U.S. Department of Energy
Office of Energy Efficiency and Renewable Energy

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INDUSTRY
VISIONS
TO
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Office of Industrial Technologies:
Summary of Program Results

U.S. DEPARTMENT OF ENERGY • WASHINGTON, DC 20585

January 1999

To Our Customers:

Driven by pressures to reduce costs, improve productivity, and cut pollution, U.S. industry is realizing the benefits of energy-efficient technologies for maintaining a competitive position. For more than twenty years, the Department of Energy's Office of Industrial Technologies under the Assistant Secretary for Energy Efficiency and Renewable Energy has been partnering with industry to develop technologies that meet industry's needs. More recently, we introduced the "Industries of the Future" concept to more explicitly involve our industrial partners in the process of setting technology-development priorities.

As a result of these efforts, over 100 commercially successful technologies have been developed and deployed, with significant impacts on the U.S. economy and environment. This report summarizes some of the benefits — energy savings, waste reduction, increased productivity, lowered carbon dioxide and air pollutant emissions, and improved product quality — which have been tracked by periodic interviews with industrial technology suppliers and users.

We encourage you to become part of this customer-driven "Industries of the Future" strategy by utilizing energy-efficient technologies already commercially available and those just emerging in the marketplace. We invite your comments and suggestions on this document, as well as on products and services that would help you move toward a clean, competitive energy future.

Sincerely,

Dan W. Reicher

Assistant Secretary
Energy Efficiency and Renewable Energy

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Working in partnership with industry, the U.S. Department of Energy's (DOE's) Office of Industrial Technologies (OIT) is helping reduce industrial energy use, emissions, and waste while boosting productivity. Operating within the Office of Energy Efficiency and Renewable Energy (EE), OIT conducts research, development, demonstration, and technology transfer efforts that are producing substantial, measurable benefits to industry. This document summarizes some of the impacts of OIT's programs through 1997.

Over the past 22 years, OIT has supported more than 500 separate research, development, and demonstration (RD&D) projects, producing over 100 technologies adopted by industrial manufacturers. In 1997 alone, successfully commercialized technologies saved more than 115 trillion Btu. While these energy savings are impressive, industry has reaped even greater benefits from the productivity improvements, reduced resource consumption, decreased emissions, and enhancements to product quality associated with these technological advances. In addition, many OIT-supported projects have significantly contributed to expanding basic knowledge about complex industrial processes and laid the foundation for the development of future energy-efficient technologies.

Since 1994, OIT has implemented an innovative, customer-driven research strategy known as Industries of the Future. This strategy ensures that OIT projects meet real industry needs and make the most of limited research resources by helping to focus public and private technology investments on industry's most critical research needs.

The Industries of the Future strategy has made it possible for entire industries, many for the first time, to work together to define and pursue their top priorities for research, development, and demonstration (RD&D). The new approach takes full advantage of the unique insights and resources industry can bring to the research planning and implementation process. By giving industry "ownership" of the process, the strategy also obtains industry commitment to the research and facilitates industry cost-sharing, which averages 50% over the life of a project. Moreover, industry's involvement essentially ensures adoption and use of the successful energy-efficient technologies.

The Industries of the Future strategy effectively integrates a broad range of efforts to meet industry's current and future needs:

- ◆ Collaborative R&D focused on selected, *energy-intensive industries*, including agriculture, aluminum, chemicals, glass, forest products, metalcasting, mining, petroleum, and steel.

- ◆ R&D in *enabling technologies*, applicable to a wide range of manufacturing industries, including combustion, sensors and controls, advanced materials, continuous-fiber ceramic composites, and distributed generation.
- ◆ *Technical assistance* through the provision of energy and environmental plant assessments as well as data, decision tools, and recognition programs promoting adoption of a systems approach to increasing the efficiency of electric motors and drive systems, compressed air, combined heat and power, and steam.
- ◆ *Financial assistance* to encourage cooperative demonstrations of emerging technologies and the development of energy-saving ideas and innovations by inventors and small businesses.

The Industries of the Future process has been widely heralded as a model for public-private partnerships. It affords industry a strong voice in the allocation of federal industrial research dollars while enabling OIT to maximize research productivity. The process takes advantage of the inherent relationship between efficiency and production costs, using market drivers to help focus scarce resources where they can effect the greatest improvements in U.S. industrial efficiency.

The Industries of the Future is a winning proposition for participating companies, U.S. industry as a whole, and the entire Nation. Participating manufacturers, suppliers, and vendors enhance their public image, expand their technical knowledge base, gain access to complementary technical expertise and facilities, and acquire a bigger voice in directing R&D in their industry. Although participating private firms may be the first to benefit from more efficient technologies through pilot testing or demonstration programs, all U.S. industries can benefit from these technologies once they have been commercialized.

OIT tracks energy savings as well as other benefits associated with the successfully commercialized technologies resulting from OIT-supported research partnerships. Specifically, the chart on page 8 shows current and cumulative energy savings as well as cumulative reductions of various air pollutants including particulates, volatile organic compounds (VOCs), nitrogen oxides (NO_x), sulfur oxides (SO_x), and the greenhouse gas, carbon dioxide (CO₂). The bulk of the document consists of four appendices. Appendix 1 describes the technologies currently available commercially, along with their applications and benefits; Appendix 2 describes the OIT-supported emerging technologies that are likely to be commercialized within the next year or two; Appendix 3 describes OIT-sponsored technologies used in commercial applications in the past that are no longer tracked; and Appendix 4 describes the methodology used to assess and track OIT-supported technologies.

Summary of OIT Program Impacts

Impacts

What OIT Programs Deliver

The U.S. Department of Energy's (DOE's) Office of Industrial Technologies (OIT), within the Office of Energy Efficiency and Renewable Energy, has been working with industry since 1976 to encourage the development and adoption of new, energy-efficient technologies. OIT's return on investment has been outstanding. OIT's cost-shared research, development, and demonstration (RD&D) and technology transfer efforts have helped industry not only use energy and materials more efficiently but also improve environmental performance, enhance product quality, and increase productivity.

By any standard, OIT programs for industry can significantly impact both industry and the Nation. Industry currently accounts for approximately 25% of the Gross National Product and 75% of exports. It provides jobs for over 25 million American workers. At the same time, industry is the largest energy-consuming sector in the U.S. economy (36%), with annual energy expenditures of more than \$110 billion. In addition, manufacturing companies spend approximately \$30 billion per year on pollution control equipment and operations.

1997 U.S. Primary Energy Consumption by Sector
(Total consumption: 90.6 quadrillion Btu)

Leveraging Scarce Dollars to Maximize Benefits

OIT works closely with industry to address priority technology needs, and funds projects on a cost-shared or cooperative basis. The research, development, and demonstration (RD&D) programs described have resulted in many full applications in industrial processes and over 100 commercialized technologies.

Although the impacts described in this document are considerable, they understate the accomplishments of OIT's programs. The estimates include the impacts of only the first generation of technology and only those that industry partners agree to provide. The estimates generally do not include the effects of second-generation technologies or spinoffs to other applications. Also OIT's programs extend well beyond OIT-developed technologies to include workshops, case studies, grants, information clearinghouses, decision tools, and cooperative programs with state and local agencies. All of these efforts are integrated to accelerate the adoption of advanced technologies that increase energy efficiency, reduce or avoid pollution, and significantly enhance industrial productivity and competitiveness. The effects of such efforts are often impossible to quantify.

OIT: Catalyst and Facilitator

OIT's most powerful role is as a catalyst and facilitator for industry – a role that government is uniquely able to play. Under OIT's innovative Industries of the Future approach, OIT targets nine U.S. industries that collectively account for nearly 75% of the energy consumed by all U.S. industries. These nine industries are:

- ◇ Agriculture
- ◇ Aluminum
- ◇ Chemicals
- ◇ Forest Products
- ◇ Glass
- ◇ Metalcasting
- ◇ Mining
- ◇ Petroleum
- ◇ Steel

Impacts

Through the Industries of the Future process, each industry develops a vision of its desired future and an associated “technology roadmap,” which then serves as a framework for guiding industry-OIT collaborative partnerships. OIT devotes over 80% of its operating budget to support the RD&D of technologies that address some of the top needs identified in these technology roadmaps. In 1998, for example, OIT dedicated approximately \$113 million of its \$136 million operating budget to cost-shared research focused on Industries of the Future.

The Industries of the Future approach also embraces efficiency enhancements in technologies that are widely used in a broad cross section of U.S. industry. Given the volume of use that these technologies receive, even a small improvement in their energy efficiency can mean substantial energy and cost savings. OIT conducts programs to advance research in each of these enabling technology areas:

- ◆ Combustion Systems
- ◆ Sensors and Controls
- ◆ Advanced Industrial Materials and Coatings/
Engineered Ceramics
- ◆ Distributed Generation
(including gasification, advanced turbine systems,
microturbines, and reciprocating engines)

Without significant waste reduction in these industries, nonproductive expenditures on pollution abatement and control are expected to continue climbing. The advanced technologies these industries and OIT will develop with the Industries of the Future approach can transform such expenditures into productive investments for new manufacturing equipment and jobs. As second- and third-world nations rush to develop their industries, these technologies will become essential for sustainable development. The Industries of the Future approach will also help position the United States to supply leading-edge technologies to these vast markets.

Facilitating Adoption of Efficient Technology

In addition to supporting research to ensure future competitiveness, OIT assists industry in assessing and adopting energy-efficient technologies and practices that are available to help industry start saving energy right away. In particular, OIT provides industrial assessments for small- and medium-size manufacturers and conducts a variety of challenge programs to encourage all industrial firms to boost system efficiencies.

Small- and medium-size manufacturers (20 to 500 employees) are particularly important to the U.S. economy because firms in that category account for over 50% of people employed by manufacturing industries. At the same time, many smaller firms lack the financial and personnel resources to conduct R&D or to aggressively implement advanced technologies. OIT’s Industrial Assessment Centers (IACs) directly serve these small- and medium-size firms. Twenty-nine university-based centers throughout the country provide manufacturing plants with free audits, analyses, and recommendations for improving productivity, increasing energy efficiency, and reducing waste. The map on page 4 shows the locations of these centers. Dollar savings from IAC assessments average \$55,000, and, on average, the plants implement about one-half of the recommended actions.

The IAC program delivers a bonus by providing engineering students with hands-on experience in conducting the audits, supervised by their professors. The program’s effectiveness has been further enhanced through the development of a “best practices” manual and training materials based on experience accumulated from hundreds of assessments performed by IAC teams.

OIT’s challenge programs help industrial firms of any size assess the potential benefits of maximizing efficiency using a systems approach. Specifically, these programs target electric motor, steam, compressed-air, and combined heat and power systems. Through these programs, OIT provides unbiased data, decision tools, technical assistance, and recognition for firms that successfully improve system efficiency.

OIT’s Mission

The Office of Industrial Technologies, through partnerships with industry, government, and nongovernmental organizations, develops and deploys advanced energy efficiency, renewable energy, and pollution-prevention technologies and practices in industrial applications.

Summary of OIT Program Impacts

The Motor Challenge Program helps U.S. manufacturers learn about and adopt efficient electric motor systems. The 20 million electric motors currently in use in industry account for 69% of the electricity used by industry. By the year 2005, over 1,000 industrial plant sites are expected to be involved in the Motor Challenge, saving about 4 billion kilowatt-hours of electricity and about 1 million metric tons of carbon equivalent annually.

The Steam Challenge program provides U.S. manufacturers with high-quality, reliable information about steam-related technologies and practices. The potential benefits to industry include saving 2.8 quadrillion Btu (quads) of energy and eliminating 43 million tons of CO₂ and 30 thousand tons of NO_x emissions. Nonenergy benefits include improved safety, reliability, and productivity. The program goal is a 20% total energy savings by 2010, which would mean \$4 billion in annual energy savings to industry. Attaining that goal would also mean a reduction in CO₂ emissions equivalent to taking 5 million cars off the road.

Similar challenge programs are in effect to help industry realize the potential savings available in compressed-air and combined heat and power systems. The Compressed Air Challenge, a voluntary collaboration among industry, utility companies, state and federal government, and technical trade associations, is dedicated to improving the performance of industrial compressed air systems with the goal of reducing energy needs and costs. The Challenge provides education, technical training, and certification to plant personnel using compressed air systems. The Combined Heat and Power Challenge seeks to improve industrial energy efficiency by helping manufacturers overcome the major barriers to using combined heat and power systems: environmental permitting, high utility charges, and complex Federal tax depreciation schedules.

OIT's Goal

- Improve resource efficiency of energy and waste-intensive industries to:*
- ◆ *reduce raw material and depletable energy use per unit output*
 - ◆ *reduce generation of wastes and pollutants*
 - ◆ *provide advanced science and technology options that dramatically increase the productivity of U.S. industry*

Locations of Industrial Assessment Centers

Giving a Boost to Inventors and State Partnerships

The Inventions and Innovation program provides grants of up to \$100,000 to individual inventors and small companies with promising ideas and inventions for improving industrial energy efficiency and environmental performance. Emphasis is placed on technologies that address the priorities identified in the Industries of the Future roadmaps. The program also offers practical information to help advance technology commercialization and provides a broad range of training and support.

The NICE³ program (National Industrial Competitiveness through Energy, Environment, and Economics) provides funding to state-industry partnerships for projects that develop and demonstrate advances in energy efficiency and clean production technologies. The partnerships match Federal funds, and awardees are expected to commercialize the process or technology. For example, in one NICE³ project, PPG Industries, Inc., developed a system to recover and reuse paint wastewater. The system reduces both energy use and waste by more than 90%, and the payback on the investment was less than nine months.

To facilitate implementation of Industries of the Future within States and all regions of the United States, OIT recently instituted a program called "States Industries of the Future." State governments, State organizations and energy-intensive industries within the States lead this program. It targets Industries of the Future that are most important within a State, determines their business and technology needs, and then delivers resources needed to meet those needs. In 1998, seventeen States received a total of \$2.5 million through 22 grant awards for projects under the States Industries of the Future program.

OIT Responds to Industry's Needs

OIT's objectives have continually evolved since its inception two decades ago, responding to a changing energy situation and shifting national priorities. The Federal government began focusing on energy supply and security issues in the late 1970s following dramatic increases in oil prices and growing concerns about the U.S. energy supply. DOE programs were aimed at increasing energy efficiency and developing alternative energy sources. By the mid-1980s, as the oil situation stabilized and oil prices declined, industry slashed expenditures for energy technology R&D. At the same time, the Federal government shifted its emphasis on energy technology toward longer-term, more fundamental R&D.

OIT recently adopted the Industries of the Future approach to help U.S. industries increase competitiveness and reduce resource and energy use today and tomorrow. The strategy seeks to simultaneously encourage expanded use of energy-efficient technologies today and to ensure that some of our most energy-intensive industries will be able to compete effectively in global markets of the future.

Industry Determines Program Direction

Increasing demands on resources have forced organizations to do more with less — to leverage scarce financial and physical resources to achieve multiple objectives. Both industry and the government have recognized the value of teamwork among key participants. The complexity of many advanced technologies and processes, requiring multidisciplinary research beyond the technical capabilities of a single company, further fuels this trend toward cooperative efforts.

Unlike past industry/government partnerships, the Industries of the Future approach requires that industry take ownership of the research planning and implementation process. Through the "technology roadmapping" process, each industry establishes a consensus on priorities for the required research. This process helps align public and private resources so they can collectively focus on solving industry's toughest technical challenges. With emphasis on "customer pull" rather than "technology push," the Industries of the Future approach obtains strong industry commitment to the research, facilitating widespread adoption of the resulting energy-efficient technologies.

OIT Mitigates Risk to Industry

OIT supports technologies that are considered too risky for individual companies to undertake; are precompetitive; have broad national application; and have significant energy, environmental, and economic benefits.

The Advanced Turbine Systems (ATS) Program, conducted cooperatively with DOE's Office of Fossil Energy, exemplifies these criteria. This program aims to develop more efficient gas turbine systems for both utility and industrial power generation (including cogeneration). Such systems will be critical, because the growth in electricity demand in the United States is expected to require an additional 15 gigawatts of new and replacement generation capacity annually after the year 2000. Management of the ATS Program is coordinated between the Environmental Protection Agency, the Electric Power Research Institute, gas turbine manufacturers, the U.S. Department of Defense, and others.

Summary of OIT Program Impacts

Impacts

OIT Keeps Industry Informed

A key facet of the OIT strategy is to provide useful information. The availability of information in the marketplace has proven to be a major factor affecting industry's acceptance and adoption of technologies. OIT's information dissemination programs improve industry decision-making, minimize risks, and accelerate the adoption of efficient technologies. OIT programs provide industry with information through brochures, hot lines, and the Internet.

OIT also provides technical assistance through its Motor, Steam, Compressed-Air, and Combined Heat and Power Challenge Programs and through its Industrial Assessment Centers. These programs distribute a variety of tools, services and information to help industry boost plant efficiency.

For more information, sign on to the OIT Website:

<http://www.oit.doe.gov>

It contains news and information about Industries of the Future, OIT programs, projects, tools, and contacts.

You may also request specific publications from:

The OIT Resource Center
(202) 586-2090

OIT Tracks Its Progress

For more than 15 years, OIT has assessed the progress of the technologies supported by its research programs. OIT managers have long recognized the importance of developing accurate data on the impacts of their programs. Such data are essential for assessing OIT's past performance and can help guide the direction of future research programs.

Energy savings associated with specific technologies are estimated by the Pacific Northwest National Laboratory (PNNL) through a rigorous data tracking and management process. Detailed results on each technology application are solicited from technology vendors or users to estimate total energy savings and emissions reductions. Several factors make this task challenging. Personnel turnover at developing organizations as well as at user companies makes it difficult to identify applications. Small companies that develop a successful technology may be bought by larger firms, or may assign the technology rights to a third party. As time goes on, the technologies may be incorporated into new products, applied in new industries, or even replaced by newer technologies.

Program benefits documented by PNNL are conservative estimates based on technology users' and developers' testimonies. These estimates include neither derivative effects, resulting from other new technologies that spin off of OIT technologies, nor the secondary benefits of the energy and cost savings accrued in the basic manufacturing industries downstream of the new technologies.

A more detailed description of the methodology used to track technologies and estimate benefits is provided in Appendix 4.

*Cumulative Production Cost Savings
minus Cumulative Appropriations*

Cumulative Federal costs for the R&D projects supported by OIT through fiscal year 1997 total \$1.46 billion. Cumulative energy savings from completed and tracked projects add up to approximately 1 quadrillion Btu, representing a cumulative production cost savings of over \$2.12 billion. These production cost savings represent the net total value of all energy saved by technologies developed with OIT support plus any non-energy production cost savings, minus the cost to industry of using the technologies (including capital costs and operating/maintenance costs).

By plotting the difference between the cumulative production savings and cumulative Federal spending for each year, the graph above shows that the benefits from OIT programs substantially outweigh costs. Since the energy savings attributable to the programs are growing rapidly as completed technologies further penetrate the market and additional technologies become commercialized by private industry, the net "cash flow" is increasing.

OIT's Successes Are Impressive

OIT's benefits-tracking process provides a wealth of information on the program's successes, much of it highlighted in this document's appendices.

Appendix 1 presents fact sheets on technologies currently in use and yielding benefits. The fact sheets include applications data, both technical and commercial, that may enable industry organizations to identify significant opportunities for adapting technologies to their particular practices.

OIT-sponsored technologies that are likely to be commercialized within the next year or two are identified in Appendix 2. Some of these emerging technologies have already yielded scientific information that has improved current industrial processes.

To complete the story of OIT's successes, Appendix 3 lists some superseded technologies that have been used in commercial applications in the past. The technologies in this category are no longer tracked. While some may still be in use, new applications of the technologies are unlikely. During the time they were tracked, these technologies yielded benefits that are counted in the cumulative tallies shown on the Technology Program Impacts chart on pages 8 and 9.

Appendix 4 presents a description of the methodology used to track technologies and estimate benefits.

The Learning Process Continues

Sometimes even technically successful technologies are unsuccessful in finding a market. OIT managers realize that valuable lessons can be learned from these failures. Understanding how or why a given technology failed can help other companies save costs. Project histories also provide critical information to be used in selecting new projects to receive OIT support and minimize costly relearning as the OIT programs evolve and personnel changes occur.

OIT has helped make unsuccessful technologies successful by recognizing different technology applications. For example, when OIT recognized that a membrane technology developed for, but not used by, the chemicals industry could be used in food processing, it enlisted the California Institute for Food and Agricultural Research to test and demonstrate the technology for that application. Together, the two organizations ran a mobile test and demonstration unit at various food industry sites, proving the feasibility of the technology in food-processing applications.

OIT carefully manages and maintains information on its programs and technologies to ensure relevant data are available to guide potential users. Although private firms participating in the R&D of a technology may be the first to benefit from its success, all U.S. industries can benefit from the technology once it has been commercialized.

Key impact categories tracked:

- Cumulative energy savings, current energy savings, type of fuel saved, units operating
- Cumulative and annual pollution reductions (*particulates, nitrogen oxides, volatile organic compounds, sulfur dioxide, carbon dioxide*)

Technology Program Impacts

Impacts

The cumulative energy savings of more than 100 completed and tracked projects is approximately 1.0 quadrillion Btu (quad), representing a net production cost savings of over \$2.1 billion. The pollution reductions resulting from OIT programs are equally impressive. For example, the 80 million tons of carbon dioxide eliminated (as shown on the chart) equals the reduction that could be achieved by taking approximately 8 million automobiles off the road for one year.

Technologies Commercially Available	Cumulative Energy Savings (10 ¹² Btu)	Current Energy Savings (10 ¹² Btu)	Cumulative Pollution Reductions (10 ³ Tons)				
			Particulates	VOCs	SO ₂	NO ₂	CO ₂
AGRICULTURE							
Continuous Cascade Fermentation System for Chemical Precursors	—	—	—	—	—	—	—
Hyperfiltration Process for Food	7.59	1.81	1.518	0.015	5.503	2.087	506.1
Membrane Filtration Technology to Process Black Olives	—	—	—	—	—	—	—
Stalk and Root Embedding Plow	—	—	—	—	—	—	—
ALUMINUM							
Aluminum Bridge Deck System	—	—	—	—	—	—	—
Aluminum-Rich Concentrate From Municipal Waste	—	—	—	—	—	—	—
Aluminum Roofing System	0.61	0.14	0.061	0.002	0.220	0.105	37.98
Onsite Process for Recovering Waste Aluminum	0.05	0.01	0.000	0.000	0.000	0.003	2.630
Recycling of Aluminum Dross/Saltcake Waste	—	—	—	—	—	—	—
CHEMICALS							
Chemical Separation by Fluid Extraction	0.44	0.21	0.002	0.000	0.035	0.031	35.46
Component Cleaning	0.47	0.16	0.094	0.001	0.341	0.129	31.34
DryWash®	—	—	—	—	—	—	—
Dual Cure Photocatalyst	—	—	—	—	—	—	—
Methanol Recovery from Hydrogen Peroxide Production	0.14	0.03	0.000	0.000	0.000	0.010	8.183
No-Clean Soldering Process	5.26	2.63	1.052	0.011	3.814	1.447	350.7
Paint Wastewater Recovery	—	—	—	—	—	—	—
Powder Paint Coating System	0.92	0.62	0.007	2.034	0.020	0.070	54.00
Reversible Chemical Association Separation Technology	—	—	—	—	—	—	—
Scrap Tire Recycling	0.05	0.04	0.000	0.000	0.000	0.004	2.923
Solvent Recovery from Effluent Streams	5.64	3.98	0.028	0.006	0.451	0.395	454.6
Ultrasonic Tank Cleaning	0.01	0.00	0.002	0.000	0.007	0.003	0.667
Variable-Frequency Microwave Furnace	—	—	—	—	—	—	—
Water-Washed Overspray Paint Recovery	—	—	—	—	—	—	—
FOREST PRODUCTS							
Chemical for Increasing Wood Pulping Yield	0.45	0.30	0.001	0.001	0.000	0.032	26.30
DELTA T Dryer Control System	—	—	—	—	—	—	—
High-Efficiency Ozone Generator System	2.78	1.39	0.556	0.006	2.016	0.765	185.4
Lignin Separation and Epoxide-Lignin Manufacturing	—	—	—	—	—	—	—
Optimizing Tissue Paper Manufacturing	—	—	—	—	—	—	—
Pallet Production Using Postconsumer Wastepaper	—	—	—	—	—	—	—
Thermodyne™ Evaporator - A Molded Pulp Products Dryer	—	—	—	—	—	—	—
XTREME Cleaner™- Removal of Light and Sticky Contaminants	0.04	0.04	0.008	0.000	0.029	0.011	2.667
GLASS							
Oxy-Fuel Firing	13.00	3.40	0.020	0.039	0.000	0.910	759.9
METALCASTING							
Cupola Furnace Process Model	—	—	—	—	—	—	—
Laser-Based Laminated Object Manufacturing	—	—	—	—	—	—	—
Precision Pattern Production - Multiple-Station Air Gauge	—	—	—	—	—	—	—
PETROLEUM							
Absorption Heat Pump/Refrigeration Unit	0.40	0.40	0.002	0.000	0.032	0.028	32.24
Biphase Rotary Separator Turbine	0.04	0.03	0.000	0.000	0.002	0.003	2.781
Catalytic Distillation	17.00	4.10	0.026	0.051	0.000	1.190	1203

— The dashes indicate that the energy savings could not be estimated or that the cumulative energy savings were estimated to be lower than 0.005 x 10¹² Btu.

(continued on the next page)

Technology Program Impacts

Impacts

	Cumulative Energy Savings (10 ¹² Btu)	Current Energy Savings (10 ¹² Btu)	Cumulative Pollution Reductions (10 ³ Tons)				
			Particulates	VOCs	SO ₂	NO ₂	CO ₂
STEEL							
Arc Furnace Post-Combustion Lance	2.46	1.45	0.492	0.005	1.784	0.677	164.0
Hydrochloric Acid Recovery System	0.10	0.04	0.019	0.000	0.069	0.026	6.738
Phase Measurement of Galvanneal	—	—	—	—	—	—	—
Portable Ultrasonic Inspection System for Testing Tubular Goods	—	—	—	—	—	—	—
Recovery of Acids and Metal Salts from Pickling Liquors	—	—	—	—	—	—	—
Temperature Measurement of Galvanneal	—	—	—	—	—	—	—
Transfer Rolls for Steel Production	—	—	—	—	—	—	—
Workpiece Analyzer	—	—	—	—	—	—	—
CROSSCUTTING TECHNOLOGIES							
Aerocylinder Replacement for Single-Action Cylinders	—	—	—	—	—	—	—
Cathodic Arc Deposition Technology	—	—	—	—	—	—	—
Chemical Vapor Deposition Optimization of Ceramic Matrix Composites	—	—	—	—	—	—	—
Diffusion and Thermal Heat Treatment of Bulk Powders	—	—	—	—	—	—	—
Direct Source to Object Radiant Heating Panels	—	—	—	—	—	—	—
D'MAND™ Hot Water Waste Prevention System	—	—	—	—	—	—	—
Energy Saving Radial Deflection Pad Bearing for Rotary Equipment	—	—	—	—	—	—	—
Evaporator Fan Controller for Medium-Temperature Walk-In Refrigerators	—	—	—	—	—	—	—
Exo-Melt Process	—	—	—	—	—	—	—
High-Efficiency Dehumidifier	—	—	—	—	—	—	—
High-Efficiency Direct-Contact Water Heater	10.9	1.80	0.016	0.033	0.000	0.763	637.1
High-Temperature Radiant Burner	—	—	—	—	—	—	—
Improved Diesel Engines	232.0	69.60	1.160	0.232	18.56	16.24	18699
Membrane System for Purified Gas Production	—	—	—	—	—	—	—
Meta-Lax Stress Relief Process	23.2	13.6	.035	.070	0.000	1.624	1356
MotorMaster+ Software	—	—	—	—	—	—	—
Nickel Aluminate Components for High-Temperature Applications	—	—	—	—	—	—	—
Particle-Size Distribution Sensor	—	—	—	—	—	—	—
Pinch Analysis and Industrial Heat Pumps	0.57	0.09	0.001	0.002	0.000	0.040	33.32
Real-Time Neural Networks for Utility Boilers	5.00	2.40	1.800	0.013	6.250	2.375	518.8
Retractable® Labyrinth Packing Seals for Turbine Shafts	52.13	6.38	14.86	0.123	51.98	20.33	5051
Reusable Vacuum Bagging for Manufacturing with Composite Materials	—	—	—	—	—	—	—
Reverse Brayton Cycle Solvent Recovery Heat Pump	1.90	0.52	0.009	0.002	0.137	0.133	148.9
SIDTEC™ Condenser Maintenance Program	—	—	—	—	—	—	—
SOLARWALL® Air Preheating System	0.49	0.10	0.030	0.001	0.107	0.065	30.09
Torsional Cylindrical Impulse Shear Soil Test for Earthquake Design	—	—	—	—	—	—	—
V-Plus Refrigerant Oil Cooling System	—	—	—	—	—	—	—
Waste Fluid Heat Recovery System	—	—	—	—	—	—	—
Waste-Minimizing Plating Barrel	0.10	0.10	0.013	0.000	0.047	0.020	6.480
OTHER INDUSTRIES							
Brick Kiln Design Using Low Thermal Mass Technology	—	—	—	—	—	—	—
Clean Energy from Municipal Solid Waste	—	—	—	—	—	—	—
Ink Jet Printer Solvent Recovery	0.03	0.03	0.005	0.000	0.019	0.007	1.893
NRT Recycling Process	—	—	—	—	—	—	—
Windamper System to Reduce Mechanical Vibration	—	—	—	—	—	—	—
TOTAL	383.8	115.4	21.82	2.645	91.40	49.52	30350
TOTAL -Technologies No Longer Commercially Available	617.1	N/A	101.3	1.424	361.0	154.4	49396
GRAND TOTAL	1001	115.4	123.1	4.069	452.4	203.9	79746

— The dashes indicate that the energy savings could not be estimated or that the cumulative energy savings were estimated to be lower than 0.005 x 10¹² Btu.

Appendix 1:

OIT-Sponsored Technologies Commercially Available

The technologies described in the following pages are in commercial use today. A brief description of each technology and the benefits associated with it are provided in the text. When possible, energy savings and air pollution emission reductions that can be attributed to the technology have been calculated, as described in Appendix 4. The following technologies are included in this appendix (organized by industry):

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◆ Dual-Cure Photocatalyst	
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◆ Paint Wastewater Recovery	
◆ Powder Paint Coating System	
◆ Reversible Chemical Association Separation Technology	
◆ Scrap Tire Recycling	
◆ Solvent Recovery from Effluent Streams	
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◇ Direct Source to Object Radiant Heating Panels	
◇ D'MAND™ Hot Water Waste Prevention System	
◇ Energy Saving Radial Deflection Pad Bearing for Rotary Equipment	
◇ Evaporator Fan Controller for Medium-Temperature Walk-In Refrigerators	
◇ Exo-Melt Process	
◇ High-Efficiency Dehumidifier	
◇ High-Efficiency Direct-Contact Water Heater	
◇ High-Temperature Radiant Burner	
◇ Improved Diesel Engines	
◇ Membrane System for Purified Gas Production	
◇ Meta-Lax Stress Relief Process	
◇ MotorMaster+ Software	
◇ Nickel Aluminide Components for High-Temperature Applications	
◇ Particle-Size Distribution Sensor	
◇ Pinch Analysis and Industrial Heat Pumps	
◇ Real-Time Neural Networks for Utility Boilers	
◇ Retractable® Labyrinth Packing Seals for Turbine Shafts	
◇ Reusable Vacuum Bagging for Manufacturing with Composite Materials	
◇ Reverse Brayton Cycle Solvent Recovery Heat Pump	
◇ SIDTEC™ Condenser Maintenance Program	
◇ SOLARWALL® Air Preheating System	
◇ Torsional Cylindrical Impulse Shear Soil Test for Earthquake Design	
◇ V-Plus Refrigerant Oil Cooling System	
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◇ Windamper System to Reduce Mechanical Vibration	

AGRICULTURE

Working with partners from the agriculture, chemicals and forestry communities, the Agriculture Industry of the Future team pursues new ways to use crops, trees and agricultural wastes to make a wide range of industrial and consumer products.

OIT-sponsored technologies commercially available include:

- ◆ Continuous Cascade Fermentation System for
Chemical Precursors 14
- ◆ Hyperfiltration Process for Food 15
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- ◆ Stalk and Root Embedding Plow 17

Continuous Cascade Fermentation System

Increases Yields and Cuts Process Time for Converting Carbohydrates to Ethanol and other Chemical Precursors

With assistance from DOE's Inventions and Innovation Program, Bio-Process Innovation (BPI), Inc., developed a proprietary cascade reactor for ethanol production from carbohydrate feedstocks that eliminates the need to fill, empty, and wash a fermenter as part of a batch operation. Feed is introduced continuously into the first of three to five stirred reactors placed in series, with the outflow of one reactor flowing into the next reactor. The effluent from the reactor is then taken to a conventional distillation process for ethanol separation and purification. Using the cascade system, this invention will reduce the time to process a feedstock to 24 hours or less compared with 36 to 48 hours needed for a conventional batch fermentation plant. The proprietary design incorporates an absorption column to extract more ethanol from the CO₂ effluent gases. BPI, Inc., also developed a highly flocculent yeast that further speeds the reaction of sugar to ethanol by maintaining cell densities of over 30 grams/liter. Continuous operations can more than double fermentation capacity of a batch ethanol facility.

A five-stage unit of 40,000 gallons reactor volume has been operating at an Iowa site since June 1996 on waste starches/sugars. A three-stage permeate mother liquor fermentation unit used to ferment starch has been operating at a second site in Minnesota since December 1996.

