste reduction strategies that can benefit from technology development. The IWRP is structured to meet its goal by improving upon these industrial waste reduction strategies.

The IWRP carries out a coordinated program that emphasizes the commercialization of new technologies by supporting a wide range of integrated activities. The program consists of five elements: Waste Characterization, Opportunity Assessments, Institutional Analysis, Technology Research and Development, and Technology and Information Transfer (see Figure 3).

Figure 3. Industrial Waste Reduction Program

Waste Characterization

Waste characterization is needed to better understand the types, locations, and magnitudes of industrial waste streams. A better understanding of these wastes will help to determine future research and development (R&D) needs. The information developed will be used to build a central industrial waste data base that will aid in funding decisions and expedite the transfer of waste reduction technology to industry.

Opportunity Assessments

Waste reduction opportunities are assessed on the basis of their energy potential, economic benefits, environmental benefits, and impacts on waste generation. Through such assessments, the program identifies priority research areas or the industrial processes that offer the optimum potential for improvements through waste reduction. The results of opportunity assessments are used by IWRP to evaluate critical waste reduction research opportunities and to gauge the need for government involvement in the technology R&D, the level of industry's willingness to participate and share costs, and the amount of funding required.

Institutional Analysis

Institutional analyses are needed to help understand the key factors that affect industrial investment in available and emerging waste reduction technologies. Many of these factors are related to financial and structural factors (e.g., cost of capital, firm size, market conditions, etc.) or to non-financial issues (e.g., regulatory requirements, liability concerns, corporate philosophy, etc.). Institutional issues can create barriers that affect corporate investment decisions and limit the adoption of new technologies. Analysis of these issues will allow IWRP to implement R&D strategies that reduce or overcome critical institutional barriers and encourage industry adoption of new waste reduction technologies.

Technology R&D Projects

R&D forms the core of the IWRP and accounts for most of its budget. Technology R&D is needed to promote the development of energy-efficient as well as environmentally and economically sound solutions for minimizing waste generation in industry. IWRP works with industry, national laboratories, and universities to conduct a variety of cross-cutting technology R&D projects aimed at reducing industrial waste generation. These efforts provide tangible results in

AUTHORITY FOR THE IWRP

The Federal role in pursuing industrial sector R&D is well established, having been mandated by legislation authorizing programs for energy conservation, first within the Federal Energy Administration (FEA), and later within the Energy Research and Development Agency (ERDA) and DOE. Formerly known as the Office of Industrial Programs, OIT has been involved in efforts to improve industrial energy efficiency since the passage of the Federal Non-Nuclear Energy Research and Development Act in 1974. Under this Act, DOE is authorized to "advance energy conservation technologies, including -- but not limited to -- productive use of waste, including garbage, sewage, agricultural waste and industrial waste heat; reuse and recycling of material and consumer products." In 1975, the Energy Policy and Conservation Act called for Federal support to increase the energy efficiency of U.S. industry, particularly the most energy-intensive industries.

NATIONAL ENERGY STRATEGY

The National Energy Strategy (NES) of 1991 strongly encourages industrial waste reduction as a means to reduce energy use in industry. As one of three goals related to industrial energy use, the NES seeks to "reduce industrial energy waste generation, increase recycling of wastes and increase use of plant- and consumer-generated wastes as process feed-stocks." The overall approach for achieving this goal is to "conduct aggressive research and development on technology and techniques to reduce the rate of waste generation and to allow wastes to be used as resources."

NATIONAL ENERGY POLICY ACT

The Energy Policy Act (EPAct) of 1992 authorizes the continuance of a five-year program to improve the energy efficiency and cost effectiveness of pollution prevention technologies and processes, including source reduction and waste minimization technologies and processes, in consultation with the Administrator of the Environmental Protection Agency.

the form of new waste reduction tools and technologies that can subsequently be commercialized and adopted by industry.

Technology and Information Transfer

This program element is needed to move IWRP-sponsored technologies into the marketplace and into plant operations. It supports and is integrated with the other program elements and with the overall OIT Technology Transfer Program. Without effective technology transfer mechanisms, industry may lose opportunities to take advantage of technologic innovations. IWRP encourages technology transfer through conferences, workshops, and a number of other outreach programs. The primary mechanism employed by IWRP, however, is direct industry participation in technology R&D, which relies on the economic driver to effect technology transfer. Through these efforts, IWRP effectively disseminates information on waste reduction practices, educates the public and private sectors about industrial waste reduction technologies, and promotes technology adoption on a commercial scale.

Program Management

The program is managed and implemented by several DOE organizations: the Office of Industrial Technologies provides overall program management and direction, and the Albuquerque Field Office (AO) and the Chicago Operations Office (CH) provide project management and other assistance to OIT. The program works with and supports waste reduction efforts with other Federal, state, and local governments; public and private sector organizations; and the international community. Extensive private industry involvement is an essential component of the program and is a prerequisite for all R&D projects. The government, industry, universities, and laboratories provide technical expertise, R&D facilities, and capabilities that are among the best in the world. These capabilities are used to support efforts that will achieve the goals of the IWRP.

Three procurement instruments are used to support the program: solicitations advertised in the *Commerce Business Daily*, unsolicited proposals⁶, and Field Work Proposals from the national laboratories. Both solicited and unsolicited proposals typically result in cost-shared, cooperative agreements with industry, universities, and others. A special grants program, known as National Industrial Competitiveness through Efficiency: Energy, Environment, and Economics (NICE³), helps to quickly move technologies to market through cost-shared projects with states and industry. The national laboratories use special procurement instruments with industry⁷ to achieve the required industrial support.

In evaluating the proposals, the IWRP uses five criteria: energy savings, waste reduction, economic attractiveness, industrial support, and need for government funds. All proposals must be able to demonstrate a minimum potential energy savings of one trillion Btu by the year 2010, assuming a

PROPOSAL EVALUATION CRITERIA

- Energy savings
- Waste reduction
- Economic attractiveness
- Industrial support
- Need for government funds

Generic Cost Sharing

Figure 4. Industrial Cost Sharing

realistic market penetration of the technology. The technologies must reduce material waste from a global perspective, and the economics must be sufficiently attractive to engage industrial interest (an internal rate of return of over 15 percent). Industrial support is required on all R&D projects, and most require a minimum of 50-percent industrial cost sharing over the life of the project (see Figure 4). Finally, the project must demonstrate a need for government funds, i.e., it must be shown that industry would not be likely to fund this project in the absence of government support.

A preliminary analysis indicates that the five industries that can benefit the most from this program are Chemicals, Petroleum, Primary Metals, Pulp and Paper, and Mining. These industries were identified on the basis of their energy consumption, waste generation, and economic contribution to the U.S. economy. While the IWRP focuses on these industries, it actively encourages participation by all industries with Standard Industrial Classifications (SIC) codes 1 through 39⁸.

The IWRP was greatly expanded in 1992 and several new projects were initiated. The current program focuses on reducing the following waste streams: volatile organic compounds (VOC), chlorofluorocarbons (CFCs), precision cleaning solvents, plating wastes, and waste gases. Additional waste streams will be incorporated into the program as funds permit.

NEED FOR GOVERNMENT FUNDS

- High technical risk
- Non exclusive
- National welfare
- Direct cooperation
- Long-term payback
- Beyond firm's or industry's ability

Impacts

The current IWRP portfolio of projects will generate substantial long-range benefits for industry and the Nation. Assuming a 10-percent commercial success rate⁹, the existing IWRP portfolio of projects has the potential in the year 2010 to:

- Reduce energy consumption by 0.89 quadrillion Btu (with a Federal expenditure of \$0.35 for each barrel of oil saved).
- Reduce waste by over 71 million tons, excluding waste waters (with a Federal expenditure of \$0.75 per ton of waste reduced).

- Improve industrial competitiveness by lowering the cost of waste management (by at least \$1 billion per year) and by improving the productivity of manufacturing.
- Leverage \$35 million in industrial R&D funds from 20 companies with \$24 million in Federal funds (in 1993 dollars).

Waste reduction can have a significant impact on the purchase and use of materials within industry. When wastes are reduced, companies use raw materials, energy, and feedstocks more efficiently, reducing their requirements for these inputs. Moreover, the numerous industry-to-industry transfers of intermediate materials and products ensure that waste reduction will have a noticeable ripple effect on materials use, purchasing, jobs, and economic growth.

Overall, industrial waste reduction is expected to create new jobs and generate significant economic growth. This growth results from two distinct economic effects: 1) a reduction in the purchase of industry inputs and 2) the economic growth associated with more cost-efficient production. At first, companies will require less material and energy as inputs are used more efficiently and less waste is produced. This may initially result in reduced sales for the companies that produce and supply these inputs. However, since waste reduction lowers the cost of production and increases profitability, more revenue will become available for capital investment and the expansion of production operations. The economic growth and new jobs generated by this expansion will far outweigh any economic dislocations that occur as a result of the temporarily reduced sales of materials and feedstocks.

The potential national impacts of industrial waste reduction are impressive. Over the period 1996 to 2010, U.S. industry could expect to:¹⁰

- Avoid producing 1.3 billion tons of waste,
- Increase the gross domestic product (GDP) by \$1,936 billion (in 1992 dollars), with a net present value of \$335 billion (1992 dollars),
- Increase employment by 16 million person-years,
- Reduce purchase of resources (energy, crude oil, natural gas, agricultural products, and organic chemicals) by \$1,241 billion.

These estimates assume a reasonable rate of adoption of waste-reducing technologies and practices by industry over the 1996 to 2010 time period.

An additional analysis was conducted to estimate the direct impact that funding of IWRP R&D projects could have on jobs creation and economic growth. For this purpose, the effect of a \$1-million incremental investment in IWRP projects was examined. Again, the results are impressive; that level of investment in the IWRP will result in:

- \$14 million added to the GDP (\$2.43 million net present value),
- 140 person-years of jobs,
- 537,000 metric tons of waste avoided, and
- \$429 million saved in reduced purchases of resources.

These estimates reflect rather conservative assumptions regarding the rate of return on private investment for waste-reducing technologies. The analysis was based on the economic performance of 75 technologies documented in case studies in the open literature.

The main thrust of the program is to commercialize new technologies that can produce measurable energy, environmental, and economic benefits. The program considers a technology to be commercialized when it is in full-scale commercial use and has begun generating benefits. The IWRP can boast of four projects that were successfully commercialized by private industry in 1992 and 1993:

- Reclaim and Reuse Waste Water (PPG Industries)
- Methanol Recovery from Hydrogen Peroxide Production (FMC Corp.)
- Solvent Reduction through Use of a No-Clean Soldering Process (Motorola Inc., Sandia National Laboratories, and Los Alamos National Laboratory)
- Dual Cure Coatings (3M Company)

These four projects are described in greater detail in the following section of the report. Descriptions of 32 active projects in the IWRP portfolio are arranged in this report according to their place in the program structure. For each project, a brief background description is provided along with any project accomplishments during FY 1993 (October 1, 1992, to September 30, 1993). If additional information is desired on any of the projects, the person listed at the end of the background description may be contacted. The address and phone numbers of contact people at DOE headquarters are provided at the end of the document.

NOTES:

1. U.S. Statistical Abstracts.
2. United States Department of Commerce, "1990 U.S. Industrial Outlook," Washington, D.C.
3. United States Department of Energy, "Monthly Energy Review," February 1992, Energy Information Administration, Washington, D.C. 20585, DOE/EIA-0035.
4. United States Department of Energy, "Industrial Waste Reduction Program, Program Plan," October 24, 1991, Office of Industrial Technologies, Washington, D.C. 20585, DOE/CE-0344.
5. United States Department of Energy, "Industrial Energy Technology, Current Awareness," Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831, DOE/IET-91.
6. United States Department of Energy, "Guide for the Submission of Unsolicited Proposals," Office of Procurement, Assistance and Program Management, Washington, D.C. 20585, DOE/PR-0014.