Commercialized Fermentation Technology Applied to Emerging Concept of Biomass Fermentation

Overview

- ◇ Commercialized by Bio-Process Innovation (BPI), Inc., in 1995
- ◇ Over 3 years operational experience
- ◇ 1 U.S. installation as of 1997

Applications

Converting carbohydrate feed stocks to ethanol or other chemical precursors

Capabilities

- ◇ Continuous rather than batch system allows quick and complete fermentation of feed stocks with a 15% to 20% sugar content (glucose, sucrose, or dextrans) to an effluent consisting of 7% to 10% ethanol.
- ◇ In-situ separation of inhibitory fermentation products.
- ◇ Uses abundant celluloses as a feedstock for alternative chemical precursors.

Benefits

Productivity

Conventional reactor processing time of 36 to 48 hours is reduced to 24 hours or less. Dramatically improves throughput by maintaining a high cell density in the reactors and operating continuously.

Profitability

Lowest the cost of producing ethanol or other fermentation chemicals from carbohydrates by cutting production labor. Can be retrofitted on fermenters currently in use in batch process ethanol production facilities.

Efficiency

Incorporates an absorption column to recover more ethanol from the CO₂ gases in the reactor. Doubles the fermentation capacity of a batch ethanol plant.

Membrane Process Improves Juice Concentration Efficiency

The concentration of liquids, particularly fruit and vegetable juices, is one of the most energy-intensive steps in the food-processing industry. Almost all concentrated juice is produced using thermal evaporation to remove water from single-strength juice. The National Food Processors Association, with co-funding from DOE, has developed a membrane hyperfiltration process to separate juice into pulp and serum (liquid) fractions. The fractions are then processed individually and more efficiently to reduce the water content. Finally, the fractions are recombined to obtain the desired product.

Hyperfiltration achieves energy and cost savings in juice processing, preservation, containerization, and transportation. The technology may expand the food-processing industry's capabilities by facilitating the development of new dried products.

Benefits

Productivity

Reduced heating requirements leads to shorter processing times. Dried pulp's low tendency to absorb moisture makes it easier to handle than regular pulp.

Product Quality

Elimination of heat processing steps yields higher-quality juice with better taste and aroma. Dried pulp has better storage stability.

Waste Reduction

Fewer packaging materials are required for concentrated juice, reducing packaging waste that must be landfilled.

Hyperfiltration Processing Sequence

Overview

- ◆ Developed by the National Food Processors Association
- ◆ Commercialized in 1990
- ◆ 14 units operating in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
1.81	7.59

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
1.312	0.489	120.7	0.362

Applications

- ◆ Preconcentration of fruit and vegetable juices prior to evaporation
- ◆ Production of tomato paste from tomato juice

Capabilities

- ◆ Can separate juice into pulp and serum.
- ◆ Serum concentrated from 5% to 60% total solids using hyperfiltration followed by evaporation.
- ◆ Can reduce energy consumption up to two-thirds over conventional practices.

Membrane Filtration Technology to Process Black Olives

Impacts

Membrane Filtration Technology Reduces Energy Use and Wastewater Generation

Processing black olives generates millions of gallons per year of liquid waste containing high concentrations of salt. Tri Valley Growers designed and constructed an operation in which all water, chemicals, and olive pomace are recycled back into the operation or converted into a useful by-product. A NICE³ grant was used to demonstrate the new system. This system eliminates the potential of contaminated groundwater with unacceptable levels of salt, eliminates the need to landfill waste material, and reduces the amount of energy required to treat the water.

The process involves a prescreening treatment using a 75-micron screen, followed by ultrafiltration and reverse osmosis. Up to 80% of the wastewater is recycled back into the plant. Concentrate from ultrafiltration and reverse osmosis is dehydrated by evaporation and converted into by-products that can be used as animal feed or fuel. The system demonstrated at Tri Valley Growers' Madera plant recycled 800,000 gallons of the 1 million gallons of water used back into the process.

Benefits

Energy Savings

Achieves energy savings by eliminating groundwater pumping and reducing electrical energy consumption.

Waste Reduction

Eliminates wastewater discharge and the need for evaporative ponds onsite.

Waste Utilization

Allows waste materials to be converted into useful by-products, such as animal feed or fuel.

Overview

- ◇ Designed and constructed by Tri Valley Growers
- ◇ 1 unit operating in 1997

Applications

All food processors; demonstrated at olive processing plant

Capabilities

Recycles 800,000 gallons of water per day for a plant using 1 million gallons of process water per day.

Zero-Discharge Wastewater Treatment and Reclamation System

Stalk and Root Embedding Plow

Impacts

New Stalk and Root Embedding Plow Prevents Post Damage and Saves Time in Preparing Fields

Disposing of cotton stalks and roots in the field after harvest is an energy-intensive operation. Nationwide, 78% of cotton farmers use conventional tillage practices that involve shredding the stalks and making several tillage passes over the field to prepare a new seedbed. These tillage operations consume over one-half of farmers' annual fuel budget, and most farmers are frustrated with the high costs and time requirements. Over the last fifty years, farmers have tried several alternative tillage systems, all of which involve uprooting the cotton plants and mixing the crop residue into the soil. All uprooters have shortcomings, and none have gained wide acceptance across the Cotton Belt.

With assistance from DOE's Inventions and Innovative Program, the University of Arizona invented the Pegasus system—a stalk, root, and agricultural debris-burying tillage machine suited for burying row crops, especially cotton, to prevent pest damage and prepare fields for crops. The rapid plow-down design is a breakthrough in cotton tillage. A narrow moldboard plow opens a deep trench in the soil next to the crop row. Then a "stuffer disk" inserts the roots and stalks into the deep trench. The whole stalks are buried in a "rope" bundle under the bed where they decompose. The machine also forms new beds, leaving the field ready for the next crop.

Rigorous research by the U.S. Department of Agriculture indicates dramatic savings in cost, time, and energy and no adverse affects. Yields with the Pegasus have ranged from the same as conventional methods to 12% greater than conventional methods.

Benefits

Productivity

Requires 75% to 80% less time to dispose of crop residue and prepare a new seedbed compared with conventional tillage practices. Saves 4 to 7 repeat passes of tillage machinery to work and prepare fields.

Profitability

U.S. Department of Agriculture tests verified operation and savings. Results in cost savings of \$50/acre compared with conventional tillage practices.

Reliability

Only requires draft power to operate; all moving parts turn with the soil as the machine is pulled.

Pest Control

For cotton, deep residue burial helps with cultural control of the pink bollworm.

Energy Savings

Saves 70% of the energy required for conventional tillage.

Air Emissions Reductions

Eliminates stalk shredding, a large contributor to dust emissions, and cuts engine air emissions by 70% compared with conventional tillage practices.

Overview

- ◆ Invented by the University of Arizona and commercialized by the Pegasus Machinery Company
- ◆ Commercialized in 1996
- ◆ 11 units operating in 1997

Applications

- ◆ Breakthrough tillage technology for agriculture
- ◆ Cotton, corn, and other row crop tillage

Capabilities

- ◆ Deeply entrenches whole stalks and roots into soil in one pass, eliminating need to shred stalks.
- ◆ Plows 7 acres/hour at 4.0 to 4.5 mph.

Front View

Back View

Side View

Stalk and Root Embedding Plow

ALUMINUM

The Aluminum Industry of the Future partnership helps to strengthen the competitive position of the U.S. aluminum industry and further national goals by promoting technologies that optimize the use of energy and materials in operations and reduce wastes and energy-related emissions.

OIT-sponsored technologies commercially available include:

- ◆ Aluminum Bridge Deck System 20
- ◆ Aluminum-Rich Concentrate From Municipal Waste 21
- ◆ Aluminum Roofing System 22
- ◆ Onsite Process for Recovering Waste Aluminum 23
- ◆ Recycling of Aluminum Dross/Saltcake Waste..... 24

New Aluminum Bridge Deck System Offers Viable Options for Aging Bridges

The U.S. Department of Transportation (DOT) has classified 159,000 of the 590,000 bridges in the United States structurally deficient. DOT also reports that a significant number of steel bridges with concrete decks will require replacement within the next 10 years. The DOT's Federal Highway Administration reports that the average bridge is replaced when it is 70 years old, with exceptions in the Northeast and upper Midwest, where most concrete bridge decks require replacement every 35 years due to the use of deicing chemicals.

Reynolds Metals Company, Inc., worked cooperatively with Oak Ridge National Laboratory to develop and refine an aluminum bridge deck panel system, consisting of aluminum multivoid extrusions joined to make panel sections. This system is a viable alternative to traditional concrete bridge decks because it is strong, lightweight, and corrosion- and fatigue-resistant. Reports about the longevity and durability of aluminum bridge decks in the United States, Canada, Europe, and Japan note impressive performance and indicate adequate wearing surfaces in harsh climates and high-traffic applications.

The aluminum bridge deck panels weigh approximately 25 pounds/square foot compared with 60 to 125 pounds/square foot for concrete bridge decks. Aluminum bridge decks can be installed in days as opposed to months for concrete bridge decks. This rapid installation minimizes bridge closures and traffic revisions, an important consideration in high-traffic-volume locations. In addition, the lightweight panels are well suited for load-restricted or historical bridges that require additional width without the added weight. Some bridges can be widened up to 300% on existing girder and foundation systems, allowing increased traffic loads. Bridges requiring retrofitting to increase their resistance against seismic forces are excellent candidates for aluminum bridge decks.

As of 1997, two bridges were renovated using the aluminum bridge deck system. The Corbin Bridge in Pennsylvania received the first aluminum bridge deck replacement in November 1996, and a Virginia bridge was constructed using the aluminum bridge deck replacements in November 1997.

Benefits

Product Quality

Weights one-fourth less than traditional concrete bridge decks; lightweight panels allow load-restricted bridges to be widened without adding weight. Significantly increases a bridge's seismic resistance. Surface wears better than traditional deck surfaces.

Productivity

Can be rapidly installed because of prefabricated, lightweight modular units, minimizing bridge downtime, road closures, and traffic revisions that lead to traffic jams. Requires low maintenance due to corrosion resistance. Does not require painting.

Overview

- ◆ Developed by Reynolds Metals Company, Inc., and Oak Ridge National Laboratory
- ◆ Commercialized in 1996
- ◆ As of 1997, two U.S. bridges use the panels

Applications

- ◆ Restoring and rehabilitating deteriorating bridges
- ◆ Constructing new bridges

Capabilities

- ◆ Long-term, durable performance in harsh climates and high-traffic-volume applications.
- ◆ Corrosion- and fatigue-resistant, even without protective coatings.
- ◆ Most viable bridge deck system when long-term durability, completion time, and life-cycle costs are considered.

Aluminum-Rich Concentrate from Municipal Waste

Impacts

Computerized Recovery System Separates Aluminum from Mixed Recyclable Streams

With assistance from DOE's Inventions and Innovation Program, Magnetic Separations System, Inc., developed a separation technology that electronically detects and removes aluminum cans from municipal solid-waste streams. The separation technology discriminates against tramp ferrous metals in the feed stream. Eddy current sensors first detect and identify aluminum, and after detection, a precisely metered air jet pulse removes the aluminum. The aluminum goes to secondary processing; the other goes to conventional recycling. This recovery system is an improvement over a previous version of the system (the *ELPAC System*) that had been proven in years of demanding service in solid-waste and glass cullet applications.

Benefits

Energy Savings

Increases the useful yield of glass and aluminum recycled streams. Using recycled aluminum and glass in production reduces energy consumption compared with glass and aluminum from raw materials.

Emissions Reductions

Using recycled aluminum and glass in production lowers furnace emissions.

Overview

- ◆ Developed by Magnetic Separation Systems, Inc.
- ◆ Over 50 installations for glass recycling and aluminum recovery currently operating in the United States

Applications

Glass and aluminum industries to remove metallic contaminants from recycled glass cullet and granulated plastics and to recover aluminum cans from mixed recyclable streams in materials recovery facilities (MRFs)

Capabilities

- ◆ Operates automatically using a microprocessor that controls position, speed, and size of aluminum in waste.
- ◆ Available in modular units with capability to process 1200, 2000, and 3000 cubic feet/hour of commingled feed.
- ◆ Eight to thirty detection channels handle feed system widths of 2, 4, and 6 feet.

Aluminum-Rich Concentrate from Municipal Waste

Aluminum Roofing System

Impacts

New Roofing Chips Create Affordable, Energy-Efficient Aluminum Roofing System

Through a grant from DOE's Inventions and Innovation Program, Transmet Corporation developed aluminum roofing chips that exhibit superior solar reflectance compared with competing roofing systems. Made in a proprietary process involving rapid solidification of small streams of liquid metal, the chips are tiny aluminum particles. When air sprayed at a rate of 3 to 4 lb/sq. ft. onto the surface of the asphalt flood coat, the chips form a highly reflective roof surface. The chips weigh only 3 to 4 pounds/100 square feet compared with stone aggregate coverings of 300 pounds/100 square feet.

Factory applications of aluminum chips to rolled roofing materials are gaining acceptance. In most cases, only minor adjustments to the manufacturer's granule equipment are needed to account for the different flow properties of chips compared with granules.

Benefits

Product Quality

Greatly extends roof life by reflecting 77% of incoming infrared solar energy and 75% of ultraviolet energy. Accelerated aging tests have shown negligible deterioration of the reflectivity and emissivity properties.

Profitability

Reduces maintenance costs. Eliminates the need for recoating. Saves as much as \$10/100 square feet compared with asphalt.

Energy Savings

Reduces building heat conductivity by up to 35%, keeping the building cooler. Covering one small commercial roof with a surface area of 10,000 square feet would result in annual energy savings of 42 million Btu.

Aluminum Roofing System

Overview

- ◆ Developed by Transmet Corporation
- ◆ Commercialized in 1984
- ◆ Installed on more than 33 million square feet of roof

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.14	0.607

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.051	0.024	8.759	0.014

Applications

- ◆ Roofing for industrial, commercial, and institutional buildings
- ◆ Filler for plastics to enhance thermal and electrical properties
- ◆ Feedstock for chemical processes that require aluminum content
- ◆ Shot-blasting media for aluminum products

Capabilities

Rapidly solidifies liquid metal to produce air-sprayable small particles.

Onsite Process for Recovering Waste Aluminum

Impacts

Efficient New Technology for Recovering Waste Aluminum in Wheel Manufacturing

Aluminum automobile wheels are produced as rough castings that are subsequently cut and ground to the desired shape and finish. During these final steps, approximately 30% of the aluminum content is machined away as chips. A new process for recycling the chips onsite rather than offsite improves the energy efficiency and productivity of chip recycling while simultaneously reducing airborne pollutants and other manufacturing wastes.

The process developed by AAP St. Marys and demonstrated using a NICE³ grant includes an efficient new technology for remelting the waste chips that increases the yield of reusable aluminum. Because the process is performed onsite, the intermediate ingot step is eliminated and each batch of chips must be melted only once, saving considerable energy. Additional energy savings result from eliminating the transportation of chips to and from an offsite recycler. An afterburner on the melting furnace reduces airborne fumes, dust, and emissions to negligible levels. A machining oil recycling technique has also been integrated into the process. AAP St. Marys has been using the process since 1993.

The process is also applicable to other metal-processing and fabricating operations that produce waste metal chips.

Benefits

Waste Reduction

Reduces volume of waste by-product (dross) by 75%. Collects used machining coolant for recycling.

Productivity

Requires that waste chips be melted only once instead of twice.

Use of Raw Materials/Feedstocks

Reduces machining coolant requirements by 50%, conserving the petroleum feedstock used to produce coolant.

Pollution Control

Uses a premelt incinerator that sharply cuts airborne fumes, dust, and emissions.

Onsite Aluminum Recycling

Overview

- ◆ Developed by AAP St. Marys
- ◆ Commercialized in 1993
- ◆ 1 unit operating

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.01	0.045

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.001	0.585	0.000

Applications

- ◆ Aluminum wheelmaking
- ◆ Other metal-processing and fabricating operations

Capabilities

- ◆ Can recycle 300 tons/month of waste aluminum chips.
- ◆ Results in a 6.5% increase in yield of usable aluminum.

New Technology for Recovering Aluminum Dross/Saltcake Waste Saves Energy and Reduces Waste

The melting process used by the secondary aluminum industry when recycling aluminum creates a waste stream known as black dross/saltcake (dross). It is estimated that up to 1 million tons of dross is generated and landfilled annually in the United States. In the past, efforts to recover useful material from the dross have resulted in recovery of only a small portion of aluminum (about 3% to 10% of processed dross). The remaining 90+% of the dross, at best some 900,000 tons, is landfilled.

With assistance from OIT's NICE³ Program, Alumitech, Inc., undertook a successful 15-month plant construction and start-up project to commercialize a process to facilitate closed-loop recycling of dross through the manufacture of industrial ceramic products from recovered nonmetallic waste.

Starting with the dross material, Alumitech separates the dross into its basic components—aluminum metal, fluxing salts, and nonmetallic products (NMP). The aluminum metal and salt fluxes can be sold back to the secondary aluminum or other industries. A project goal was to commercialize a new process to make NMP usable for a variety of product applications. Prior to this project, the NMP had no other use and was therefore landfilled.

The new process focused on making engineered slag additive products from the NMP, targeting multiple applications in the steel industry. Additionally, the processed NMP has been used as a feedstock for ceramic fiber used for a variety of high-temperature insulation applications.

Benefits

Energy Savings

Significant energy savings result from aluminum recovery and energy savings associated with NMP-product developments.

Waste Reduction

Closed-loop recycling eliminates all dross landfilling.

Productivity

Engineered slag additive product increases productivity in the steel-making industry through reduced heat time.

Use of Raw Materials/Feedstocks

Recovers materials for use as feedstocks in other process operations, thus conserving raw materials.

Overview

- ◆ Developed by Alumitech, Inc.
- ◆ Commercialized in 1997
- ◆ 1 unit operating in 1997

Applications

- ◆ Secondary aluminum process waste steams
- ◆ Steel-making slag products and ceramic fiber feedstock developed from waste material

Capabilities

Provides complete closed-loop recycling of secondary aluminum black dross/saltcake waste streams.

CHEMICALS

OIT's Chemicals Industry of the Future team facilitates partnerships for the chemical enterprise that will save energy, make the most efficient use of this country's carbon-based resources, protect the environment, and ensure the vitality of the chemical industry well into the 21st century.

OIT-sponsored technologies commercially available include:

◆ Chemical Separation by Fluid Extraction	26
◆ Component Cleaning	27
◆ DryWash®	28
◆ Dual-Cure Photocatalyst	29
◆ Methanol Recovery from Hydrogen Peroxide Production	30
◆ No-Clean Soldering Process	31
◆ Paint Wastewater Recovery	32
◆ Powder Paint Coating System.....	33
◆ Reversible Chemical Association Separation Technology	34
◆ Scrap Tire Recycling	35
◆ Solvent Recovery from Effluent Streams	36
◆ Ultrasonic Tank Cleaning	37
◆ Variable-Frequency Microwave Furnace	38
◆ Water-Washed Overspray Paint Recovery	39

New Technology for Remediation/Chemical Recovery Applications Reduces Waste

OIT and CF Systems have developed a new technology for removing hazardous organic compounds from contaminated solid or liquid waste streams. The technology, known as solvent extraction, is significantly more energy-efficient than conventional thermal hazardous waste treatment methods. It can also be used to recover organic chemicals that are normally lost in effluents from industrial processes because they are not recoverable using the conventional technology.

The solvent extraction technology uses a liquefied gas solvent, such as propane or carbon dioxide, to extract organic contaminants from solids, sludges, and aqueous streams. Following extraction and separation, both the solvent and the extracted chemicals are recovered; the chemicals can then be recycled, reused, or sent to disposal. The treated residues are no longer hazardous and may be used as process feedstock. Fluid extraction technology produces no harmful atmospheric emissions, is noninvasive, and can operate near populated areas.

Benefits

Waste Reduction

Recovers organic compounds that cannot be recovered using conventional technology. At refineries, recovers oil from waste streams that would normally be discarded.

Use of Raw Materials/Feedstocks

Recovers chemicals for use as feedstock in other process operations, thus conserving petroleum feedstock for the production of new chemicals.

Solvent Extraction Remediation Process

Overview

- ◆ Developed by CF Systems
- ◆ Commercialized in 1991
- ◆ 1 unit operating in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.21	0.44

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.017	0.015	16.93	0.001

Applications

- ◆ Recovery of oil in waste streams at refineries
- ◆ Treatment of ongoing organic chemical wastes
- ◆ Remediation of contaminated soils, sludges, wastewaters, clays, silts, and sediments

Capabilities

- ◆ Can replace energy-intensive thermal treatment processes for remediation projects.
- ◆ Can be used to meet current regulations for organic contaminants, including benzene, toluene, xylene, trichloroethylene, tetrachloroethylene, polynuclear aromatics, naphthalene, PCBs, dioxins, furans, and alcohols.

SUPERCRITICAL CO₂ –

A New Chemical Product for Industrial Cleaning

New equipment that converts atmospheric gas into a fluid and then returns it back to a gas has enabled fluids in their supercritical state, particularly supercritical carbon dioxide (CO₂), to find numerous new energy-saving applications for cleaning materials ranging from textiles to precision electronic parts. Chlorofluorocarbon (CFC) solvents have been used by industry for decades to clean the organic residue and particulate matter that collects on metals, plastics, ceramics, optical and electronic components during manufacture. However, CFC's must be replaced by other cleaning solvents because their use has been implicated in the depletion of the ozone layer and global warming problems.

A number of industrial firms, three National Laboratories, and OIT formed a consortium to develop a new chemical for industrial cleaning based on supercritical fluid technology. The use of supercritical CO₂ eliminates the energy required for the "bake-out" heat used to evaporate the cleaning solvents during industrial drying and shortens the process time. This new process also eliminates the use of and the treatment and disposal costs associated with CFC solvents.

Benefits

Waste Reduction

Eliminates harmful CFC emissions to the atmosphere. Eliminates the liquid waste produced in water-based cleaning systems.

Productivity

Requires less labor and operates with a shorter batch cycle time than CFC-based systems. Reduces energy required for precision cleaning because of lower temperature requirements.

Supercritical CO₂ Cleaning

Overview

- ◆ Developed by three National Laboratories and numerous industrial firms
- ◆ Commercialized in 1995
- ◆ 23 units installed in 1997

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.16	0.47

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.116	0.044	10.67	0.032

Applications

- ◆ Precision cleaning metals, plastics, ceramics, and optical materials
- ◆ Cleaning printed wire boards and other electronic components
- ◆ Dry cleaning
- ◆ Other cleaning applications where CFCs are used

Capabilities

- ◆ Cleans as well as CFC-based systems and better than water-based systems.
- ◆ Low operating temperatures and pressures reduce energy use.

A New Generation of Chemicals for Cleaning Applications

With OIT support, Raytheon Environmental Systems (formerly Hughes Environmental) and Los Alamos National Laboratory used defense-related expertise in supercritical fluids to develop DryWash®, an entirely new CO₂-based system for dry cleaning fabrics. Current dry-cleaning practice uses perchlorethylene as the cleaning solvent to loosen and remove dirt from the fibers of clothing material. However, the dry-cleaning industry must eliminate its use of perchlorethylene because both the atmospheric emissions and the chemical itself are responsible for numerous environmental problems. Based on the desirable characteristics of CO₂ – it is inert, stable, non-corrosive, and non-flammable – the DryWash® system introduces a new generation of technology to the dry cleaning industry.

DryWash® uses liquid CO₂ as the base solvent, but adds a new surfactant (dirt removing detergent additive), and then applies this new combination of cleaning liquids with a unique spraying device and agitation mechanism – all in a self-contained system. The DryWash® process soaks the clothes in a liquid CO₂ filled tub at 700 to 750 pounds per square unit and 54°F to 58°F. The load is agitated further using high velocity fluid jets of CO₂. At the end of the cycle, the dirt and oily residue drop out and CO₂ pressure is lowered, allowing for the efficient recycling of CO₂.

Global Technologies LLC began introducing the DryWash® system in Europe in the fall of 1998 and plans to start marketing in the United States in mid-1999.

Overview

- ◆ Developed by Hughes Environmental Systems and being marketed by Global Technologies, LLC
- ◆ Being Commercialized in Europe in 1998

Applications

Replaces conventional dry-cleaning systems that use perchlorethylene or petroleum-based solvents

Capabilities

- ◆ Uses an environmentally benign solvent (CO₂) rather than hazardous solvents.
- ◆ Cleans equal to or better than conventional systems.
- ◆ Reduces cycle time by eliminating the energy-intensive drying step in the process.

Benefits

- ◆ Lower operating costs.
- ◆ 50% shorter cycle time.
- ◆ No heat needed for drying.
- ◆ No waste disposal or CO₂ release (closed system recycling).
- ◆ Equal or better performance in oily, particulate soil and stain removal.
- ◆ Decreased dirt redeposition and dye transfer.

Low VOC Coating Process Reduces Emissions

As part of a constant search for new technologies that protect our environment and make the most efficient use of carbon-based resources, 3M, with support from OIT, developed a new generation of paints, coatings, adhesives, and sealants for civilian and military applications. Traditional volatile organic compound (VOC)-based coatings release undesirable organic chemical vapors into the atmosphere during the drying or curing phase of the coating application. Even several new low- or no-VOC coatings developed prior to 3M's process sacrifice performance, appearance, and ease of application compared with this new process.

The basis of the dual-cure process is a novel photocatalyst system that allows light-activated, simultaneous polymerization of two monomers to produce a material consisting of two independent but interpenetrating polymer networks (IPNs). The properties of these IPNs are generally superior to either separate component.

Because of the variety of monomers that can be used, the dual-cure process allows greater flexibility in tailoring the final properties of the cured coatings for specific applications. The process has VOC emission levels substantially below those obtainable with conventional coating technologies, as well as shorter cure times.

Benefits

Productivity

Reduces application time. Requires no solvent disposal. Requires no heat for evaporative drying.

Product Quality

Has greater durability, tensile strength, and flexibility.

Cost Savings

Cost is comparable to current coatings cost. Requires no solvent.

Overview

- ◆ Developed by 3M
- ◆ Commercialized in 1993

Applications

- ◆ Paints, adhesives, sealants, and other coatings for civilian and military aerospace applications
- ◆ Coatings on the backing of high-temperature electrical insulation tape

Capabilities

- ◆ Uses photocatalysts (activated by exposure to light) to simultaneously polymerize two monomers to produce a novel coating without VOC-emitting solvents.
- ◆ Cure of the coatings has been demonstrated at temperatures as low as 60°F.

Methanol Recovery from Hydrogen Peroxide Production

Impacts

New Process Recovers and Cleans Contaminated Methanol for Reuse

Hydrogen peroxide production uses a catalyst that must be periodically regenerated with a methanol wash and soak. During this process, the methanol is contaminated with organic solvents, hydrogen peroxide, and metal ions. FMC Corporation developed and demonstrated, using a NICE³ grant, a new methanol recovery process at its Pasadena, Texas, hydrogen peroxide plant. The process uses steam distillation to recover the spent methanol, spraying steam directly into the column unlike conventional distillation columns that are heated through an external reboiler.

Recovering the methanol for reuse eliminates the fuel requirements to transport and incinerate it and reduces virgin methanol requirements. Although the system was originally projected to recycle about 90% of the hazardous waste methanol, recovery efficiencies of closer to 99% have been achieved. Steam distillation also allows for safer operation of the distillation column, preventing buildup of potentially flammable or even explosive contaminants in its bottom.

Benefits

Use of Raw Materials/Feedstocks

Reduces requirements for virgin methanol by an amount equivalent to that recovered (90% to 98%), conserving petroleum feedstock.

Waste Reduction

Reduces or eliminates incineration of contaminated methanol.

Worker Safety

Dilutes undesirable peroxides and metal ions in the distillation column, reducing the risk of fire or explosion.

Overview

- ◇ Developed by FMC Corporation
- ◇ Commercialized in 1993
- ◇ 2 units operating in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.03	0.14

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.002	1.754	0.000

Applications

- ◇ All industrial production of hydrogen peroxide by the organic process
- ◇ Any industrial plant where spent methanol occurs as a waste stream

Capabilities

- ◇ Recovery efficiency ranges between 90% and 98% by volume of methanol.
- ◇ Net costs for manufacturing hydrogen peroxide reduced by \$0.019/pound.

Methanol Recovery Process

CFC-Free Cleaning Process for Electronic Assemblies Reduces Waste

Numerous soldering operations are required to attach all the components during circuit board and electronic assembly manufacture. Current conventional soldering techniques leave a residue that must be cleaned with chlorofluorocarbon (CFC) solvents. Research has shown that CFCs are responsible for environmental and climate problems. As a result, CFC use is being phased out as part of an international agreement between the United States and other countries around the world.

The impact of this change will require that the electronic industry make some fundamental changes in the way circuit boards and assemblies are produced. OIT, working with Sandia, Los Alamos National Laboratories and Motorola, Inc., have developed a no-clean soldering process to address the needed changes. This low-residue approach to cleaning sprays adipic acid flux on the printed wire board (PWB), eliminating the oxides that form when the PWB is exposed to oxygen. The acid, applied prior to soldering, burns away during the soldering step, totally eliminating the need to use CFC solvents for cleaning. In contrast, in the conventional soldering process, CFC solvents were needed to remove rosin-activated flux and prevent the accumulation of moisture that corrodes components, causing electrical shorts.

The no-clean soldering process is used by approximately 90% of the commercial PWB manufacturers, including Motorola and Ford.

Benefits

Waste Reduction

Eliminates ozone-depleting CFC emissions.

Use of Raw Materials/Feedstocks

Reduces the use of petroleum feedstock otherwise consumed as solvents used for cleaning.

Energy Savings

Decreases energy consumption by eliminating the electricity required to run the cleaning process.

Applications

All wave soldering machines that use Freon TMS or 1,1,1 trichloroethane as the cleaning solvent (used in the manufacture of electronic assemblies)

Capabilities

Process requires no post-soldering cleaning.

Electronic assemblies manufactured with the process meet military reliability specifications.

Overview

- ◆ Developed by Sandia and Los Alamos National Laboratories and Motorola, Inc.
- ◆ Commercialized in 1990
- ◆ Implemented at Motorola facilities

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
2.63	5.26

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
1.907	0.723	175.4	0.526

Benefits

Waste Reduction

Eliminates ozone-depleting CFC emissions.

Use of Raw Materials/Feedstocks

Reduces the use of petroleum feedstock otherwise consumed as solvents used for cleaning.

Energy Savings

Decreases energy consumption by eliminating the electricity required to run the cleaning process.

Applications

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Diagram

The diagram illustrates the No-Clean Soldering Process. It shows a circuit board being processed by a wave solder. Adipic acid flux is applied to the board before it enters the wave solder. The flux evaporates, leaving a residue on the board. The board then passes through a wave solder, which is covered by a formic acid vapor and nitrogen cover blanket. This process eliminates the need for CFC solvents for cleaning. The final product is a clean circuit board.

For more information, call: Amy Manheim • (202) 586-1507 • DOE Office of Industrial Technologies

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Technology to Reclaim and Reuse Wastewater Minimizes Hazardous Waste

PPG Industries, Inc., developed and demonstrated, using a NICE³ grant, a system to reclaim and reuse wastewater generated during equipment cleaning used in water-based paint production operations. The system vastly reduces the volume of wastewater contaminated with metals and solvents that must be disposed of as hazardous waste.

The contaminated wastewater is collected separately from other wastes. It is prefiltered to remove large solids and then moved to the ultrafiltration unit where suspended solids and high-molecular-weight particles are removed. The smallest impurities are removed by the reverse osmosis unit, which has smaller pore sizes than the ultrafiltration unit. The reclaimed water is pumped to a storage tank from which it can be drawn for reuse in cleaning.

Using the system at the host PPG facility has reduced the number of annual tanker truck trips to a hazardous waste facility from 65 to 4. The technology has great potential to reduce wastewater throughout the coating industry.

Benefits

Waste Reduction

Achieves a 20-fold reduction in volume of hazardous waste requiring expensive treatment, storage, and disposal.

Pollution Control

Allows the new, highly concentrated waste stream to be handled by the plant's conventional treatment facility. Air pollutant emissions are reduced as a result of the reduction in hazardous waste that must be transported and incinerated.

Natural Resources

A single installation reduces fresh-water requirements by hundreds of thousands of gallons annually.

Overview

- ◆ Developed by PPG Industries, Inc.
- ◆ First installed in 1992
- ◆ 1 unit operating in 1997

Applications

- ◆ Reclaiming industrial wastewater for reuse in a process
- ◆ Automotive coatings and painting industry and other water-based coating industries

Capabilities

- ◆ Recovers 95% of the wastewater.
- ◆ Reclaims water highly suited for cleaning purposes.
- ◆ Saves energy otherwise used to transport and incinerate wastewater.
- ◆ Reduces process costs by reclaiming large volumes of water and by minimizing hazardous waste disposal.

The Water Treatment System at PPG's Cleveland Plant

Full-Body Powder Antichip Process Reduces Waste Emissions

Chipping paint is a major cause of customer dissatisfaction with U.S.-produced automobiles. The current standard for applying antichip primer to vehicles is a solvent-borne paint spray system that has a transfer efficiency (ratio of paint solids deposited on the vehicle to total volume used) of about 50%. In addition to generating a paint sludge by-product that must be landfilled, the process emits volatile organic compounds (VOCs) into the atmosphere. Chrysler Corporation developed and demonstrated, using a NICE³ grant, an innovative, new powder antichip process that contains no solvents and, considering recycling, has an effective transfer efficiency exceeding 90%. The new system virtually eliminates VOC emissions and paint sludge generation, eliminating the costs to transport and dispose of sludge.

Energy requirements for the powder process are much lower than for solvent-based processes. Though process air at 70°F is required for the application of either coating, in the new process a much smaller quantity of air needs to be heated and the air from the powder booth can be recycled and reused directly because it contains no solvents. The energy that had been required to incinerate VOCs from the conventional process is also conserved.

Benefits

Energy Savings

Reduced air requirements and ability to recycle process air leads to greatly reduced air-heating requirements. Also eliminates energy requirements for incinerating VOCs.