7. Treager, R., et al, "Technology Transfer - What's in It for Me?" Chemical Engineering Progress, AIChE, December 1990, pp. 73-77.
8. Standard Industrial Classification codes, which include agriculture, mining, construction, and manufacturing.
9. Based upon the historical success rate for the Office of Industrial Technologies.
10. Teclaw, Charles, "Estimate of Returns on DOE Investments in the Industrial Waste Reduction Program (IWRP)," March 19, 1993, Los Alamos National Laboratory, Los Alamos, NM.

SUCCESSFULLY COMMERCIALIZED PROJECTS

The term "successfully commercialized" is used in this report to describe technologies, products, or processes that have been adopted by industry and are being used profitably at a commercial scale. While these technologies were developed with joint government-industry funding under the IWRP program, they have now reached the stage at which the private sector has assumed full responsibility for their continued development, use, and marketing. Furthermore, these "successfully commercialized" technologies are generating tangible energy, economic, and environmental benefits. These benefits include improved energy and materials utilization, enhanced industrial competitiveness, and reduced wastes. The following technology projects were jointly supported by the IWRP and the private sector. They met the above criteria for successful commercialization in FY 1992 and FY 1993:

- Reclaim and Reuse Waste Water: Water-based Paint (PPG Industries)
- Methanol Recovery from Hydrogen Peroxide Production (FMC Corporation)
- Evaluation of a No-Clean Soldering Process (Motorola Inc., Sandia National Laboratories, and Los Alamos National Laboratory)
- Dual Cure Coatings (3M Company)

Detailed discussions of each project follow.

Reclaim and Reuse Waste Water: Water-based Paint (PPG Industries)

Background

The Cleveland plant of Pittsburgh Plate Glass (PPG) Industries manufactures both solvent-based and water-based coatings for the automobile industry. To ensure product quality, the processing equipment for water-based products is frequently cleaned with water. This process generates thousands of gallons of unusable waste water that must be treated as hazardous waste and transported to a state-licensed incinerator for disposal.

The goal of this project, which began in October 1991 as part of the first NICE³ solicitation, was to develop a system for cleaning the paint rinse waste water so that it could be reused. Engineers at PPG designed a progressive membrane-based separation system capable of recycling 95 percent of the waste water. The non-thermal, non-vaporization, physical separation system utilizes both ultrafiltration and reverse osmosis membranes in a two-stage process to remove both suspended solids and small impurities from the waste water. The cleaned and recycled water emerging from the separation system is then pumped to a holding tank for reuse. The remaining five percent of highly concentrated waste water is all that must be collected for disposal by conventional methods.

PPG has experienced significant energy savings as a result of reducing its production of contaminated waste water. Reduced fuel use for transporting waste, reduced fuel use for

incineration, and reduced treatment requirements for deionized water have yielded energy savings of 3.6 billion Btu (3.8 trillion joules) per year. The environmental benefits of PPG's ultrafiltration/reverse osmosis system are also substantial. The volume of hazardous waste requiring disposal at the Cleveland plant has been reduced from 400,000 gallons (1.5 million liters) to 20,000 gallons (75,000 liters) per year. Atmospheric emissions are also expected to decrease because of the reduced need for waste incineration and reduced need for waste transportation. In the past, tanker trucks traveled 350 miles (560 km.) to the waste energy recovery facility 65 times each year. Now, only four trips are necessary, reducing annual emissions by several hundred thousand kilograms.

The point of contact for this project is Maura Tinter, PPG Industries, Inc., 3800 West 143rd Street, Cleveland, OH 44111, (216) 671-7752. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

The new separations system, a two-membrane, cationic, ultrafiltration/reverse osmosis unit, has processed over 48 batches to date with an average operating efficiency of 87 percent. Through July 1993, the plant reduced waste water generation by 86 percent as compared with 1992. As part of the commercialization effort, PPG plans to install additional units in all of its painting facilities and transfer this technology to the rest of industry. The company has produced a video highlighting the technology and plans to make presentations at trade shows and conferences.

Methanol Recovery From Hydrogen Peroxide Production (FMC Corporation)

Background

Each year, the production and purification of chemicals produces approximately 436 million pounds (198 million kg.) of hazardous methanol waste in the United States. Until June 1991, this methanol was disposed of by burning it as a waste fuel in cement kilns. Since that time, environmental regulations have prohibited this method of hazardous waste disposal; it must now be burned in incinerators--an expensive and energy-intensive process.

High methanol disposal costs, as well as increasing methanol production costs, led DOE and the U.S. Environmental Protection Agency (EPA) to work with FMC Corporation in finding a way to recover and reuse methanol at FMC's hydrogen peroxide plant in Pasadena, Texas. Purification of crude hydrogen peroxide requires a catalyst to remove any dissolved contaminants from the processing stream. Periodically, the catalyst must be regenerated to maintain its activity, a process that involves a methanol wash and soak. During regeneration, the methanol is contaminated with organic solvents, trace quantities of hydrogen peroxide, and metal cations. This contaminated methanol can be either treated as a hazardous waste and incinerated or decontaminated and reused.

With the help of a \$96,000 grant from the DOE- and EPA-sponsored NICE³ program in 1991, engineers at FMC Corporation's hydrogen peroxide plant investigated the use of a new steam

distillation technique that recovers the contaminated methanol by spraying steam directly into the distillation column. The new process allows 90 percent of the methanol to be recovered and reused.

In addition to recovering a high percentage of methanol, the direct steam distillation technique allows for safer operation of the distillation column. In traditional distillation, steam or another heat source is indirectly applied through an external reboiler. In the new technique, by contrast, steam acts as a dilutant, preventing the buildup of undesirable quantities of hydrogen peroxide and metal cations in the bottom of the distillation column. As a result, two potential hazards are avoided: 1) generation of oxygen from the decomposition of hydrogen peroxide by metal ions, which can lead to methanol fire or explosion; and 2) violent decomposition or detonation reactions catalyzed by the metal ions and activated by a high concentration of hydrogen peroxide in the bottom of the column.

Based on the original projected efficiency of 90 percent, energy savings were estimated at 19.2 billion Btu (20.3 trillion joules) per year. Using the unit's actual recovery of 98.6 percent for 1992, annual energy savings are estimated at 25.2 billion Btu (26.6 trillion joules). At 98.6 percent efficiency, the unit is saving 1.93 million lbs. (877,000 kg.) of methanol each year. In 1992, the system recovered 276,104 gallons (1.04 million liters) of methanol and saved another 502,080 gallons (1.9 million liters) from being sent off-site to an incinerator.

The point of contact for this project is Curt Silvering, FMC Corporation, 12000 Bay Area, Pasadena, TX 77507, (713) 474-8759. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

Construction of FMC's methanol recovery system began in the fall of 1991; the system began operating in March 1992. To date, the system has greatly reduced the plant's generation of waste methanol, resulting in significant energy and economic savings and a cleaner environment. The methanol recovery unit has allowed FMC to reduce its energy consumption, waste, and emissions, resulting in a better environment and an improved bottom line (more than \$500,000 in annual operating expenses in 1992). Any industry with a waste methanol stream can apply this technology and take advantage of these same benefits.

FMC officials gave a presentation on this project at the Industrial Energy Technology Conference in Houston, Texas. As part of FMC's commercialization effort, the company plans to replicate the methanol recovery system at five additional FMC plants and transfer this technology to the rest of the industry.

Evaluation of a No-Clean Soldering Process

(Motorola, Inc., Sandia National Laboratories, and Los Alamos National Laboratory)

Background

Throughout the electronics industry, ozone-depleting chlorofluorocarbons (CFCs) are the solvents of choice to clean solder flux from electronic assemblies. However, because of their ozone-depleting properties, the U.S. government signed an international agreement (the Montreal Protocol) to eliminate the production of CFCs by the year 2000. With IWRP support, Sandia National Laboratories has joined with Motorola, Inc. and Los Alamos National Laboratory to address the problem of eliminating CFC solvent cleaning systems from electronics assembly production.

Under IWRP's first Cooperative Research and Development Agreement (CRADA), which was initiated in July 1991, researchers at Sandia, Los Alamos, and Motorola have developed a wave solder process for electronic printed wire boards (PWBs) that entirely eliminates the need for cleaning solvents. The process uses a dilute adipic acid flux in an inert atmosphere to remove oxidation prior to soldering and inhibit oxidation during soldering; when this process is used, no solvent cleaning of the board is required. The objectives of the project were to demonstrate the long-term reliability of the no-clean solder process and greatly accelerate its adoption and use. In addition, the project will provide a basis for changing military specification MIL-2000, which currently establishes standards for the manufacture of about 50 percent of electronic products.

An estimated 11,000 tons per year of equivalent CFC-11 ozone-depleting emissions are generated by the U.S. electronics industry as a result of in-line cleaning of electronic assemblies. It is the goal of this program to eliminate 100 percent of this waste. An estimated annual energy savings of 18 trillion Btu (19 quadrillion joules) could also be achieved, assuming the elimination of 90 percent of the Freon post-solder cleaning operations associated with the wave soldering machines in commercial and military use.

The point of contact for this project is Ron Iman, Sandia National Laboratories, Department 6613, P.O. Box 5800, Albuquerque, NM 87185, (505)844-8834. The DOE headquarters contact is Tom Foust.

Accomplishments for FY 1993

This project, which concluded in February 1993, successfully demonstrated that the new process could provide solder results that are at least as good and often better than those achieved with current resin flux specifications. Several technical papers, educational broadcasts, and publications have provided initial distribution of project results to U.S. industry. During FY 1993, as part of their commercialization efforts, Motorola, Sandia National Laboratories, and Los Alamos National Laboratory provided project results and data to over 270 companies. The research partners also held a conference in Albuquerque, New Mexico, to provide information on the **Elimination of Cleaning of Electronic Circuits after Solder Assembly**. The conference was attended by over 175 interested participants from nearly 100 companies. Other commercialization activities included the distribution of a comprehensive project report entitled

Evaluation of a No-Clean Soldering Process Designed to Eliminate the Use of Ozone Depleting Chemicals.

Motorola is implementing this new process throughout its corporate manufacturing structure. The results are being shared with all U.S. industries (e.g., Honeywell, IBM, Boeing, Hughes, Ford, and General Motors) that have an interest in cleaning electronic printed wire boards.

Dual Cure Coatings (3M Company)

Background

Increasingly stringent environmental regulations have been implemented to minimize or eliminate emissions of volatile organic compounds (VOCs). A substantial portion of these emissions are associated with the general use of solvents in industry, including paints and other coating systems. To meet the new regulations, many industries need new, solventless or near solventless coatings that are easily applied and quickly cured, and have physical properties equivalent or superior to those of conventional coatings.

With support from IWRP, the 3M Corporation has developed a commercially viable, solvent-free technique that can be used to cure mixed polymer systems used in coatings, inks, and adhesives. The dual cure photocatalyst system uses organic chemicals containing a metallic structure that is sensitive to light. It is currently being developed for making coatings from mixtures of two chemicals, urethane/acrylate (U/A) or epoxy/acrylate (E/A). Initial markets for the new coating include aircraft topcoats and primers and saturation coatings for the backing of high-temperature electrical tape.

The project was initiated in September 1988 as the result of a competitive solicitation to reduce industrial waste gases. The use of organic, photo-sensitive catalysts to simultaneously light cure two different chemical types has been successfully demonstrated in pilot-scale coating production runs, and tests are in progress for formulation development, application techniques, and curing procedures. Both U/A and E/A formulations have exhibited strength and elongation characteristics close to those of the chemicals currently used in coatings.

With anticipated market penetration, the technology is estimated to save 27 trillion Btu (28.5 quadrillion joules) in the year 2010 as a result of the reduced energy requirements for curing processes and the avoided manufacture and disposal of VOCs. Estimated waste reduction would include 260,000 tons per year of VOC emissions as well as 2.2 million tons per year of carbon dioxide emissions.

The point of contact for this project is Kevin Kinzer, 3M Center Bldg. 201-2N-19, St. Paul, MN 55144-1000, (612) 733-6575. The DOE headquarters contact is Bruce Cranford.

Accomplishments for FY 1993

Significant progress was made on improving the performance of the urethane/acrylate formulation being used for the aerospace topcoat application. 3M and Boeing tested both aircraft topcoat formulations against Boeing Material Specifications (BMS) with promising results. Boeing is interested in the formulations because of their quick curing properties as well as their low VOC emissions.

Work on the third demonstration application, solventless treatments for electrical tape backings, has been completed. Optimal dual cure resin formulations were identified and utilized in preparing complete tape constructions. These tapes were evaluated against benchmark Underwriters Laboratories (UL) and internal 3M specifications for electrical tape performance. In most cases, the properties of the tapes produced from the dual cure backings were comparable to those of the control products currently being made by solvent-based processes.

During FY 1993, several presentations on the dual cure technology were made at various national and international conferences, including the 3rd Solvent Substitution Workshop held in December in Phoenix, Arizona, and the Pollution Prevention Conference on Low- and No-VOC Coating Technologies held in May in San Diego, California.

3M's first commercialization venture with this technology occurred in FY 1993. It was applied in an adhesive used to produce resin-bonded, flexible, diamond grinding disks that allow polishing of marble tiles to a higher gloss than previously possible. 3M commercialization plans include marketing this technology to industry.

Publication

K. E. Kinzer, *Dual Cure Low-VOC Coating Process, Phase III Semi-Annual Technical Progress Report (October 1, 1992 - March 31, 1993)*, Contract No. DE-AC04-88ID12692, Report No. DOE/ID/12692-4, (to be published).

WASTE CHARACTERIZATION

Identify/Evaluate Data

Simultaneous Waste and Energy-Environmental Economic Tabulations (SWEEET)
(Department of Commerce, Bureau of the Census)

Background

In September 1990, as part of DOE's Industrial Waste Reduction Program, the U.S. Census Bureau's Center for Economic Studies (CES) undertook a multi-phase project to explore methods for analyzing existing data in order to identify specific products and processes that are major sources of industrial waste and energy use. The lack of summarized data has been a persistent barrier to effective implementation of waste reduction/minimization programs. The project involves the identification, collection, and evaluation of existing micro level data. The project is also exploring the development and evaluation of methodologies to conduct information-oriented research on energy and waste problems within manufacturing industries. The objective is to isolate specific criteria that will establish linkages between identifiable industrial plant characteristics and the need for research and development of waste-reducing production technologies. The project will also identify where this R&D would be most beneficial.

The point of contact for this project is Robert McGuckin, U.S. Department of Commerce, Bureau of the Census, Washington, DC 20233-6300, (301) 763-2337. The DOE headquarters contact is Tom Foust.

Accomplishments for FY 1993

Over the past year, the analysis method was developed and applied to toxic waste from the U.S. chemical industries. This effort involved linking plant-level data from the Environmental Protection Agency's (EPA's) Toxic Release Inventory Program and CES's Research Database for 1987 and 1990. An experimental model related toxic waste to a plant's location, ownership, primary product, and input expenditures. The results indicate that the following are the top candidates for new technology R&D: production of finishes for manufacturers, thermosetting and thermoplastic resins and plastics, liquefied refinery gases, special-purpose coatings, and synthetic rubber. A report on the methods and conclusions of this project is scheduled for publication.

Application of Results to R&D & Life Cycle Analysis

Lifecycle Computer Aided Data (L-CAD) Project (Pacific Northwest Laboratory)

Background

Under the Lifecycle Computer Aided Data (L-CAD) project, Pacific Northwest Laboratory (PNL) is developing a product-based lifecycle analysis database and modeling environment. The model is being designed to facilitate the use of environmental lifecycle analysis (LCA) in industrial applications, including process and product design, process evaluation, and product certification. In addition, the L-CAD model will be used to help incorporate full lifecycle evaluations of technologies in IWRP program planning activities. This project has been in progress since the last quarter of 1992.

The point of contact for this project is Ken Humphreys, Pacific Northwest Laboratory, P.O. Box 999, Richland, WA 99352, (509) 375-4279. The DOE headquarters contact is Tom Foust.

Accomplishments for FY 1993

During FY 1993, PNL began development of the initial computerized prototype, which is scheduled for release to the user community in the second quarter of FY 1994. Rapid computer software interface prototyping techniques were used to develop a number of interface concepts that will be used in the prototype version. In addition, solicitations were run in *Commerce Business Daily* for members of a stakeholder advisory group, as well as for potential subcontractors for data collection tasks. An initial trial of lifecycle inventory analysis was completed for aluminum production. This initial analysis was used primarily to evaluate the computerized data specifications for the L-CAD database.

Presentations on the L-CAD project were delivered at the American Institute for Chemical Engineers (AIChE) Summer National Meeting in Seattle, WA, and at the Second Symposium on Environmentally Conscious Manufacturing, held in Rosslyn, VA.

OPPORTUNITY ASSESSMENTS

Identify Industry Needs

Report on Critical Technologies and Industrial Waste Reduction (Sandia National Laboratories)

Background

Key leaders of industry and government have advocated a significant national investment in industrial technologies on the basis of their importance to the economy. A wide variety of technologies have been identified as "critical" by the U.S. government, foreign governments, and representatives of industry and environmental groups. In February 1993, researchers at Sandia National Laboratories began to analyze ten lists and reports compiled by these organizations. The advocated technologies were evaluated in terms of their potential positive or negative waste reduction impacts. These impacts were considered as broadly as possible (e.g., impacts on energy, environment, competitiveness, and commercial time-scale), but emphasis was given to technologies with applications in manufacturing. A set of 19 technologies was selected (*Artificial Intelligence, Biotechnology, Catalysis, Electrical Storage, Environmental Modeling & Measuring & Database Systems, Flexible Computer-Integrated Manufacturing, High Fuel Economy & Low Emission Engines, Human Interface and Visualization Technologies, Hydrogen Fuel Cells, Materials Synthesis, Design and Processing, Microelectronics, Precision-Micro Fabrication, Recycling/Waste Control/Processing, Semiconductors, Packaging & Interconnections, Sensors, Separations (membranes, etc.), and Superconductors*). These critical technologies will be used by the IWRP as one tool for focusing its waste reduction efforts. The IWRP goal is to understand the potential energy and environmental impacts of these technologies in order to influence their design, development, and application to reduce industrial waste. Early identification of the potential of these technologies, both as causes of and solutions to industrial waste problems, will enable IWRP to promote waste reduction at considerably less cost to society than "end-of-pipe" solutions.

The point of contact for this project is Tina Kaarsberg, contractor for Sandia National Laboratories, (703) 516-6226. The DOE headquarters contact is Bruce Cranford.

Accomplishments for FY 1993

- February 1993, project assigned with 2-month analysis time, outline work plan approved.
- March 1993 drafts delivered.
- April 1993, final analysis sent to technical editors.
- May 1993, draft returned and presentation made at annual program review.

- June-September 1993, reviews by DOE and Sandia National Laboratories resulted in expanded analysis and continued work on format.
- September 1993, sent to outside reviewers
- October 1993, outside reviewers comments returned and addressed--final delivered to DOE

Workshop on Waste Reduction R&D Priorities for Industrial Manufacturers
(Center for Waste Reduction Technologies)

Background

The large, process-oriented industries (such as chemical manufacturers, primary metals, pulp and paper, petroleum refining, and so forth) that use very large quantities of chemicals and other feedstocks have developed successful technologies and strategies to minimize wastes. However, manufacturers outside of these industries, those that use moderate quantities of chemicals for specialized purposes, may not be able to achieve the economies-of-scale necessary to profitably implement these technologies. Moreover, existing pollution prevention technology programs may not be addressing the special waste reduction needs of these companies.

In early FY 1993, DOE's Industrial Waste Reduction Program and the American Institute for Chemical Engineers' Center for Waste Reduction Technologies (CWRT) began planning a workshop to identify waste reduction and utilization opportunities for manufacturers outside the large process industries. The overall objective of the workshop was to identify R&D needs for technologies and practices that can help these manufacturers reduce waste in current and future operations. In particular, the IWRP and the CWRT wished to find out if there are substantial R&D needs that are not being addressed by their respective waste reduction programs. In particular, IWRP and CWRT sought to identify R&D opportunities that, if addressed, might yield significant energy and environmental benefits.

The workshop was conducted by Jack Eisenhower of Energetics, Incorporated, 7164 Columbia Gateway Drive, Columbia, MD 21046, (410) 290-0370. The DOE headquarters contact is Bruce Cranford.

Accomplishments for FY 1993

The workshop was held September 28-29, 1993, in Arlington, Virginia. The results were based on the expert judgements and opinions of the 14 industry participants on the panel, which included representatives from both the chemical user community and the chemical producer industry. Work groups focused on the problems and R&D needs associated with **finishing and assembly operations** and **environmentally conscious manufacturing**. Initial analysis of the results uncovered seven common themes:

- ***Production/Process Control*** - the need to develop tighter monitoring and control systems.
- ***Life-Cycle Analysis*** - the need to develop consistent analytical tools and supporting data on alternative technologies and processes over the life cycle of materials.
- ***Separations*** - the need for improved separation and recovery processes.
- ***Materials Substitution and Utilization*** - the need for new or modified materials.
- ***Environmental Assessment Methodologies*** - the need to develop methods for characterizing waste streams and estimating the environmental risks of alternative designs.
- ***Biological Controls*** - the need for biotechnological solutions to industrial waste problems.
- ***Laboratory Waste*** - the need to develop better information, handling methods, and treatment systems for laboratory chemicals and wastes.

These results suggest two important points that affect R&D investment decisions by DOE. First, chemical users need better assessment tools to evaluate the merits of alternative products, designs, and production processes and to understand the full life-cycle impacts of their products. Second, many of the opportunities to improve the waste profile of their products exist outside of their industries. For example, new paints and coatings need to be developed within the chemical industry to help paint manufacturers reduce VOC emissions. In addition, post-consumer recycling of their products, which would likely be accomplished outside their industry, was a key concern of manufacturers. Therefore, many of the opportunities to assist the non-process industries may not require significant technology R&D investments in these industries.

Publication

Jack Eisenhauer and Shawna McQueen, *Waste Reduction R&D Priorities for Industrial Manufacturers: A DOE/CWRT Workshop*, prepared for OIT and CWRT, January 1994.

Energy Policy Act Section 2108 Report to Congress (Sandia National Laboratories)

Background

Within the Energy Policy Act (EPA) of 1992, the Energy Efficient Environmental Program (Section 2108) requires DOE to identify opportunities for demonstrating energy-efficient pollution prevention technologies and processes and to report the results within one year. Section 2108 directs DOE to apply a systems approach to minimizing the adverse environmental effects of industrial production in the most cost-effective and energy-efficient manner. It further directs DOE to incorporate into its systems approach a consideration of the entire materials and energy cycle, with the goal of minimizing adverse environmental impacts. The work was to be completed by 1995, but the FY 1994 budget does not include funds for work on this task.

The point of contact for this project is Ed Weinbrecht, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, (505) 844-9982. The DOE headquarters contact is Bruce Cranford.