Waste Reduction

Contains no solvents, thereby reducing potential VOC emissions. Higher transfer efficiency reduces overspray, virtually eliminating solid-waste generation.

Use of Raw Materials

Conserves raw materials used to manufacture virgin coatings.

Overview

- ◆ Developed by the Chrysler Corporation
- ◆ Commercialized in 1995

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.62	0.92

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.013	0.047	36.39	0.005

Applications

Antichip primer application for automobiles

Capabilities

- ◆ Has transfer efficiency exceeding 90%.
- ◆ Has greatly reduced air-heating requirements.

New Separation Technology Helps U.S. Chemical Industry "Go Green"

Cargill, Inc., has recently commercialized a novel separation approach researched and developed at the University of California at Berkeley and Lawrence Berkeley Laboratory through funding from OIT. The approach, reversible chemical association, involves the use of an organic solvent or complexing agent to bind with chemical products in process streams. The chemical and physical properties of the solvent/complexing agent, as well as that of the product-agent, allow simple separation and recovery from the process stream. In turn, the product from the product-agent can be easily removed and recovered for concentration and purification. The technology eliminates the need for evaporation-the conventional, energy-intensive alternative step. The first application of the separation technique is the recovery of carboxylic acids, such as lactic acid and citric acid, from biomass and industrial waste streams.

Cargill, Inc., has been using the technology in an \$8 million pilot plant built in 1993 to develop biodegradable plant-based plastics. The plastics are made from lactic acid, a by-product of fermented sugars found in milk, sugar beets, corn, and other grains. The plant is producing 10 million pounds/year of rice-like pellets of the raw material to be sold to packaging companies. Cargill is also using the process at a full-scale, 250 million pounds/year plant for producing lactic acid.

Benefits

Use of Raw Materials/Feedstocks

Recovers carboxylic acids, glycols, and other valuable chemical products and intermediates from renewable resources instead of oil.

Waste Reduction

Eliminates the massive amounts of calcium sulfate waste product associated with traditional carboxylic acid recovery techniques. The acids are extracted with chemicals that can be recycled.

Competitiveness

May allow companies to make acid-based products previously too expensive to manufacture.

Overview

- ◇ Developed by the University of California at Berkeley and Lawrence Berkeley Laboratory
- ◇ Commercialized in 1993 by Cargill, Inc.
- ◇ 1 unit operating 1997

Applications

- ◇ Recovery of chemicals produced by fermentation of biomass, by petrochemical routes, or from natural products
- ◇ Production of citric acid and lactic acid for use in developing biodegradable plastics
- ◇ Production of other carboxylic acids, including acetic and adipic acids
- ◇ Production of ethylene glycol, propylene glycol, glycerol, sucrose, corn products, amino acids, monohydric alcohols, and phenol
- ◇ Processing of large-volume aqueous waste streams from the pulp and paper and food-processing industries

Capabilities

- ◇ Can selectively remove and recover substances containing COOH and OH groups from aqueous solutions.
- ◇ Removes desired substance(s) from the aqueous stream, eliminating the need for evaporation.
- ◇ Plant capable of producing 250 million pounds/year of lactic acid is being built.

Scrap Tire Recycling Reduces Waste

Recycling scrap tires presents a major opportunity for recovering valuable automotive materials. Each year 188 million worn-out tires, equivalent to 5 billion pounds of tire rubber and 200 million pounds of steel and fiber, are added to the over 800 million scrap tires already in landfills. OIT and Composite Particles, Inc., have developed a technology to economically convert these tires into higher-value products, conserving energy and raw materials while reducing the landfilling of scrap tires. This technology is the first truly economic method of recycling scrap tires and will eliminate potential environmental problems associated with tire disposal.

In the new process, the surface of finely ground tire rubber is briefly exposed to temperature-controlled oxidizing gases. This surface treatment enhances bonding with polymers, thus allowing the treated rubber to be substituted for high-priced polymers. By combining the surface-treated rubber particles with materials with which they are normally incompatible, unique composites with improved strength tear resistance, resilience, and other properties are formed. These composites can be used in tires, shoe soles, adhesives, and other products. The steel and cord from the tires are separated and sold as by-products. Substantial energy savings result because the energy required to shred, grind, and treat the tire rubber is 28,000 to 98,000 Btu/pound less than that needed to produce the polymers being replaced. The surface-treated rubber is currently being used to manufacture wheelchair tires. Several other manufacturers are evaluating various uses for the treated tire rubber.

Benefits

Waste Reduction

Reduces landfilling of scrap tires.

Use of Raw Materials

Use of recycled rubber conserves the raw materials and energy needed to produce virgin polymers.

Product Quality

Surface-treated rubber offers better wet traction, improved strength and impact resistance, and better flexibility compared with polymers.

Profitability

Yields cost savings to manufacturers because recycled rubber costs \$0.45/pound compared with \$2.00/pound for polymers.

Overview

- ◆ Developed by Composite Particles, Inc.
- ◆ Commercialized in 1995
- ◆ 600,000 pounds of surface-treated rubber sold in 1997

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.04	0.05

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.003	2.338	0.000

Applications

Recycling the approximate 188 million scrap tires generated annually

Capabilities

Surface-treated recycled rubber can be substituted for high-priced polymers in applications such as nonpneumatic tires and wheels, shoe soles, latex coatings, epoxy and urethane adhesives, and carpet underlay.

Polar Surface

Double Bond Surface

Scrap Tire Recycling Process

Membrane Separation Offers an Economical and Environmentally Friendly Way to Recover Industrial Solvents

OIT and Membrane Technology and Research, Inc., have developed a membrane separation system for recovering volatile organic compounds (VOCs) and chlorofluorocarbons (CFCs) from producer and user streams. The technology works by first compressing the contaminated air stream and then condensing. Condensed solvent vapor is collected for reuse. The gas mixture then flows into the membrane unit, where a highly selective membrane separates the gas into an organic-enriched permeate stream and an organic-depleted stream. The organic enriched permeate is recycled to the compressor, while the organic-depleted air is vented.

As of 1997, 47 VaporSep™ units have been installed; 38 of them in the United States.

Benefits

Worker Health and Safety

Maintains solvent concentrations below worker exposure limits.

Waste Reduction

Eliminates atmospheric release of VOCs. Eliminates the secondary waste streams generated from conventional systems.

Productivity

Is easier to install, start up, operate, and maintain than conventional condensation and carbon adsorption systems.

Profitability

Reduces energy costs from reduced energy use, recovers solvents for far less than their purchase price, and eliminates hazardous waste disposal costs.

Solvent Recovery from Effluent Streams

Overview

- ◆ Developed by Membrane Technology and Research, Inc.
- ◆ Commercialized in 1990 and marketed under the trade name VaporSep™
- ◆ 38 units operating in the United States in 1997

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
3.98	5.64

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.318	0.279	320.8	0.020

Applications

- ◆ Vinyl chloride from polyvinyl chloride manufacturing
- ◆ Refrigerants from chillers
- ◆ CFCs and ethylene oxide from sterilizers
- ◆ Hexane and nitrogen from polyolefin degassing
- ◆ VOCs from petrochemical and pharmaceutical processes

Capabilities

- ◆ Particularly useful for solvent vapors too diluted for compression-condensation or too concentrated for carbon adsorption.
- ◆ Recovers solvents for reuse without the need for refrigeration.
- ◆ Has recovery efficiency of 99% for VOCs.

Ultrasonic Tank Cleaning Now a Viable Alternative to Solvent Cleaning

Although ultrasonic cleaning has long been the standard for small-scale cleaning applications, its technical limitations have precluded its use in larger applications. Chemical and pharmaceutical companies, for example, typically use volatile organic compound (VOC)-emitting solvents to clean their storage tanks in a process that is both labor-and energy-intensive. A new ultrasonic tubular resonator, developed by TELSONIC Ultrasonics and demonstrated using a NICE³ grant at DuPont-Merck Pharmaceutical Company, overcomes these limitations and has cleaned tanks with capacities of up to 2,300 gallons. The energy wave produced by the Tube Resonator propagates in all directions, rather than in a single direction like conventional ultrasonic systems, so a tank can be cleaned with less ultrasonic energy. The unit is small and can be placed into the tank through an opening in the top, eliminating the need for maintenance workers to enter the tank as required with conventional cleaning.

The resonator cleans tanks more quickly and thoroughly than solvents, uses less energy, and reduces labor and material costs. By eliminating the need to process spent solvents, ultrasonic cleaning also eliminates VOC emissions and hazardous wastes.

Benefits

Waste Reduction

Eliminates the use of VOC-emitting cleaning solvents such as methanol, ethanol, and methylene chloride, and their associated hazardous waste streams. Eliminates VOC emissions from the incineration of the spent solvent.

Productivity

Reduces cleaning time from about 1 day to 1 hour.

Use of Raw Materials/Feedstocks

Conserves the petroleum feedstock otherwise needed to produce cleaning solvents.

Overview

- ◆ Developed by TELSONIC Ultrasonics
- ◆ Demonstrated by DuPont-Merck Pharmaceutical Company
- ◆ Commercialized in the United States in 1994
- ◆ 17 units operating in the United States in 1995

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.004	0.01

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.003	0.001	0.267	0.001

Applications

- ◆ Cleaning residue from tanks used in chemical and pharmaceutical processing
- ◆ Cleaning paint tanks such as those used in automotive painting operations

Capabilities

- ◆ Can clean tanks with capacities up to 2,300 gallons.
- ◆ Produces bubbles that are small enough to penetrate microscopic crevices, resulting in superior cleaning.
- ◆ Typical cleaning cycle times range from 1 to 3 hours compared with 8 to 24 hours for conventional cleaning methods.
- ◆ Saves the thermal energy used to convert the solvents from liquid to vapor.

New Microwave Furnace Shows Promise in a Variety of Materials Applications

Microwave heating can speed the curing of thermo-setting resins and polymer-matrix composites. Conventional microwave furnaces use standing waves that create a nonuniform energy distribution in the working cavity. Lambda Technologies and OIT have developed MicroCure™, a variable-frequency microwave furnace that eliminates nonuniform energy distribution and provides reproducible heating with every batch. By sweeping the frequency over a range, the power distribution becomes uniform because of the superposition of thousands of individual microwave modes.

Various types of polymer products can be uniformly cured, often in 5% of the time of conventional processing. For example, the new furnace has reduced the curing time of net-shaped polymer matrix composites from 10 hours to 30 minutes. The new furnaces have been scaled up to hold large volumes of materials in the microwave cavity while still producing high-quality products and maintaining excellent process control.

MicroCure furnaces are being used in the electronics industry to manufacture circuit boards. Because the MicroCure furnace operates at lower temperatures than conventional furnaces, the stress on circuit board components, such as silicon chips, is reduced. In addition, circuit board manufacturers using the MicroCure furnace can replace convention adhesives with solventless adhesives requiring lower curing temperatures, reducing emissions caused by conventional solvents.

Benefits

Productivity

Reduces the time required for heat treatment by up to 95% over conventional furnaces, significantly reducing energy use.

Product Quality

Provides greater consistency in material microstructure, reproducible heating characteristics, and uniform power distribution.

Competitiveness

Control of the reaction rate by coupling microwave energy at the molecular level allows new material structures not possible with conventional heating techniques.

Variable frequency microwave furnace system block diagram

Overview

- ◆ Developed by Lambda Technologies
- ◆ Commercialized in 1994
- ◆ At least 15 commercial units operating in 1997

Applications

- ◆ Developing new materials and materials processes, including epoxy curing, ceramic sintering, polymer matrix composite processing, composite joining and/or fusing and surface treatments
- ◆ Plasma processing, including chemical vapor deposition, chemical vapor infiltration, and surface cleaning and modification
- ◆ Drying large-volumes of textiles, ceramics, and rubber products
- ◆ Biomedical processing, including sterilization and uniform thawing

Capabilities

- ◆ Can operate at a fixed, preset frequency over a range of 1 to 18 GHz or in controlled swept frequency mode.
- ◆ Has power levels ranging from 700 W to 2 kW.

Water-Washed Overspray Paint Recovery

Impacts

Process for Recovery and Reuse of Water-Washed Overspray Paint Reduces Waste

Industrial water-wash paint operations, such as those used to paint automobiles, have transfer efficiencies (the percentage of paint sprayed that actually adheres to the item being painted) ranging from 30% to 70%. As a result, approximately half of all paint purchased for these operations is wasted. Landfilling has been the only feasible treatment option because no cost-effective recycling techniques exist to handle tacky, agglomerated paint sludge. Caterpillar, Inc., has developed and demonstrated, using a NICE³ grant, the Spangler process—an economically feasible process for recovering and chemically and physically processing oversprayed paint, and reusing the reclaimed material in new, high-performance paints and coatings.

In the Spangler process, oversprayed particles suspended in water are captured and encapsulated by hydrophobic fumed silica particles. This encapsulation essentially detackifies the paint by-product without detrimentally altering its chemistry as a recyclable feedstock. After drying, the product—known as Precured Pigment Resin (PPR)—is pulverized and packaged to be returned to coatings suppliers for blending into new paint. Not only does PPR have no negative effect on the quality of the coating to which it is added, it may actually improve the anticorrosion properties of some paints. In addition to paint, PPR can be used in products such as electrodeposition coatings, interior/exterior maintenance coatings, and polyurethane primer. Caterpillar is currently refining the process and expects to use the product in-house and sell it commercially to other users.

Overview

- ◆ Developed by Caterpillar, Inc.
- ◆ Commercialized in 1995

Applications

Industrial water-wash paint operations such as automotive and construction equipment assembly plants

Capabilities

- ◆ Recovers and processes oversprayed paint for reuse in high-performance coatings.
- ◆ Detackifies oversprayed paint waste without destructively altering its composition.

Benefits

Waste Reduction

Reclaims large quantities of oversprayed paint for reuse, eliminating landfilling millions of pounds of water-washed paint sludge annually.

Use of Raw Materials

Conserves raw materials used to manufacture virgin paints and coatings.

Profitability

Represents a cost-effective method of treating a paint waste by-product, especially as landfill fees continue to increase.

Spangler Process for Recovery and Reuse of Water-Washed Overspray Paint

FOREST PRODUCTS

Working with industry partners, the Forest Products Industry of the Future team focuses on pre-competitive research, development and demonstration in six technology areas: sustainable forestry, environmental performance, energy performance, capital effectiveness, recycling, and sensors and controls. The strategy supports the national goals of reduced energy consumption, environmental compatibility, and resource efficiency to maintain a strong U.S. manufacturing base.

OIT-sponsored technologies commercially available include:

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Chemical for Increasing Wood Pulping Yield

Impacts

Novel Chemistry Improves Pulp Yield While Reducing Energy and Chemical Requirements

Unevenly processed wood chips in the pulp industry result in poor-quality pulp, often requiring reprocessing. ChemStone, Inc., in cooperation with OIT's NICE³ program, has demonstrated a cooking aid that reduces the amount of virgin wood feedstock needed to process wood chips and increases pulp yield and quality. The cooking aid is a molecule that remains soluble in the highly alkaline and hot pulp cooking environment. The molecules help pulp cooking liquors penetrate the chips, resulting in more uniform cooking. The rate of penetration into the chips enables the mill to produce a more uniform fiber in less time and with less energy. This chemistry eliminates overcooking the external chip to effectively cook the internal chip and eliminates the need to reprocess the uncooked portion.

The process greatly reduces sulfur-based emissions such as hydrogen sulfide and methyl mercaptans. Approximately 1 million tons of emission gases are eliminated. Nine U.S. mills are currently using this novel chemistry either full time or for part of their production. ChemStone is currently establishing a distribution network in South Africa, Europe, Indonesia, Canada, and Mexico.

Benefits

Product Quality

Produces better-quality pulp through less harsh cooking of the wood chips and less refining of the pulp, reducing rejects.

Use of Raw Materials/Feedstocks

Reduces consumption of raw wood for required production. Uses less bleaching chemicals to reach the required brightness.

Pollution Prevention

Reduces sulfur-based emissions such as hydrogen sulfide and methyl mercaptans.

ChemStone Programs for Mill Optimization

Overview

- ◇ Developed by ChemStone, Inc.
- ◇ Nine pulp mills currently using the technology

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.30	0.45

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.021	17.54	0.000

Applications

All pulping processes

Capabilities

- ◇ Results in 4% to 5% increase in yield per ton of wood.
- ◇ Rejected pulp is reduced by 2% to 50%, depending on the length of the cook.
- ◇ Reduces the amount of fiber required for paper quality.

DELTA T Dryer Control System

Impacts

DELTA T Dryer Control System Improves Product, Saves Energy

Conventional industrial dryers rely on an “after-the-fact” feedback control system because they measure product moisture content at the dryer exit. The DELTA T control system developed by Drying Technology, Inc., with assistance from DOE’s Inventions and Innovation Program, is a more precise system to control variation in exiting product moisture content. The DELTA T system significantly improves control capability because it measures moisture content continuously prior to the throughput exiting the dryer—it is the only control system with this capability.

The DELTA T unit uses two temperature sensors and an algorithm that relates product moisture content to two factors; the temperature drop of hot air after contact with the product, and the production rate or feed rate. With this algorithm, it is possible to monitor and thus control product moisture before it exits the dryer, a distinct advantage over feedback-type controls. The control narrows the range of moisture between the driest and wettest product exiting the dryer by 33% to 50%. This range allows the average moisture content to be 0.5% to 4% higher. By lowering the variation in moisture content, average moisture content can be higher, which raises production 5% to 35%. Operating at a higher moisture content also lowers energy use by 10% to 20%. Additionally, reducing over- and under-drying improves the product quality.

Benefits

Product Quality
Prevents overdrying and underdrying. Improves color, taste, and texture of food products.

Safety
Eliminates in-dryer fires in forest product drying operations.

Energy Savings
Requires 10% to 20% less energy for drying than conventional drying methods.

Emissions Reductions
Lower throughput product temperatures reduce the amount of volatile organic compound (VOC) emissions. Reduces emissions associated with fuel combustion by 10% to 20%.

Overview

- ◆ Developed by John W. Robinson of Drying Technology, Inc.
- ◆ Commercialized in 1986; sales of \$850,000/year
- ◆ Over 175 systems operating in the United States, Canada, and Columbia, South America
- ◆ Installing 30 units/year as new industrial applications emerge

Applications

Industrial dryer control for plywood, lumber, textiles, carpet, food, snack food, plastic pellets, mining, paper, corn wet milling, pet food, oriented strand board (OSB), tobacco, non-wovens, and activated carbon

Capabilities

Can control a variety of drying systems, including rotary, rotary louver, conveyor, flash, spray, fluidized-bed, and batch lumber kilns.

DELTA T Dryer Control System

For more information, call: Lisa Tunstall-German • (202) 586-2487 • DOE Office of Industrial Technologies 43

High-Efficiency Ozone Generator System

Impacts

Higher Concentrations of Ozone with Lower Power Requirements

With assistance from DOE's Inventions and Innovation Program, Life Support Systems has developed an ozone generator that uses highly insulating materials and higher pressures to produce ozone at higher concentrations with lower power requirements. With these innovations, the system reduces power requirements by 60% compared with conventional ozone systems. The Life Support system produces ozone for disinfectants, sterilizing agents, potable water treatment, industrial waste, wastewater, and sewage.

Although chlorine is inexpensive and reliable, the costs to treat its waste streams are high. Environmental Protection Agency (EPA) inspections have found dioxin (attributed to the presence of bleach) in water discharged from paper-pulping mills. As a result, the EPA has developed an aggressive strategy to eliminate the presence of dioxin in discharges from pulp and paper mills into U.S. waters. Regulations in Northern Europe have already banned the use of chlorine bleach in pulping mills. The efficient Life Support Systems' ozone generator offers the paper industry an economical alternative to chlorine pulp bleaching. While the generator has demonstrated direct energy savings over chlorine-based bleaching, a greater benefit is in eliminating the need to remediate effluent water.

Benefits

Profitability

Eliminates costs and fines associated with chlorine waste.

Pollution Prevention

Eliminates dioxin, a toxic by-product of chlorine bleaching, and releases cleaner process water to the environment.

Energy Savings and Emissions Reductions

Reduces energy consumption by over 60% compared with conventional ozone systems.

Human Health

Health care applications of ozone have potential to save millions of lives.

High-Efficiency Ozone Generator System

Overview

- ◆ Developed by Life Support Systems
- ◆ Commercialized in 1996
- ◆ Four pulp and paper plants with units operating since 1996

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
1.39	2.78

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
1.008	0.382	92.69	0.278

Applications

- ◆ Pulp and paper plant product bleaching
- ◆ Industrial waste treatment
- ◆ Wastewater and sewage treatment
- ◆ Disinfectant and sterilizing agent
- ◆ Food products sanitation with ozonated water wash
- ◆ Pyrogen-free, contaminant-free water for ultra-pure hospital water systems

Capabilities

- ◆ Eliminates the need for chlorine in pulp bleaching and other industries.
- ◆ Generates higher concentrations of ozone (9% to 14%) over conventional ozone-generating systems (3% to 6%) with lower power requirements.
- ◆ Stronger oxidizer than conventional chlorine bleaching and sterilization systems.

Lignin Separation and Epoxide-Lignin Manufacturing

Impacts

Lignin-Derived Resins Recovered from Mill Process Waste Find 20 New Uses with More on the Way

Inventor Ken Kurple received a grant from DOE's Inventions and Innovation Program to perfect a patent for extracting lignin from black liquor (paper mill waste) by lowering the pH (alkalinity) of the black liquor and making the lignin insoluble. After filtering out the lignin, the process removes impurities and adds special ingredients to create a manufacturing resin from what was unrecoverable waste. Before lignin recovery was perfected, industry was incinerating approximately 16 million tons of black liquor annually. A replacement product for petroleum, the new resin is now used in products such as canoe seats, car spoilers, and a traction-enhancing tire spray, or as a binder for particle board and plywood in the forest products and furniture industries.

A primary industrial application for Lenox Polymers is the production of foundry castings for automotive transmission housings, steam pipe fittings, air motor castings, and governor housings. Recently, Lenox signed a marketing, development, and supply agreement with PPG Industries, to develop specific lignin products for the automotive market.

Benefits

Profitability

By substituting a renewable, environmentally friendly resource for petroleum derived resins, saves petroleum for higher-value uses. Produces a lower-cost manufacturing resin with improved performance.

Product Quality

Proven success in production of foundry castings and as a durable material in a variety of plastic and automotive products.

Waste Reduction

Lignin extraction lowers disposal costs for pulp mills and reduces the amount of black liquor burned, cutting air emissions and lowering costs to comply with environmental laws and air emission ceilings.

Employee Health

Reduces employee exposure to formaldehyde.

Overview

- ◆ Lenox Polymers has established licensing or partnership agreements with companies in Germany, Japan, and the United States since 1994
- ◆ Technology received a Michigan Technology Award

Applications

- ◆ Resource recovery in pulp and paper industry
- ◆ Resins for the automotive, foundry, plastics, architectural, military, furniture, marine, and agricultural industries

Capabilities

- ◆ Able to treat black liquor from pulp mills to extract lignin, which is filtered and modified to create manufacturing resins that substitute for urea-formaldehyde, polyester, phenolic, and polyurethane resins.
- ◆ Resins can withstand high temperatures and are flame resistant and formaldehyde-free.

Lignin Separation and Epoxide-Lignin Manufacturing

Optimizing Tissue Paper Manufacturing Increases Paper Recycling

Government standards and customer requests led Erving Paper Mills, Inc., to modernize its de-inking process to increase the amount of recovered office paper used in producing paper napkins and tissue. De-inking is the process of removing inks, dirt, and other contaminants from the fibers used in making paper products. Waste paper is made into a slurry and the contaminants are removed mechanically by size.

Using a NICE³ grant, Erving Paper Mills demonstrated changes to its process, which included de-ink equipment upgrades, on-line image analysis, alternative chemistry trials, and other energy conservation projects. These improvements reduced energy and toxic chemical usage and increased the amount of recovered office paper content of the feedstock. The de-inking equipment improvements included system reconfiguration, new high-efficiency cleaners, a new high-efficiency flotation cell, and a new high-efficiency washer. These improvements resulted in higher dirt removal efficiencies, better washing, improved process water clarification, and lower bleaching requirements.

Benefits

Energy Savings

Lower pulping temperatures decrease fuel oil usage. Conservation projects resulted in reduced electrical energy.

Emissions Reductions

Lower pulping temperature and new continuous-belt washer decreases solvent usage, resulting in reduced VOC emissions.

Use of Raw Materials/Feedstocks

Increasing amount of recovered office paper decreases amount of virgin pulp used. Changes to de-inking process decreases use of several controlled chemicals.

Overview

- ◇ Developed by Erving Paper Mills, Inc.
- ◇ System modifications began in late 1996

Applications

- ◇ Production of tissue and napkin products
- ◇ Pulp and paper mills

Capabilities

Recovered office paper content was increased from 14.5% in 1995 to >30% in second quarter of 1997.

Pallet Production Using Postconsumer Wastepaper

Impacts

Use of Recycled Paper Shown Viable in Several Products

Industries in Japan, Korea, Taiwan, and other countries typically produce paper products composed of recycled paper using up to 50% mixed waste—magazines, newspapers, and linerboard. U.S. industries, in contrast, use a much higher fraction of virgin wood fiber in their products. With assistance from OIT's NICE³ program, Damage Prevention Products Corp. (DPPC) has demonstrated the use of 100% postconsumer waste paper (PCW) with a 40% mixed-waste component in a variety of products. The first product demonstrated was a shipping pallet containing at least 40% mixed-waste paper.

The manufacture of pallets and other recycled paper/paperboard products is of particular interest in California, which has passed mandates to reduce PCW streams. The recycled products conserve raw materials and energy, save space in landfills, reduce water usage, and decrease air and water pollution, making them appealing to environmentally conscious customers. Several large national companies have tested the 40% mixed-waste paper pallets and have determined that they meet or exceed all standards. DPPC has fully commercialized the technology and is applying it to additional products such as moisture-resistant honeycomb-core paper for use in the interior walls of homes.

Corrugated Paper Pallet Partially Made from Postconsumer Waste Paper

Overview

- ◆ Developed by Damage Prevention Products Corp.
- ◆ 1 unit operating in 1997

Applications

- ◆ Production of shipping pallets for freight transport
- ◆ Manufacture of roofing felt and honeycomb structures for use in housing construction

Capabilities

- ◆ Products made from 100% PCW, of which 40% is mixed waste—magazines, newspapers, and linerboard—are just as strong as those made from wood and stronger than those made from virgin paper products.
- ◆ Substitution of virgin wood with this recycled/mixed-waste product reduces energy requirements by 60%.

Benefits

Waste Reduction

Substitution of virgin wood fiber with this recycled/mixed-waste product reduces wastewater by 35% and air pollution by nearly 75%.

Use of Raw Materials/Feedstocks

Reduces virgin wood requirements for producing pallets and other paperboard products.

Natural Resources

40% substitution of recycled paper for virgin paper reduces water requirements by 50%.

Energy Savings

Annual energy savings estimated to be 300 million Btu; cumulative savings estimated to be 1.65 billion Btu.

Thermodyne™ Evaporator – A Molded Pulp Products Dryer

Impacts

Thermodyne™ Evaporator—A Substantially Improved Molded Pulp Products Dryer

With assistance from DOE's Inventions and Innovation Program, Merrill Air Engineers demonstrated that its Thermodyne™ dryer outperforms conventional molded pulp dryers. Unlike other dryers, the Thermodyne™ dryer reheats water vapor released from the product being dried to create superheated steam that is directed onto the material being dried. Conventional paper dryers exhaust this liberated water outdoors, causing a large visible plume and dumping valuable heat. The Thermodyne™ dryer is sealed so internal vapor (moisture) cannot escape into the insulated dryer walls. The retained water vapor passes through indirect integral heaters to raise its temperature to a level that allows for substantially faster drying rates than if drying in relatively dry air. An absence of oxygen in the dryer also means the drying temperature can be higher and the retained water vapor can help protect and evenly dry the material. The released water vapor also helps control internal temperatures by mixing with the superheated steam, dropping its temperature to a more desirable level. Finally, the system recovers heat and harmful volatile organic compounds (VOCs) from the dryers' condensate, substantially reducing the amount released into the atmosphere.

Benefits

Product Quality

The superheated steam-drying environment suppresses oxygen, reducing the chance of scorching or burning the product under higher and faster drying temperatures. Other quality enhancements include less warping, reduced case hardening, and no discoloration.

Productivity

Process promotes easier stacking and wrapping.

Profitability

Process promotes lower shipping costs and lowers product losses.

Energy Savings and Emissions Reductions

Substantially reduces energy requirements by eliminating the thermal energy needed to make up air exhausted from conventional dryers. Uses up to 50% less energy than a conventional dryer with the potential of saving up to 5 million Btu/ton of pulp. Captures volatile organic carbon (VOC) emissions by containing condensable gases.

Overview

- ◆ Developed by Merrill Air Engineers
- ◆ Commercialized in 1997
- ◆ One unit operating in the United Kingdom and 2 advanced units being installed in the United States in 1999

Applications

Forest products industry for manufacturing molded fiber articles and for drying pulp, cotton, cellulose, and wood veneers

Capabilities

- ◆ Fully capable of replacing conventional drying systems in the forest products industry.
- ◆ Handles a wide variety of forest products and can be applied to agricultural applications.

Thermodyne™ Evaporator—A Molded Pulp Products Dryer

XTREME Cleaner™ – Removal of Light and Sticky Contaminants

Impacts

Centrifugal Cleaner Removes Light and Sticky Contaminants from Waste Paper

Americans now recover 45% of all paper used in the United States. Some brown paper grades, wax curtain-coated board, polyethylene-laminated paper, glue-containing magazine backs, and other secondary fiber sources contain contaminants like “stickies,” wax, polyethylene, and binding glue that either make recycling impossible or cause an array of operating or product-related problems. Until recently, the treatment technology for removing the contaminants was not completely effective. A major breakthrough was the development of the XTREME Cleaner™, a centrifugal cleaner that replaces conventional dispersion systems in paper mills using waste paper.

The XTREME Cleaner removes lightweight debris in all types of pulp slurries. It uses long residence times in a small-diameter cleaner to maximize separating very small contaminants that are close to the specific gravity of the fiber itself. Coupled with an advanced design through-flow cleaner, such as the XX-Clone™, in the tailing position, only two stages are needed to minimize fiber loss and maximize contaminant removal efficiency. The XTREME Cleaner uses 50% less energy than conventional dispersion systems, resulting in significant cost savings to paper mills. The cleaner allows paper mills to use lower-grade, lower-cost furnish without compromising the quality of the final paper product. Paper mills using the cleaner system have reported savings of \$3,500 to \$11,000 per day just by using the lower-grade furnish.

Benefits

Energy Savings/Productivity

Uses 3 hp to operate compared with 5 or 6 hp for conventional dispersion systems. Produces a 40% to 60% reduction in machine breaks or paper breaks, which are costly to paper mills due to downtime. Eliminates downtime to clean sticky contaminant build-up from processing machinery.

Product Quality

Allows paper mills to use a lower-grade, lower-cost furnish while still producing the same or higher-quality end product. Assists paper mills in meeting or exceeding quality end-product requirements in less time.

Environmental

Greatly reduces the amount of waste paper being landfilled. Reduces the amount of chemicals and energy necessary to process recycled paper compared with producing paper from raw wood material.

System Losses

- 4.2% Volume
- 0.6% Weight

XTREME Cleaner™

Overview

- ◆ Developed by Thermo Black Clawson
- ◆ Commercialized in 1997
- ◆ Operating in three waste paper recycling plants in 1997

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.04	0.04

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.029	0.011	2.667	0.008

Applications

Used in paper mills to recycle waste paper containing “stickies,” wax, polyethylene, and binding glue

Capabilities

- ◆ Effectively removes lightweight sticky contaminants from all types of pulp slurries.
- ◆ Improved kneading or “liberation” unit better detaches and separates impurities from waste paper fibers.
- ◆ Improved vortex separation device allows greater unit capacity, longer treatment times, and higher consistency operation.

GLASS

The Glass Industry of the Future partnership is developing improved manufacturing processes and techniques that reduce energy consumption, boost productivity, and enhance glass strength and quality. Advanced processes and materials technologies enable the industry to operate more cleanly, significantly reduce air pollutants, and increase recycling.

OIT-sponsored technologies commercially available include:

- ◆ Oxy-Fuel Firing..... 52

Oxy-Fuel Combustion Saves Energy and Reduces Emissions

Combustion using pure oxygen is more fuel-efficient than combustion using ambient air. OIT and Praxair, Inc., have demonstrated an oxygen-enriched combustion system for glass-melting furnaces that significantly reduces melting energy requirements. The system uses an advanced oxygen supply system known as vacuum pressure swing adsorption, an energy-efficient variation of the conventional pressure swing adsorption technology.

Approximately two-thirds of the 103 units currently in use in the United States are on smaller furnaces, where energy savings of up to 45% have been achieved. The remaining units are on larger furnaces, where energy savings have averaged about 15%. A major benefit of oxy-fuel firing is environmental; emissions of NO_x are reduced by up to 90% and particulates by up to 30%. These reductions, together with energy savings and other benefits, make oxy-fuel firing an attractive solution for helping glass producers meet increasingly restrictive environmental regulations.

About one-fourth of all glass-melting capacity in the United States has been converted to oxy-fuel firing.

Overview

- ◇ Developed by Praxair, Inc.
- ◇ Commercialized in 1990
- ◇ 103 units operating in the United States

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
3.4	13

Emissions Reductions (Thousand Tons, 1997)

SO_x	NO_x	CO_2	Particulates
0.000	0.238	198.7	0.005

Applications

- ◇ Most container glass and fiberglass melters
- ◇ Regenerative and nonregenerative melters

Capabilities

- ◇ Vacuum pressure swing absorption is economical for melters producing up to 100 tons/day of glass.
- ◇ Cryogenic separation is used for the larger melters.

Benefits

Product Quality

Reduces defects in the glass because of improved melter control.

Productivity

Increases furnace production rate up to 25% over combustion with ambient air.