Accomplishments for FY 1993

- A literature search of waste-reducing technologies was initiated in late April to provide background information. This effort concluded on July 1, 1993.
- Two industry expert panels were conducted:
 - Criteria Panel - Opportunities for Energy-Efficient, Pollution Prevention Technology Demonstrations - June 8, 1993
 - Energy-Efficient, Pollution Prevention Technology Demonstrations in the Petroleum Industry - July 23, 1993

Publications

- A *Summary Report - Assessment and Opportunity Identification of Energy Efficient Pollution Prevention Technologies and Processes* was prepared and submitted to the DOE review process on August 4, 1993.
- A draft detailed report was prepared as support to the *Summary Report*. It will be issued in final form once the *Summary Report* has been submitted to Congress.

TECHNOLOGY RESEARCH & DEVELOPMENT

General

National Industrial Competitiveness Through Efficiency: Energy, Environment, and Economics (NICE³)

Background

Improved energy efficiency and reduced pollution (materials waste) are closely related, and both involve process innovation. Improvements to existing subprocesses (to obtain energy or pollution benefits) often result in add-on elements, which tend to raise the cost of a process and lower its competitiveness at some level. The National Industrial Competitiveness through Efficiency: Energy, Environment, and Economics (NICE³) program approaches waste minimization with a view toward improving the whole process.

The NICE³ program began in 1990. Its purpose is to solicit industry participation in developing process modifications that simultaneously address energy efficiency, pollution efficiency, and competitiveness (defined as total dollars required for manufacture per dollar of product produced). All three efficiencies must be affected positively. The second purpose of the program is to promote coordination and cooperation among EPA, DOE, and government offices at the state, regional and Federal level.

The DOE headquarters point of contact for this project is Alan Schroeder.

Accomplishments for FY 1993

During FY 1993, the program received increased funding and was expanded to include all fifty states. The following FY 1993 awards (\$2,400K) were being negotiated.

- **UV Curing for Aluminum Cans** (Colorado Office of Energy Conservation, Coors Brewing Co.)
- **Automated Dye bath Reuse in Carpet Manufacturing** (The Georgia Hazardous Waste Management Authority and Shaw Industries)
- **Cullet Feedstock Purification in the Glass Container Manufacturing Industry Using Advanced Optical Sortation** (Alpine Technology, Oregon State University, Oregon Department of Energy)
- **Hydrochloric Acid Recovery System** (Oregon Department of Energy and Beta Control Systems Inc.)
- **Bioconversion of Low-Value Molasses By-product to High-Value Organic Acid Phytochleates (Fertilizer Enhancement)** (Michigan Biotechnology Institute, Hawaiian Commercial and Sugar Co., Donlar-Galbraith Intl., Uniroyal Chemical, and Cherry Marketing Inst.)
- **Closed Loop Solvent Recovery System** (Lubrizol and the Texas Water Commission)

- **Aluminum Spent Potliner Recycling** (Washington State Department of Ecology and Columbia Aluminum Corp.)
- **Electrophotographic Screening** (Thomson Consumer Electronics, Inc., Indiana Department of Commerce and the Office of Energy Policy)

Operational Efficiencies

Collection of Vapor-Liquid Equilibrium (VLE) Data for Acid Gas - Mixed Amine Systems Using Fourier Transform Infrared Spectroscopy (Texas A&M University, Texas Engineering Experiment Station)

Background

Before natural gas is used to produce heat and power, or used as a feedstock for chemicals production, it is commonly purified by removing the acid gases -- mainly hydrogen sulfide and carbon dioxide. Purification is usually accomplished by contacting the contaminated gas stream with compounds called alkanolamines to absorb the acid gases; those gasses can then be stripped away from the absorbent by adding heat. The energy efficiency of the process depends on the accurate prediction of the vapor-liquid equilibrium (VLE) behavior of the various acid gas-alkanolamine mixtures. Because the VLE behavior of these mixtures is not well-known, the purification system is often operated very inefficiently, with excessive energy consumed for reboiling and pumping operations.

In October of 1990, researchers began work on an analytical technique to improve the measurement of VLE data in acid gas-alkanolamine systems. They developed a new technique based on quantitative infrared absorption. The technique will be authenticated using existing VLE data, and will then be applied to investigate both current and new amine systems over the full range of operating conditions.

The energy savings for the simulated MDEA (methyldiethanolamine) unit were around 50 percent. Assuming 2,500 units are converted, the energy savings are 3.5×10^{14} Btu saved per year. For 2,500 units in the year 2010, the total amount of waste gas reduction will be 1.42×10^8 tons per year (5.67×10^4 tons of waste gas each year per unit x 2,500 units).

The point of contact for this project is Dr. Jerry Bullin, Texas Engineering Experiment Station, 308 Wisenbaker Engineering Research Center, Mail Stop 3577, Texas A&M University, College Station, TX 77843, (409) 845-3306. The DOE headquarters contact is Charlie Russomanno.

Accomplishments for FY 1993

The preliminary measured values of carbon dioxide (CO₂) dissolved in the CO₂-nitrogen (N₂)-amine (DEA)-water (H₂O) system agree with literature data for CO₂ dissolved at higher partial pressures (0.005-0.1 pounds per square inch absolute, or psia) and extend published values to much lower pressures (to 0.0003 psia). Measured values of hydrogen sulfide gas (H₂S) solubility

in this system agree with published values to within 10 percent for partial pressures above 0.1 psia. Modifications of the developed apparatus resulted in much lower background levels of carbon dioxide and water, measurements of H₂S-DEA and CO₂-DEA species in the liquid cell, more stable and reproducible infrared energy throughput, and therefore much greater precision for measurements of samples at low levels.

In-Process Recycle

Membrane Vapor Recovery Systems (Membrane Technology and Research)

Background

Numerous industrial and commercial processes produce gas streams containing condensable organic vapors. Venting such gases to the atmosphere wastes resources and causes pollution problems. Effluent air streams are currently treated with simple condensation, which captures only a small fraction of the organic components emitted. This project addresses the development of a system that combines condensation and membrane separation to improve in-plant recycling of gas streams containing volatile organic compounds (VOCs). If successfully demonstrated, such a system would significantly reduce VOC emissions from many processes.

The demonstration system began operation in October 1990. It has been operated at Membrane Technology and Research, Inc.'s facilities with organic cleaning compound substitutes for chlorinated hydrocarbons, chlorofluorocarbons (CFCs), and fuel hydrocarbons. The efficiency of VOC removal from the feed stream was between 80 and 99.8 percent. Removal efficiency increased with increasing VOC content and decreasing VOC volatility.

An estimated 50 trillion Btu can be saved annually by recovering the organic vapor emissions from storage tanks as well as the solvent and monomer emissions from reactors. By the year 2010, waste could be reduced by 950,000 tons per year. Since storage tanks and reactors are responsible for only a fraction of total VOC emissions, however, the actual savings are expected to be even larger. Total energy savings could amount to several hundred trillion Btu per year. Similarly, total waste reduction could amount to several million tons per year.

The point of contact for this project is Hans Wijmans, Membrane Technology and Research, Inc., (415) 328-2228. The DOE headquarters contact is Charlie Russomanno.

Accomplishments for FY 1993

The membrane organic vapor separation system has recently been installed at an Ethyl Corporation plant, where it will be used to recover a hydrocarbon vapor from a process waste stream. The energy saved by installing membrane vapor recovery systems is equal to the energy value of the captured organic vapors that would otherwise escape into the atmosphere.

Presentations

A paper highlighting the work performed under this DOE contract was presented at the two meetings listed below. On both occasions, the speaker was Hans Wijmans.

- Waste Stream Minimization and Utilization Technology Fair, April 22-23, 1993, Austin, TX
- AIChE 1993 Summer National Meeting, August 16-17, 1993, Seattle, WA

The paper presented at these meetings is entitled "Recovery of VOCs by Membranes: Field Demonstration System". It was prepared by David Dortmund, Thomas Hofmann, Marc Jacobs, Denny Karmaruddin, Jürgen Kaschemekat, and Hans Wijmans.

Recycled Paper in Freight Pallet Production

(California Integrated Waste Management Board, Damage Prevention Products)

Background

In response to growing concerns about the amount of post-consumer waste being generated, California has passed mandates to reduce this waste stream. Recycling efforts are an important part of the solution to the post-consumer waste problem, but new uses for recycled materials must be developed. Many products incorporate various amounts of recycled paper content, while other products use only virgin material.

This project, which began in June of 1993, will demonstrate how a typical paper product manufacturer can fill 40 percent of its raw material fiber requirements with post-consumer mixed paper waste (PAW), and the resulting product will be equivalent to products made with virgin fiber in terms of quality and production. Damage Prevention Products, Inc. (DPP) normally produces pallets from 100-percent virgin corrugated paper; DPP has agreed to demonstrate the use of post-consumer mixed waste paper at a 40-percent substitution level.

Energy savings of 60 percent are estimated. In 2010, with 40-percent adoption at the Nation's potential PAW-using facilities, total annual savings are estimated to be 0.31 trillion Btu per year. For every ton of PAW substituted for virgin fiber, the process saves 50 percent of water usage and 60 percent of energy usage. At the same time, waste water is reduced by 35 percent, and air pollution by 74 percent. By 2010, this substitution can prevent an estimated 1.9 billion pounds of pollution per year, saving 2.9 million cubic yards of landfill space.

The point of contact for this project is Timothy X. Dunn, California Integrated Waste Management Board, 8800 Cal Center Drive, Sacramento, CA 95826, (916) 255-2398/2182. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

Due to a change in industrial partners, this project has only recently commenced. DPP is in the process of buying test equipment and paper containing 40-percent post-consumer waste. The products produced will be tested against virgin paper product standards.

On-site Aluminum Recycling: Automobile Wheels (Ohio Department of Development, AAP St. Marys)

Background

AAP St. Marys makes cast aluminum automobile wheels from ingots for use in domestic and foreign automobiles. The machining of rough castings produces aluminum chips that are contaminated with cutting oils and coolant. The contaminated chips are trucked to an off-site recycling station where the chips are cleaned and melted into ingots (as an intermediate step). The ingots are then shipped back to AAP St. Marys for remelting into molten aluminum for casting wheels. This process creates an excessive amount of waste by-products, and a new technology is needed for the recycling process.

This project, which began in early 1993, will introduce a new, more efficient technology for remelting the considerable volume of aluminum chips that are produced, thereby increasing the yield of usable aluminum by 6.5 percent. Automated conveyors will transport chips from the machining operation directly to the new remelting operation for recycling. Energy usage and costs will be reduced by avoiding the transportation of chips off-site and by reducing by half the number of times each batch of chips has to be remelted (due to the elimination of aluminum ingots as an intermediate step). Lastly, the new remelting operation will employ a new, more efficient pump for stirring the molten aluminum during the recycling process.

Aluminum wheelmakers are expected to save 117 billion Btu annually. Annual pollution prevention is estimated at 7,840 to 25,298 tons in 2010.

The point of contact for this project is Frank Kobayashi, AAP St. Marys, 1100 McKinley Road, St. Marys, OH 45885, (419) 394-7840. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

Previous technical difficulties were remedied, and chip utilization is up to 200 tons. Wheels have been produced using recycled chips on five different casting machines for three different wheel types with satisfactory results. Chip utilization is scheduled to increase to 300 tons; at this utilization rate, the need to transport chips off-site will be virtually eliminated.