Profitability

Eliminates the need for a heat recovery system because of the large reduction in exhaust gas volume.

METALCASTING

The Metalcasting Industry of the Future partnership seeks to develop advanced manufacturing technologies that increase productivity and reduce energy consumption in casting, to develop advanced materials technologies that improve the performance of cast products, and to increase recycling and reuse of foundry by-products.

OIT-sponsored technologies commercially available include:

- ◆ Cupola Furnace Process Model 54
- ◆ Laser-Based Laminated Object Manufacturing 55
- ◆ Precision Pattern Production – Multiple-Station Air Gauge 56

Cupola Furnace Process Model Optimizes Foundry Melting Operations

OIT joined with the American Foundrymen's Society and more than 20 industry sponsors to develop a comprehensive mathematical model of the cupola furnace, a type of furnace used to melt iron that is subsequently cast into a variety of products. The mathematical model was incorporated into a user-friendly artificial intelligence program that can help the operator optimize the temperature, processing time, and other key variables of furnace operation. Based on input data, the new process control system accurately predicts the metal temperature, composition, and melt rate in steady-state conditions, permitting better control of cupola operations and yielding a variety of benefits.

The major benefits of the new process model are improved energy efficiency, improved product quality, and reduced waste. Optimized processing times and furnace temperatures lower furnace oxygen requirements and increase metal melting rates, reducing furnace fuel (primarily coke) requirements. Improved furnace control reduces the oxidative loss of alloying elements (including carbon, silicon, and manganese), losses that affect the final properties and quality of the cast component. The melted metal has more uniform and predictable composition, which reduces the number of castings rejected because of quality problems. The process model was tested at several industry facilities and has been distributed to the project's industry sponsors. The model can also be used off-line as a predictive tool to guide and formulate the strategy of melting operations in response to changes in process inputs.

Typical Cupola Furnace

Overview

- ◇ Developed by the American Foundrymen's Society, GM-Research, and more than 20 industry sponsors
- ◇ Distributed to sponsors in 1995
- ◇ GM-Research currently using the model for experiments at DOE's Albany, Oregon facility.

Applications

Cupola furnaces are used to remelt and recover scrap iron created during the forming of gray iron, malleable iron, and ductile iron in metalcasting

Capabilities

- ◇ Can predict metal temperature, composition, and melt rate in steady-state conditions.
- ◇ Permits control of cupola operations based on fluid flow, heat transfer, and mass balances.

Benefits

Energy Savings

Optimized furnace control results in increased energy efficiency and reduced fuel consumption.

Product Quality

Reduces oxidative loss of alloying elements such as carbon, silicon, and manganese.

Waste Reduction

Reduces scrap castings because of more uniform and predictable iron compositions.

Laser-Based Laminated Object Manufacturing

Impacts

Laminated Object Manufacturing® Speeds Product Development and Cuts Prototyping Costs

Producing prototypes, models, or molds to create new products has always been a barrier for manufacturers. High-cost artisans painstakingly and slowly handcraft new prototypes with expensive metals. With assistance from DOE's Inventions and Innovation Program, Michael Feygin developed the Laminated Object Manufacturing® (LOM™) machine. The LOM™ machine works with computer design software to produce physical objects. Using high-quality paper, plastic, or a composite, the LOM™ machines can produce small, intricate, thin-wall models and masters; complex, thick-wall casting patterns; and solid cores, forming tools and cavity molds.

The system's software slices the geometry along the vertical axis into many layers. A rechargeable laser cuts cross-sectional layers in an outline of the material's top layer with crosshatched excess material. Once all layers have been laminated and cut, excess material is removed to expose the finished part.

Benefits

Energy Savings

Direct energy savings accrue from reduced electrical demand to run the LOM™, which uses a laser to cut paper versus a computer numerically controlled (CNC) machine that mills a metal model.

Waste Reduction

Eliminates scrap from machined metal prototypes necessitated by redesigns of preproduction models. Uses low-cost sheet paper instead of limited shelf life, high-cost photopolymer.

Productivity

Reduces unnecessary machining time and saves associated labor. LOM™ works in hours or days versus a CNC that takes days or weeks.

Laser-Based Laminated Object Manufacturing

Overview

- ◆ Commercialized in 1991 by Helisys Inc. (formerly Hydronetics)
- ◆ Over 170 installations worldwide

Applications

- ◆ Designing and manufacturing industrial and consumer products
- ◆ Patterns and molds for the foundry and investment casting industries
- ◆ Manufacturing heavy equipment for mining and agricultural industries

Capabilities

- ◆ Has large part envelope that can accommodate multiple smaller parts.
- ◆ Fabricates models from low-cost paper instead of photopolymer or metal.
- ◆ Reduces fabrication time from weeks to days.
- ◆ Can operate unattended overnight.
- ◆ Reduces expensive machine shop labor.
- ◆ Allows complete flexibility in prototype redesign and perfectly cuts intricate internal geometry the first time.

Precision Pattern Production – Multiple-Station Air Gauge

Impacts

Measurement System for Metalcasting Patterns Increases Productivity, Reduces Waste

The 30-sensor air gauge system for the metalcasting industry allows precise, accurate, noncontact measurement of low-modulus materials (e.g., lost foam polystyrene patterns, investment casting wax patterns) by incorporating the air gauge technology and a computer interface. The multiple-station air gauge, which was developed under a cooperative agreement with OIT, the University of Alabama at Birmingham, and Matrix Technologies, can determine the location of 30 separate part surfaces without direct physical contact between sensors and surfaces. With this technology, parts can be completely and accurately gauged on the plant floor in a few seconds (as opposed to a few hours with conventional techniques), without damaging casting patterns.

The gauge works by blowing air on surfaces and monitoring the pressure ratios created by airflows between a central primary air chamber and 30 separate secondary chambers. It precisely measures defects and flaws throughout the casting process, reducing scrapped parts and the number of castings that must be reworked. By reducing machining and rework time, the technology also increases the energy efficiency of the casting process. The gauge is commercially available from Matrix Technologies.

Benefits

Productivity

Reduces processing time and product reject rate because measurements are made on-line during the production process, not off-line in a laboratory. A skilled operator is not required to operate the custom-designed system.

Product Quality

Meets high-quality production standards quickly and cost-effectively.

Waste Reduction

Reduces scrap generation and product reworking because corrections are made early in the production run.

Overview

- ◆ Developed by the University of Alabama at Birmingham and Matrix Technologies
- ◆ Commercialized in 1994
- ◆ Fourteen 30-sensor units operating in 1997

Applications

- ◆ Precision pattern dimensional measurements of plastic foam models used to produce dies, exhaust manifolds, engine heads, and other close-tolerance castings
- ◆ Precision measurements in the production of jet aircraft parts, orthopedic implants, and glass products

Capabilities

- ◆ Measures delicate foam models without touching them.
- ◆ Can take up to 30 measurements in less than one minute, right on the shop floor.
- ◆ Takes accurate measurements to within 0.0005 inch.

Precision Pattern Production – Multiple-Station Air Gauge

PETROLEUM

The Petroleum Industry of the Future partnership aims to improve the energy and environmental performance of petroleum processes.

OIT-sponsored technologies commercially available include:

- ◆ Absorption Heat Pump/Refrigeration Unit 58
- ◆ Biphase Rotary Separator Turbine 59
- ◆ Catalytic Distillation 60

Absorption Heat Pump/Refrigeration Unit

Impacts

Advanced Water Ammonia Absorption Cooling Finds Profitable Application in Refinery Operations

Ambient cooling with cooling towers is usually preferred for cooling refinery columns because refrigeration systems have higher first costs, create compressor operation and maintenance headaches, and significantly increase electricity demand. With assistance from DOE's Inventions and Innovation Program, Energy Concepts Company developed an advanced waste-heat-powered ammonia refrigeration unit that overcomes the disadvantages of a refrigeration system by recovering more fuel from a reformer and raising column capacity of a cracker. The unit debottlenecks the wet-gas process compressors in a cracker by cooling their inlet vapors and also condenses out salable liquid products from the fuel or flare gas stream.

A commercial unit operating at the Colorado Refining Company in Commerce City, Colorado, is providing 265 tons of capacity to refrigerate gas/treat gas streams and is recovering 65,000 barrels/year of LPG. The unit is powered by the 290°F waste heat content of the reformer reactor effluent. The absorption cooling system is directly integrated into the refinery processes and uses enhanced, highly compact heat and mass transfer components. The refinery's investment is expected to be paid back in less than two years as a result of increased recovery of salable product from fuel.

Overview

- ◆ Developed by Energy Concepts Company
- ◆ First commercial unit installed at a refinery in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.4	0.4

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.032	0.028	32.24	0.002

Applications

- ◆ Resource recovery in refinery and chemical industries
- ◆ Refrigeration and space conditioning for commercial and industrial facilities

Capabilities

- ◆ Water/ammonia absorption cycle can be powered from any heat source.
- ◆ Can deliver temperatures as low as -50°F and as high as 500°F.

Benefits

Profitability

Reduces energy intensity for a facility and increases throughput for fluid catalytic crackers that have a bottle-neck due to an overloaded wet-gas compressor. Applying refrigeration to refinery fuel gas header streams can recover hundreds of thousands of dollars worth of liquefied petroleum gas (LPG) annually.

Absorption Heat Pump/Refrigeration Unit

New Turbine Recovers Energy from Complex Industrial Waste Streams

The waste energy released during depressurization of single-phase process streams (consisting of either a liquid or a vapor) in the chemical and petroleum industries is commonly recovered using gas or steam turbines. However, energy is often not recovered from streams that result in a two-phase flow (consisting of both a liquid and a vapor) during depressurization. Conventional turbines cannot be used efficiently with two-phase flows because they may not withstand the forces released during the rapid evaporation of the liquid to a vapor. In many of these processes, such as those created during oil and gas production, the quantity of energy released during depressurization can be very large—up to 20 million Btu/hour.

OIT contributed to the development of a biphase rotary separator turbine by Biphase Energy Systems that converts some of the waste energy contained in a two-phase process stream into mechanical power while simultaneously separating the gaseous and liquid phases for further processing and/or additional recovery. The system uses a two-phase nozzle that converts the thermal and pressure energy of a liquid and vapor mixture to kinetic energy. The resulting high-velocity two-phase mixture impinges on a rotating cylinder or rotor to produce shaft power.

Benefits

Waste Reduction

Reduces wastes associated with currently unrecovered pressurized process waste streams.

Reliability

Has only one moving part and is not affected by sudden changes in load that would damage a conventional turbine.

Profitability

Reduces on-board power generation needs for oil/gas separation on offshore platforms. Eliminates the need for large oil/gas separator tanks, increasing platform processing capacity.

Advanced Biphase Rotary Separator Turbine

Overview

- ◆ Developed by Biphase Energy Systems, Inc.
- ◆ Commercialized in 1994
- ◆ 2 units operating in the United States in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.03	0.04

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.001	0.002	2.086	0.000

Applications

Recovery of waste energy from pressurized process streams that separate into liquid and gas when depressurized; such streams occur during

- ◆ Oil and gas production
- ◆ Ammonia and urea production
- ◆ Refrigeration and separation of hydrocarbons and methanol production
- ◆ Hydrosulfurization
- ◆ Coal liquefaction or gasification
- ◆ Hydrocracking of petroleum
- ◆ Sugar-beet liquor concentration
- ◆ Liquefaction of natural gas
- ◆ Pulp digester blowdown

Capabilities

- ◆ Recovers waste energy from two-phase flow streams.
- ◆ Provides clean gas/liquid separation by repressurizing or concentrating the liquid.
- ◆ Provides mechanical energy for electric or shaft power generation.

Catalytic Distillation Has Become a Major Commercial Success

Distillation is one of the most energy-intensive industrial processes, accounting for over 40% of the energy consumed by the chemical industry each year. The single-stage, catalytic reaction/distillation process developed by Chemical Research and Licensing and OIT has become a major commercial success while improving the energy efficiency and productivity of certain chemical production processes. Methyl tertiary butyl ether (MTBE) is produced by reacting methanol with isobutylene over an acid resin catalyst. Tertiary amyl methyl ether (TAME) is produced in a similar way by reacting methanol with isoamylene. Catalytic distillation saves energy by using the heat released by the reaction to drive the distillation process, eliminating the need for separate energy input.

Specifically, the technology is being used to produce gasoline additives such as MTBE and TAME, thus helping U.S. refiners produce the reformulated gasoline mandated by the Clean Air Act Amendments of 1990. As of 1997, 79 units were operating worldwide, 43 of them in the United States.

Benefits

Productivity

Single-stage process, coupled with higher product yield, reduces processing time and lowers production costs per pound.

Product Quality

Greater than 99% isobutylene conversion for MTBE production. Higher product yield increases product purity by 25% for isoamylene conversion to TAME.

Pollution Control

Will help refiners more cost-effectively reconfigure plants to meet government gasoline oxygenate levels.

Use of Raw Materials/Feedstocks

More product is produced from the same amount of raw feedstock, reducing raw material input.

MTBE Production Using Catalytic Distillation

Overview

- ◆ Developed by Chemical Research and Licensing and Neochem
- ◆ Commercialized in 1982
- ◆ 43 units operating in the United States in 1997 and 79 units worldwide

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
4.10	17.0

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.287	0290.1	0.006

Applications

- ◆ Production of MTBE and TAME—both gasoline additives
- ◆ Production of cumene and ethyl benzene

Capabilities

- ◆ Conversion efficiency >99% for production of MTBE from isobutylene (compared with 97% for conventional distillation).
- ◆ Conversion efficiency >95% for production of TAME from isoamylene (compared with 70% for conventional distillation).

STEEL

The Steel Industry of the Future partnership seeks improvements in the resource efficiency, productivity, and cost-effectiveness of iron- and steel-making processes. It also encourages technologies to recover and reuse the iron content of scrap and steel mill wastes.

OIT-sponsored technologies commercially available include:

- ◆ Arc Furnace Post-Combustion Lance 62
- ◆ Hydrochloric Acid Recovery System 63
- ◆ Phase Measurement of Galvanneal 64
- ◆ Portable Ultrasonic Inspection System for Testing Tubular Goods 65
- ◆ Recovery of Acids and Metal Salts from Pickling Liquors 66
- ◆ Temperature Measurement of Galvanneal 67
- ◆ Transfer Rolls for Steel Production 68
- ◆ Workpiece Analyzer 69

Arc Furnace Post-Combustion Lance

Impacts

Arc Furnace Post-Combustion Lance Increases Productivity and Saves Energy in Steelmaking

Post-combustion research in a basic oxygen steelmaking furnace has resulted in the development of a new technology that is now being applied in electric arc furnaces to increase productivity, reduce energy requirements, and improve control. The system consists of a water-cooled lance and controls to inject oxygen to combust the carbon monoxide in and above the furnace's foamy slag. The result is a savings of 30 kWh/ton of steel and a 5% to 8% increase in productivity.

The technology was developed by Union Carbide, now Praxair, Inc., with support from both OIT and the American Iron and Steel Institute. It is currently in operation on three electric arc furnaces in the United States and is being marketed worldwide. The potential U.S. market for this technology is nearly 50 million tons of steelmaking capacity.

Benefits

Productivity

Increases electric arc furnace productivity by 5% to 8%.

Product Quality

Improves steel quality and reduces amount of substandard steel through improved process control.

Post-Combustion Lance:

- Post-combusts CO low in the furnace
- Saves power and increases productivity
- Provides highest reported heat transfer efficiency
- Prevents any side effects

Post-Combustion Concept

Overview

- ◇ Developed by Union Carbide, now Praxair, Inc.
- ◇ Commercialized in 1994
- ◇ 6 units operating in the United States in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
1.45	2.46

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
1.051	0.399	96.69	0.290

Applications

Steelmaking operations using electric arc furnaces

Capabilities

- ◇ Results in energy savings of 30 kWh/ton of steel.
- ◇ Improves control of steelmaking process.
- ◇ Post-combusts carbon monoxide to low levels in the furnace.
- ◇ Provides high heat transfer efficiency.

Hydrochloric Acid Recovery System

Impacts

On-Site Hydrochloric Acid Recovery System Helps Steel Manufacturers Handle Wastes

Galvanizing and other steel fabrication processes often use pickling—immersion in a tank of hydrochloric acid (HCl)—to clean raw steel. The technology for recycling used HCl has been available to large installations for some time. Beta Control Systems, Inc., using a NICE³ grant, demonstrated the cost-effective use of this technology in smaller facilities. The closed-loop technology incorporates an evaporator, absorption column, and stripper to clean and concentrate the acid, readying it for reuse. The innovative design uses the latest superplastics and state-of-the-art electronic controls to recycle the acid to exact user specifications.

Benefits of the new recovery system include reduced demand for virgin HCl, the elimination of the use of chemicals for neutralizing waste acid, and energy and cost savings associated with transporting and disposing of the acid. The system will provide small- and medium-size galvanizers that use HCl pickling—representing approximately 60% of the galvanizing industry—with a cost-effective method of waste control. This method translates into a potential reduction in the generation of spent HCl and neutralized sludge of more than 40,000 tons annually.

Benefits

Waste Reduction

Recycles waste HCl for reuse, eliminating disposal of spent HCl and neutralized sludge.

Use of Raw Materials/Feedstocks

Reduces the demand for virgin HCl, conserving petroleum feedstock.

Profitability

Costs less than transporting and disposing of waste acid. Eliminates long-term liabilities of waste disposal. Generates a saleable by-product (iron chloride) that can be used in fertilizer, animal feed, and waste treatment applications.

Hydrochloric Acid Recovery System

Overview

- ◆ Developed by Beta Control Systems, Inc.
- ◆ Commercialized in 1994
- ◆ 5 units operating in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.04	0.10

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.028	0.011	2.695	0.008

Applications

- ◆ Galvanizing operations
- ◆ Steel manufacturers
- ◆ Some specialty metals and electronics

Capabilities

- ◆ Provides cost-effective version of closed-loop HCl recovery system for small- and medium-size plants.
- ◆ Recovers HCl at the source, eliminating disposal and transportation costs.

Phase Measurement of Galvanneal

Impacts

On-Line Phase Measurement of Galvanneal Provides Better Quality Components

During the galvannealing process, steel is first coated with zinc and then passed through a furnace that causes some of the iron in the steel to migrate into the zinc layer. Galvannealed steel has superior properties in terms of weldability and coating and paint adhesion, both critical in metal-forming processes such as the production of automobile body parts. Operating experience has shown that galvanneal properties are related to the phase distribution (exact chemical composition) of the iron in the zinc. Because of molecular interactions, certain phase distributions of iron in zinc yield the most desirable properties. OIT, the Jet Propulsion Laboratory, and Data Measurement Corporation joined together to develop a method of measuring the phase distribution of galvannealed steel on-line, providing instant feedback on product properties and quality.

The new measurement technology uses x-ray fluorescence techniques to rapidly and nondestructively sense and measure the phase distribution of galvannealed steel. The chemical composition (specifically the iron content) of the galvanneal coating on the steel is measured for discrete layers of defined thickness. The technology provides the furnace operator with faster feedback on galvanneal quality, which in turn reduces product variability. The ability to provide a superior quality product will help the U.S. metals industry gain a competitive advantage while improving productivity. Tighter control of the process will enable operators to reduce furnace temperature, thereby saving energy.

Benefits

Energy Savings

Allows precise galvanneal furnace set points to be determined, lowering furnace operating temperature by at least 10%.

Product Quality

On-line system measures properties for entire length of component, allowing entire product to be in-spec.

Productivity/Waste Reduction

Reduces amount of out-of-spec product, decreasing scrap generation and product reworking requirements.

Overview

- ◆ Developed by Jet Propulsion Laboratory and Data Measurement Corporation (now Radiometrie)
- ◆ Marketed by Radiometrie
- ◆ Commercialized in 1996

Applications

Galvannealing operations in the steel and metals fabrication industries, including production of automobile bodies

Capabilities

- ◆ Can operate on-line at typical galvanneal line speeds of 600 feet/minute.
- ◆ Has an accuracy of $\pm 0.5\%$.
- ◆ Requires only two 20-kV x-ray sources.

Phase Measurement of Galvanneal (ideal structure)

Portable Ultrasonic Inspection System for Testing Tubular Goods

Impacts

Portable Ultrasonic Inspection System for Testing Tubular Goods Delivers More Accurate Results

With a grant from DOE's Inventions and Innovation Program, Tubular Ultrasound, Inc., perfected and commercialized an inspection system to find imperfections and wall-thinning conditions in tubular goods used in critical applications (e.g., used by the oil and gas exploration and production industry and in refineries or chemical plants). The new test system uses ultrasound emission and detection to conduct tests on high-strength tubular goods. It replaces a radioactive test method and delivers more accurate results. It has also made improvements over existing ultrasonic and electromagnetic test systems. Because of the high throughput rate, tubular material manufacturers have readily accepted the Tubular Ultrasound system. In addition, end users have adopted the system because of its relatively low cost and portability. The system has fully digital instrumentation and is used in the United States and Europe.

Benefits

Product Quality

Costs less than electromagnetic test methods while furnishing more accurate tests.

Productivity and Profitability

Costs less, is faster, and more sensitive than other ultrasonic and electromagnetic test systems. Eliminates initial installation of defective tubular material, cutting downtime for refits; increases well productivity. Higher throughput rate cuts inspection time for manufacturers and speeds testing in the field. Permits application of lighter wall tubular material by lowering risk of failure.

Pollution Control

Detection of imperfections and wall thinning prevents piping failures and lowers the potential for hydrocarbon and chemical spills.

Overview

- ◆ Developed by Tubular Ultrasound, Inc.
- ◆ Commercialized in 1992 at a U.S. steel tube mill
- ◆ Currently used third-generation systems setting a new industry standard

Applications

- ◆ Manufacturing quality control for high-strength tubular goods
- ◆ Inspecting tubular material to maintain integrity and prevent spills in several industries, including oil and gas field exploration and production, refineries, and chemical plants

Capabilities

- ◆ Is an easy-to-install portable system with a large diameter range.
- ◆ Can be permanently installed in tube mills to verify product quality.
- ◆ Can be installed in the field so end users can verify the quality of tubular goods prior to or after installation.
- ◆ Has fully digital instrumentation.

Portable Ultrasonic Inspection System for Testing Tubular Goods

Recovery of Acids and Metal Salts from Pickling Liquors

Impacts

Acid and Salt Recovery Now Cost-Effective for Smaller Manufacturers

Steel fabrication processes often use pickling (immersing steel in acid) to remove oxide layers from recently heated steel. Technology for recycling the hydrochloric acid has been available for large installations for some time. The Green Technology Group, in collaboration with DOE's Inventions and Innovation Program, developed the Pickliq® process to make acid recovery cost-effective for smaller facilities.

The Pickliq® process combines diffusion dialysis, energy transfer, and low-temperature crystallization technologies to efficiently recover acids and metal salts. It has demonstrated significant gains in production capacity, quality control, and productivity by maintaining pickling tank acid and iron concentrations at preset levels. Bath uniformity and predictable performance raises output and minimizes rejects and rework. To manufacturers, these benefits are even more important than the simple cost savings from eliminating waste. Additional benefits include reduced demand for virgin acids, elimination of chemicals to neutralize waste acid, as well as energy and cost savings associated with acid transportation and disposal.

The process has widespread application in the primary metals industries. It is also applicable in the metal-finishing and circuit board industries for recovering acids and metal salts from all types of etches and metal strips.

Benefits

Productivity

Significantly improves process uniformity and product quality, reduces downtime associated with acid revitalization, improves overall process effectiveness and throughput, and reduces rework. Optimal pickling bath acid concentrations are continuously maintained.

Waste Reduction

Recycles acid for reuse, eliminating disposal of spent acid and neutralized sludge. Reduces the demand for virgin acids, conserving petroleum feedstock.

Profitability

Costs less than transporting and disposing of waste acid. Eliminates long-term liabilities of waste disposal. Generates a saleable by-product (metal salts) that can be used in a variety of applications. Results in rapid payback estimated at 1 to 2 years.

Overview

- ◆ Developed by Green Technology Group
- ◆ First commercial unit installed in 1998

Applications

- ◆ Wire and strip mills
- ◆ Hot dip and other galvanizing operations
- ◆ Steel manufacturers
- ◆ Chemical milling
- ◆ Circuit board manufacturers
- ◆ Anodizing
- ◆ Other metal-finishing operations

Capabilities

- ◆ Provides better process control and product quality.
- ◆ Maintains acid baths at optimum concentration.
- ◆ Permits continuous operation.
- ◆ Can recover hydrochloric, sulfuric, nitric, hydrofluoric, and other acids (including nonmineral acids).
- ◆ Recovers metal salts into a saleable by-product. Metals with recoverable salts include ferrous, nickel, copper, zinc, tin, manganese, and aluminum.

Recovery of Acids and Metal Salts from Pickling Liquors

Advanced Temperature Measurement of Galvannealed Steel

Galvannealed steel is used extensively by the automotive and appliance industries for its corrosion resistance, weldability, and paint adhesion properties. It is produced by dipping a steel strip in a liquid zinc bath and then passing it through a furnace. As the steel strip is heated, an exchange of zinc and iron atoms occurs at the surface, producing the galvanneal coating. The properties of the coating are determined by the distribution of iron and zinc, for which temperature is the controlling factor. Conventional methods for measuring the steel's surface temperature are unreliable because the coating characteristics rapidly change and current control techniques rely largely on visual inspection. A joint effort between OIT, Oak Ridge National Laboratory, and 15 North American steelmakers has developed an advanced temperature sensor for accurate in-process measurement of galvannealed steel.

The system relies on phosphor thermography (originally developed for uranium processing) to provide instantaneous feedback on the quality of the galvanneal coating. Using the temperature-dependency of a phosphor's fluorescence decay rate, the system can accurately measure the temperature of the steel without touching its surface. This approach provides operators with real-time data on furnace temperature, leading to enhanced product quality and reduced production costs. Costly off-line testing and off-spec products are also minimized, improving overall efficiency. These improvements are expected to help increase U.S. steelmakers' competitiveness worldwide and move the steel industry toward realizing their vision for the plant of the future. Additional applications of the technology are being explored in other steelmaking processes as well as in other industries.

Galvanneal Thermometry System Developed for the American Iron and Steel Institute (AISI)

Overview

- ◆ Developed by Oak Ridge National Laboratory for the American Iron and Steel Institute's Advanced Process Control Program
- ◆ Marketed by Bailey Engineers, Inc.
- ◆ Commercialized in 1997

Applications

Process control for the production of galvannealed steel used in automobiles, appliances, and other products

Capabilities

- ◆ Performs on-line, noncontact, quick-response measurements.
- ◆ Insensitive to surface quality, emissivity, and electromagnetic interference.
- ◆ Accurate to $\pm 5^\circ\text{F}$.

Benefits

Energy Savings

Enables accurate in-process galvanneal furnace control, typically reducing operating temperatures.

Product Quality

On-line measurement system reduces variability and enhances product quality. Allows products to be developed meeting tighter tolerances.

Productivity/Waste Reduction

Minimizes out-of-spec product, increasing yield and reducing waste, to improve overall production efficiency.

Transfer Rolls for Steel Production

Impacts

New Nickel Aluminum Transfer Rolls for High-Temperature Applications

A new nickel aluminum alloy developed by Oak Ridge National Laboratory, in conjunction with OIT, has tremendous potential to transform the steel heat-treating industry. Nickel aluminides are strong, hard intermetallic materials that resist wear, deformation, and fatigue from repeated stress or high temperatures. Because they become stronger and harder at high temperatures, nickel aluminide transfer rolls are well suited to replace steel transfer rolls in heat treat roller hearth furnaces.

Sandusky International, Inc., manufactures nickel aluminide transfer rolls used to move steel plates through the heat treatment process. The furnace heats the plates from 1475°F. to 1650°F. to soften them so they can be further processed into other products. Conventional rolls made from steel lose their strength and sag in intense heat, causing the steel plates to vibrate as they move through the heat treatment process. In addition, conventional rolls develop oxide particles on their surfaces that scratch the steel plates, requiring that the processed steel be scrapped. The nickel aluminide rolls do not sag, and the oxides produced on the rolls are smooth so they do not scratch the steel plates.

One Sandusky customer, a major U.S. steel producer, has replaced 20% of its conventional steel rolls with Sandusky's nickel aluminide rolls used for heat-treating steel. The steel producer expects to replace weekly furnace maintenance shutdowns with quarterly maintenance to clean and replace rolls once the producer retrofits the entire heat treatment operation with nickel aluminide rolls. Weekly furnace shutdowns require a lot of energy because the furnace must first be cooled to ambient air temperature for maintenance and then heated to 1800°F. for steel-processing. Eliminating weekly maintenance will increase production and energy efficiency. In addition, the nickel aluminide rolls will produce steel plates having greater, more consistent quality with fewer scratches, reducing the amount of steel scrapped due to imperfections.

Overview

- ◆ Nickel aluminide developed by Oak Ridge National Laboratory
- ◆ Licensed to Sandusky International, Inc.
- ◆ Nickel aluminide transfer rolls technology commercialized in 1993

Applications

Used in heat treat roller hearth furnaces to move high-temperature steel plates through the heat treatment process

Capabilities

Can operate in temperatures as high as 2100°F.

Benefits

Product Quality

Two to three times stronger than conventional steel roll assemblies. Strength increases at temperatures greater than 1475°F. High aluminum content resists oxidation and carburization at high temperatures without adhering to steel. Resistant to corrosion.

Profitability

Extends component life three to five times at life-cycle costs 75% less than costs of steel rolls. Produces steel plates having greater, more consistent quality.

Productivity

Increased roll life reduces furnace shutdowns to replace worn components, resulting in increased production. Replaces weekly maintenance and furnace shutdowns with quarterly maintenance. Time previously used for maintenance can be used for heat-treating steel, increasing mill production by approximately 25%.

Energy and Environmental Savings

Eliminating weekly furnace shutdowns increases the mill's energy efficiency. Reduces damage to steel during heat-treating, resulting in less steel scrap.

Workpiece Analyzer

Textron Systems as subcontractor to Surface Combustion, Inc., in partnership with DOE, have developed a remote, noncontact, laser ultrasonic sensor for use in a wide range of process control and materials characterization applications. Greater emphasis by industry on product quality and process efficiency has resulted in the need for "real time" information on critical material properties, information that can then be used to optimize process control. The new LaserWave system uses a conventional, low-power, pulsed laser to remotely generate surface and bulk ultrasound waves. Advanced optical detection and signal-processing technologies are employed to provide accurate and unique system capabilities. The result is a compact, low-cost packaged system that is insensitive to external vibrations common in industrial settings and operates independently from emissivity changes in the target.

The commercially available laser-wave system can measure workpiece temperature (the focus of the OIT Project), determine workpiece thickness, locate material flaws, detect grain size in metal-processing, detect bonding defects in diffusion bonding, and monitor materials transition in real time. When used to measure the temperature of a metal workpiece being heat-treated in an industrial furnace, the system can permit better process control, resulting in improvements up to 5% in both production rate and energy efficiency. The system has scientific and laboratory applications in addition to industrial applications.

Pulsed Impulse Laser Beam
(ultrasound generation)

Detection Laser (DL) Beam
(detection on same side can be used to determine workpiece surface temperature)

Rayleigh (surface) waves

Bulk Ultrasound Waves (impinging)

Workpiece

Bulk Ultrasound Waves (reflective)

Detection Laser Beam
(detection on opposite side can be used to determine workpiece average temperature)

Two configurations are possible depending on the location of the DL

LaserWave™ Operating Principle

Overview

- ◆ Developed by Surface Combustion, Inc., and Textron Systems Division
- ◆ Commercialized in 1995
- ◆ 1 unit sold to date

Applications

- ◆ Measuring thickness, coating thickness, and surface and bulk temperatures
- ◆ Measuring density changes, phase transformation, and surface hardness
- ◆ Locating material cracks and other flaws

Capabilities

- ◆ Provides real-time process feedback on a variety of material properties.
- ◆ Is noncontact and measurements are nondestructive.
- ◆ Can operate with a moving target.
- ◆ Insensitive to external vibrations.

Benefits

Energy Savings

Saves energy through greater process control and possible reduction in furnace residence time for heat-treating applications.

Product Quality

Real-time measurement of material properties and location of defects leads to improved product quality.

Productivity

High-speed processing shortens time to detect material property changes and increases production rate.

CROSSCUTTING TECHNOLOGIES

OIT supports the development of crosscutting technologies that address common needs within different industries. Some technologies are broad-based (e.g., advanced motors and burners), while others are applicable to industry groups (e.g., metal finishing). Innovations that improve the performance of commonly used industrial equipment and industrial facilities are also encouraged.

OIT-sponsored technologies commercially available include:

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◆ Waste Fluid Heat Recovery System	99
◆ Waste-Minimizing Plating Barrel	100

Aerocylinder Replacement for Single-Action Cylinders

Impacts

Aerocylinder Saves Compressed Air, Lowers Maintenance and Improves Production in Metal Parts Fabrication

With assistance from DOE's Inventions and Innovation Program, George Bozich and Kenneth Smedberg commercialized an invention to replace conventional single-action compressed-air cylinders. Industry has used conventional air cylinders, a rod and piston inside a rigid metallic canister, as die cushions to assist in holding sheet metal during forming operations and as counterbalances to absorb shock to press components.

No matter how precisely manufactured and installed, these cylinders and their air systems required maintenance almost monthly to avoid excessive compressed-air loss and faulty stamping due to press-induced vibration, mechanical wear, and aging gaskets. Until the Aerocylinder, innovation in the basic components used in metal-stamping presses and hammers had been almost nonexistent since 1900. The Aerocylinder is made of stacked air bags (called actuators) that have neither moving parts to wear out nor a rigid guidance system to become misaligned. The air bags are flexible elastomer containers made of synthetic rubber, fabric, and plastic. Like automobile tires, the specific materials used and the number of plies determine the strength and flexibility of the actuators needed for different service and tonnage ratings.

The most significant advantage of the Aerocylinder over existing technology is the prevention of air loss, a common problem and major energy waster in the auto industry (commonly, 2 cubic feet/minute of compressed air is lost for every 4 cubic foot/minute delivered). Aside from lower initial cost, other advantages include the ability to: prevent misalignment, a key reason for cylinder failure; maintain part-forming consistency; allow much longer run times between scheduled maintenance; and minimize unscheduled downtime. Aerocylinders were designed for the metal-forming industry and are used by Ford and GM for automotive part stamping. Applications include metal forging as well as uses in the mining, forestry, offshore drilling, and steel industries.

Benefits

Energy Savings

Saves an average of 32,000 kWh per year per installation.

Productivity

Improves productivity by reducing downtime and prolonging equipment life.

Worker Safety and Health

Enhances safety by preventing failure of high-pressure systems.

Product Quality

Improves equipment performance leading to consistent quality.

Emission Reductions

400 installations cut carbon dioxide emissions by 23,200 metric tons per year.

Overview

- ◆ Developed by George Bozich and Kenneth Smedberg and marketed by Aero products
- ◆ Commercialization began in 1990
- ◆ Installed on more than 400 stamping and welding presses in 1997

Applications

- ◆ Accepted and used in automobile manufacturing industry
- ◆ Other applications include mining, forestry, drilling, and steel operations

Capabilities

Machinery shock absorbers for mining, forestry, drilling, and steel fabrication industries that replace conventional, single-action compressed-air cylinders in industrial forging, stamping, and welding applications.

*Aerocylinder Replacement for
Single-Action Cylinders*

Cathodic Arc Plasma (CAP) Physical Vapor Deposition can Produce Lower Cost Parts

Vacuum Plating Technology Corporation has developed and demonstrated, using a NICE³ grant, a cathodic arc plasma (CAP) physical vapor deposition (PVD) system that can achieve decorative as well as functional coatings. The resulting finish is attractive and has good weather and abrasion resistance.

The deposition rate for the CAP system varies widely from nanometers per minute to tens-of-micrometers per minute. The required deposition rate depends on the desired film morphology, substrate temperature limitations, and whether the material being deposited is a metal or a compound.

The CAP system can produce parts at a lower cost than current technologies (such as electroplating) because it uses less material, requires less energy and labor to operate, has lower maintenance costs, and requires less floor space.

Benefits

Energy Savings

Because of thin coatings, requires about one-half the electric energy of conventional electroplating.

Environmental

Uses no water, has no emissions, and produces only minute amounts of solid waste.

Product Quality

Provides lifetime coatings with superior finish properties.

Overview

- ◆ Developed by Vacuum Plating Technology Corporation
- ◆ Commercialized in 1995

Applications

Metal thin-film coatings of zirconium nitride, titanium nitride, and chromium on a wide variety of substrates, including stainless steel, brass, zinc, aluminum, and plastics

Capabilities

- ◆ Provides high-quality, uniform, smooth, pinhole-free, and broad-area films.
- ◆ Has flexibility for thin or thick coatings.
- ◆ Can coat complex shapes.
- ◆ Achieves coatings with good scratch-, wear-, and corrosion-resistant properties.

Cathode Arc Plasma PVD Principle

Chemical Vapor Deposition Optimizes Industrial and Aerospace Ceramic Matrix Composites

Ceramic matrix composites comprise an emerging technology that is practical for a wide range of industrial and aerospace applications. Ceramic matrix composites are extremely heat-tolerant and corrosion-resistant, making them ideal for applications requiring lightweight materials capable of withstanding high temperatures.

Chemical vapor deposition (CVD) is used to enhance the physical characteristics of the ceramic matrix composites. AlliedSignal Composites, Inc., uses CVD to apply a thin, even interface coating to the surface of ceramic fibers. A coating of silicon carbide is then added to further strengthen the composite, making it stronger than conventional composites and shatterproof upon failure.

Sandia National Laboratory partnered with AlliedSignal Composites, a major producer of high-tech ceramic composites, to optimize the CVD process presently used by AlliedSignal. Researchers used a Sandia research reactor, originally funded by OIT, to determine identities and amounts of gaseous-phase species present during CVD. Sandia researchers developed a computer model whose predictions are now being used to increase the throughput of two AlliedSignal coating reactors. The partnership saved AlliedSignal approximately \$1 million in development time and expenses.

CVD Process

Overview

- ◆ Developed by Sandia National Laboratory in cooperation with AlliedSignal Composites, Inc.
- ◆ Commercialized in 1997
- ◆ 2 CVD reactors presently use the optimized coating process to make ceramic matrix composites

Applications

- ◆ Liners in jet engines
- ◆ Leading edges of jet turbine engine vanes
- ◆ Liquid oxygen thrusters in rockets
- ◆ Components for the reusable launch vehicle for space shuttles

Capabilities

- ◆ CVD ceramic composites can replace superalloys in numerous aerospace and industry applications.
- ◆ Can withstand high-temperature, corrosive environments better than traditional superalloys.

Benefits

Product Quality

CVD ceramic composites weigh about one-third less than superalloy counterparts, have greater strength and toughness than conventional alloys, and will not shatter when failed.

Productivity

Computer software operates reactors at optimal conditions and reduces the time to process CVD ceramic composites. Reduces the number of reactor operations. Increases the number of parts processed per operation, resulting in greater productivity.

Energy Savings

In turbine engines, CVD ceramic composites allow higher operating temperatures that produce greater fuel efficiency.

Diffusion and Thermal Heat Treatment of Bulk Powders

Impacts

New Process to Heat Treat Bulk Metal Powders Reduces Processing Times and Produces Superior Product

Through a grant from DOE's Inventions and Innovation Program, Kemp Development Corporation developed a new process that uses a sealed rotary kiln under a vacuum to diffusion treat and/or heat treat bulk metal powders and to treat solid parts with bulk powders. The tumbling action of the rotating cylinder causes the metal particles to flow in a fluidized manner and to experience constant mixing. This action constantly exposes a new layer of metal particles to the hot cylinder surface inside the kiln, increasing heat transfer several fold. In addition, the vacuum prevents the formation of oxides on the surface of the metal particles during heating and cooling periods. Adjusting the rotation rate of the drum produces a several-fold increase in gas phase reaction kinetics. In addition, controlling drum speed can vary particle flow behavior over a wide range. In one application, yield was increased 30% and space utilization 500%. In addition, the equipment is simple and less expensive to install than conventional equipment.

Benefits

Productivity

Reduces processing times to coat and heat treat materials while producing a superior product. Can create new products that take advantage of more thorough powder processing.

Reliability

Corrosion or erosion control coatings increase end product lifetimes.

Waste Reduction

Automated loading and unloading of bulk powders reduces or eliminates waste.

Profitability

By completely eliminating the need to break apart powders, reduces annealing and associated costs by about 90%. Potential for substantial savings also exists in thermal spray, steel shot, and specialty powder markets. By using exact time, temperature, and gas contact, produces exacting surface treatments for boronizing and aluminizing.

Environmental Savings

Uses 90% less greenhouse gases, methane, and hydrogen in processing.

Diffusion and Thermal Heat Treatment of Bulk Powders

Overview

- ◆ Commercialized by Kemp Development Corporation in 1998
- ◆ Licensed to ACTON Materials, Inc., for treating powders and to PMAC for surface treating solid parts.

Applications

- ◆ Heat treating powdered metal
- ◆ Alloying powdered metals to produce aluminides, carbides, and nitrides and surface treating of solid parts; i.e., boronizing, aluminizing, nitriding, and carburizing
- ◆ Processing steel waste streams to improve recycling of ferric chloride
- ◆ Refining powder metals; i.e., tungsten or cobalt from ores

Capabilities

- ◆ Can process many types of bulk powders, including those destined for frits, glasses, ceramics, refractories, metals, and composites.
- ◆ Can heat treat bulk powders to 1050°C.
- ◆ Can coat metals on ceramics and ceramics on metals.
- ◆ Can produce encapsulated metal powders for thermal storage at temperatures ranging from cryogenic to over 1,000°C. These metal powders can be melted without losing their characteristics.

Direct Source to Object Radiant Heating Panels

Impacts

Electric Radiant Heating System Significantly Reduces Heating and Energy Requirements

Under a grant from DOE's Inventions and Innovation Program, Solid State Heating Corporation, Inc., commercialized a novel radiant heating panel. Because the flat panels integrate into walls or ceilings, installation costs are low. The radiant heater has a long life and no mechanical heat delivery system is required. A radiant heating system will also lower the cost of space heating by approximately 52% compared with electric resistance baseboard heating.

Radiant heating allows a building designer to lower the space-heating requirement for the whole structure and eliminates the need to heat unoccupied areas. Rooms can be maintained at temperatures 6°F to 8°F cooler when using this system and the same comfort level remains for occupants. When the unit is energized comfort is felt immediately even though room temperature is lowered to conserve energy.

Benefits

Productivity

Improves worker output due to increased work space comfort by reducing noise and eliminating heated air movement caused by conventional systems.

Energy Savings

Quick response and immediate heating raises comfort level while ambient air temperature can be 6°F to 8°F cooler than with other system types. Easily accommodates zonal heating systems that eliminate heating of unoccupied spaces in structures. Can lower the cost of heating by 52% compared with baseboard electric resistance systems.

Profitability

Panels have no moving parts and install easily in walls or ceilings. Operates on multiple voltages. Low current draw reduces power required by 30% to 50%. Requires no maintenance.

Environmental

Suitable for clean rooms since it can eliminate the need for forced-air or hydronic heating systems with associated contaminants. General energy savings reduces emissions associated with power production.

Ceiling Mounting

Overview

- ◆ Developed by Solid State Heating Corporation, Inc.
- ◆ Commercialized in 1983
- ◆ Total sales exceed \$6 million

Applications

- ◆ Precise temperature control for spaces or production material in manufacturing or processing
- ◆ Individually controlled work space-heating system for manufacturing and commercial facilities, including clean rooms
- ◆ Space-heating systems for buildings

Capabilities

- ◆ Replaces individual electric resistance heaters, complementing central space-heating systems or installed as the primary heating system for a building.
- ◆ Provides precise temperature control for spaces or materials used in manufacturing or processing.
- ◆ Localizes thermal energy where needed because panels are individually controlled with rapid thermal heating.
- ◆ Increases safety in locations with combustible vapors.

Process Directed Mounting

Direct Source to Object Radiant Heating Panels

D'MAND™ Hot Water Waste Prevention System

Impacts

D'MAND™ System Reduces Water Heating Energy Requirements and Water Waste

Advanced Conservation Technology, Inc., offers a novel system that conserves water and energy in water-heating systems. The system employs a logic that returns water in the hot water pipe to the boiler through the cold-water line until a preset temperature is reached. In conventional systems, water standing in the pipe is sent down the sewer drain until heated water arrives, wasting water. A conventional recirculating system is also wasteful because unused, recirculated heated water rejects heat through the entire loop.

The system employs a thermal sensor so the fixture demanding water only receives it at a prescribed minimum temperature. Retrofit installations are simple because no return pipe line to the water heater needs to be installed. In the residential D'MAND™ Pumping System, the high-performance pump, integrated controller and electronic zone valve are located at the hot water fixture most distant from the water heater. In industrial and commercial installations, each point-of-use fixture can be set up to operate manually, or include motion detectors so that circulation begins the moment a worker enters the facility. The system shuts off automatically when hot water is not needed.

Commercial applications include doctor's offices, hospitals, veterinary clinics, kitchens, salons, day care facilities, and ships. Industries are using the system in factory tool shops and restrooms. Another example of an industrial application is a periodic parts washing station that uses a second occupancy sensor to start the water stream when the parts appear under the faucet.

Overview

- ◆ Developed by Advanced Conservation Technology, Inc.
- ◆ Commercialized in 1992

Applications

- ◆ Industrial process water-heating and service hot water systems for industrial facilities
- ◆ Commercial and institutional water-heating systems
- ◆ Single-family and multifamily residential water-heating systems

Capabilities

- ◆ Water savings of 4,000 gallons/day for industrial and hotel applications and 12,000 gallons/year for residential applications.
- ◆ Can be retrofitted into existing recirculating water heating systems.

Benefits

Profitability

Can negotiate for lower sewer system charges based on documented process water savings in industrial applications. Has lower first costs and operating costs compared with recirculating systems.

Reliability

Extends water-heating system life compared with conventional recirculating systems because pumping only occurs on demand and returned water agitates storage tank. Lower tank temperature will extend system lifetime as much as 20% in residential systems.

Energy Savings

In building applications, lowering water heater temperatures between 10°F and 25°F will save 5% to 15% of energy used for water heating. One hundred industrial installations that save 4,000 gallons per day of water would save 7.8 billion Btu per year.

D'MAND™ Water Heating Sensor System

Energy Saving Radial Deflection Pad Bearing for Rotary Equipment

Impacts

Innovative Pad Bearings Improve Machine Reliability and Life and Save Energy

With support from DOE's Inventions and Innovation Program, Russell Ide developed and demonstrated the superior performance of a unique pad support-bearing system for rotating machinery. Available through KMC, this invention creates a hydrodynamic support structure that allows the pads to deflect and follow the thrust collar under high-load conditions at start-up. The bearing consists of 16 chromium copper pads that form a shaped hydrodynamic wedge to carry the load on a thin fluid film. Inward pad movement as the wedge forms virtually locks the shaft into position, even for heavy-bearing loads, and provides good high-speed stability. Since pad deflection occurs instantaneously at start-up, the bearing is suitable for machinery that frequently cycles on and off. Because the pads eliminate metal-to-metal contact, wear and power consumption are extremely low. Load-carrying capacity has exceeded 4000 psi, but will vary depending on lubricant type and operating temperature.

Benefits

Other

Bearing lifetime two to three times longer than conventional technology and tolerates lubricant contamination. Maintains shaft location with more accuracy and can be used on a wide range of bearing grade materials.

Energy Savings

Requires 20% lower power consumption than conventional bearings. Equipment runtime to maintenance is two times longer than conventional bearings while raising power factor and output. Cumulative gain in power production amounts to one million horsepower.

Overview

- ◇ Commercialized by KMC, Inc.
- ◇ First introduced to industry in 1989
- ◇ 125,000 units installed in 1997

Applications

Bearings for rotational equipment; examples include automotive turbochargers, airplane engines, oil drilling equipment, and other machine parts that rotate at moderate to high speeds

Capabilities

- ◇ Has high-load capacity.
- ◇ Provides high-speed stability.
- ◇ Only requires low-viscosity lubricants.
- ◇ Superior heat dissipation offers wide operating temperature range.
- ◇ Has excellent start/stop capabilities.

Hydrodynamic Multi-Deflection Pad Bearing

Evaporator Fan Controller for Medium-Temperature Walk-In Refrigerators

Impacts

Fan Controller Saves Energy in Two Ways

With assistance from DOE's Inventions and Innovation Program, Advanced Refrigeration Technologies (ART) commercialized an innovative control strategy for walk-in refrigeration systems. The ART Evaporator Fan Controller is inexpensive and easy to install.

The concept and operation of the ART Controller is technically quite simple: refrigerant flow is sensed by temperature differential at the expansion valve within the evaporator. When refrigerant is not flowing through the evaporator/evaporators, voltage is dropped to the evaporator fans, saving energy in two ways. First and foremost, the evaporator fans consume less energy. Secondly, heat introduced to the refrigerated chamber from the evaporator fan motors is decreased. This decrease in heat coupled with a decrease in thermal inversion, results in a decreased overall box load, thereby reducing the compressor/condenser on-duty cycle. The slow fan speed maintains air circulation to avoid temperature stratification. The lower air speed also maintains natural product moisture, thereby increasing shelf life.

Benefits

Energy Savings

Reduces evaporator and compressor energy consumption by 30% to 50%.

Product Quality

Less air movement maintains the natural moisture in open moist product, so freshness/shelf life is increased without affecting overall relative humidity within the refrigerated chamber.

Productivity

Even temperature distribution and lower air velocity improve working conditions and result in workers keeping refrigerated spaces closed.

Profitability

Lower running times increase equipment life span and cut maintenance and replacement costs.

Average daily energy consumption for a 29,200 Btu evaporator

Overview

- ◆ Developed by Advanced Refrigeration Technologies, Inc.
- ◆ Commercialized in 1997
- ◆ Ten units operating in 1997

Applications

Decrease in energy consumption from medium-temperature walk-in refrigeration systems in

- ◆ restaurants, cafeterias/mess halls
- ◆ commissaries
- ◆ correctional facilities
- ◆ grocery and convenience stores
- ◆ clubs, bars, taverns
- ◆ hospitals
- ◆ colleges; other educational facilities
- ◆ naval vessels
- ◆ custom industrial applications

Capabilities

- ◆ Control logic cuts evaporator and compressor energy consumption and lengthens component life.
- ◆ Controller can be retrofitted into existing refrigeration systems or incorporated in the design of new equipment.

Energy-Efficient Processing Technique for Advanced Materials

Nickel and iron aluminides are new classes of advanced materials that exhibit excellent oxidation and carburization resistance up to 2000°F. Their ordered structure, unlike the structure of conventional alloys, makes aluminides more resistant to fatigue conditions. Furthermore, the alloying elements in nickel and iron aluminides cost less than many of the alloying elements in more commonly used stainless steels and superalloys. Until very recently, a lack of both knowledge and willingness by processors to produce high-aluminum-content aluminides prevented these materials from becoming commercially available. A major breakthrough in their production was the development of the Exo-Melt process by Oak Ridge National Laboratory and OIT. This process is based on the principle that the formation of intermetallic compounds is exothermic and is accompanied by the release of large amounts of heat.

To take advantage of this heat, alloying elements for furnace loading are divided into top and bottom sections of the crucible to maximize the heat released during melting. When melting Ni₃Al-based alloy, aluminum and some of the nickel are loaded into the top, resulting in the formation of NiAl. The remaining nickel is loaded into the bottom and alloying elements are sandwiched in between. An exothermic reaction in the top layer of the melt stock causes liquid droplets of superheated NiAl to dissolve the alloying elements and drip down to the remaining nickel. The net effect is an energy savings of close to 50%. To date, the Exo-Melt process has been used in the production of more than 168,000 lb of Ni₃Al-based IC-221M alloy.

Benefits

Energy Savings/Productivity

Reduces melting energy requirements and melting time by maximizing use of the heat released during the formation of intermetallic compounds.

Product Quality

Minimizes oxidation of alloying elements by reducing residence time at high temperatures.

Profitability

Increases refractory or crucible life because operating time at high temperatures is minimized.

Exo-Melt Process

Overview

- ◇ Developed by Oak Ridge National Laboratory
- ◇ Commercialized in 1994
- ◇ Used to produce more than 168,000 pounds of advanced materials in 1997

Applications

- ◇ Production of nickel aluminides, iron aluminides, and titanium aluminides for use in cast and wrought products, including furnace components, tools, and dies
- ◇ Production of accessories for the chemical industry

Capabilities

- ◇ Maximizes the use of heat released during melting of the alloying elements and uses it to heat the remaining melt stock.
- ◇ For the production of Ni₃Al-based IC-221M alloy, requires 2.9 kWh to produce an 18-pound batch versus 5.5 kWh for the conventional melting process.
- ◇ Can be used in bench-, pilot-, and manufacturing-scale applications.

High-Efficiency Dehumidifier for Air-Conditioning Systems Reduces Energy Use

Heat Pipe Technology, Inc. (HPT, Inc.), originally researched a heat pipe technology used in NASA's space programs. Through a grant from DOE's Inventions and Innovation Program, HPT, Inc., revised the technology for several commercial uses.

The HPT, Inc., system can fit any air-conditioning system. Built in two sections, one section resides in the warm return airstream and the other in the cold supply airstream. The heat pipe automatically operates whenever the air-conditioning system runs. The first section absorbs heat from the return air before it reaches the cooling coil, which lowers the operating temperature of the evaporator coil, which in turn increases the moisture removal capacity of the system by 50% to 100%. This precooling effect lowers the cooling load on the compressor, which can be downsized in new or retrofitted installations. The heat absorbed by the first section of the heat pipe is transferred to the second section to reheat the supply air for humidity control. Lower humidity indoor air feels more comfortable, so cooling temperature thermostat settings can be higher to save more energy (generally, each 1°F rise in the thermostat setting results in a 7% savings in electricity costs). Successful end-use applications include storage facilities (warehouses, chemical storage, paper products); the food industries (supermarkets, restaurants, food-processing plants); public and commercial buildings; health facilities (hospitals, clinics, laboratories, fitness centers); indoor pools and spas; and schools, libraries, archives, and museums.

High-Efficiency Dehumidifier Heat Pipe in A/C System Application

Overview

- ◆ Developed by Heat Pipe Technology, Inc.
- ◆ Commercialized in 1991
- ◆ \$4 million in sales in 1997
- ◆ 10,000 systems operating in the United States in 1997

Applications

- ◆ Humidity control for material processes
- ◆ Space cooling and dehumidifying for industrial, commercial, institutional, and residential buildings
- ◆ Agriculture and industrial dehumidifying and drying (rice drying application improves productivity)

Capabilities

- ◆ Enhances dehumidifying capacity of cooling and refrigeration systems.
- ◆ Applicable for new equipment or retrofit systems.
- ◆ Recovers reheat energy.

Benefits

Improved Indoor-Air Quality

Increases the dehumidifying capacity of an air conditioner by as much as 91%, which improves health conditions, such as arthritis, and helps prevent the growth of mold, mildew, fungus, and dust mites—all common allergens. Capable of helping cure “sick building” problems with conditioned fresh air. Improves worker productivity as a result.

Preservation

Reduces humidity-related deterioration of artwork, books, walls, carpets, and other furnishings.

Reliability

Eliminates the need for reheat or desiccant systems and operates with no mechanical or electrical input.

Energy Savings

Uses 50% less energy than electric reheat and about 25% less energy than air conditioning systems using other types of reheat.

High-Efficiency Direct-Contact Water Heater

Impacts

Direct-Contact Water-Heating System Increases Heater Efficiency and Reduces Operating Costs

Through a grant from DOE's Inventions and Innovation Program, KEMCO Systems, Inc., created a near ideal heat transfer system for commercial and industrial water-heating systems. KEMCO'S water-heating system employs a water-cooled burner sleeve and combustion zone to extract all possible energy from natural gas combustion by bringing water into direct contact with a submerged-flame, jet-type burner. The incoming water is directed through stainless steel walls of the combustion zone. The balance of water to be heated is sprayed into the top of the vessel, where it absorbs heat from the exiting flue gases. The spray falls directly into the open flame, collects in the bottom of the tank, then is pumped to the storage tank or load. This system captures the related latent heat of vaporization, which can represent as much as 13% of the total heat. Compared with a water heating system with a 70% conversion efficiency, a KEMCO boiler improves efficiency by 40%.

A KEMCO 15 million Btu/hour unit that replaced steam boilers at the Ford Motor Company's automotive assembly plant in Edison, New Jersey, saves approximately \$400,000/year. A Wisconsin concrete producer found that fuel savings from its KEMCO heater amounted to \$0.15/cubic yard of concrete produced. A hospital in Green Bay, Wisconsin, installed a KEMCO heater in its laundry facility and is the first laundry to reuse all of its hot water.

Benefits

Profitability

Uses a direct-contact heater with a stainless steel atmospheric vessel, saving costs of employing licensed operators and eliminating the need to buy insurance for a high-pressure system, conduct annual inspections, and buy boiler treatments and chemicals.

Environmental Savings

Direct-flame heating significantly lowers oxygen content of the heated water, reducing corrosive properties of the heated water and reducing air emissions from gas combustion.

High-Efficiency Water Heater

Overview

- ◆ Commercialized by KEMCO Systems, Inc.
- ◆ First introduced to the laundry, textile, and tanning industries in the 1980's
- ◆ Over 3,750 U.S. installations and 4,000 plus systems operating in 1997

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
1.80	10.9

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.126	105.2	0.003

Applications

Industrial or commercial water-heating, including auto manufacturing phosphate degreasing, concrete production, apparel wet-processing, pulp and paper plants, hatcheries, food-processing plants, and laundry systems

Capabilities

- ◆ Provides instantaneous water heating within seconds, not hours.
- ◆ Can provide flow rates from 10 to 500 gallons/minute.
- ◆ Available in 1.2 to 25 million Btu/hour capacities, USDA-FDA-U.L. approved.

OIT Development Eliminates Global Warming Gas In Semiconductor Manufacturing

Alzeta Corporation announced that since introducing the high-temperature radiant burner just 18 months ago, it has delivered more than 250 of the burners – a burner type developed with support from OIT. The high-temperature radiant burner forms the core of a thermal processing unit that destroys up to 99.9% of one of the most potent classes of global warming gases known – the perfluorocarbons (PFCs). PFCs, which included C_2F_6 and difficult-to-destroy CF_4 , are generated during the semiconductor manufacturing process. PFCs are among the most potent greenhouse gases known, having high global warming potential and extremely long atmospheric life times. For example, C_2F_6 has a warming potential 9,200 times that of CO_2 and an atmospheric lifetime of 10,000 years. The long lifetime means that even small emissions will contribute to the cumulative atmospheric global warming burden that will persist for thousands of years. The PFC destruction system, the TPU 4200, received a “best products” award from *Semiconductor International* magazine and is sold by Edwards High Vacuum International. Edwards selected the Alzeta burner for its ability to operate reliably at high process temperatures and provide uniform, well controlled heat. The TPU 4200 is placed downstream of semiconductor wafer etching “tools” made by Applied Materials and Novellus. Because plants have multiple tools to serve multiple production lines, several TPU 4200 units are generally installed in each plant. TPU 4200 customers include well known companies such as Advanced Micro Devices, Hewlett Packard, and Motorola, as well as several manufacturers in Japan

Benefits

Energy Savings

Provides up to 2% increase in thermal efficiency while increasing boiler steam output by up to 20%.

Pollution Control

Reduces NO_x emissions by up to 80%.

Productivity

Reduces maintenance and associated downtime by eliminating soot buildup.

Ease of Installation

Manufactured in standard-size cylindrical segments to facilitate shipping and installation.

Overview

- ◆ Developed by Alzeta Corporation
- ◆ Commercialized in 1995

Applications

- ◆ Gas-fired boilers
- ◆ Adiabatic thermal oxidizers for destroying hazardous volatile organic compounds
- ◆ Paper dryers
- ◆ Other boilers, furnaces, dryers, and combustion equipment applications

Capabilities

- ◆ Can operate reliably with higher-than-normal process temperatures.
- ◆ Has uniform and well-controlled heat flux.

High-Temperature Radiant Burner

Improved Diesel Engines

Impacts

Redesigned Diesel Engines Improve Heavy Truck Fuel Economy

The KIVA computer model resulted from the efforts of a diesel engine working group established under DOE auspices in 1979 to guide the development and application of diagnostic tools and computer models. Under the guidance of this group, the multidimensional KIVA model was developed to help engine designers overcome some of the technical barriers to advanced, more fuel-efficient engines.

KIVA allows designers to visualize and infer the effects of alterations to engine geometry without actually building the engine. Cummins Engine Company has used KIVA as part of piston design modifications and other modifications to diesel engines for heavy trucks. In a cooperative effort with DOE, Cummins has also improved engine breathing, pulse-preserving manifolds, and turbocharger design. Cummins has improved the diesel engine sufficiently to increase the mileage by nearly one-half mile/gallon. With millions of trucks and buses currently on the road, this improvement in engine efficiency yields a significant improvement in energy savings.

Benefits

Productivity

Reduces time required from engine design to production.

Waste Reduction

Optimization in engine performance considerably reduces emissions, including unburned hydrocarbons.

Competitiveness

Helps the U.S. automotive industry strengthen its competitive position relative to Europe and Japan.

Overview

- ◆ KIVA computer model developed by Los Alamos National Laboratory, Sandia National Laboratories, Southwest Research Institute, and others
- ◆ Commercialized in 1991
- ◆ Cummins Engine Company the first to use KIVA to redesign diesel engines for improved energy efficiency

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
69.6	232

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
5.568	4.872	5610	0.348

Applications

- ◆ Visualizing effect of design changes on engine performance
- ◆ Assessing engine ability to use alternative fuels or reduce emissions
- ◆ Optimizing engine operation to reduce emissions

Capabilities

- ◆ Can simulate precombustion fluid motion, chemical kinetics, flame propagation, and combustion dynamics occurring in engines.
- ◆ Can nonintrusively investigate airflow and diesel spray characteristics.

Membrane System for Purified Gas Production

Impacts

Hollow-Fiber Membrane System Improves Combustion Efficiency of Industrial Burners

Industrial burners are typically fired with a mixture of fuel and ambient air, which contains 21% oxygen and 79% nitrogen. Because only the oxygen is used in the combustion process, the energy consumed in heating the nitrogen represents an energy loss. Recognizing the need for increased combustion efficiency, OIT funded A/G Technology to develop a membrane-based air separation process to produce oxygen-enriched combustion air. The new semipermeable, polymeric membrane system—known as a hollow-fiber membrane system—increases the oxygen content of air to about 35% at less cost and lower energy demand than cryogenics or pressure swing absorption, the two most commonly used air separation processes.

The hollow-fiber membrane unit consists of thousands of hollow polymer fibers inserted into a cartridge, which is then potted inside a pressure vessel. The unit is highly compact and can be combined with other units to form a system whose flow rates are compatible with a wide range of industrial applications. Approximately 66 of the units are currently in use. A/G Technology has also adapted the system to produce purified nitrogen streams for other industrial applications.

Benefits

Productivity

Unit's portability and modularity increase its operating flexibility and applicability to both small- and large-scale operations.

Profitability

Has lower operating and maintenance costs than conventional air separation technologies. Eliminates costs associated with renting, shipping, and storing gas cylinders for conventional technologies.

Overview

- ◆ Developed by A/G Technology
- ◆ Commercialized in 1987
- ◆ 63 units operating in 1997

Applications

- ◆ Production of oxygen-enriched combustion air for industrial burners used in high-temperature applications in the steel, aluminum, copper and brass, glass, and carbon black industries
- ◆ Production of purified nitrogen streams

Capabilities

- ◆ Single-stage membrane system can increase the oxygen content of air from 21% to 35%.
- ◆ Multistage membrane system can increase the oxygen content to 45%.
- ◆ Hollow-fiber membrane has greater ability to separate oxygen from nitrogen than conventional membranes.

AVIR™ Gas Separation Cartridge

Meta-Lax Stress Relief Process

Impacts

Meta-Lax Stress Relief Method Eliminates Pollution and Reduces Fuel Consumption

Operations such as machining and casting can introduce stresses that degrade product performance. Stress relief by heat treatment prevents distortion and crack propagation. Heat treating requirements contribute to higher production and energy costs.

With help from DOE's Inventions and Innovation Program, Bonal Technologies, Inc., developed the Meta-Lax process that applies subresonant vibrational energy to relieve stress in metal objects. The process is particularly effective with welded structures and can be applied during or after welding. Meta-Lax equipment is portable and yields results much faster than conventional, unmovable heat-treating furnaces (30-minute average compared with 6 hours for a furnace).

Benefits

Product Quality

Work piece performance is comparable or better than thermally stress relieved parts. The process causes no degradation of mechanical properties, distortion or scaling. With welding, finer, uniform grain structures are generated, giving higher ductility (up to 400%) and impact strength (up to 100%). Weld cracking is reduced by 95%, also weld distortion and porosity is lowered. The need for postweld stress relief is eliminated.

Productivity

Requires 98% less time for stress relief. Reduces processing costs 95%. Fabrications time reduced 25%, milling time reduced 40%, grinding time reduced 50%.

Material Savings

Raw material is saved though increased fatigue life (5% to 300%) and reduced scrap rate (50% to 100%).

Pollution Control

Pollution-free operation.

Energy Savings

Vibrational stress relief reduces energy consumption by 98% compared with a natural-gas-fired heat-treating furnace.

Overview

- ◆ Commercialized in 1991
- ◆ 668 units operating in United States

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
13.6	23.2

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.952	794.9	0.020

Applications

- ◆ Metal fabrication and machining industries; applicable to castings, forgings, weldments, and metal plates
- ◆ Stress relief of parts used in several industries such as automotive, aerospace, mining, defense, paper production, and shipbuilding

Capabilities

- ◆ Uses mild subharmonic vibrational energy to relieve stress, a proven substitute for 80% to 90% heat treating metalworking applications.
- ◆ Treats a wider variety of work pieces with versatile, portable unit.

Meta-Lax Stress Relief Process

User-Friendly Software Facilitates Selection of Energy-Efficient Motors

Three-phase electric motors and the systems they drive account for 69% of electricity use in the industrial sector and over 50% of all electricity consumed in the United States. Energy-efficient motors are available that can reduce energy use and operating costs, but they tend to have higher capital costs. Although most high-efficiency motors repay their additional cost quickly in energy savings, many potential users need help finding the right motor for a particular application. To encourage the use of high- and premium-efficiency motors, OIT and the Bonneville Power Administration funded the development of the MotorMaster+ software by the Washington State University Cooperative Extension Energy Program.

Updated annually, the user-friendly, Windows-based MotorMaster+ contains an abundance of motor management features. Users can create a detailed inventory of motor systems, listing nameplate, field measurement, and operating data. A motor history feature helps track maintenance and system improvement actions. Motor replacement analysis is easily performed on an individual or batch basis with results presented in terms of payback or return on investment. MotorMaster+ also has a savings tracker feature that allows plant personnel to document the energy, demand, and dollar savings and environmental benefits from their energy management program.

A new version of the software (Version 3.0) became available in fall 1998. New features include multiuser access over a local or wide-area network, variable-load capability, improved motor load and efficiency estimation algorithms, and an updated manufacturer price and performance database. MotorMaster+ 3.0 will be available through OIT's Motor Challenge Program on disk, on CD-ROM, and downloadable from their website.

Benefits

Energy Savings

Encourages the use of energy-efficient motors, resulting in potentially substantial energy and demand savings.

Pollution Control

Energy savings result in decreased emissions and other environmental damage associated with electric power production.