Development of Superior Asphalt Recycling Agents **(Texas A&M)**

Background

About 27 million tons of asphalt and nearly twenty times as much aggregate are consumed each year to build and maintain over two million miles of roads in this country. Some recycling is being done, but results do not always produce asphalt that is as durable as new asphalt. The only significant impediment to wider adaptation of this technology is the lack of adequate specifications for high-quality recycling agents. If they were available, such agents could rejuvenate much more or all of the hard, older material into a ductile, long-lasting material with "new material" properties. In this project, supercritical fractions from asphalt will be separated and rebled to produce candidate compositions for superior asphalt recycling agents. Various aged asphalts will be made, characterized, and tested with the candidate recycling agents as initial screening for appropriate combinations of recycling agent and aged asphalt. Processing conditions and procedures for the commercial production of the recycling agents and for the recycle blending will be developed. In the year 2010, recycling of about one-third of roadway asphalt would save about 364 trillion Btu per year. The corresponding waste reduction would total about 182 million tons of asphalt concrete road material (5 percent asphalt and 95 percent aggregate rock) and 100 million gallons of diesel fuel. Phase I, Technical Feasibility, began in August 1993. Only Phase I is included in this cost-shared project because the economic potential for this technology is so great that private industry is expected to fund development and commercialization during later project phases.

The point of contact for this project is Jerry A. Bullin, Chemical Engineering Department, Texas A&M, College Station, TX 77843, (409) 845-3306. The DOE headquarters contact is Merrill Smith.

Accomplishments for FY 1993

Two batches of asphalt were fractionated by chemical extraction. Selected chemical components will be candidates for recycling agents. Some asphalt road materials were artificially aged in a laboratory oven. These materials will be used for comparisons with road-core samples taken from old highways that are being re-paved. This process uses partial recycling of the road material by hot-blending with recycling agents. Numerous core samples were taken of old road material, fresh road material hot-mix, the recycling agent, and the rejuvenated road material as it was hot-recycled in place. Selected recycling agents have been identified by Texas A&M as possible candidates for use on this project.

Process Redesign

Silicon Oxide Utilization (Dow Corning Corp.)

Background

The growth of the U.S. silicon/ferrosilicon industry has stagnated since low-cost imports have devastated its profitability. The current open-hearth furnace technology wastes energy and produces significant quantities of very fine particle "fume" (SiO_2), which is a respiratory hazard. To replace this energy-inefficient, polluting, alternating current (ac) electrical process for smelting silicon and ferrosilicon, researchers have developed a closed-furnace, direct current (dc), electrical production technology.

By the year 2010, it is estimated that 100 percent of U.S. silicon production will come from closed-furnace technology. Based on silicon and ferrosilicon demand predictions, the energy savings in the year 2010 will be 86×10^{12} Btu per year. The yield for a 20-megawatt (MW) furnace will increase from 22×10^6 lbs. per year to 30.8×10^6 lbs. per year. Corresponding reductions in annual emissions of carbon dioxide are predicted to be 1.0 to 3.2 million tons. In addition, the new technology will avoid the annual creation of 0.4 million tons of very fine silicon dioxide fume particles.

The point of contact for this project is James B. May, Dow Corning Corporation, MS #128, 3901 S. Saginaw Rd., Midland, MI 48686-0995, (517) 496-6047. The DOE headquarters contact is Bruce Cranford.

Accomplishments for FY 1993

The start-up and commissioning of a 6-MW closed-furnace pilot plant was completed with the conclusion of the third furnace testing in October 1992. Later that month, the 6-MW pilot plant was formally dedicated. At about one third of commercial size, the furnace was recognized as the world's largest silicon closed-furnace. It is the most energy-efficient silicon furnace of its size and a symbol of international cooperation. During the remainder of the fiscal year, five tests were conducted to obtain the best production from the furnace. The production of ferrosilicon from low-cost materials (waste taconite and waste coke fines or coke breeze), fed through a hollow electrode, was demonstrated in a 1.2-MW electrical dc closed-furnace at MacAlloy (Charleston, SC). The technology may also be applied to silicon produced from similarly low-cost sand and waste coke process residue.

Publication

V. D. Dosaj, et al., *The Smelting of Taconite to Produce Ferrosilicon*, Iron and Steel Society, 50th Electric Furnace Conference, Atlanta, GA, November 10-13, 1992.

Hydrogen Sulfide Utilization (Argonne National Laboratory)

Background

Hydrogen sulfide is a very toxic waste gas that is generated during natural gas production. It is also generated during petroleum refining when hydrogen is used to remove sulfur from the petroleum (hydrodesulfurization). Due to toxicity, EPA regulations prohibit the release of hydrogen sulfide into the atmosphere. The current waste-treatment technology recovers 99.0 to 99.5 percent of the sulfur contained in hydrogen sulfide; the remaining 1.0 to 0.5 percent is emitted as sulfur dioxide. The contained hydrogen is converted into water, which is then purged from the process. This technology consumes about 0.73 trillion Btu per plant each year. Hydrogen is a valuable, energy-intensive industrial raw material that must be generated from increasingly scarce hydrocarbon resources. In refining operations, a new plasma-chemical technology would recover and recycle this hydrogen, thereby displacing the hydrogen production required for desulfurization. Also, in some natural gas production facilities, hydrogen could be recovered from hydrogen sulfide waste streams and sold on the merchant market, thereby displacing hydrogen production at separate facilities.

This technology is expected to save an estimated 20 trillion Btu in the year 2010. By the year 2020, the expected number of new plants using the plasma-chemical technology is projected to be 250, with a total annual energy savings of 52 trillion Btu per year.

The point of contact for this project is John Harkness, Argonne National Laboratory, ES Div. Bldg 362, 9700 S. Cass Avenue, Argonne, IL 60439, (708) 252-7636. The DOE headquarters contact is Tom Foust.

Accomplishments for FY 1993

- Demonstrated plasma operation above one atmosphere (up to 1.3 atm).
- Obtained an "isolated" plasma by increasing the feed velocity and modifying the flow pattern into the plasma zone.
- Determined the effects of high carbon-dioxide concentrations on hydrogen-sulfide dissociation and hydrogen production.
- Determined the mechanism for decreased hydrogen production attributable to carbon dioxide.
- Received U.S. Patent # 5,211,923.

Publication

John B.L. Harkness, Richard D. Doctor, and Edward J. Daniels, *Plasma-Chemical Conversion of Hydrogen Sulfide into Hydrogen and Sulfur*. Proceedings of the World Congress III on Engineering and Environment, Beijing, P.R. China, October 12-14, 1993.

VOC Control Strategies: Recycle and Recover Technologies

(New York State Energy Office and Energy Research and Development Agency, Niagara Mohawk Power Corporation, Carrier Corporation, Mechanical Technology Inc., and Chemsystems Software)

Background

Many industries rely on the use of solvents at intermediate points in their production process. In many processes, the solvent ends its cycle as a vapor contaminant in a warm air stream. Due to environmental and public health issues, manufacturers have been left with three choices: (1) eliminate or modify organic and halo-organic solvent use in the process; (2) incinerate solvents before release; or (3) recover and recycle solvents from the solvent-laden air. The purpose of this project, which began in April 1992, is to develop and transfer an innovative approach for VOC minimization and recovery technologies. This project will demonstrate an energy-efficient solvent-condensing system that is designed for small businesses and small applications. The project will also involve the training of technical personnel (government and industry) in the use of a VOC screening model and a survey of participants on the usefulness of this VOC software for their particular applications.

The estimated potential savings in process energy is 30 trillion Btu per year. Toxic organic emissions are initially targeted for reduction, but air/liquid/solid wastes will also be reduced.

The contact person for this project is John Reese, New York State Energy Office, Agency Building #2, Empire State Plaza, Albany, NY 12223, (518) 473-1911. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

The debugging of training and modeling software has been completed. A training session was held for future software trainers. Chemsystems is preparing to modify the software in response to suggestions received during that training session. The carbon bed (part of the solvent condensing system) was delivered in September and testing commenced in October. A presentation on the VOC program was given to representatives of companies involved in surface coating of wood products.

Ultraviolet Curing: Pressure Sensitive Labels

(Ohio Department of Development and Avery-Dennison Fasson Films Division)

Background

Avery-Dennison's Fasson Films Division (FFD) manufactures pressure-sensitive labels with silicone-coated paper or plastic release liners (the backing material behind peel-off mailing labels). Currently, solvents are used in manufacturing its silicone-coating release liners. The new process, which was implemented in December 1992, eliminates the solvent-based process and uses an ultra-violet (UV) curing system. This process utilizes no solvents and reduces manufacturing costs. The UV silicone system consists of a silicone polymer, an antimony or acid-based catalyst, and a photo initiator. The resultant compound is 100-percent solids, so that no solvent emissions are produced. The system cures almost instantly when exposed to high-intensity UV light. In the absence of UV light, the compound is relatively inert and has extremely long pot life. This gives it the ability to be reused from run to run.

With 70-percent adoption, the 65 U.S. plants making pressure-sensitive labels with release liners will save an estimated 604 billion Btu annually. An estimated 5.2 million pounds of hazardous waste will be avoided nationally if full adoption of the technology occurs.

The point of contact for this project is Tom Dice, Avery-Dennison, Fasson Films Division, 250 Chester Street, Painesville, OH 44077, (216) 639-3268. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

UV lamp delivery is scheduled for December 1993, with final installation planned for mid-January 1994. Trials with General Electric (GE) Silicone have been unsuccessful. Additional tests are planned for mid October. Equipment layout and preliminary design work on the new line has been completed. Final design development is in progress and solicitations have gone out for outside contractors to perform the installation. Start-up is scheduled for January 1994.

Electric Tundish (Holding Furnace): Continuous Copper Alloy Casting

(Ohio Department of Development, AMPCO Metal Manufacturing Company, Inc.)

Background

This project, which began in March 1993, addresses the continuous casting of bar stock in certain copper alloys. During casting, a superheated reservoir of molten alloy is maintained in a continuously heated holding furnace (tundish). These tundishes are currently heated exclusively by fuel gas or oil, and are only 20-percent energy efficient. The proposed electric induction heating system will be 98-percent energy efficient. It will also eliminate the corrosive, polluting waste gases that cause porosity problems in the bar stock (due to the entrapment of waste combustion gases in the casting). With reduced porosity, better quality parts can be produced,

which means they can be more elegantly designed and downsized, reducing overall material and energy consumption.

The two principal innovations that make this innovative device commercially feasible are the tapered-diameter induction coil embedded in the refractory lining of the furnace and the shielding device, which prevents induction of the support structure of the apparatus and the water jacket. This electric induction process will eliminate the problem of hydrogen gas entrainment in the molten bath (a problem that occurs due to metal contact with combustion gases). The new technology will be targeted for use at foundries and in the continuous casting of bar stock.

By 2010, this technology is estimated to save 206 billion Btu annually, assuming a 70-percent adoption rate at U.S. foundries. In addition, an estimated 147 million pounds of pollution will be prevented annually. Wastes include toxic lead vapor and nickel emissions, along with large amounts of carbon dioxide, carbon monoxide, and nitrogen oxides.

The point of contact for this project is W. D. Nielsen, Jr., AMPCO Metal Manufacturing Company, Inc., 5311 West River Road, North, Lorain, Oh 44055, (216) 277-1226. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

Installation and start-up of the first unit was completed in August. Based on preliminary results, it is encouraging to report noticeable improvements in all segments of the project. Orders have been placed for three additional units with installation/start-up in October and November 1993. Tabulation of results will commence when all of the installations are operating.

Ultrasonic Dishwashing

(California Division of Water Resources and Ultrasonic Products, Inc.)

Background

Typically, commercial washers use large volumes of high-temperature water, pressure jetted with caustic chemicals. The wash water temperature in these washers is 140-160°F, and the sanitizing rinse temperature is 180°F. In the fall of 1991, design and fabrication began on two ultrasonic washing systems, one for dining room ware and one for kitchen ware. The innovation developed by Ultrasonic Products, Inc. (UPI) of Ventura, CA, utilizes an omni-directional ultrasonic transducer that can be molded into the geometry of the dishwashing unit. The new, ultrasonic system allows waves to permeate into the interior of objects with no "dead spots." The cleaning action is derived from the mechanical action of micro-bubbles that implode on the surface of the item to be cleaned at a rate of 40,000 times per second. This permits the use of much cooler water (100°F).