Productivity/Profitability

Using properly sized energy-efficient motors reduces energy consumption, improves reliability, and reduces operating and maintenance costs.

Overview

- ◆ Developed by Washington State University Cooperative Extension Energy Program
- ◆ Available through the OIT's Motor Challenge Program
- ◆ Over 6,000 users have registered for the software

Applications

- ◆ Selecting the best available energy-efficient motor for a given application
- ◆ Facilitating motor system management with inventory and maintenance history features

Capabilities

- ◆ Contains price and performance data for more than 17,500 motors from 17 manufacturers.
- ◆ Calculates the energy, demand, and dollar savings associated with an energy-efficient motor.
- ◆ Performs simple payback and detailed life-cycle cost analyses to support purchase decisions.
- ◆ Reports reductions in greenhouse gas emissions.

Electric-Motor Systems—an Integrated System of Electric Motors, Drives, and Mechanical Equipment

Nickel Aluminide Components Can Replace Steel Alloy Components in High-Temperature Applications

A new nickel aluminum alloy developed by Oak Ridge National Laboratory (ORNL) in collaboration with several industrial partners has tremendous potential to transform the metal heat-treating, processing, and casting industries. Nickel aluminides are strong, hard intermetallic materials that resist wear, deformation, and fatigue from repeated stress or high temperatures. Because they become stronger and harder at high temperatures, components made from nickel aluminide are well suited to replace steel alloy components in high-temperature applications. Approximately 12 industries have licensed ORNL's nickel aluminide alloy compositions for various industrial applications.

Nickel Aluminide Dies for Hot-Pressing Neodymium-Iron-Boron Magnets

Metallamics is manufacturing and selling nickel aluminide dies for hot-pressing neodymium-iron-boron magnets using materials technology developed by ORNL. The new dies last up to ten times longer than conventional dies and impart an improved microstructure to the magnets. This technology can be applied to other high-temperature molding applications by further developing cost-effective machining technologies.

Nickel Aluminide Punches for Glass Molding

Metallamics, Inc. is also refining a process for manufacturing a precision-cast nickel aluminide alloy punch for glass molds that operates at up to 1550°F. The punch improves product quality, lowers production costs, reduces the number of rejects, and minimizes reworking of materials. The number of parts produced with the new punch is several times greater than that obtained with conventional punches.

Benefits

Product Quality

- ◆ Lighter and five times stronger than stainless steel.
- ◆ Strength increases at temperatures greater than 1475°F.
- ◆ High aluminum content resists oxidation and carburization at high temperatures.
- ◆ Resistant to corrosion.

Profitability

- ◆ Extends component life three to five times at life-cycle costs 75% less than costs of components made with conventional alloys.
- ◆ In steel processing, produces greater, more consistent quality of steel.

Productivity

- ◆ Increased component life reduces plant downtime to replace worn components.

Overview

- ◆ Developed by Oak Ridge National Laboratory
- ◆ Commercialized in 1994
- ◆ Technology licensed to 12 companies

Applications

- ◆ Components for oxidizing and carburizing environments, including heat trays, furnace rolls, shear blades, molds, radiant tubes, high-temperature material-handling equipment, and automotive components
- ◆ Casting, heat-treating, and forging operations
- ◆ Dies for casting neodymium-iron-boron magnets
- ◆ Punches for glass molding

Capabilities

- ◆ Can operate in temperatures as high as 2400°F.
- ◆ Can be cast using investment, lost foam, green sand, and centrifugal methods, permitting a variety of surface finishes.

Improved Characterization of Slurries Reduces Energy Use and Improves Product Quality and Productivity

Slurries—mixtures of solids and liquids—are found throughout the industrial sector but occur most commonly in the chemicals, food-processing, and pulp and paper industries. The lack of an effective method of measuring particle-size distribution for slurries containing very small particles (less than 1 micrometer in diameter) at the high concentrations commonly found in industry is a major cause of overgrinding and low yield in the production of pigments, clays, and numerous other materials. Pen Kem, Inc., in cooperation with OIT, developed a new sensor to measure particle-size distribution in slurries. The sensor system uses a computer-based mathematical model to estimate particle-size distribution from the behavior of ultrasound as it passes through a solid/liquid suspension of a given concentration.

The new sensor is faster, more precise, and has more operating capabilities than conventional particle-size measurement systems. It also provides additional information not available with those systems; information that can be used to improve product quality and productivity. A laboratory version of the particle-size distribution sensor has been commercialized; nine units are operating worldwide (four in the United States) for research in industry, government, and academia.

Benefits

Energy Savings

Reduces grinding electricity requirements by eliminating overgrinding. Reduces thermal drying needs because slurries with more uniform distribution of particle sizes undergo mechanical dewatering more efficiently.

Product Quality/Productivity

Reduces production of substandard material, lowering reworking costs and improving product yields.

Competitiveness

Allows the design of improved products with characteristics that better meet customer needs.

Overview

- ◆ Developed by Pen Kem, Inc.
- ◆ Laboratory version commercialized in 1994
- ◆ 4 units operating in the United States in 1997

Applications

- ◆ Measures the size of particles within slurries such as those found in the chemicals, pharmaceuticals, cement, clay, food-processing, and pulp and paper industries
- ◆ Specific applications in the characterization of abrasives, catalysts, ceramic slips, emulsions, glass powders, inks, metal oxides and powders, minerals, ores, phosphors, and pigments

Capabilities

- ◆ Can analyze slurries at concentrations as high as 50%.
- ◆ Can be used with particles ranging in size from nanometers to microns.
- ◆ Measures samples without dilution.
- ◆ Can be used with mixed slurries.

Particle-Size Distribution of Mixed Systems

Pinch Analysis Heat Plants Integrate Individual Operations, Improving Efficiency

Industry almost exclusively relies on the combustion of fossil fuels to supply process heat, resulting in large emissions of carbon dioxide and other pollutants. Using industrial heat pumps to recycle the waste heat currently being thrown away can save energy while reducing combustion-related emissions. In the late 1980s, OIT began actively seeking more opportunities to demonstrate heat pumps in industrial applications. This effort used a pinch analysis to optimize process heat integration in a plant containing numerous individual process streams.

A pinch analysis of a wet-corn-milling plant in Alabama showed that modifying the existing heat exchangers (evaporators) would save 56 million Btu/hour. Adding a third heat pump to the two existing heat pumps would save an additional 16 million Btu/hour. New thermal vapor recompression heat pumps were added to two existing evaporators in the early 1990s, with overall process fuel use reduced by as much as 33%.

Benefits

Energy Savings

Achieves energy savings through heat pumps, heat recycling within the processes, and improved heat-exchange networks.

Waste Utilization

Can use energy otherwise discharged as waste heat.

Profitability

Use of heat pumps eliminates capital expenditures associated with new boilers, cooling towers, and evaporation systems needed to expand production.

Pinch Analysis

Overview

- ◆ DOE-sponsored pinch analyses begun in 1988
- ◆ 14 plants studied
- ◆ 8 companies proceeded with retrofit heat pump designs
- ◆ 1 company installed new heat pump equipment

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.09	0.57

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.000	0.006	5.261	0.000

Applications

- ◆ Locating the most productive process modifications and heat pump opportunities within a complex process to improve overall process efficiency
- ◆ All major process industries

Capabilities

Pinch analysis

- ◆ Tracks energy flows and shows where heat is being lost or wasted.
- ◆ Identifies the areas where energy can be conserved for the least amount of money.

Industrial heat pumps

- ◆ Can economically "lift" heat from one process stream to another at approximately 50°F to 100°F and deliver heat at up to 350°F.
- ◆ Typically use electricity, high-pressure steam, or waste heat.

Real-Time Neural Networks for Combustion Optimization of Utility Boilers Reduce Emissions

Nitrogen oxides (NO_x) resulting from the combustion of fossil fuels are damaging to the environment. NO_x emissions from coal-fired boilers, such as those used by industry and electric utilities, can be reduced by appropriately manipulating combustion process set points. However, it is beyond the capability of existing plant control systems to optimize these set points during actual plant operation. Pegasus Technologies developed and demonstrated, using a NICE³ grant, the NeuSIGHT system to optimize combustion control settings for minimal NO_x emissions while maintaining the required exit gas temperatures, levels of unburned carbon, and flue gas corrosives. The on-line system dynamically adapts to changes in plant operating conditions and accommodates equipment performance variations throughout typical maintenance cycles. In many cases, this approach can eliminate the need to install low-NO_x burners to meet regulatory requirements.

The computer model, which uses an advanced form of artificial intelligence known as a neural networks, has been shown to be capable of improving boiler efficiency by as much as 5% and reducing NO_x emissions by 20% to 60%. Emissions of CO₂ and SO_x would also be reduced in direct proportion to the amount of fuel saved. The cost of reducing NO_x emissions using the model is much lower than the cost of installing low-NO_x burners or catalytic converters. To date, 20 units have been sold. Pegasus Technologies forecasts that 37% of the U.S. pulverized coal plants and 25% of plants worldwide will use neural network systems by 2010.

Benefits

Waste Reduction

Reduces emissions of combustion products, including NO_x, SO_x, and CO₂.

Natural Resources

Reduces the need for new power plants for utility expansion projects, thus reducing associated impacts on land and water.

Profitability

Improved heat rate means that more electricity is produced per unit of CO₂ and SO_x emitted.

Real-Time Neural Networks for Combustion Optimization – Process Flow Diagram

Overview

- ◆ Developed by Pegasus Technologies
- ◆ Commercialized in 1995
- ◆ 20 units currently operating

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
2.4	5

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
3.000	1.140	249.0	0.864

Applications

Coal-fired boilers, particularly those with capacities of 25MW or greater

Capabilities

- ◆ Reduces NO_x emissions by 20% to 60% while maintaining or improving plant thermal efficiency and reducing SO_x and CO₂ emission levels.
- ◆ Generates set point targets that are optimized to dynamically balance the trade-offs between NO_x emissions, heat rate, and unburned carbon.

Retractable® Labyrinth Packing Seals for Turbine Shafts

Impacts

Retractable® Labyrinth Packing Seals for Turbine Shafts Provide Significant Energy Efficiency Improvements

A grant from DOE's Inventions and Innovation Program helped redesign shaft sealing rings for turbines that will end wear damage and improve turbine efficiency. The Retractable® Packing rings self-adjust from the gap required for turbine start-up to that required during normal operation. This innovative technology offers savings in both energy and operating costs through improved efficiency and reliability.

Conventional labyrinth seals are segmented and positioned by radial flat springs. Retractable® Packing replaces the flat springs with coil springs between the segments to enlarge shaft clearance during start-up to avoid damage caused by thermal distortion and vibration as the unit passes through its critical speed zone. High-pressure steam enters the ring segment to restore design clearance for normal operation. The innovative seals have clearances exceeding original equipment specifications.

The seals are easy to install because they have fewer parts than conventional turbine labyrinth seals. An improved tooth design also reduces blade tip seal rubbing and the seals can be custom fit onsite with an optional brush for upgrading or retrofitting turbines.

Overview

- ◆ Commercialized by TurboCare Division of Demag Delaval Corporation
- ◆ Patented field-proven design with over 10 years of operating experience
- ◆ Installed in over 400 units worldwide, in turbines with capacities from 11 to 1100 MW

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
6.379	52.13

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
6.361	2.487	618.1	1.819

Applications

Utility and industrial steam turbines for power generation or mechanical drives

Capabilities

Available for new steam turbines or retrofits to improve seal clearance beyond original design specifications.

Benefits

Reliability

Prolongs turbine life by making start-ups smoother and eliminating component wear.

Profitability

Lowers maintenance costs.

Productivity

Increases power plant efficiency.

Energy Savings

Higher turbine efficiency lowers heat rates from 1% to 2%. Tighter clearances increase power output between 1% and 4%.

Retractable Labyrinth Packing Seals for Turbine Shafts

Reusable Vacuum Bagging for Manufacturing with Composite Materials

Impacts

Reusable Vacuum Bagging a Major Innovation for Manufacturing with Composite Materials

Manufacturing high-performance composite parts often requires build up of many layers of continuous-filament or woven-fabric lamina. Voids and air bubbles must be removed between layers to ensure the product meets specifications and will not delaminate. With a grant from DOE's Inventions and Innovation Program, inventor Cosby Newsom demonstrated the merits of a new vacuum-bagging technology to replace a thin-film and sticky-tape method that had prevailed in industry for 40 years. This reusable vacuum bagger uses the same silicon form for 100- to 200-part runs. Depending on the length of production runs, costs per cure have been cut by 40% to 50%. The technology employs a patented keyhole and channel seal to create an airtight, separable joint between the channel (bonded to the tool base) and the keyhole (bonded to the flexible, silicone rubber diaphragm). Applying a vacuum between the diaphragm and tool and the lay-up uniformly seals the part. The lay-up and tool can be put into an autoclave to increase pressure or to cure the part. No cleanup is required after parts have been cured. The keyhole seal and channel separate easily to remove the part and no material is scrapped. The tooling is quickly ready to accept another part.

Companies using Bondline Products' Reusable Vacuum Bagging system include large firms such as Boeing, Lockheed, and Goodyear, as well as smaller companies involved in composite material fabrication.

Benefits

Productivity

Significantly improves process uniformity and product quality. Speeds production process by employing less skilled labor and shortening tool turnaround. Improves overall process effectiveness and throughput by consistently maintaining cure conditions. Reduces rework resulting from bag wrinkles, vacuum losses, and bridging.

Waste Reduction

Reduces use of expensive disposable materials, eliminating disposal costs. Eliminates need for throw-away breather material by evacuating bulk while maintaining vacuum. Conserves petroleum feedstock.

Profitability

Applications have pay backs after five uses. Labor costs cut by 40% or more in laminating applications.

Overview

- ◆ Developed by Bondline Products
- ◆ Commercialization began in 1988
- ◆ Accepted by high technology manufacturers of composite laminates

Applications

- ◆ Airtight vacuum bagging system for autoclave or oven curing and debulking of composite parts
- ◆ Designing and fabricating large and small parts made with composite materials for aircraft, aerospace, transportation, electronic, recreation, and other industries

Capabilities

- ◆ Flexible silicon diaphragm can be reused 100 to 200 times.
- ◆ Can convert existing tools or design into new ones.
- ◆ Concept adaptable to pressurized autoclave mandrills.
- ◆ Tolerates temperatures to 400°F and autoclave pressures.

Silicone Rubber Vacuum Bag

Reusable Vacuum Bagging for Manufacturing with Composite Materials

Reverse Brayton Cycle Solvent Recovery Heat Pump

Impacts

Brayton Cycle Heat Pump Recovers Solvents Economically and Efficiently

Under an OIT contract, 3M and Nucon International developed a Brayton cycle solvent recovery heat pump with inherent cooling and heating capabilities that economically and efficiently recovers solvents. The reverse Brayton cycle works as follows:

To recover solvents, the heat pump first compresses the solvent-laden gas stream and extracts heat from it at a constant pressure in a regenerator (the reverse part). Most of the solvent is condensed. As the solvent stream continues through the process, a lower temperature is achieved through turboexpansion, condensing the remaining solvent. The work performed by the turboexpander partially drives the turbocompressor. To complete the cycle, the cold, solvent-free gases pass through to the other side of the regenerator to recoup the heat.

The Brayton cycle heat pump can be integrated with a carbon adsorption/inert-gas process to regenerate the adsorbent bed. This approach provides a more economical implementation of inert-gas regeneration by allowing lower temperatures as the inlet solvent concentration decreases in the regeneration step.

Benefits

Productivity

Reduces the time to reach steady state from 2 hours to 10 minutes. Offers increased operational capacity between regenerations. Does not generate corrosive acids that shorten equipment life. Use of a mobile Brayton cycle heat pump enables multiple sites to be serviced by a single system.

Product Quality

Encourages industry to use more expensive solvents to achieve higher-quality products (e.g., the manufacture of magnetic tape).

Waste Reduction

Effectively recovers volatile organic compounds (VOCs) and chlorofluorocarbons (CFCs) otherwise constituting a waste stream requiring treatment, storage, and disposal as hazardous waste. No emission exists in closed-cycle systems.

Use of Raw Materials/Feedstocks

Reduces demand for new solvents, saving petroleum feedstock and energy used to produce virgin solvents.

Reverse Brayton Cycle Solvent Recovery Heat Pump

Overview

- ◇ Developed by 3M and Nucon International
- ◇ Commercialized in 1989
- ◇ 10 units operating in 1997, 7 operating in the United States

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.52	1.90

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.037	0.036	40.76	0.002

Applications

- ◇ Recovery of VOCs and CFCs from industrial waste streams
- ◇ Adhesive, coating, dry-cleaning, film and tape manufacturing, petrochemical, plastic foam, printing, textile, pharmaceutical, food-processing, and wood composite industries

Capabilities

- ◇ Recovers VOCs and CFCs economically and efficiently through condensation.
- ◇ Can be integrated with carbon adsorption process to regenerate adsorbent beds.

SIDTEC™ Condenser Maintenance Program

Impacts

SIDTEC™ Condenser Maintenance Program

With assistance from DOE's Inventions and Innovation Program, Superior I.D. Tube Cleaners (SIDTEC™), Inc., invented the SIDTEC™ mechanical on-line condenser maintenance service program for thermal power plants. In power plants using surface water to cool condensers, water-borne debris and microorganisms accumulate on strainers and pipes, reducing water flow and the condenser's heat transfer ability. Condensers must be cleaned regularly to maintain system efficiency and to keep the power plant operating.

The SIDTEC™ program incorporates a two-part tube cleaner and a recovery system. The cleaning elements, or Rockets™, are injected into the condenser cooling water system, conveyed through the condenser tubes with the normal flow of water, and recovered in the discharge. The cleaning element contacts the tube surfaces, wiping away mud, silt, and biofouling deposits. Near-neutral buoyancy ensures even distribution throughout all condenser tubes. The product replaces conventional cleaning systems, such as automatic tube-cleaning systems or sponge balls; chemicals used to clean the condensers; and off-line mechanical tube-cleaning, which is costly in manpower and lost generation while the unit is off-line.

On-line Condenser Tube Cleaner

Overview

- ◆ Invented by James Echols of Superior I.D. Tube Cleaners (SIDTEC), Inc., and licensed to Betz Water Management Group
- ◆ Commercialized in 1992
- ◆ Six plants currently under long-term contracts valued at almost \$1.3 million annually in the United States

Applications

Maintaining water-side tube cleanliness in the main steam condenser in thermal power plants

Capabilities

- ◆ Mechanically removes condenser tube deposits through the use of proprietary, ultra-high molecular weight polyethylene Rocket™ tube cleaners.
- ◆ Near-neutral buoyancy provides even distribution through all condenser tubes.
- ◆ Design handles both soft and hard deposits using nonabrasive or abrasive cleaning elements.
- ◆ Skimming recovery systems have greater than 99.95% efficiency and require no downtime for skimming system installation.

Benefits

Profitability

Potential savings for one 500-MW plant are \$350,000 annually.

Reliability

Rocket™ tube cleaners do not impact circulating water pump performance.

Water Quality

Reduces the accumulation of bacterial slime, mud, dirt, and silt on heat transfer surfaces without the use of biocides such as chlorine and bromine.

SOLARWALL® Air Preheating System

Impacts

SOLARWALL® Air Preheating System Offers Industry Dramatic Energy Savings

Through a grant from DOE's Inventions and Innovation Program, Conserval Systems, Inc., developed an innovative yet simple air-preheating system, the SOLARWALL® system, that uses solar energy to increase the temperature of incoming ventilation and makeup air. The system draws air through perforated south-facing panels attached to the wall. These transpired air collectors are about half the cost of glazed flat plate collectors and operate with higher efficiencies. At night they recapture heat escaping through building walls and in summer the system lowers cooling loads by preventing solar radiation from striking a building's south wall. The largest U.S. SOLARWALL® installation is located at a Fort Carson helicopter hanger, where 7800 square feet of solar walls save 3.3 billion Btu of natural gas.

Benefits

Energy Savings

Operating efficiency of up to 75% can raise air temperature by as much as 61°F to 104°F (40°C), depending on flow rate. An industrial installation saves \$10 to \$30/square meter of wall.

Emissions Reductions

Reduces greenhouse gas emissions by using renewable solar energy instead of fossil fuel for ventilation heating.

Profitability

Performance data from the Federal Express distribution center in Colorado indicate annual savings of \$11,000. Simple payback ranges from 0 to 3 years for new construction and 5 to 7 years for most retrofit installations. Eligible for federal solar energy tax credits and 5-year accelerated depreciation schedule.

Productivity

Improves comfort levels and increases ventilation rates, increasing productivity. Can improve product quality in open-combustion flame processes due to more homogenous temperatures.

SOLARWALL® Air Preheating System for Buildings

Overview

- ◆ Developed by Conserval Systems, Inc.
- ◆ Field tests and first U.S. installation in 1990
- ◆ In 1997, 21 systems operating in the United States and 100 worldwide

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.103	0.494

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.022	0.014	6.275	0.006

Applications

- ◆ Manufacturing plant and industrial facility heating and ventilation systems, especially those required to meet OSHA air-change ventilation standards
- ◆ Preheating combustion air for furnaces
- ◆ Industrial and agricultural drying
- ◆ Industrial, commercial, and institutional buildings

Capabilities

- ◆ Modular design is easily customized for any size building; installs on walls or roofs.
- ◆ Can be installed on new construction and easily retrofits on existing facilities as an energy conservation measure.
- Can accommodate photovoltaic panels to generate solar electricity.

Torsional Cylindrical Impulse Shear Soil Test For Earthquake Design

Impacts

Advanced Soil-Testing Technique Offers Potential for Lowering the Cost of Building Earthquake-Resistant Structures

With assistance from the DOE's Inventions and Innovation Program, Dynamic In-Situ Geotechnical Testing, Inc., designed and tested a new soil-testing system for engineering new structures. Its Torsional Cylindrical Impulse Shear system creates and measures an impulse soil shear to gather data for critical structural designs (e.g., oil pipelines, power plants, bridges). The new system is potentially better than previous methods because testing is conducted onsite without disturbing the soil to the point of skewing results. The improved data is vital to structural and safety engineers who must design foundations and structures considering the strength of the soils on which a facility rests. Raising the level of certainty about soil characteristics in both low- and high-activity seismic zones can prevent overbuilding and wasting energy and material resources. In active seismic zones, better designed structures will minimize disruption of vital services. The Federal Highway Administration, Florida Department of Transportation, and National Science Foundation have all implemented system tests.

Torsional Cylindrical Impulse Shear Soil Test For Earthquake Design

Overview

- ◆ Developed by Dynamic In-Situ Geotechnical Testing, Inc.
- ◆ Market introduction in 1992

Applications

Engineering structures and infrastructure for industrial manufacturing facilities, utilities, and the oil and gas industry

Capabilities

- ◆ Furnishes reliable site data on soil characteristics using a less-destructive method that improves accuracy.
- ◆ Tests provide soil data for seismic resistant design.

Benefits

Product Quality

Increases safety and reliability of structures, especially those located in seismically active areas.

Energy Savings

Accrue indirectly from the ability to design structures with greater certainty using the most appropriate materials.

Emissions Reductions

Offshore oil and gas rigs and pipelines built to better standards lessen the chances of catastrophic failures and major fuel spills.

V-Plus Refrigerant Oil Cooling System

Impacts

Refrigerant Oil Cooling System Cuts Energy use 2% to 5%

With assistance from DOE's Inventions and Innovation Program, Vilter Manufacturing Corporation proved that adding its refrigerant pump system, the V-Plus System, to screw compressors for industrial refrigeration and cooling systems increases system capacity, extends system lifetime, and saves energy. Vilter's single-screw compressor is a rotary, oil-injected, positive-displacement machine that can operate with commonly used industrial refrigerants. It consists of a cylindrical main screw with six helical grooves and two planar gaterotors. The gaterotors engage with the main screw to form the compressor chamber. Vilter also offers dual-screw compressor system packages with this technology. Further, the V-Plus system can be added to other types of compressor-driven refrigeration systems.

The invention saves energy and increases screw compressor life by injecting refrigerant liquid into the outlet stream of the compressor to cool the lubricant oil. Besides cutting the horsepower needed for the compressor, the oil cooling increases compressor longevity because no capacity is sacrificed like that in-compressor refrigerant injection systems. This system is cheaper to install than "after cooler" external water-cooling systems and is less costly to operate.

System with V-Plus Oil Cooler

Overview

- ◇ Invented and patented by Vilter Manufacturing Corporation
- ◇ Over 100 units operating in 1998 in the United States; over 200 worldwide

Applications

- ◇ Agricultural sector refrigeration systems for food processing and storage
- ◇ Climate control systems for industrial, commercial, and institutional buildings

Capabilities

- ◇ Can be retrofit to any medium to large compressor-driven refrigeration or cooling system to raise compressor capacity, cut duty cycle, and increase system efficiency.
- ◇ Available on Vilter compressors with displacements from 100 cubic feet/minute to 1800 cubic feet/minute.

Benefits

Productivity

Improves compressor operation and life. Raises compressor capacity compared with systems that inject refrigerant into the compressor.

Energy Savings

V-Plus-equipped systems reduce the horsepower requirement by 2% to 5%, depending on configuration and operating characteristics. Reduces electricity use by 2% to 5% for refrigeration and cooling.

Heat Recovery System Extracts Energy from Waste Fluids

With assistance from DOE's Inventions and Innovation Program, Water Film Energy, Inc., developed a new coil and tube design for heat exchangers that increases heat transfer coefficients by two to four times compared with conventional designs. Named the GFX system, the unit is a double-walled, vented copper heat exchanger that forces fluid to flow as a film. Gray water or waste streams flow through the inner drain section while makeup or incoming water supply flows through the outer coiled jacket. The design, IAMPO- and UL-approved, incorporates equal flow rates on both sides of the heat exchanger for optimum efficiency. GFX's lack of internal welds eliminates cross-contamination problems caused by weld failures and tube leaks common to shell and tube heat exchangers. A common industrial application is to cool effluent to meet environmental or waste treatment regulations. Eliminating the potential for cross-contamination, ensures low maintenance costs and guarantees consistent energy savings.

Benefits

Profitability

Has lower first costs and operating costs compared with buying and maintaining larger or multiple-process heating units/systems.

Productivity

Reduces scale formation and maintenance required to maintain boiler peak efficiency.

Energy Savings

Reduces energy consumption by recovering heat usually lost through disposal of waste. Can recover up to 85% of the heat carried to settling ponds or the sewer. Hospitality industry installations have demonstrated a simple payback of 1.7 years.

Other

Preheating potable water for dairy cattle increases fluid intake and boosts milk production. Cooling wastewater sent to settling or holding ponds reduces the evaporation rate, cutting down the release of foul aromatics.

Overview

- ◆ Invented and developed by Water Film Energy, Inc.; Manufactured by Vaughn Manufacturing Corporation
- ◆ Commercialized in 1997
- ◆ Over 100 units installed in the United States

Applications

- ◆ Agricultural, chemical, refining, textile, food preparation, and other processing industries requiring heated supply water for processing
- ◆ Commercial buildings, heat recovery to complement electric and boiler water-heating systems
- ◆ Single-family and multifamily residential building water-heating systems

Capabilities

- ◆ Can be installed on nearly any system between the drain and sewer or holding pond.
- ◆ Units come in several sizes and can be ganged to create an "energy recovery wall" for larger facilities.
- ◆ Design promotes self-cleaning and low-residence time prevents unwanted biological growth or fouling.

Building Application

Industrial Application

Water Preheating Application - from Dye Waste

Waste Fluid Heat Recovery System

Waste-Minimizing Plating Barrel Increases Productivity

Plating barrels are used in metal plating operations to hold the parts to be plated. Traditional barrel designs have a wall thickness ranging from $\frac{1}{2}$ in. to 1 in., with thousands of holes drilled into the walls to allow electrical current and plating solution into the vessel. The wall thickness is required to provide adequate structural integrity. However, it lowers the efficiency of transferring plating solution into and out of the barrel and diminishes the ability to push electrical current through the holes and onto the parts being plated.

The Whyco barrel, developed by Whyco Technologies, Inc., and demonstrated using a NICE³ grant, is constructed by machining a staggered pattern of rectangular-shaped pockets into the traditional thick-walled polypropylene barrel. After machining, the barrel's structure resembles a honeycomb formation into which thousands of small, now shorter, holes are drilled. This patented staggered-cell design allows for the greatest number of holes per open area while maintaining structural integrity. This thin-walled honeycomb structure increases the hydrodynamic pumping action during barrel rotation, creating greater solution transfer than the traditional barrel design. The Whyco barrel also has higher current density plating leading to faster plating cycles, reduced bath concentration due to higher mass transfer rates, and better plating of difficult chemistries such as alloy plating.

To date, more than 395 of these innovative barrels are in use at Whyco and other plating companies.

Whyco's Staggered-Cell Design

Overview

- ◆ Developed by Whyco Technologies, Inc.
- ◆ Commercialized in 1997
- ◆ Currently more than 395 plating barrels in use

Energy Savings

(Trillion Btu)

1997	Cumulative through 1997
0.100	0.100

Emissions Reductions

(Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.047	0.020	6.480	0.013

Applications

Metal-plating operations; metal finishing and electroplating

Capabilities

Increases process efficiency of metal plating operations.

Benefits

Productivity

Reduces process time and increases productivity by more than 22%.

Waste Reduction

Enhanced drainage and rinsing properties significantly reduce solid waste and wastewater.

Use of Raw Materials

Due to increased chemical solution flow, can use plating solutions of lower concentrations.

OTHER INDUSTRIES

OIT-sponsored technologies commercially available include:

- ◆ Brick Kiln Design Using Low Thermal Mass Technology 102
- ◆ Clean Energy from Municipal Solid Waste 103
- ◆ Ink Jet Printer Solvent Recovery 104
- ◆ NRT Recycling Process 105
- ◆ Windamper System to Reduce Mechanical Vibration..... 106

Brick Kiln Design Using Low Thermal Mass Technology

Impacts

Innovative Brick Kiln Using Low Thermal Mass and Low-NO_x Technologies

Swindell Dressler, and Pacific Clay Brick have successfully developed and demonstrated, using a NICE³ grant, a low thermal mass tunnel brick kiln to replace traditional tunnel kiln designs. This demonstration, taking place at Pacific Clay Brick, uses three technical innovations: ceramic fiber insulation in lieu of traditional refractory brick, a lower profile stack design for brick kiln cars, and more but smaller low-NO_x gas burners.

Replacing traditional refractory brick with ceramic fiber insulation allows the new design to reach operating temperature in about 1 hour compared to 24 hours for traditional designs. Additionally, the low thermal mass ceramic fiber bricks absorb less heat so more heat is available to fire the bricks.

A lower profile stack design for the bricks on the kiln cars means that bricks are placed 4 to 5 layers high instead of 15 layers high with traditional kilns. This lower profile stack design allows for better heat penetration into the bricks and better process control.

Reduced annual NO_x emissions result from several process changes, including lower kiln firing temperatures (2100°F versus 2250°F), newer high-velocity burners, and a fully automated Process Management System that will maintain set points including furnace zone and rapid cool zone temperatures.

Benefits

Waste Reduction

Reduces rejection rate due to better process control and even heat distribution.

Productivity

Reduces time to preheat kiln to operating temperature from 24 hours to 1 hour.

Overview

- ◇ Developed by Swindell Dressler
- ◇ Commercialized in 1997
- ◇ 1 unit operating in 1997

Applications

Brick and ceramic material kilns

Capabilities

- ◇ Uses low thermal mass kiln design to reduce energy consumption and increase throughput.
- ◇ Has better process control with better placement of more but smaller burners.
- ◇ Employs low-NO_x burners.

Clean Energy from Municipal Solid Waste

Impacts

New Process Converts Municipal Solid Waste and Sewage Sludge to a Flexible, Higher Energy Density Liquid Fuel

With assistance from DOE's Inventions and Innovation Program, EnerTech Environmental, Inc., developed a new method for creating fuels from municipal solid waste (MSW) and sewage sludge. The innovative and unique *SlurryCarb*[™] process completely reduces MSW to a liquid form, then treats it in a heated anaerobic pressure unit to rearrange the slurry molecularly. This step produces an homogeneous, clean fuel with an energy density 400% greater than untreated material and it removes water without evaporation. The carbonization process also removes chlorine and slag compounds as well as waste streams in the flue gases at a lower cost per ton of pollutants. The result is a high-energy renewable "E-Fuel" that can be injected with less than 20% excess air into a pulverized coal boiler that is cleaner to burn than most coals. The United States produces over 210 million tons of MSW and 8 million tons of municipal sewage sludge every year for which disposal has become economically and environmentally more costly.

Benefits

Product Quality

Produces a fuel that has higher energy density than raw waste and is transportable as a slurry (7,720 Btu/lb, composition 52.2% solids by weight).

Emissions Reductions

Removes 98% of feed chlorine and slag compounds prior to combustion. Results in CO₂, NO_x, trace metal, and dioxin emissions well below the Environmental Protection Agency's New Source Performance Standards for municipal waste combustion. Displaces portion of coal in electric power plants for utilities and cogeneration facilities.

Waste Utilization

Displaces oil and gas combustion fuels while disposing of pulp and paper mill sludge, industrial wastewater sludge, and agricultural wastes.

Overview

- ◆ Concept developed by EnerTech Environmental Inc.
- ◆ First 20 ton/day municipal solid-waste (MSW) processing unit started operating in 1997 in Japan in conjunction with Mitsubishi Corp.
- ◆ U.S. commercial unit (50 to 100 ton/day) in planning stage for construction in 1999

Applications

Treating waste to create a renewable fuel for electric power or industrial applications from municipal sewage sludge, municipal solid waste, agricultural products, industrial sludge, animal manure, and other organic material

Capabilities

- ◆ Can operate economically at lower capacities (100 to 500 tons/day). This allows smaller facilities to participate.
- ◆ Converts MSW and other organic wastes to high-grade renewable fuel.
- ◆ Provides clean and affordable fuel that can be utilized within the current energy infrastructure.
- ◆ Integrates with current waste management methods or can stand alone.