Based on 15,184 commercial dishwashing units purchased annually, national energy savings of 7.6 trillion Btu per year are estimated, assuming the new technology dominates the market. Final energy savings may approach 10 times this estimate as older units are replaced. The annual

reduction of waste water is estimated at 9.49 billion gallons per year. An estimated 54.7 million pounds of NO_x will also be prevented nationally.

The point of contact for this project is David H. Evans, Ultrasonic Products, Inc, 3600 Harbor Boulevard, Suite #117, Channel Islands Harbor, CA 93035, (805) 984-1817. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

Design and fabrication of the electrical control system is 70-percent complete. Modification of the jet spraying system for the water spray is 40-percent complete. Off-the-shelf equipment has been identified to perform the function of the tray handling mechanism. UPI will reportedly be filmed by an Australian Public TV Station in late October 1993 at the University of California - Santa Barbara.

Ultrasonic Tank Cleaning: Pharmaceutical Industry

(New Jersey Department of Energy and Environmental Protection and DuPont-Merck)

Background

Chemical and pharmaceutical companies in the United States have long used solvents to clean tanks. Cleaning with these solvents results in the emission of VOCs from the cleaning process and from the incineration or other disposal methods for the spent solvent. The key reason for the exclusion of ultrasonics in large-scale tank cleaning applications is that most ultrasonic transducers produce an energy wave that is uni-directional. Even when using a cluster of uni-directional ultrasonic transducers, "dead spots" can form. DuPont-Merck will employ a tubular resonator that allows homogenous, radial, omni-directional sound distribution, which minimizes "dead spots". This project began in March 1993 with the development of this tubular resonator. The resonator also makes it possible to clean the interior of tanks and containers that can only be accessed through a small opening. With the high costs of energy, solvents, and waste disposal, water-based ultrasonic cleaning offers an attractive alternative to conventional, solvent-based cleaning.

Energy savings at the DuPont-Merck Deepwater facility are estimated at 112 million Btu per year. An additional 3.39 billion Btu are saved by not buying 177,021 lbs. of solvent at an estimated embodied energy of 19,200 Btu/lb. Hazardous waste is expected to be reduced by 45 percent. The reduction in solvent use is estimated at 88.5 tons per year, with potential national savings possibly 1,000 times that amount.

The point of contact for this project is Angelo C. Piro, DuPont-Merck Pharmaceutical Company Chambers Works, Deepwater, NJ 08023, (609) 540-4827. The DOE headquarters contact is Alan Schroeder.

Accomplishments for FY 1993

The design and installation of the mounting brackets used for mounting the transducer to the tank input hatch are nearly complete. Additional transducers have arrived and are in good condition. The first unit was tested on 10 cleaning runs in three tanks with the following results (total): 3.2 million Btu saved, 6100 lbs. solvent not used in cleaning cycles, time to clean tanks reduced from 104 to 14 hours, and \$6,000 saved due to avoided solvent purchase and disposal costs.

Solicitation, Waste Reduction in the Petroleum Industry (Albuquerque Operations Office)

Background

The 12 billion tons of waste that industry transfers to the environment each year contribute to global warming, acid precipitation, ozone depletion, and habitat destruction. IWRP has identified the petroleum industry as an area of high priority based on its energy consumption, hazardous waste production, and value added to the GDP.

In September 1992, the Albuquerque Operations Office issued a solicitation for industrial partners to develop cost-effective technologies that reduce or minimize energy consumption through waste material reduction in the petroleum industry. This solicitation specifies that national energy savings shall be at least 1×10^{12} Btu per year in the year 2010. The amount of industrial waste reduced shall be in the evaluation criteria for solicitation selection.

The point of contact for this project is Porter Grace, U.S. DOE Albuquerque, P.O. Box 5400 (TTCS), NM 87115-5400, (505) 845-5210. The contact at DOE headquarters is Charlie Russomanno.

Accomplishments for FY 1993

The solicitation was closed in January 1993. The contracts are scheduled to be awarded during FY 1994.

Solvent Waste Minimization by Supercritical Carbon Dioxide Cleaning

(Hughes Aircraft, IBM, Autoclave Engineers, Honeywell Defense Avionics, The Boeing Company, DOE/AL, PNL, SNL, LANL)

Background

Numerous companies rely on halons, chlorofluorocarbons (CFCs), carbon tetrachloride, and other fully halogenated alkanes to clean organic contaminants and particulates off of metals, plastics, composites, ceramics, electronic components, and other materials. These halogenated solvents are being eliminated from use because they are suspected of depleting the stratospheric ozone layer. Alternative cleaning technologies, such as aqueous cleaning, can replace halogenated

solvents in some applications, but in others, viable replacements have yet to be found. Supercritical fluids (SCF), particularly CO₂, have been identified as promising energy-conserving alternatives to using CFCs or other chlorinated solvents. More information is needed on the applicability of supercritical carbon dioxide and its operating parameters in this application. The research will determine whether supercritical carbon dioxide is capable of cleaning the materials adequately. The research will be performed in conjunction with industry so that the technology can be exchanged as it is developed.

This technology is estimated to save 40×10^{12} Btu per year compared to the energy used with CFC cleaning or other identified substitutes (such as aqueous cleaning), with an associated waste reduction of approximately 1×10^6 tons of CFCs or waste water.

The point of contact for this project is Gerald Maestas, Los Alamos National Laboratory, MS F643, Los Alamos, NM 87544, (505) 667 3973. The DOE headquarters contact is Tom Foust.

Accomplishments for FY 1993

- PNL investigators extended the capabilities of the Berty reactor, which they are using to research cleaning operations. The unit has been fitted with necessary pumps and plumbing in order to carry out both co-solvent addition and CO₂ recycling. PNL has a view cell arrangement, which has been used to determine critical point behavior of several mixed solvent systems of interest.
- The Autoclave Superscrub unit was made fully operational at Los Alamos after an extended wait for facilities modification. The system is heavily instrumented to allow for determination of whole-system operational capabilities during various cleaning procedures. In addition to the Superscrub, several smaller units were purchased and brought on line.
- SNL brought a high-pressure view cell assembly to operational status for the determination of solubility data, and for the evaluation of the effects of co-solvent mixtures on the critical behavior of CO₂. Aerosol modeling of a separator began at SNL.
- A generic model of cleaning was developed and the various experimental parameters within the model are being evaluated by all partners. Factors include the dependence of the kinetics of cleaning solubility, flow rate, diffusion constants, solubility parameters, surface work functions, surface roughness, contaminant type, and contaminant distribution.

Electroplating Waste Minimization

(The Boeing Company, DOE/AL, Los Alamos National Laboratory)

Background

Both the commercial electroplating industry and DOE currently generate large quantities of toxic metal wastes that are converted to hydroxide sludges and sent for disposal. The current method of disposal wastes valuable metals and energy and costs millions of dollars annually. The goal

of this project, which began in August 1991, is to separate and purify these metal wastes from the aqueous solutions before the sludge is formed. The objective is to allow reuse of these former plating wastes as reagents in the front end of the plating process. Energy savings will accrue from the reduction in raw materials, mining expenditures, metals processing, transportation, sludge processing, and sludge disposal. These separation and purification processes will also reduce industry's liability while reducing environmental pollution from toxic metal wastes. Moreover, this technology will slow the rapid growth of our inventory of stored metal sludges, which is becoming a state and national liability. The research will focus on mixed-metal baths (Zinc-Nickel, Zinc-Tin, and Nickel-Tungsten) because they are the most difficult baths to recycle and because they are beginning to replace the highly hazardous cadmium (Cd) and chromium (Cr) baths.

The energy savings that would result from avoiding the discard of metals as waste (because of changes in mining, processing, and transport) would be 2.3×10^{13} Btu per year total. The average electroplating plant will reduce heavy metal discharge by 18.5 tons each year per unit if it uses recycling. If 2,440 electroplating plants adopt metal recycling by 2010, approximately 4.1×10^4 tons of metal could be saved each year.

The point of contact for this project is Barbara F. Smith, Los Alamos National Laboratory, Analytical Chemistry Group (CLS-1), MS G740, Los Alamos, NM 87545, (505) 667-2391. The contact at DOE headquarters is Tom Foust.

Accomplishments for FY 1993

- A best available technology review was performed to identify the available technologies and technology needs.
- A four-pronged approach has been defined and developed for each bath type (plating bath life extension, plating rinse waters, discarded plating bath water, and other general plating waste water).
- The plating bath life extension approach consists of using electrodialysis to reduce the buildup of salts or base in the plating baths. Sodium hydroxide removal experiments were very successful, giving nearly a quantitative yield of protons and less than 5 parts per million (ppm) migration of metal ion into the waste stream.
- The waste water treatment approach involves the use of ultrafiltration with water-soluble chelating polymers. Several water-soluble chelating polymers have been developed. Two-gallon bench-scale tests have been performed. An 80-gallon pilot-scale apparatus is being built for demonstration at Boeing next year.
- The metal-ion recovery approach from spent baths involves the use of advanced membrane technology with traditional liquid-liquid extractants. The liquid-liquid extraction (LLE) modules from Hoechst-Celanese are under evaluation for metal-ion extraction. They are being characterized for their transport characteristics, organic and aqueous flow properties, efficiency, and uniformity from module to module. Since the

organic flow properties were found to be nonuniform, researchers have been designing a new module to overcome this problem.

Presentation

B. F. Smith, "Zinc-Nickel (A Cadmium Replacement) Control," American Institute of Chemical Engineers Summer National Meeting, Seattle, WA (August 15, 1993).

Publication

N. N. Sauer and B. F. Smith, *Metal-Ion Recycle Technology for Metal Electroplating Waste Waters*, Los Alamos National Laboratory, LA-12532-MS, UC-367, June 1993.

Revitalize the U.S. Silicon/Ferrosilicon Industry, Silicon Technology Competitive Cooperative (STCC)

(Silicon Technology Competitive Cooperative)

Background

Low-cost imports have devastated the profitability of the U.S. silicon/ferrosilicon industry. The U.S. industry currently uses electric-arc open furnaces with alternating current (ac) and top-of-furnace feed systems for raw materials. The South Carolina Research Authority (SCRA) is switching to dc power and injecting part of the feedstock through a hollow electrode to reduce production costs, energy usage, and emissions in a moderate-risk approach to an affordable-capital-cost furnace retrofit. Seven U.S. ferrosilicon producers, all members of the Ferroalloys Association, formed the Silicon Technology Competitive Cooperative (STCC), and are assisting the SCRA in this research through the STCC Technical Team and the STCC Executive Committee. The project was initiated in March 1993. The contracted scope is for Phase I, Exploratory Development. Tests will be performed in an existing 1.5-MW furnace at the MacAlloy facilities in North Charleston, SC. Until test results are available, this project was very conservatively assigned the balance of the silicon/ferrosilicon market (2 million lb. per year).

Energy savings for the year 2010 are estimated at 2×10^{12} Btu per year. The corresponding reduction in annual emissions of carbon dioxide are estimated at about 0.05 million tons.

The point of contact for this project is Dennis Allen, South Carolina Research Authority, 5300 International Blvd., North Charleston, SC 29418, (803) 760-3568. The contact at DOE headquarters is Bruce Cranford.

Accomplishments for FY 1993

A kickoff meeting was held in March. The technical analysis and general engineering design for modifications to the existing test furnace were completed. Material requirements and performance projections were established, and procurement of materials was initiated. Several meetings of the STCC Technical Team and the STCC Executive Committee were held to discuss

coordination, design, and testing issues. Modifications to the testbed furnace are underway. The project Test Plan has been put in final form. All seven producer members have signed their cost-share agreements and are participating in all phases of the project.

Biological/Chemical Caprolactam Production Process (Allied Signal)

Background

Currently, nylon 6 is manufactured from caprolactam. The chemical conversion of cumene to caprolactam is a complex, multi-step process that is energy intensive and generates considerable waste. Nylon 6 can also be produced from caprolactone and ammonia in a very efficient process using known chemistry. At present, however, caprolactone's market price renders this route uneconomical. The biological process being developed would provide a one-step cost-effective process for producing caprolactone. This project, which began in May 1993, seeks to establish the technical feasibility of a biomanufacturing process for the conversion of cyclohexane into caprolactone by optimizing and scaling up a laboratory-demonstrated bioprocess to pilot-plant scale. Energy efficiencies have yet to be demonstrated, but at 50 percent of the current energy usage and assuming a 60-percent market penetration for the bioprocess, energy savings would be about 12×10^{12} Btu per year by 2010. The corresponding reduction in wastes produced would be 0.2 million pounds of cumene, 0.8 million pounds of phenol, 1.6 million pounds of acetone, and 31 million pounds of ammonium sulfate.

The point of contact for this project is Haya Zemel, Allied Signal, Inc., R&T, 50 East Algonquin Road, Des Plaines, IL 60017-5016, (708) 391-3518. The contact at DOE headquarters is Merrill Smith.

Accomplishments for FY 1993

Allied Signal, Inc. (ASI) started growing and isolating candidate cyclohexane-consuming microbes in a mixture of microorganisms from a remedial treatment bioreactor. Cultures were tested for tolerance to higher concentrations of cyclohexane as feedstock and to determine, analytically, if cyclohexane conversion was occurring. Researchers began evaluating growth media for cultivating microbes that only consume cyclohexane.

Novel Selective Surface Flow (SSF) Membranes For Recovery of Hydrogen From Waste Gas Streams (Air Products and Chemicals, Inc.)

Background

U.S. petroleum and chemical industries produce very large hydrogen-containing waste streams (estimated to be 800 million standard cubic feet per day [scfd]). Currently, the hydrogen from these waste streams is either being released to the atmosphere because dilute-gas recovery is not

economical, or burned as fuel to produce steam. In either case, the chemical value of this gas is being lost. In April 1993, Air Products and Chemicals, Inc. (APCI) began developing a new class of gas separation membranes that are designed to enrich gas streams containing low concentrations of hydrogen (H_2) at low pressures. These selective surface flow (SSF) membranes, in conjunction with conventional pressure swing adsorption (PSA) systems, will be used to efficiently recover high-purity hydrogen from waste gases. By the year 2010, with 75-percent hydrogen recovery and a market share of 30 percent, this technology would recover about 250 million scfd of hydrogen for an energy savings of about 30×10^{12} Btu per year. Avoiding the burning this hydrogen would reduce nitrogen oxide (NO_x) emissions by 440 tons per year.

The point of contact for this project is Madhu Anand, Air Products and Chemicals, Inc., 7201 Hamilton Boulevard, Allentown, PA 18195-5400, (215) 481-6561. The contact at DOE headquarters is Charlie Russomanno.

Accomplishments for FY 1993

APCI began screening materials for hollow-tube membrane supports by coating the candidate materials with the membrane material and evaluating separation performance. Membrane-coating techniques are also being evaluated. Work was initiated on the design and construction of a multiple-tube membrane housing and test system, and APCI completed the preliminary design of a membrane-coating apparatus for manufacturing tubular membranes more quickly and uniformly. APCI has produced hollow-tube membranes with separation performance levels approaching targeted values while maintaining 10 times the through-put of flat-sheet membranes.

Solicitation: Waste Reduction in the Metals and Pulp and Paper Industries (Chicago Operations Office)

Background

Industry discharges 12 billion tons of waste to the environment each year. These wastes contribute to global warming, acid precipitation, ozone depletion, and habitat destruction. A significant portion of these wastes could be reduced with the development and commercialization of new technologies for waste materials reduction.

This solicitation targets the metals and pulp and paper industries. The IWRP Plan identifies the metals and pulp and paper industries as areas of high priority based on their energy consumption, hazardous waste production, and value added to the GDP. This project will issue a solicitation for cooperative R&D projects that will develop cost-effective technologies for reducing energy consumption through waste-material utilization. Energy savings will be at least 10^{12} Btu per year in the year 2010.

The point of contact for this project is Norm Swift, U.S. Department of Energy, Chicago Operations Office, 9800 S. Cass Avenue, Argonne, IL 60439, (708) 252-6028. The contact at DOE headquarters is Merrill Smith.

Accomplishments

Solicitations were placed in the *Commerce Business Daily* on July 28, 1993. Numerous replies were received and CRADA contracts are to be awarded in FY 1994.

TECHNOLOGY TRANSFER

Technology Exchange

Waste Stream Minimization/Utilization Technologies Showcased

Background

The Innovative Concepts (InnCon) Technology and Business Opportunities Fair is part of the Innovative Concepts Program, which is sponsored by DOE's Invention and Innovation Division. This sixth cycle of the program was co-sponsored by several other divisions within the DOE and by the Texas Department of Commerce. Other supporting agencies included the Licensing Executive Society and the National Technology Transfer Center. The fair gives concept presenters and developers an opportunity to discuss their concepts, market opportunities, test results, and savings potentials.

The first Innovative Concepts Fair was held in 1984 and focused on 12 innovative ways to reduce energy consumption in commercial buildings. Subsequent fairs have focused on waste-minimization and energy-saving concepts involving commercial buildings, separations technologies, and building retrofits.

The point of contact for this project is Elliot Levine, U.S. Department of Energy, Innovative Concepts Program, 1000 Independence Avenue, S.W., Washington, DC 20585, (202) 586-1476.

Accomplishments for FY 1993

To date, six InnCon Technology Fairs have presented project results. Interest in the program continues to build. At the last fair, about 200 investors, industrial representatives, academics, and government sponsors discussed with the presenters the potential of over 40 state-of-the-art concepts. The format was a mixture of formal technical presentations, panel discussions on "doing business" with different governmental agencies, keynote speakers from major waste technology companies, poster sessions for informal business discussions, and networking opportunities at lunches and receptions. It is too soon to measure quantitatively the effects of this year's fair on investments in new concepts, but all participants made strong positive comments at the conclusion of the event.

The fair marked the end of a cycle that occupied more than a year of preparation. Elements in the cycle include selecting a topic, soliciting and selecting concepts, preparing concept presentations, developing technology briefs and proceedings, conducting a Commercialization Planning Workshop, and hosting the fair.

Information Exchange

IWRP Technical Program Plan Section Update

Background

The Industrial Waste Reduction Program Plan was originally published in October 1991. In August 1992, the Technical Program Section was revised to reflect current-program direction and project results. Specifically, the section was expanded to include more detail on program structure and strategies and to present current accomplishments and milestones.

The point of contact for this program is Ed Weinbrecht, Sandia National Laboratories, P.O. Box 5800, Albuquerque, NM 87185, (505) 844-9982. The contact at DOE headquarters is Bruce Cranford.

Accomplishments for FY 1993

At a team meeting in Albuquerque, New Mexico, several drafts were prepared and reviewed during the first two quarters of FY 1993. The revisions were approved by DOE/EE's Office of Industrial Technologies' (OIT's) management in September 1993, and distributed September 17, 1993.

Program Evaluation

IWRP Annual Program Review

Background

The IWRP conducts an annual program review in order to brief DOE program management personnel and to foster communication and information exchange among program participants.

The point of contact for this project at DOE headquarters is Charlie Russomanno.

Accomplishments for FY 1993

The FY 1993 review was held May 18-20 in Santa Fe, New Mexico. Approximately 70 participants from industry, government, universities, and the national laboratories engaged in a free exchange of information on waste-reduction progress, problems, and opportunities. Discussions covered 40 projects that were funded by IWRP in FYs 1992 and 1993. Additionally, a tour of Sandia National Laboratories was provided; a similar tour of Los Alamos National Laboratory was pre-empted by a visit from President Clinton. The proceedings were documented and distributed in July 1993.

Proposal Evaluation - OTEA/NIST Technology Evaluation Services for The U.S. Department of Energy (DOE)

(National Institute of Standards & Technology/Office of Technology Evaluation & Assessment)

Background

The National Institute of Standards and Technology (NIST) Office of Technology Evaluation and Assessment (OTEA) provides DOE with a technology evaluation service on demand. Selected proposals for technology development that are submitted to DOE are forwarded to OTEA for evaluation. OTEA evaluates these proposals in accordance with criteria established by DOE. This activity was initiated in April 1992 to provide DOE with impartial technology evaluation services of a purely advisory nature. Future evaluation services will be revised to meet DOE requirements.

The point of contact for this project is Joe Dhillon, Office of Technology Evaluation and Assessment, U.S. Department of Commerce, Gaithersburg, MD 20899, (301) 975-5500. The contact at DOE headquarters is Tom Foust.

Accomplishments for FY 1993

- OTEA reviewed four ongoing projects for conformance to IWRP program goals. OTEA obtained two independent reviews from professionals familiar with the technologies involved for each of the ongoing projects. OTEA/NIST prepared final review summaries and mailed the complete reports to DOE's Albuquerque Field Office with copies sent to DOE Headquarters.
- OTEA conducted technical reviews of six proposals (in response to the petroleum industry solicitation) received from the Albuquerque Field Office. OTEA obtained two consultant reviews for each of the proposals. OTEA/NIST prepared the final executive summary for each proposal reviewed. In addition, each proposal was scored and then all of the proposals were ranked.
- A presentation was made on the OTEA proposal/project review process at the DOE/IWRP Program Review meeting held in Santa Fe, New Mexico.

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ACRONYMS AND ABBREVIATIONS

AIChE	American Institute for Chemical Engineers
AO	Albuquerque Field Office
APCI	Air Products and Chemicals, Inc.
ASI	Allied Signal, Inc.
atm	Atmosphere
BMS	Boeing Material Specifications
Btu	British Thermal Units
CES	Center for Economic Studies, U.S. Bureau of the Census
CFC	Chlorofluorocarbons
CH	Chicago Operations Office
CRADA	Cooperative Research and Development Agreement
dc	Direct current
DOC	Department of Commerce
DOE	U.S. Department of Energy
DPP	Damage Prevention Products, Inc.
E/A	Epoxy/acrylate
EPA	U.S. Environmental Protection Agency
EPact	Energy Policy Act
ERDA	Energy Research and Development Agency
F	Fahrenheit
FEA	Federal Energy Administration
FFD	Avery-Dennison's Fasson Films Division
FY	Fiscal year
GDP	Gross domestic product
GE	General Electric
InnCon	Innovative Concepts
IWRP	Industrial Waste Reduction Program
IWUCP	Industrial Waste Utilization and Conversion Program
kg.	Kilograms
km.	Kilometers
L-CAD	Lifecycle Computer Aided Data
LANL	Los Alamos National Laboratory
lb.	Pound
LCA	Lifecycle analysis
LLE	Liquid-liquid extraction
MDEA	Methyldiethanolamine
MTR	Membrane Technology and Research, Inc.
MW	Megawatts
NICE ³	National Industrial Competitiveness through Efficiency: Energy, Environment, and Economics
NIST	National Institute of Standards and Technology
OIT	Office of Industrial Technologies
OTEA	Office of Technology Evaluation and Assessment

PAW	Post-consumer mixed paper waste
PNL	Pacific Northwest Laboratory
ppm	Parts per million
PSA	Pressure swing adsorption
psia	Pounds per square inch absolute
PWB	Printed wire boards
R&D	Research and development
SCF	Supercritical fluids
scfd	Standard cubic feet per day
SCRA	South Carolina Research Authority
SNL	Sandia National Laboratories
SSF	Selective surface flow
STCC	Silicon Technology Competitive Cooperative
U/A	Urethane/acrylate
UL	Underwriters Laboratories
UV	Ultraviolet
VLE	Vapor-liquid equilibrium
VOC	Volatile organic compounds