Clean Energy from Municipal Solid Waste

Ink Jet Printer Solvent Recovery System for Commercial Printing Applications Reduces Emissions

Quad/Tech International (QTI) developed a new solvent recovery system (SRS) for commercial printers. This system was demonstrated using a NICE³ grant. The SRS captures and reuses 60% to 70% of the volatile organic compounds (VOCs) associated with the printing process. The SRS can also reduce the amount of ink and solvent that would have been lost as vapor by up to 50% on average, resulting in a significant reduction in emissions. Additionally, because less fluid is used, the fluid containers do not have to be changed as often, resulting in labor savings and less downtime on the production line. Lastly, reduced VOC and acetone emissions make the work environment healthier for employees.

The SRS consists of a closed-loop ink supply tank that directs solvent vapors discharged from the tank through a vent tube. The vent tube is connected to a condenser that cools the vapors so nearly all the solvent is condensed. The vapors are then returned via the vent to the ink supply tank.

QTI has over 400 of these units currently in operation.

The Quad/Tech Solvent Recovery System (SRS)

Overview

- ◆ Developed by Quad/Tech International (QTI)
- ◆ Commercialized in 1997
- ◆ Over 440 units operating

Energy Savings (Trillion Btu)

1997	Cumulative through 1997
0.03	0.03

Emissions Reductions (Thousand Tons, 1997)

SO _x	NO _x	CO ₂	Particulates
0.019	0.007	1.893	0.005

Applications

Capturing and reusing VOCs in commercial printing processes

Capabilities

- ◆ Recovers 60% to 70% of VOCs.
- ◆ Reduces ink and solvent loss by vapor capture.
- ◆ Increases compliance capability with environmental regulations governing VOC release.

Benefits

Use of Raw Materials/Feedstocks

Recovery of ink and solvent reduces make-up streams, saving ink and solvent feedstocks.

Productivity

Recovers ink and solvent lost as vapor, resulting in less downtime to replace depleted fluid reservoirs.

New NRT Recycling Process is Meeting the Municipal Solid-Waste Challenge

The United States generates an estimated 200 million tons of municipal solid waste (MSW) each year. Environmental concerns are making landfill disposal costly. With help from OIT, National Recovery Technologies, Inc. (NRT), developed a recycling process that is significantly impacting the MSW problem. The NRT process integrates various separation equipment to remove newsprint, cardboard, aluminum, ferrous metals, glass, plastics, wood, compostable food wastes, and other recyclables from the MSW waste stream.

The key to the new recycling technology is the automation of processes for extracting recyclable materials from MSW en masse without requiring presorting by hand. This approach improves the cost-effectiveness of waste handling while maximizing the rate of recycling within a community.

Currently, four NRT systems are being used in the United States and one in Canada. The four U.S. systems process about 4800 tons of mixed MSW per day.

Benefits

Waste Utilization

Recovers metals, paper and paperboard, glass, and plastics for recycling. The waste stream that cannot be recycled is suitable for use as a fuel to produce energy.

Waste Reduction

Reduces the amount of MSW and other waste streams that must be landfilled. Helps communities meet their recycling goals and State mandates to recycle.

Use of Raw Materials/Feedstocks

Conserves petroleum feedstock, ores, and other resources used in new material production. Also saves the energy required to produce an equivalent amount of new materials and eliminates resulting environmental impacts.

Overview

- ◆ Developed by National Recovery Technologies, Inc.
- ◆ Individual system components commercialized in the 1980s
- ◆ Integrated mixed-waste recycling system commercialized in the 1990s
- ◆ Processed about 4800 tons of mixed MSW per day in 1997

Applications

- ◆ Removing mixed recyclable materials from MSW
- ◆ Processing certain industrial waste, commercial waste, and construction and demolition debris

Capabilities

- ◆ Removes aluminum, steel, glass, cardboard, newsprint, mixed paper, plastics, wood, batteries, tires, and compostable humus from a municipal waste stream.
- ◆ Separates various material streams, such as plastic or glass, into individual streams by color or material type.
- ◆ Systems as large as 1500 tons/day of waste have been installed.

NRT Recycling Process

Windamper System to Reduce Mechanical Vibration

Impacts

AR Windamper and AR Twister Overcome Galloping on High-Voltage Electric Power Lines

Ice and snow build-up on high-voltage electric power lines in moderate to high winds causes high-amplitude, low-frequency mechanical vibration called galloping. When power lines react aeroelastically to these conditions, undamped vibration tears apart transmission towers and fittings or propels lines into each other, shorting out large circuits. Besides causing costly electric system outages and structural damage, this dramatic phenomenon steals power through higher electricity line losses that occur when other conductors have to carry more power to compensate for a tripped or damaged line. In a 1981 survey, 17 of 38 utilities reported that galloping was a moderate to severe problem, and 11 reported that they had a galloping event at least once a year. Fifty-seven percent of the incidents included flashover (power outage occurring when lines propel into each other), and 60% included structural damage.

Damage to transmission equipment can be reduced by employing technologies developed by Research Consulting Associates (RCA) in collaboration with DOE's Inventions and Innovation Program. The AR Windamper developed by RCA is an aerodynamic device that clamps to high-voltage overhead transmission lines to overcome galloping. The system introduces damping force by twisting the conductor to cancel the aerodynamic lift caused by clinging ice and snow. Another RCA product, the AR Twister, accomplishes the same result using an inertial device that can also be used to dampen the vibration of guy wires on tall broadcast towers.

Benefits

Reliability

Ensures reliable power distribution during severe weather.

Safety

Protects transmission equipment from catastrophic failure and surrounding facilities from collateral damage.

Overview

- ◇ Developed by Research Consulting Associates
- ◇ AR Twister introduced commercially for utility applications in 1988
- ◇ AR Windamper installed on Western Area Power Administration and 10 utility company transmission lines as well as in 3 steel plants
- ◇ More than 25 utilities and companies have installed AR Windamper and AR Twister during the last decade

Applications

General protection of power, communications, and transmission lines, especially in the sleet belt extending through the central United States and the Eastern Canadian provinces

Capabilities

- ◇ Protects power transmission lines by eliminating the "galloping" phenomenon in spans of 1000 feet or longer for single or bundled conductors.
- ◇ Applicable to tower guy wires.

Windamper System to Reduce Mechanical Vibration

Appendix 2:

OIT Emerging Technologies

This appendix provides brief descriptions of OIT-sponsored technologies that we expect to be commercialized within the next year or two. More information on these projects is available through the OIT website, or by contacting the OIT program manager listed. Phone numbers for the OIT contacts can be found on the inside back cover of the document.

Technologies emerging from the Inventions and Innovation and NICE³ Programs are shown with and icons.

The following emerging technologies are included:

Agriculture 110

Anaerobic Pump
Energy-Efficient Food Blanching
Reactor/Separator for Ethanol and Other Chemical Precursors from Cellulosics
Sensor System to Monitor Gaseous Nitrogen Transfer

Aluminum 110-111

Aluminum Salt Cake: Electrodialysis Processing of Brine
Aluminum Scrap Decoater
Molten Aluminum Explosion Prevention
Novel Technique for Increasing Corrosion Resistance of Aluminum and Aluminum Alloys
Oxygen-Enhanced Combustion
Removal of Molten Salts

Chemicals 111-113

Advanced Distillation Control
Advanced Electrodeionization Technology
Biological Conversion of Waste Gases into Acetic Acid
Concurrent Distillation
Electrochemical Reactors (*Conducting Polymers*)
Electronic Refrigerant Leak Detector
Flexible Chemical Processing of Post-consumer Polymeric Materials into Chemicals
High-performance Polymeric Membrane Technology
Inorganic Polymer Membranes
Low-Platinum Loading, Hydrophilic Fuel Cell Electrode for Use with a Proton Exchange Membrane
Low-Temperature Aqueous Phase Catalytic Gasification (*TEES*[®])
Novel Catalytic Reactor
Novel Membrane-Based Process for Producing Lactate Esters
Plastics, Fibers, and Solvents from Biosynthetically Derived Organic Acids
Plastic Foam and Film Recovery through Thermal Densification
Recovery and Reuse of Flexible Polyurethane Foam from Shredder Residue
Recovery of Chlorosilane Intermediates
Replacement of Thermally Produced Calcined Clay with Chemically Structured Pigments
Selective Surface-Flow Membranes for High-Pressure Gas Separation Applications
Use of Recovered Plastics in Durable Goods Manufacturing

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Impulse Drying of Paper	
Low-emission Drying of Lumber and Wood Panel Products	
Marker-Aided Selection Methods for Wood Property Traits	
METHANE De-NOx® Reburn Process	
Multi-port Cylinder Drying	
On-Site, On-Demand Generation of Chlorine Dioxide at Reduced Cost	
Paper Mill Sludge Utilization: Biofine Technology	
Removal of Bark from Whole Logs	
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Advanced Temperature Measurement System	
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In-Situ, Whisker-Reinforced Glass Ceramic	
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Oxygen-Enriched Air-Staging (OEAS) Technology	
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Clean Cast Steel	
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Simple Visualization Tools for Part and Die Design	
Thermal Treatment of Metals with a Mechanically Fluidized Vacuum Machine	
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Mining	117
Wireless System for Coal Mine Monitoring and Control	
Petroleum	118
Advanced Fluid Catalytic Cracker (FCC) Model	
Petroleum Fouling Mitigation	
Radial Cutting Torch (RCT) – Pipe Cutting Apparatus	
Robotics Inspection System for Storage Tanks	
Sulfide Reduction and Increased Oil Recovery	
Waste-Heat-Driven Absorption Chiller	
Steel	119-120
Continuous Casting and Inside Rolling of Hollow Rounds	
Dilute Oxygen Combustion	
Electrochemical Dezincing of Steel Scrap	
Hot-Dip Batch Galvanizing	
Intelligent Systems for Induction Hardening	
Microstructure Engineering for Hot Strip Mills	
On-Line Non-Destructive Mechanical Properties Measurement	
Optical Sensors and Controls for Improved Basic Oxygen Furnace (BOF) Operations	
Oscillating Combustion	
Oxy-Fuel Burners for Steel Reheating	
Processing Electric Arc Furnace (EAF) Dust into Salable Chemical Products	

(continued on the next page)

Crosscutting Technologies 120-123

Advanced Turbine System
 The Anderson-Quin Cycle
 Aqua-Shear
 Catalytic Combustion
 Ceramic Cutting Tool Reinforced with Hafnium Carbide Single-Crystal Fiber
 Compression Dynamics
 Continuous Fiber Ceramic Composite (CFCC): Burner Screens
 Continuous Fiber Ceramic Composite (CFCC): Combustion Liner
 Continuous Fiber Ceramic Composite (CFCC): Hot Gas Filters
 Continuous Fiber Ceramic Composite (CFCC): Immersion Tubes
 Forced Internal Recirculation Burner
 Melt De-sulfurization
 Method for Recycling Hazardous Waste
 Modified Pure-Air Combustion MODIPAC
 Power Factor System by Means of Continuous Modulation
 Radiation-Stabilized Burner
 Recuperator of Flue Gas Heat
 Simultaneous Heat and Mass Transfer
 Structural Monitoring System Using Fiber Optics
 Synthesis and Sintering of Fine and Ultrafine Grain Sodium Zirconium Phosphate (NaZP) Ceramics
 Thermal Energy Storage for Small, Packaged Terminal Air-Conditioning Units
 Thermobarrier Coatings
 Thermoelectric Generator for Diesel Engines
 Two-phase Hero Turbine with Curved No-Separation Nozzles
 Ultra Low-Head Ambient Pressure Hydro Turbine
 Wear Resistant Composite Structure of Vitreous Carbon Containing Convuluted Fibers
 WeldComputer™ Resistance Welder Adaptive Control

Other Industries 124-125

Alvar Engine
 AutoTherm
 Charge Distribution Analysis
 Combustion of Municipal Solid Wastes with Oil Shale in a Circulating Fluidized Bed
 Electrolytic Regeneration of Acid Cupric Chloride Printed Circuit Board Etchant
 Environmental Tensometer
 High-Speed Bandsaw with Precision, Diamond-Particulate Edge
 Insulation Containment Apparatus – The Ultimate ‘R’
 Irrigation Valve Solenoid Energy Saver
 Mechanical, Infinitely-Variable – Speed Transmission for Automotive Use
 Mobile Zone Optimized Control System for Ultra-Efficient Surface-Coating Operations
 Novel Fuel Injection System for Diesel Engines
 Novel Procedure for Fabrication of MOSFETS
 Peripheral Blade Mower
 QUBUS III Technology for Producing Ethanol
 RoboSort Technology for the Recycling Industry
 Sag-Resistant Pinhole-Free Coatings (*Thane-Coat*)
 Textile Brine Separation
 Ultraviolet Crosslinking of Polybis (*Methoxyetho-xethoxy Phosphazene*)

Agriculture

◇ Anaerobic Pump

This invention uses a new process and hardware design for a more efficient two-stage digestion of wet-solid-organic wastes to produce a methane-CO₂ mixture. The second stage of the process increases the kinetics by vacuum removal of about half the metabolically-formed ammonia.

OIT Contact: Ramesh Jain

◇ Energy-Efficient Food Blanching

This innovative blanching technology re-circulates and reuses steam, dramatically reducing water, energy, and wastewater. A new process control system will be demonstrated that tests products during blanching for a key enzyme indicator. This test will help reduce blanch times and increase product quality.

OIT Contact: Lisa Barnett

◇ Reactor/Separator for Ethanol and Other Chemical Precursors from Cellulosics

A continuous fermentation process produces fuel-grade ethanol and other chemical precursors from waste biomass. Based on laboratory and pilot plant data, the cost of this process is expected to be about half that of a conventional batch fermentation process that uses food grains for raw materials.

OIT Contact: Rolf Butters

◇ Sensor System to Monitor Gaseous Nitrogen Transfer

An integrated-optics (IO) sensor system can monitor and measure ammonia concentrations that result from nitrogen transfer (loss) from agricultural croplands and/or industrial operations in the range of 100 parts-per-billion and above. The device will have applications in agriculture and industrial refrigeration systems.

OIT Contact: Brian Volintine

Aluminum

◇ Aluminum Salt Cake:

Electrodialysis Processing of Brine

This project aims to eliminate landfilling of aluminum salt cake by developing technologies that will separate salt cake into constituents (aluminum, salt, and nonmetallic products). Salt recovery consumes more energy and incurs more costs than any other unit operation in the recovery of salt cake constituents. If successful, an OIT-sponsored salt-recovery process based on electrodialysis will be more cost-effective than the established technology (evaporation with vapor recompression).

OIT Contact: Charles Russomanno

◇ Aluminum Scrap Decoater

This innovation de-coats scrap aluminum parts in a controlled atmosphere with limited oxygen to avoid scrap oil combustion and scrap oxidation. The resulting gases are then combusted in an incinerator, apart from the scrap, to destroy the volatile organic compounds. The heat released from this atmospheric combustion drives the de-coating process.

OIT Contact: Lisa Barnett

◇ Molten Aluminum Explosion Prevention

Research underway will improve industry's understanding of the conditions that trigger aluminum-water explosions, as well as the reasons and extent to which certain coatings prevent those explosions. One result of the research will be a basic understanding of the entrapment of heat over submerged coated and uncoated surfaces.

OIT Contact: Ramesh Jain

Aluminum

(continued)

◆ Novel Technique for Increasing Corrosion Resistance of Aluminum and Aluminum Alloys

A new process imparts a corrosion-resistant coating to aluminum and aluminum alloys. The process uses nontoxic lithium and magnesium salts, with or without heat treatment, to replace the currently used hexavalent chromium, which is known to be a highly toxic carcinogen.

OIT Contact: David Crouch

◆ Oxygen-Enhanced Combustion

This technology integrates a novel combustion system that has high efficiency, high capacity and low NO_x emissions, with an innovative, low-cost oxygen-generation process that uses vacuum-swing absorption. This integrated burner/oxygen-supply system offers enhanced productivity, increased energy efficiency, reduced operating costs, and low NO_x emissions.

OIT Contact: Ramesh Jain

◆ Removal of Molten Salts

When chloride salts agglomerate and migrate to the surface of an ingot or casting, defects occur. The technology under development aims to detect and reduce chloride salts in molten aluminum. It uses a simple electrical probe to sense the presence of salts and a filter that selectively removes liquid salts from the liquid metal.

OIT Contact: Lynne Gillette

Chemicals

◆ Advanced Distillation Control

The operating characteristics of distillation columns in the refining and chemical industries strongly affect the quality of the final products and the maximum production rates achievable. This project focuses on developing the methods and data needed to make advanced, economics-based control decisions for distillation columns.

OIT Contact: Charles Russomanno

◆ Advanced Electrodeionization Technology

This technology combines the advantages of ion exchange (an adsorption technology) with those of electro-dialysis (a membrane separation) for a wide range of potential applications in the chemical industry including product purification, waste recovery, and water recycling. Targeted applications include removal of catalysts from process streams, product polishing, and waste salt recovery.

OIT Contact: Charles Russomanno

◆ Biological Conversion of

Waste Gases into Acetic Acid

About five billion pounds of waste CO₂, CO and H₂ are discharged annually into the U.S. environment as by-products of the twenty-one domestic manufactures of carbon black. This project developed a biological conversion process that at ordinary temperature and pressure, using simple equipment, can selectively utilize the dilute waste streams to produce acetic acid.

OIT Contact: Merrill Smith

◆ Concurrent Distillation

This project aims to improve the performance of high-pressure distillation trays by using a con-current flow design and to establish the economics of the process. The research will provide the design information and performance correlations necessary to manufacture the tray (called the "Trutna Tray"). During the course of the project, the tray is being pilot tested in an industrial application.

OIT Contact: Brian Volintine

Chemicals (continued)

◇ Electrochemical Reactors (Conducting Polymers)

The chloralkali industry consumes about two percent of the electrical energy generated in the United States. Therefore, for years, this industry has been attempting to find ways to reduce its energy consumption. A new technology, under development with OIT support, could reduce electricity consumption by 30 % or more. The novel membrane-electrode assembly significantly reduces voltage requirements in the electrochemical reactor by replacing a hydrogen-evolving cathode with an oxygen-consuming cathode. In the demonstration phase, this technology showed exceptional performance, significantly reducing voltage requirements.

OIT Contact: Charles Sorrell

◇ Electronic Refrigerant Leak Detector

This invention is a portable, hand-held, refrigerant leak detector to be used by air-conditioning and refrigeration technicians. The sensor uses a semiconducting thin film of metal phthalocyanine (MPC) deposited on a silicon chip.

OIT Contact: Rolf Butters

◇ Flexible Chemical Processing of Post-consumer Polymeric Materials into Chemicals

A new thermo-chemical process can convert polymers from a wide variety of recycled materials into valuable chemicals. The first stage of the process uses selective catalytic pyrolysis to recover high-value chemicals. The second stage converts the unreacted organic material into synthesis gas, which can then be converted to a variety of chemicals for use in the chemicals industry.

OIT Contact: Charles Russomanno

◇ High-performance Polymeric Membrane Technology

A membrane process – pervaporation – can remove volatile organic compounds (VOCs) from wastewater and recover the VOCs for reuse. Pervaporation has significant advantages over conventional waste treatment processes, such as steam or air stripping, carbon adsorption or biological treatment, because it is energy-efficient, modular, and recovers a reusable product.

OIT Contact: Charles Russomanno

Chemicals (continued)

◇ Inorganic Polymer Membranes

Highly solvent-resistant polymer membranes, known as polyphosphazenes, which are under development with OIT support, can operate in high-temperature and/or harsh environments. These membranes separate chlorinated hydrocarbons and other organics from water, acid gases from other gases, and volatile organic compounds from waste streams.

OIT Contact: Ehr-Ping Huang Fu

◇ Low-Platinum Loading, Hydrophilic Fuel Cell Electrode for Use with a Proton Exchange Membrane

This invention demonstrates a new and radical design approach for a Proton Exchange Membrane (PEM) fuel cell. The electrode design uses a hydrophilic membrane, instead of the conventional hydrophobic one. This electrode provides more efficient hydration with good water control and better hydronium ion migration rates, and thus more power density.

OIT Contact: Rolf Butters

◇ Low-Temperature Aqueous Phase Catalytic Gasification (TEES®)

TEES® uses aqueous phase catalytic gasification for treatment of wet organic waste from organic chemical manufacturing. This innovative process catalytically converts organics in water to methane, carbon dioxide, and clean water. It has the potential to help the organic chemical manufacturing industry solve several energy and environmental needs.

OIT Contact: Charles Russomanno

◇ Novel Catalytic Reactor

This patented concept for catalyzed reactions uses a specially designed porous tube with mixing elements. The novel design decreases the generation of undesirable reaction by-products by: (1) controlling the introduction and mixing of reactants to minimize concentration and temperature gradients, and (2) regulating the ratio of reactants to products as the reaction proceeds. This new technology offers the potential for reducing the cost of chemical manufacturing by 10%.

OIT Contact: Charles Russomanno

Chemicals

(continued)

Chemicals

(continued)

◆ Novel Membrane-Based Process for Producing Lactate Esters

This research aims to develop nontoxic replacements for halogenated and toxic solvents. The new method uses proprietary advanced fermentation, membrane separation, and chemical conversion technologies to convert renewable carbohydrate feedstocks into lactate esters in an energy-efficient and cost-effective way.

OIT Contact: Charles Russomanno

◆ Plastics, Fibers, and Solvents from Biosynthetically Derived Organic Acids

Biologically-derived succinic acid is produced by fermenting glucose sugar from corn. After separation and purification, the succinic acid is used as a chemical intermediate that is converted into chemical feedstocks. The feedstocks are then used to make a wide assortment of products such as plastics for automobiles and household items, fibers for clothing, food additives, and solvents for paints and paint removers.

OIT Contact: Gloria Kulesa

◆ Plastic Foam and Film Recovery Through Thermal Densification

A new high-throughput densifier being demonstrated for industrial plastic foam and film allows recovery of foam and film excesses. Ground foam is introduced into an air stream that enters a heated chamber where it is melted into pellets.

OIT Contact: Lisa Barnett

◆ Recovery and Reuse of Flexible Polyurethane Foam from Shredder Residue

This technology separates and recovers recyclable constituents of auto-shredder residue. The process involves three steps: drying, physical separation, and selective dissolution and recovery of selected thermoplastics. Various marketable products are recovered, including clean polyurethane foam.

OIT Contact: Simon Friedrich

◆ Recovery of Chlorosilane Intermediates

The Direct Process for production of methylchlorosilanes produces a mix of chlorosilanes and by-products. This new waste-conversion technology transforms the direct-process residue into more-useful, valuable chlorosilane monomers. A pilot plant is operating in Carrollton, Kentucky.

OIT Contact: Brian Volintine

◆ Replacement of Thermally Produced Calcined Clay with Chemically Structured Pigments

This innovative chemical process will produce a high-capacity layered composite pigment to replace calcined clay, which is used in paper manufacture (for coated papers) and other industries. The manufacture of calcined clay requires large amounts of thermal energy, so this innovation will reduce energy use.

OIT Contact: Rolf Butters

◆ Selective Surface-Flow Membranes for High-Pressure Gas Separation Applications

The active transport membranes (ATMs) under development can encapsulate or immobilize novel chemical absorbents for ammonia and acid gases. The ATMs are being developed in hollow-fiber form. The on-going research also focuses on defining membrane properties as a function of membrane structure and operating envelope.

OIT Contact: Charles Russomanno

◆ Use of Recovered Plastics in Durable Goods Manufacturing

Using a new energy- and cost-effective method, manufacturers of durable plastic products can recover and reuse scrap plastic. The integrated process involves size reduction, materials liberation, materials separation, and cleaning.

OIT Contact: Lisa Barnett

Forest Products

◇ Feedstock-to-Products Characterization

Research underway will lead to integrated, real-time total quality control that applies analytical spectroscopy and chemometrics. The technology can be used on-line throughout the wood/paper manufacturing process.

OIT Contact: Eric Lightner

◇ High-Efficiency Chlorine Dioxide Delignification

This project focuses on developing a fundamental understanding of the mechanisms of chlorine dioxide delignification of low-kappa kraft pulps, and on identifying new methods to improve the efficiency and effectiveness of this bleaching agent. The goal is to develop new bleaching technologies that permit enhanced delignification while reducing the generation of chlorinated organic compounds.

OIT Contact: Gloria Kulesa

◇ Impulse Drying of Paper

This technology uses an induction heater to heat the final roll in the press section of the paper mill, lowering the moisture content of the paper entering the drying section. This greatly reduces the energy required in subsequent drying steps. Impulse drying also increases paper strength and improves printability.

OIT Contact: Valri Robinson

◇ Low-emission Drying of Lumber and Wood Panel Products

This project is building and testing a pilot-scale radio frequency (RF) pretreatment unit that extracts and collects volatile organic compounds (VOCs) from lumber before it is sent to a conventional wood-drying kiln. Brief RF treatment of softwood lumber under low headspace conditions removes over 70% of the VOCs (principally terpenes), which are later condensed and recovered. The process simultaneously eliminates the need for VOC controls during wood drying (currently an energy- and capital-intensive process) and recovers a saleable chemical feedstock used to make turpentine.

OIT Contact: Merrill Smith

Forest Products

(continued)

◇ Marker-Aided Selection Methods for Wood Property Traits

New analytical techniques under development will help researchers quickly identify molecular markers associated with component wood properties in Loblolly pine and hybrid poplar. The markers will then be used to select superior genotypes or to identify DNA sequences that determine component wood properties.

OIT Contact: Elliott Levine

◇ METHANE De-NO_x® Reburn Process

This project is testing the effectiveness of the METHANE De-NO_x® Reburn technology developed by the Institute of Gas Technology in overcoming operating problems in biomass-fired stoker boilers. The project involves retrofitting a 300-million-Btu/hr stoker-fired boiler fueled with waste wood and paper sludge and testing its ability to increase sludge firing rates, improve thermal efficiency, reduce NO_x emissions, and decrease input of natural gas for co-firing. Commercial implementation of the technology would allow the forest products industry to use (rather than landfill) more wood waste solids and sludges, reduce consumption of natural gas, reduce NO_x emissions, and improve boiler thermal efficiency.

OIT Contact: Patricia Hoffman

◇ Multi-port Cylinder Drying

This project is developing, and conducting limited pilot-scale testing of, a compact heat exchanger technology designed to increase paper drying rates in steam-heated cylinder dryers by more than 30%. The concept involves the flow of steam through multi-port passages in close proximity to the dryer surface. The multi-port design minimizes condensate formation, which reduces heat flow, and maximizes the heat transfer surface area. Commercial benefits include reduced energy consumption, improved productivity, and downsized dryer section.

OIT Contact: Ingrid Watson

Forest Products

(continued)

◆ On-Site, On-Demand Generation of Chlorine Dioxide at Reduced Cost

Due to environmental constraints on the use of elemental chlorine, the pulp and paper industry is turning to chlorine dioxide (ClO_2) as an alternative bleaching agent. The result has been an increased demand for ClO_2 , which by current methods is costly to produce. Investigators are developing and testing a new electrode technology with a unique, three-dimensional cathode that will provide U.S. mills with an efficient and cost-effective method for producing chlorate (the chemical precursor to ClO_2) on-site. The technology will reduce the electricity requirements for electrochemical chlorate production and facilitate the use of ClO_2 as a chlorine alternative.

OIT Contact: Ingrid Watson

◆ Paper Mill Sludge Utilization: Biofine Technology

Using the Biofine Technology, low-grade waste-cellulosic by-products from paper mills, municipal solid waste plants, and other sources can be converted into levulinic acid, a versatile chemical that is an intermediary to several other products. The conversion of cellulose to levulinic acid is accomplished via high-temperature, dilute-acid hydrolysis in a novel reactor configuration.

OIT Contact: Merrill Smith

● Removal of Bark from Whole Logs

This invention removes bark from de-limbed tree stems by raising stems from the bottom of a mass of stems and dropping them on top of the pile. The bark is loosened and removed as a result of the compressive and shear forces associated with the impact.

OIT Contact: David Crouch

◆ Volatile Organic Compound Control in Kraft Mills

A new computer model will enable users to simulate the partitioning of volatile organic compounds in both the liquid and gas streams of pulp and papermaking unit operations.

OIT Contact: Simon Friedrich

Glass

◆ Advanced Combustion Space Model for Glass Melting

Improved understanding and modeling of the combustion process in glass melting will result in innovative furnace designs that will have higher combustion and furnace efficiencies, minimized pollutant formation (primarily NO_x reduction), and improved glass quality.

OIT Contact: Charles Sorrell

◆ Advanced Temperature Measurement System

A temperature sensor under development with OIT support will minimize drift (or improve the ability to identify drift). The sensor will also help increase the lifetime of the insulator, outer protective sheath (thimble), and inner protective sheath, and reduce data-transmission interference.

OIT Contact: Eric Lightner

◆ Energy Efficient, Electric Rotary Furnace for Glass Molding of Precision Optical Blanks

A novel electrically heated rotary furnace can save energy in glass molding (i.e., repressing) of precision optical blanks. The gas-fired furnaces conventionally used in this industrial segment lose about 93% of the heat in the exhaust stack. The electric furnace does not incur this loss because it does not use such a stack.

OIT Contact: Rolf Butters

◆ In-Situ, Whisker-Reinforced Glass Ceramic

This invention involves forming titanium whiskers in-situ in a series of low-thermal-expansion glasses and glass ceramics. This will permit the use of whisker reinforcement in high-volume, high-speed production processes, such as extrusion or molding.

OIT Contact: Rolf Butters

Glass (continued)

◇ Integrated Batch and Cullet Preheat for Glass Furnaces

This project is demonstrating the technical viability, system reliability, and economic benefits of batch and cullet preheating to improve the overall economics of furnaces in glass production. Tests are being conducted using both conventional preheated air and oxygen-fuel combustion. The technology uses discarded system heat to preheat the batch and cullet material being fed to the furnace.

OIT Contact: Rolf Butters

◇ Oxygen-Enriched Air-Staging (OEAS) Technology

This advanced combustion modification technique combines oxygen enrichment with air-staged combustion for endport and sideport glass furnaces. The technology reduces NO_x emissions, energy consumption, waste, and costs.

OIT Contact: Ramesh Jain

◇ Phase/Doppler Laser Light-Scattering System

A new phase/Doppler laser light-scattering system, under development with support from OIT, can be applied to on-line measurements of small diameter (< 15 micrometer) fibers during fiberglass manufacturing.

OIT Contact: Rolf Butters

◇ Single-Crystal Whisker Electric Light Filament

This novel single-crystal ceramic fiber can be used as a high-efficiency, high-temperature electric light bulb filament. The light produced will be more similar to sunlight in color distribution than light from conventional light bulbs. The ceramic filament material will have a lower vapor pressure and will extend bulb life.

OIT Contact: Rolf Butters

◇ Ultraviolet Curing of Fiberglass Sleeving

This new process uses ultraviolet curing of fiberglass sleeving manufactured for the electrical industry. The sleeving consists primarily of fiberglass and acrylic plastic. The acrylic plastic can be cured by ultraviolet light rather than heat, saving energy, reducing pollution, and increasing productivity.

OIT Contact: Lisa Barnett

Metalcasting

◇ Atmospheric Recovery and Regeneration in Heat-Treating Operations

High-temperature furnace processes used in manufacturing (e.g., heat treating, brazing, and sintering) typically maintain inert gas "atmospheres" over the process. This new technology recovers, cleans, and reuses over 90% of the furnace-atmosphere gas.

OIT Contact: Lisa Barnett

◇ Clean Cast Steel

Project participants are developing ways to improve cast product quality by removing or minimizing oxide defects that require weld repair. Cleaner castings can be obtained by reducing the head height and pouring temperature, increasing the level of silicon and manganese in the bath after oxygen injection, and increasing the amount of slag thinner. Industry participants have seen significant reductions in inclusions and in the number of welds requiring repair.

OIT Contact: Harvey Wong

◇ Intelligent Control of the Cupola Furnace

This project involves designing and constructing a controller for the cupola process using intelligent (neural network) and conventional control methods. The use of a real-time control system to operate the cupola furnace will result in greater efficiency. Improved control will reduce material and processing costs, reduce scrap and improve product quality.

OIT Contact: Harvey Wong

◇ Lost Foam Casting Technology

Lost foam casting is a highly flexible process suitable for casting metal components with complex geometries. Research supported by OIT has led to a greater understanding of the process and to new control measures. These will increase foundry energy efficient and reduce scrap. Emerging technologies from the OIT-supported research include: in-plant quality assurance procedures to measure casting parameters; a sand-density gauge to measure the rate of sand compaction; and vibrational analysis instrumentation which, when coupled with the density gauge, allows the compaction cycle to be optimized to reduce compaction time and pattern distortion.

OIT Contact: Harvey Wong

Metalcasting (continued)

◆ Simple Visualization Tools for Part and Die Design

A simple qualitative method is being developed to visualize potential design problems in die-casting. The software is intended to help minimize flow-related filling problems, thermal problems in the die, and solidification-related defects in the cast part.

OIT Contact: Harvey Wong

◆ Thermal Treatment of Metals with a Mechanically Fluidized Vacuum Machine

This invention consists of a vacuum heat-treating/annealing machine with a rotating drum that uses a fluidized medium of small ceramic spheres to transfer heat from the drum sides to the parts to be heated. The ceramic particles give improved heat transfer rates and temperature control. The unit is smaller and less costly than conventional heat treatment units.

OIT Contact: Rolf Butters

◆ Three-Dimensional Objects by Photosolidification

This improved process for fabricating three-dimensional objects involves solidifying a liquid polymer with ultraviolet radiation. The process can be directly driven by computer-aided design data, permitting the fully automatic fabrication of newly designed, complex parts in minutes.

OIT Contact: David Crouch

Mining

◆ Wireless System for Coal Mine Monitoring and Control

This invention uses a through-the-earth radio communications system for underground coal mines and other deep-shaft mines. It controls and monitors underground equipment and can serve as an emergency communications system.