INDEX

3M	1, 10, 13, 17, 18
AAP St. Marys	29
acrylate	17, 18, 51, 52
agricultural	4, 6, 9
Agriculture	8
Air Products	41, 42, 51
Alpine Technology	25
aluminum	20, 25, 26, 29
American Institute of Chemical Engineers (AIChE)	7, 20, 28, 40, 51
amine	26
AMPCO	34, 35
Argonne National Laboratory (ANL)	32, 42
atmosphere	16, 27, 32, 41, 51
ATMOSPHERIC EMISSION ISSUES	
global warming	37, 42
Waste Gas	26, 32, 41
Autoclave Engineers	37
Avery-Dennison	34, 51
Beta Control Systems	25
Bioconversion	25
Biotechnology	21, 25
Boeing	17, 18, 37-39, 51
Bureau of the Census	19, 51
cadmium	39, 40
capital	6, 9, 40
Carbon dioxide	26
Carbon monoxide	35
Carrier	33
Catalysis	21
cement	14
Center for Waste Reduction Technologies (CWRT)	22, 23
ceramics	37
CFC	16, 38, 51
chemical	7, 17, 19, 20, 22, 23, 25, 30, 32, 33, 36, 40-42, 51
chemical engineering	7, 30
Chemsystems Software	33
Cherry Marketing	25
chromium	39
Cleaning	3, 8, 13, 16, 17, 27, 35-38
Closed Furnace	31
CO	25, 38, 45
CO2	26, 27, 38
Columbia Aluminum	26

commercialization	1, 5, 13-16, 18, 30, 42, 45
COMPANIES	
3M	1, 10, 13, 17, 18
AAP St. Marys	29
Air Products	41, 42, 51
Alpine Technology	25
AMPCO	34, 35
Autoclave Engineers	37
Avery-Dennison	34, 51
Beta Control Systems	25
Boeing	17, 18, 37-39, 51
Carrier	33
Chemsystems Software	33
Cherry Marketing	25
Columbia Aluminum	26
Coors	25
Donlar-Galbraith	25
Dow Corning	31
DuPont	36
DuPont-Merck	36
Energetics	22
FMC	1, 10, 13-15
Ford	17
General Electric (GE)	34, 51
Hawaiian Commercial and Sugar	25
Hoechst-Celanese	39
Honeywell	17, 37
Hughes	17, 37
IBM	17, 37
Lubrizol	25
MacAlloy	31, 40
Membrane Technology and Research	27, 51
Mohawk	33
Motorola	1, 10, 13, 16, 17
PPG	1, 10, 13, 14
Shaw Industries	25
Thomson Consumer Electronics	26
Ultrasonic Products	35, 36
Uniroyal	25
Computer	20, 21, 51
Congress	23, 24, 33
conservation	6, 25
contract	18, 28
contractor	21
Coors	25
copper	34

cost sharing	8
cost-shared	1, 4, 7, 30
costs	3, 6, 14, 29, 34, 36-38, 40
CRADA	16, 43, 51
cyclohexane	41
Department of Commerce (DoC)	3, 19, 26, 45, 47, 51
Department of Energy (DoE)	1, 2, 1, 3, 4, 6, 7, 9, 10, 14-42, 45-47, 49, 51
Desulfurization	32
Donlar-Galbraith	25
DuPont	36
DuPont-Merck	36
economic	1, 3, 4, 6-10, 13, 15, 19, 30, 51
economic growth	3, 9
economic health	3
Economics	7, 8, 25, 51
Electric induction	34, 35
Electroplating	38-40
emission	21, 36
employment	9
Energetics	22
energy	1, 2, 1, 3, 4, 6-10, 13-17, 19, 21-29, 31-42, 45, 47, 49, 51
CO	25, 38, 45
coke	31
electric	31, 34, 35, 40, 51
H2	42
hydrogen	1, 10, 13-15, 21, 26, 32, 33, 35, 41, 42
natural gas	9, 26, 32
oil	1, 8, 9, 34
petroleum	3, 8, 22, 24, 32, 37, 41, 47
waste heat	6
wood	33
energy conservation	6, 25
energy consumption	1, 3, 8, 15, 35, 37, 42, 45
energy research	6, 33, 51
environment	1, 3, 7, 15, 20, 21, 25, 33, 37, 42, 51
Environmental Protection Agency (EPA)	6, 14, 19, 25, 32, 51
feedstock	5, 25, 26, 40, 41
ferroalloys	40
ferrosilicon	31, 40
fertilizer	25
field	7, 28, 47, 51
fiscal year	1, 31, 51
FMC	1, 10, 13-15
Ford	17
Freon	16
fuel	4, 13, 14, 21, 27, 30, 34, 42

GASES

ammonia	41
carbon dioxide	26
carbon monoxide	35
Carbon Tetrachloride	37
CFC	16, 38, 51
CFC-11	16
Chlorofluorocarbons	8, 16, 27, 37, 51
CO	25, 38, 45
CO2	26, 27, 38
freon	16
H2	42
H2S	26, 27
hydrogen	1, 10, 13-15, 21, 26, 32, 33, 35, 41, 42
hydrogen sulfide	26, 32, 33
Mercury	27, 51
Methanol	1, 10, 13-15
NOx	36, 42
ozone	16, 17, 37, 42
Silicon Oxide	31
VOC	8, 17, 18, 23, 27, 33, 52
General Electric (GE)	34, 51
glass	13, 25
Global warming	37, 42
goal	1, 4-6, 13, 16, 21, 23, 38
GOVERNMENT ORGANIZATIONS	
Bureau of the Census	19, 51
Department of Commerce (DoC)	3, 19, 26, 45, 47, 51
Department of Energy (DoE)	1, 2, 1, 3, 4, 6, 7, 9, 10, 14-42, 45-47, 49, 51
Environmental Protection Agency (EPA)	6, 14, 19, 25, 32, 51
National Institute for Standards and Technology (NIST)	47, 51
Office of Industrial Programs	6
grant	14
greenhouse	4
H2	42
H2S	26, 27
Hawaiian Commercial and Sugar	25
hazardous waste	13, 14, 25, 34, 36, 37, 42
Hoechst-Celanese	39
Honeywell	17, 37
Hughes	17, 37
Hydrodesulfurization	32
hydrogen sulfide	26, 32, 33
IBM	17, 37
industrial sector	3, 6
industrial support	7, 8

industrial waste	1, 2, 1, 3-7, 9, 17, 19, 21-23, 37, 46, 51
industry	1, 3, 4, 3-10, 13-18, 21-25, 30, 31, 33, 36-40, 42, 46, 47
innovation	25, 35, 45
Innovative Concepts Program	45
institutional	1, 5, 6
invention	45
Iron and Steel	31
Landfill	28
lead	15, 35
legislation	6
LIQUIDS	
plasma	32, 33
pulp	8, 22, 42
water	1, 10, 13, 14, 25-28, 32, 35, 36, 38, 39
long-term	3, 8, 16
Los Alamos National Laboratory (LANL)	37, 51
Lubrizol	25
MacAlloy	31, 40
material	4, 6, 8, 9, 18, 28, 30, 32, 34, 35, 37, 40, 42, 51
materials substitution	23
measurement	26
Membrane Technology and Research	27, 51
Michigan Biotechnology Institute	25
Milestones	46
minimization	6, 19, 25, 28, 33, 37, 38, 45
Mining	8, 39
monthly	3
Motorola	1, 10, 13, 16, 17
N2	26
National Institute for Standards and Technology (NIST)	47, 51
NATIONAL LABORATORIES	1, 6, 7, 10, 13, 16, 21-24, 46, 52
Argonne National Laboratory (ANL)	32, 42
Los Alamos National Laboratory (LANL)	37, 51
Pacific Northwest Laboratory (PNL)	20, 37, 38, 52
Sandia National Laboratories (SNL)	1, 10, 13, 16, 21-24, 37, 38, 46, 52
Niagara Mohawk	33
nickel	35, 39, 40
nitrogen	26, 35, 42
non-nuclear energy	6
NOx	36, 42
objectives	4, 16
Office of Industrial Programs	6
Oregon State University	25
Organic Vapors	27
ORGANIZATIONS	
American Institute of Chemical Engineers (AIChE)	7, 20, 28, 40, 51

Center for Waste Reduction Technologies (CWRT)	22, 23
Innovative Concepts Program	45
Michigan Biotechnology Institute	25
Oak Ridge	4
Silicon Technology Competitive Cooperative	40, 52
South Carolina Research Authority	40, 52
Ozone	16, 17, 37, 42
Ozone Depletion	37, 42
Pacific Northwest Laboratory (PNL)	20, 37, 38, 52
paper	8, 22, 28, 29, 34, 42, 52
particulates	37
patent	32
pilot plant	31
PLAN	
Program Plan	3, 46
plasma	32, 33
policy	6, 23, 26, 51
pollution	6, 18, 22-25, 27-29, 35, 39
pollution prevention	6, 18, 22-24, 29
PPG	1, 10, 13, 14
president	46
private sector	7, 13
productivity	1, 4, 9
Program Management	7, 46
Program Review	21, 46, 47
pulp	8, 22, 42
Purification	14, 25, 26, 39
R&D	1, 5-9, 19, 20, 22, 23, 42, 52
R&D OPPORTUNITIES	22
recovery system	15, 25
Recycling	5, 6, 13, 21, 23, 26-30, 38, 39
reduce waste	1, 8, 22
regulations	14, 17, 32
regulatory	6
renewable	1, 2, 4, 49
retrofit	40
risk	8, 40
Sandia National Laboratories (SNL)	1, 10, 13, 16, 21-24, 37, 38, 46, 52
Separation	13, 23, 27, 39, 42
Shaw Industries	25
SiC	8
Silicon Oxide	31
Silicon Technology Competitive Cooperative	40, 52
solder	16
Soldering	1, 10, 13, 16, 17
solicitation	13, 17, 37, 42, 47

SOLIDS

aluminum	20, 25, 26, 29
cadmium	39, 40
ceramics	37
chromium	39
copper	34
lead	15, 35
nickel	35, 39, 40
paper	8, 22, 28, 29, 34, 42, 52
sulfur	32, 33
wood	33
zinc	39, 40
solvent recovery	25
solventless	17, 18
source reduction	6
South Carolina Research Authority	40, 52
sulfur	32, 33
Supercritical	30, 37, 38, 52
surface coating	33

TECHNOLOGIES

bioconversion	25
biotechnology	21, 25
catalysis	21
cleaning	3, 8, 13, 16, 17, 27, 35-38
Closed Furnace	31
computer	20, 21, 51
desulfurization	32
electric induction	34, 35
electroplating	38-40
hydrodesulfurization	32
mining	8, 39
purification	14, 25, 26, 39
recovery system	15, 25
recycling	5, 6, 13, 21, 23, 26-30, 38, 39
separation	13, 23, 27, 39, 42
soldering	1, 10, 13, 16, 17
supercritical	30, 37, 38, 52
treatment	3, 4, 14, 23, 32, 39, 41
ultrasonic	35, 36
ultraviolet curing	34
Technology Transfer	7, 45
Texas A&M University	26, 30
Thomson Consumer Electronics	26
toxicity	32
transportation	3, 14, 29, 39
Treatment	3, 4, 14, 23, 32, 39, 41

Ultrasonic	35, 36
Ultrasonic Products	35, 36
ultraviolet curing	34
Uniroyal	25
UNIVERSITIES	
Oregon State University	25
Texas A&M University	26, 30
VOC	8, 17, 18, 23, 27, 33, 52
Waste Gas	26, 32, 41
water	1, 10, 13, 14, 25-28, 32, 35, 36, 38, 39
wood	33
zinc	39, 40

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END