OIT Contact: David Crouch

Petroleum

◇ Advanced Fluid Catalytic Cracker (FCC) Model

This simulation model, aimed at studying cracking reaction kinetics and designing more efficient FCC units, can help decrease catalyst utilization, increase production of light gasoline fractions, reduce operating and capital costs, reduce aromatics and sulfur in gasoline, and lower air pollutant emission rates.

OIT Contact: Charles Russomanno

◇ Petroleum Fouling Mitigation

This project developed analytical methods to determine the effects of temperature, pressure, and other conditions on heat-exchanger fouling in petroleum refineries. Research resulted in advanced heat exchanger designs and ways to operate heat exchangers to eliminate or reduce fouling.

OIT Contact: Charles Russomanno

◇ Radial Cutting Torch (RCT) – Pipe Cutting Apparatus

This novel oil-field tool cuts pipes inside an oil or gas well. The tool is lowered on a wire line to a described depth, locked in place, and fired with an electrical charge.

OIT Contact: David Crouch

Petroleum

(continued)

◇ Robotics Inspection System for Storage Tanks

This technology consists of a remotely operated robotic inspection vehicle that can be submerged in bulk-liquid storage tanks to inspect for structural and corrosion problems.

OIT Contact: Lisa Barnett

◇ Sulfide Reduction and Increased Oil Recovery

This technology grows anaerobic heterotrophic denitrifying bacteria to consume and prevent the formation of hydrogen and iron sulfides in oil and gas reservoirs.

OIT Contact: Ramesh Jain

◇ Waste-Heat-Driven Absorption Chiller

This novel waste-heat-driven process chiller operates on an absorption refrigeration cycle. The chiller has been operating since August, 1997 at a refinery in Colorado. The technology economically condenses hydrocarbon fuel vapors that would otherwise be flared as waste, and generates \$1,000,000 annually in additional fuel sales.

OIT Contact: Paul Scheihing

Steel

◆ Continuous Casting and Inside Rolling of Hollow Rounds

This project is developing a mechanism and method for continuously casting and hot-working hollow round steel cylinders for use in manufacturing high-quality seamless steel pipe and tubing.

OIT Contact: Lisa Tunstall-German

◆ Dilute Oxygen Combustion

The Dilute Oxygen Combustion (DOC) system for steel and other high-temperature applications achieves clean and efficient combustion by reacting fuel with injected hot dilute oxygen.

OIT Contact: Gideon Varga

◆ Electrochemical Dezincing of Steel Scrap

The technology separates steel scrap into dezincified steel scrap and metallic zinc. The removal of zinc from steel scrap increases the recyclability of steelmaking dust and eliminates zinc from wastewater streams.

OIT Contact: Gobind Jagtiani

◆ Hot-Dip Batch Galvanizing

An innovative lead-free galvanizing process uses advanced surface preparation techniques, thermally stable flux, and a preheating method, while eliminating top-flux and lead from the galvanizing process.

OIT Contact: Lisa Barnett

◆ Intelligent Systems for Induction Hardening

Research efforts are focusing on (1) developing closed-loop process controllers to improve process precision, (2) developing computationally rigorous models of process and material interactions, and (3) using the knowledge to develop optimized processes to improve the quality and reliability of components with optimized properties.

OIT Contact: Eric Lightner

Steel

(continued)

◆ Microstructure Engineering for Hot Strip Mills

Computer models aimed at improving the hot rolling process are linking mechanical properties to the process parameters of the mill. These models help predict mechanical properties on-line of A-36 carbon steel as well as DQSK, HSLA-V, and HSLA-Nb grade steels. They will allow steel companies to optimize their hot rolling practices, particularly those involving cooling and coiling. In addition to enhancing output and quality, they will reduce the time and cost of developing new grades of steel by allowing off-line experimentation.

OIT Contact: Eric Lightner

◆ On-Line Non-Destructive Mechanical

Properties Measurement

This technology targets one of the steel industry's greatest challenges – the consistent production of large quantities of steel with well-controlled and uniform mechanical properties. On-line sensors are being developed to reliably and non-destructively monitor properties of cold rolled steel (yield and tensile strength, elongation and strain hardening value). The technology employs a laser ultrasonics approach – using a laser to direct ultrasonic waves at the steel strip. Irregularities in the microstructure reduce the strength of the waves. Changes are detected by a second laser, which translates the pulses into a digital signal for computer analysis and display. The development of on-line sensors will enable steel producers to take measurements as the steel is being made, enhancing productivity and reducing scrap material.

OIT Contact: Eric Lightner

◆ Optical Sensors and Controls for Improved Basic Oxygen Furnace (BOF) Operations

This project is developing laser-based sensors that measure the furnace temperature and composition of off-gases, to provide an early and direct indication of when the steelmaking process is complete. In addition, the project is investigating the use of an optical sensor, mounted in the tip of the oxygen lance, to measure the temperature of the hot spot zone of the steel melt. These technologies have also been extended to two other laser-based sensor applications that measure the height of the bath in the furnace and contour the inner surface of a hot BOF furnace in a matter of minutes.

OIT Contact: Eric Lightner

Steel (continued)

◆ Oscillating Combustion

Oscillating combustion involves the creation of successive fuel-rich and fuel-lean zones within the flame. This technology reduces the formation of NO_x and increases the heat transfer from the flame to the load. This technology is currently being tested at a steel plant.

OIT Contact: Gideon Varga

◆ Oxy-Fuel Burners for Steel Reheating

This project will demonstrate the economic, environmental, and quality benefits of an advanced oxy-fuel combustion system for a continuous slab-reheat furnace. The oxy-fuel combustion system reduces furnace rebuild costs, fuel consumption, and NO_x , SO_x , CO_2 , and CO emissions.

OIT Contact: Lisa Barnett

◆ Processing Electric Arc Furnace (EAF) Dust into Saleable Chemical Products

This unique technology will hydro-metallurgically process EAF dust into saleable products. EAF dust is oxidized and digested in acid and then treated by a series of individual steps to isolate and retrieve individual components of the dust.

OIT Contact: Lisa Barnett

Crosscutting Technologies

◆ Advanced Turbine System

An advanced turbine system (ATS) developed under the OIT ATS program offers an innovative design combining proven technology with new concepts, including a unique centerframe section that interconnects turbine and compressor sections in a different arrangement than conventional gas turbines. The likely first commercial installation of this technology is planned for mid-1999.

OIT Contact: Patricia Hoffman

◆ The Anderson-Quin Cycle

A novel combined cycle for power generation consists of five subcycles: inlet refrigeration, gas turbine, steam cycle, bottoming cycle, and heat pump. The five cycles combine to give a power plant a high thermal efficiency.

OIT Contact: Ramesh Jain

◆ Aqua-Shear

This invention is a mixer with no moving parts. The mixer consists of a drum enclosing several perforated plates. The plates cause the liquids entering from each end of the drum to pass tangentially at high shear rates, causing the liquids to rotate in opposite directions, resulting in intense mixing. The device can also mix liquids with solids and gases.

OIT Contact: Ramesh Jain

◆ Catalytic Combustion

Low-emission combustion technologies are being developed for industrial gas turbines for use in on-site power generation and cogeneration. These technologies offer flameless combustion that essentially eliminates toxic emissions. The catalyst within the flameless combustion system limits the temperature in the combustor to below the temperature where nitrogen oxides (NO_x) are created. Emission levels will be reduced to less than 5 parts per million (ppm) NO_x and less than 10 ppm carbon monoxide.

OIT Contact: Patricia Hoffman

Crosscutting Technologies

(continued)

◆ Ceramic Cutting Tool Reinforced with Hafnium Carbide Single-Crystal Fiber

A proprietary high-temperature process makes single-crystal hafnium carbide crystals with a controlled ratio of length to diameter. The process can also combine crystals into ceramics as a reinforcing medium to the ceramic matrix. The first application is a fiber-reinforced ceramic that can be used to manufacture cutting tools that will cut ferrous metals 10 to 20 times faster than currently available cutting tools.

OIT Contact: Rolf Butters

◆ Compression Dynamics

A new class of valves is being developed for reciprocating compressors used for natural gas transmission and other industrial applications. Efficiency improvements of 2% to 16% have been achieved during multiple tests, and the long-term reliability of the design has been demonstrated.

OIT Contact: Rolf Butters

◆ Continuous Fiber Ceramic Composite (CFCC): Burner Screens

New CFCC reverberatory screens can improve the efficiency of natural gas burners in industrial applications, such as paper or paint drying, metal treating, and glass forming. These screens act as a secondary source of radiation, increasing the radiant output by greater than 50%. Test screens have passed over 100 hours and 15,000 thermal cycles on an actual radiant burner test rig.

OIT Contact: Merrill Smith

◆ Continuous Fiber Ceramic Composite (CFCC): Combustion Liner

Using CFCC combustion liners in gas turbines allows them to operate at the higher temperatures needed to increase their efficiency. CFCC combustion liners can also significantly reduce harmful emissions, including nitrogen oxides and carbon monoxide. Field tests have been successful, and the first commercial installation of a turbine with a ceramic combustor liner is expected to take place in 1999.

OIT Contact: Patricia Hoffman

Crosscutting Technologies

(continued)

◆ Continuous Fiber Ceramic Composite (CFCC): Hot Gas Filters

Hot gas filters remove fine coal ash particles in pressurized fluidized bed combustion systems and coal gasification systems. The filters, which are porous closed-end tubes, can also be used for particulate removal in the chemical and petroleum industries. Due to their toughness and thermal shock resistance, filters made of CFCCs overcome current filter failures, such as the inability to survive back-pressure pulses used for cleaning. Recently, hot gas filters developed under DOE's CFCC program were successfully tested at pressurized fluidized bed combustor facilities in Finland and Alabama.

OIT Contact: Merrill Smith

◆ Continuous Fiber Ceramic Composite (CFCC): Immersion Tubes

Tubular heating elements made of CFCCs are being developed for use in holding furnaces at aluminum casting facilities to keep the hot aluminum molten. The CFCC tubes are extremely tough and durable and can be immersed in the metal rather than suspended above it. This increases efficiency, allows for more uniform heating, reduces the potential for contamination, and results in less down time when compared to the use of monolithic ceramic tubes. The CFCC tubes have survived over 1,000 hours and 31 cycles in a single-tube aluminum melter.

OIT Contact: Debbie Haught

◆ Forced Internal Recirculation Burner

In developmental testing at 20 MMBtu/hr on an industrial boiler, this new burner routinely realized 6 parts per million NO_x. This exceptionally low level was reached using a combination of air staging, premixed combustion, enhanced heat transfer to load and forced internal re-circulation of combustion products within the boiler's combustion zone. Further reductions of NO_x are believed possible. The burner will be applicable to a wide range of boilers in the 50-100 MM Btu/hr range.

OIT Contact: Gideon Varga

Crosscutting Technologies

(continued)

◆ Melt De-sulfurization

A new process that efficiently removes sulfur from metals at low cost could reduce the cost of electricity production. Nickel-based superalloys, used in high-strength blades for advanced combustion gas turbines, are strongly affected by sulfur in the metal, even in small amounts. (Sulfur causes the protective oxide to flake off). This new de-sulfurization process is applied to the metal alloy in the molten state, resulting in the quick removal of large quantities of sulfur at a low cost. Longer blade life will lead to lower electricity costs.

OIT Contact: Patricia Hoffman

◆ Method for Recycling Hazardous Waste

This new process mixes smelter dust, sludge from metal finishers and other materials, e.g., mill scales or aluminum pot liners in a furnace, and converts them into mineral wool, zinc oxide, and pig iron.

OIT Contact: Ramesh Jain

◆ Modified Pure-Air Combustion MODIPAC

A supercritical wet-air coal-burning process for electric power generation reduces flue gas emissions, increases energy efficiency, and reduces costs.

OIT Contact: Ramesh Jain

◆ Power Factor System by Means of Continuous Modulation

This variable power factor controller uses a fixed-size capacitor. The current drain of the capacitor can be altered as desired by varying the voltage applied to it. This variable voltage is obtained using a specifically-designed autotransformer with one or a pair of "sliding" contacts.

OIT Contact: Ramesh Jain

Crosscutting Technologies

(continued)

◆ Radiation-Stabilized Burner

A new radiation-stabilized burner is expected deliver NO_x emissions below 9 parts per million (ppm) at the same cost as current 30-ppm burner performance. "Ports" in the radiant burner surface can significantly increase the heat flux from radiant-type burners.

OIT Contact: Gideon Varga

◆ Recuperator of Flue Gas Heat

This new system, which recovers heat normally lost in flue gases of a furnace, makes use of a flexible metallic sleeve installed over the flue gas pipe as a heat exchanger. The sleeve is ducted to the return air inlet. An automatic damper controls the airflow through the heat exchanger.

OIT Contact: Ramesh Jain

◆ Simultaneous Heat and Mass Transfer

A novel air conditioner or heat pump uses desiccants for dehumidifying outside air and evaporative cooling to obtain necessary final supply air conditions. It supplies occupied space with 100% outside air without recycling inside air and does not use chlorofluorocarbon refrigerants.

OIT Contact: Rolf Butters

◆ Structural Monitoring System Using Fiber Optics

A new system uses a continuous fiber optic cable to monitor the behavior of a structure. Potential applications include monitoring strain levels in nuclear and fossil fuel power plant structures; sag and strain in electric powerlines; and strain of oil and gas pipelines, oil tankers, storage tanks, and dams.

OIT Contact: Rolf Butters

Crosscutting Technologies (continued)

◆ Synthesis and Sintering of Fine and Ultrafine Grain Sodium Zirconium Phosphate (NaZP) Ceramics

A series of low-thermal-expansion compounds of the sodium zirconium phosphate (NaZP) family has ultra-low thermal expansion coefficients and high thermal shock resistance. NaZP can be heated to 1300 degrees Celcius without thermal shock effects. The intended application for NaZP is thermal insulation.

OIT Contact: Ramesh Jain

◆ Thermal Energy Storage for Small, Packaged Terminal Air-Conditioning Units

This thermal energy storage system can be used with a rooftop air-conditioning unit or small unitary air-conditioning system. The system can be applied to existing air-conditioning units or new installations to reduce the installed capacity, duct sizes, and air flow rates.

OIT Contact: Rolf Butters

◆ Thermobarrier Coatings

Thermal barrier coatings for industrial gas turbine components are critical for higher temperature operation and longer lifetimes. Current coatings do not last over 8,000 hours and advanced coatings under development are targeted for 25,000 hours and improved corrosion resistance. Coated components include combustor liners, blades and vanes.

OIT Contact: Patricia Hoffman

◆ Thermoelectric Generator for Diesel Engines

This new technology generates electric energy from waste heat and has many applications in the power industry, as well as in the Chemical and Petroleum industries. One possible application is as an array on the exhaust of the gas turbine to increase efficiency. Heavy earth moving equipment for mining presents another potential application.

OIT Contact: Lisa Tunstall-German

Crosscutting Technologies (continued)

◆ Two-phase Hero Turbine with Curved No-Separation Nozzles

A turbine with converging-diverging nozzles achieves higher efficiency by avoiding abrupt flashing and water-steam phase separations by balancing out accelerations that are lateral to the flow.

OIT Contact: Ramesh Jain

◆ Ultra Low-Head Ambient Pressure Hydro Turbine

A horizontal expansion turbine with variable-pitch radial blades produces maximum power with small heads ranging from 5 to 15 feet and larger flows ranging from 10 to 5000 cu. ft/sec.

OIT Contact: Ramesh Jain

◆ Wear Resistant Composite Structure of Vitreous Carbon Containing Convuluted Fibers

A novel method makes a composite material consisting of a vitreous carbon matrix containing convuluted fibers. The resulting product has better wear resistance, lower coefficient of friction and higher electrical conductivity than competing materials.

OIT Contact: David Crouch

◆ WeldComputer™ Resistance Welder Adaptive Control

This system consists of a programmable power controller, line voltage monitoring, and compensation equipment, and, as an option, other sensors and compensation circuitry that can monitor parameters affecting weld quality. The unit can be sold as original equipment or retrofitted to existing units.

OIT Contact: David Crouch

Other Industries

◆ Alvar Engine

This internal combustion engine is designed to enable a variable-compression ratio by means of small secondary cylinders and pistons attached to the primary cylinders. The phase between secondary and primary pistons determines the compression ratio, which can be varied to enable better load matching under partial-load conditions, enhancing efficiency.

OIT Contact: Ramesh Jain

◆ AutoTherm

This automotive system captures waste heat, providing for personal comfort of the driver during periods when the automobile is not in use. The automatic system continues to circulate engine water through the vehicle's heating system using a patented fractional horsepower pump and system, maintaining a comfortable temperature in a stationary vehicle for extended time periods.

OIT Contact: Rolf Butters

◆ Charge Distribution Analysis

A new instrument and technique measures properties of semiconductors, catalysts, and other substances that were previously unmeasurable.

OIT Contact: Lisa Tunstall-German

◆ Combustion of Municipal Solid Wastes with Oil Shale in a Circulating Fluidized Bed

This process disposes of municipal solid waste with oil shale and generates electric power.

OIT Contact: Ramesh Jain

◆ Electrolytic Regeneration of Acid Cupric Chloride Printed Circuit Board Etchant

An electrochemical process regenerates spent chemicals formed through etchant action in the production of etched printed circuit boards. The process uses a unique arrangement of one anode and two separately controlled cathodes acting electrolytically on the etchant solution.

OIT Contact: David Crouch

Other Industries

(continued)

◆ Environmental Tensometer

This invention is used for high temperature testing of the tensile strength and related physical properties of single-filament refractory fibers under varying atmospheric conditions. The system integrates a furnace, testing unit, gas-handling system, vacuum system, and PC-based software.

OIT Contact: Ramesh Jain

◆ High-Speed Bandsaw with Precision, Diamond-Particulate Edge

A uniquely constructed bandsaw blade can be used for cutting silicon ingots in the manufacture of semiconductors.

OIT Contact: Ramesh Jain

◆ Insulation Containment Apparatus—The Ultimate 'R'

Invention is an insulation containment system is designed to fit around heating, ventilating, and air conditioning (HVAC) ductwork and reduce heat loss or gain. The system consists of fiberboard sections folded into smaller parts that can fit through a limited attic access opening or hatch. Once placed in the attic, sections are opened and positioned around the ductwork and filled with insulation.

OIT Contact: Rolf Butters

◆ Irrigation Valve Solenoid Energy Saver

This electronic module can be compactly installed close to a DC solenoid irrigation valve. It reduces overall installation costs, reduces electric current to operate the valve by 70% and allows a greater use of irrigation techniques.

OIT Contact: Ramesh Jain

◆ Mechanical, Infinitely-Variable-Speed Transmission for Automotive Use

In this novel automotive traction-drive continuously variable transmission (CVT), power is transmitted through a rigid circular metal ring instead of a V-belt. A two-mode power split design transmits power either directly or through the CVT and uses a ball/ramp mechanism downstream of the output sheave to limit frictional force.

OIT Contact: Ramesh Jain

Other Industries

(continued)

◆ Mobile Zone Optimized Control System for Ultra-Efficient Surface-Coating Operations

This novel spray paint booth ventilation system incorporates a movable operator cab. The cab is flushed with treated makeup air, while the rest of the spray booth uses recirculated air. The operator in the cab is protected from fire and explosive risks and does not need to wear protective gear.

OIT Contact: Rolf Butters

◆ Novel Fuel Injection System for Diesel Engines

This high-pressure, electronic, common-rail fuel injection system for diesel engines uses a plunger/barrel-type pump. The pump generates high pressure for the common rail with four equally spaced pumping elements around a cam-shaft. The opposed design of the pump balances the camshaft to allow nearly unlimited pump pressure capabilities.

OIT Contact: David Crouch

◆ Novel Procedure for Fabrication of MOSFETS

A new process for producing metal oxide semiconductor field effect transistors (MOSFETS) requires fewer fabrication steps than in conventional processing. This leads to greater yields per batch and saves energy.

OIT Contact: Ramesh Jain

◆ Peripheral Blade Mower

This mower has a novel blade design that eliminates the likelihood of accidents caused by mower-thrown objects, improves cutting efficiency, and is also adequate for mulching.

OIT Contact: Ramesh Jain

◆ QUBUS III Technology for Producing Ethanol

This technology uses a novel approach to produce ethanol. Cellulose from a leafy source is disrupted at low temperatures by an explosive ammonia boil. Conventional enzymatic hydrolysis and fermentation follow, leading to ethanol.

OIT Contact: Rolf Butters

Other Industries

(continued)

◆ RoboSort Technology for the Recycling Industry

Using imaging, computing, and human-machine communication technologies, this novel system combines high-speed pattern recognition with high-speed mechanical robotic hardware to help human operators in the recycling industry make efficient identification/sorting decisions. The mechanical robotic system does the physical work of sorting materials from each other based on rapid real-time decisions made by human operators using pattern recognition. The RoboSort unit increases the typical sorting rate by a factor of between two and three.

OIT Contact: Simon Friedrich

◆ Sag-Resistant Pinhole-Free Coatings (*Thane-Coat*)

A novel coating material with a high concentration of solids cures without the formation of pinholes.

OIT Contact: Lisa Tunstall-German

◆ Textile Brine Separation

Nanofiltration, combined with selected color removal technologies, provides beneficial reuse and removal of salt and color. Nanofiltration, used to filter selected dye bath "dumps", reduces the volume of colored wastewater for treatment, while providing for the beneficial reuse of brine solution in dyeing.

OIT Contact: Lisa Barnett

◆ Ultraviolet Crosslinking of Polybis (*Methoxyethoxy-xethoxy Phosphazene*)

This process makes solid-polymer electrolyte, which could be used in high-energy density batteries, such as those needed for powering electric vehicles.

OIT Contact: Lisa Tunstall-German

Appendix 3:

OIT Historical Technology Successes

This appendix briefly describes OIT-sponsored technologies that are no longer tracked, but that were commercialized in the past and had an impact on industrial productivity, energy use, and environmental emissions. These technologies include:

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Biomass Grain Dryer

Originally developed for grain-drying processes, this heat exchanger system later expanded into the furniture industry. By burning husklage, wood waste, or other biomass fuels, the process quickly disposed of combustible waste, provided an alternative energy source, and saved landfilling fees. Used within both the corn and furniture manufacturing industries, this system resulted in a cumulative 1.35 trillion Btu in energy savings and reduced landfill scrap by thousands of tons since being commercialized.

Cement Particle-Size Classifier

A system was developed to control the size distribution of cement particles and to help reduce the current energy-intensive regrinding process. Cement products produced from the improved particle distribution consumed less energy and were of better quality. This system yielded a total of approximately 13 trillion Btu in energy savings since its commercialization in 1984.

Co-combustion of Coal and Refuse-Derived Fuel

A system was designed to convert municipal solid waste into fuel pellets that were co-fired with coal to supplement coal supplies and reduce emissions. A co-combustion mix of refuse-derived fuel pellets and coal was shown to be capable of reducing acid gas emissions when compared with a plant using coal alone. In addition to a reduction in emissions and solid waste in landfills, the process also displaced the use of a fossil-fuel-based energy source.

Cogeneration – Coal-Fired Steam Turbine

Using a coal-fired boiler and turbine exhaust steam system, a cogeneration process was developed for use primarily within the textile industry. The 16 systems installed saved more than 31 trillion Btu of energy/year and significantly reduced emissions due to lower demand for utility-generated electricity.

Cogeneration – Slow Speed Diesel Engine

This stationary internal combustion, slow-speed, two-stroke diesel engine was developed to accommodate limited space and/or varying load demands. The compact, slow-speed diesel engine has excellent efficiency, greater load flexibility, and lower fuel and maintenance costs than conventional cogeneration options. The three installed units have saved a total of approximately 20 trillion Btu of energy.

Coil Coating Ovens

This system was developed to recover thermal energy previously lost in the solvent-based paint curing/incineration process. Heat, recovered from solvent vapor combustion in zone incinerators, was routed back into the curing oven to vaporize more solvent. The thermal incinerators normally used were replaced by afterburners and a waste heat boiler to produce process steam. A three-fourths reduction in natural gas requirements and a reduction in pollution control energy resulted in over 35 trillion Btu of cumulative energy savings since the system was commercialized. The savings were increased even further as a result of a technology upgrade that eliminated the zone-burning portion of the process.

Combination Grain Drying

Designed to prevent spoilage during storage and reduce energy consumption, this system used a high-speed dryer and storage bin equipped with a drying fan. The grain was first dried by a high-speed, hot-air dryer, then transferred to a drying/storage bin that delivered ambient air to cool and further dry the grain to a moisture content of around 14%. This combination drying method improved grain quality, increased drying capacity, and reduced propane and natural gas consumption.

Computer-Controlled Oven

To lower volatile organic compound (VOC) emissions, the computer-controlled oven technology was developed that permits operation at a higher percentage of lower explosive limits, reducing in dilution air requirements and the energy required to heat the high-temperature ovens. Optimizing airflows reduces VOC emissions that, in turn, reduces VOC incineration requirements. Fifteen installations saved a cumulative total of 27.75 trillion Btu of energy since being commercialized in 1982.

Cupola Stack Air Injection

This process reduced the carbon monoxide (CO) content of the effluents from a cupola furnace and improved the efficiency of combustion in the furnace during production of gray iron. This process eliminated the need for afterburners and the large amounts of energy they used to reduce the CO content in the emissions. By injecting air into the exhaust gases below the furnace charging door, the CO was ignited at temperatures already existing in the stack, with the resulting final exhaust gas having a CO concentration of less than 1%. Cupola stack air injection saved a total of 80 billion Btu of energy before being superseded by more advanced technology.

Dye Bath Reuse

To reduce the use of chemicals, water, and energy, two process modifications were developed for batch-dyeing textiles. These modified processes involved reconstituting and recycling the spent dye bath, eliminating the final rinse-water step. These modifications resulted in a cumulative energy savings of 2 trillion Btu prior to being replaced with advanced technologies.

Electric Tundish

An enclosed and more efficient holding furnace or tundish was developed and demonstrated for the continuous casting of copper alloys. Switching to electricity to heat the tundish rather than gas or oil results in an energy efficiency increase from 20% to 98%. Four tundishes were installed in 1994 and operated until the manufacturing facility closed in 1996.

Energy-Efficient Canning

A thermal syphon recycle system using a recycling steam jet vacuum compressor and a recirculation pump and heat exchanger outside of the cooker were two methods developed to improve energy efficiency in the canning industry. From the installation of 100 new or retrofitted units, a cumulative energy savings of nearly 3 trillion Btu were realized.

Energy-Efficient Fertilizer Production (Pipe Cross Reactor)

An ammonia granulation technology was developed to reduce moisture content and energy consumption in the production of pellet fertilizers. The process employed a pipe-cross configured reactor, mounted within a granulator, where liquid raw materials were mixed and then dried via heat from the chemical reaction. Seven reactors were constructed that produced a superior product with a 1% moisture content, reduced pollution, and contributed a cumulative energy savings of 2.6 trillion Btu.

Fluidized-Bed Waste Heat Recovery System

A self-cleaning waste heat recovery system was developed to replace industrial furnace conventional recuperators. The new system employed finned heat exchange tubes submerged in a bed of spherical alumina particles that absorbed heat from the hot gas and transferred it to the finned tubes. The water flowing through the tubes was converted to steam for use elsewhere in the plants while the alumina particle agitation kept the tubing clean and distributed the heat evenly.

Foam Processing

To replace the very energy-intensive wet processing of textiles, a process was developed to substitute medium-density foam for some of the water processing. A 50% to 70% moisture retention reduction was realized along with a significant decrease in energy previously required for drying, water usage, and pollution control. This technology, and several similar techniques, achieved a cumulative energy savings of more than 11 trillion Btu.

Heat Exchanger Dryer

This modified multideck dryer that incorporated a heat recovery system, was developed for the wood board products industry. Air-to-air, air-to-water, and air-to-liquid heat exchangers enabled the previously lost heat from exhaust gases to be reused throughout the plant. Three installations yielded nearly 800 billion Btu in cumulative energy savings.

High-Effectiveness Plate-Fin Recuperator

New materials and fabrication techniques made the previously cost prohibitive plate-fin recuperators more economically feasible for a larger number of industrial applications. The recuperators can recover 90% of the energy from exhaust as hot as 1550°F, are more compact than conventional techniques, and use a flexible flow pattern. Further, the new technology provides more heat transfer surface per cubic foot of volume and is often used in nonfouling heat recovery applications. More than 100 units were installed with a cumulative energy savings of around 5 trillion Btu.

High-Efficiency Weld Unit

An inverter welding power source that included a multiprocess capability was developed for arc welding processes. Up to 75% smaller in size and weight than conventional units, this system's portability and improved weld quality also provided energy savings of up to 45% over conventional power sources. More than 75,000 units were sold, resulting in a cumulative energy savings of 21 trillion Btu before they were replaced by more advanced welding technology.

High-Temperature Burner Duct Recuperators

Two ceramic tube recuperators, able to withstand 2000°F+ temperatures, were designed to recover heat from high-temperature industrial furnace exhausts. Used in iron forging and steel production, fuel consumption was reduced by approximately 50%.

Humidity Sensor (Heat Flux Dew-Point Hygrometer)

Designed to reduce heat lost through dryer exhaust gas, a heat-flux dew-point hygrometer was developed for the textile, paper, and food industries. Insensitive to contaminants and high temperatures, the hygrometer improved industrial drying processes and reduced energy consumption.

Humidity Sensor (Optical)

An optical humidity sensor (hygrometer) that determines humidity by measuring the absorption of ultraviolet light was developed for the pulp and paper industry. Replacing less reliable humidity sensors, the hygrometer maximizes drying efficiency by optimizing the balance of exhausted and makeup air. Multiple installations realized a cumulative energy savings of 20 billion Btu.

Hyperfiltration – Textiles

Hyperfiltration, a membrane-based separation technique, was adapted to treat textile industry wastewater. This process also found widespread use in the food-processing, biotechnology, pharmaceutical, pulp/paper, chemical, electronic, and nuclear industries. Allowing recovery of raw materials and minimizing waste, this process achieved a cumulative energy savings of nearly 1 trillion Btu.

Irrigation Systems

The design of efficient low-pressure impact sprinklers, low-pressure spray heads, and improved drop tubes upgraded center-pivot irrigation systems dramatically. Operating at lower pressures, these systems required 10% less water intake, reduced runoff, and yielded a cumulative energy savings of approximately 49 trillion Btu due to reduced pumping requirements.

Membrane Separation of Sweeteners

A system to preconcentrate corn steep water was accomplished via a hollow-fiber membrane process. Resistant to fouling, this system extracted more than 50% of the water from the corn steep stream prior to evaporation, thus significantly reducing energy requirements. Additionally, a spin-off technology was commercialized for wastewater treatment.

Nitrogen-Methanol Carburization

A system was developed for steel manufacturers that replaced the conventional endothermic atmosphere process with a nitrogen-methanol carburization process. In addition to improving the strength, hardness, and wear resistance of the steel parts, the system proved more reliable and easier to operate. Significant reductions in carbon dioxide and other pollutants were noted along with a cumulative energy savings of 12 trillion Btu.

Organic Rankine-Cycle Bottoming Unit

This organic Rankine-cycle system was developed to replace less-efficient, conventional steam Rankine-cycle systems in generating electricity from lower temperature waste-heat sources. It was found to be adaptable to a variety of solar and geo-thermal energy applications as well as suitable for many types of industrial waste-heat streams. The system consists of a standard Rankine-cycle engine, toluene as the working fluid, a waste-heat boiler, a waste-gas flow-control valve, system controls, and an electric generator. The installation of several units cumulatively saved 500 billion Btu of energy.

PET Bottle Separator

Recycling certain plastics for conversion into fuel oil necessitated the development of a separation process that could sort containers of PET (polyethylene terephthalate), high-density polyethylene, and aluminum. One bottling plant using this process recycled 18 million pounds of PET and saved a total of 1.2 trillion Btu of energy.

Plating Waste Concentrator

A low-cost, vapor-recompression evaporation system was developed for the plating and surface-finishing industry to reduce water pollution and recover costly plating chemicals. The waste concentrator was designed with two evaporators, one to concentrate the wastewater and the other to use waste heat as an energy source. Recovery of plating metals, reduced hazardous material treatment costs, and energy recycling all contributed to improved operating costs and energy efficiencies. This technology was used in 62 applications and resulted in a cumulative energy savings of 3 trillion Btu.

Recuperators

A cross-flow ceramic recuperator made of cordierite (a magnesium-aluminum silicate) was developed to recover heat from exhaust gases in high-temperature (up to 2600°F) furnaces. Corrosion and oxidation resistant, the compactly sized recuperator eliminated the need for a flue gas dilution system. These units cumulatively saved over 24 trillion Btu in energy and reduced both thermal and emissions pollution.

Slot Forge Furnace/Recuperator

A high-performance slot forge furnace design that incorporated a ceramic shell-and-tube recuperator was developed to recover approximately half of the heat energy previously lost in the furnace exhaust gases. Additionally, modified recirculation burners, improved temperature and air/fuel ratio controls, and lightweight furnace wall insulation reduced energy requirements per pound of steel by approximately 4100 Btu. The use of this technology resulted in a cumulative energy savings of 13 trillion Btu.

Solar Process Heat

This project was developed to expand the use of solar process heating systems primarily within the government and institutional sectors. Reducing the need for fossil fuels, solar heat supplies water preheating, process hot water, and steam as well as process hot air, cooling, and refrigeration.

VOC Control Assessment Software

A computer software project was developed to audit and select low-cost recovery methods for volatile organic compounds (VOCs) in small-scale applications. Simultaneously, an energy-efficient solvent condensing system was designed for small manufacturers with VOC emissions of 25 tons/year or less.

Waste Atactic Polypropylene to Fuel

This pyrolysis process converted a polypropylene plastic by-product, called atactic polypropylene, to fuel oil and gas. A total of 17 million pounds/year of atactic polypropylene was pyrolyzed into 2 million gallons/year of commercial-grade fuel oil that yielded a cumulative energy savings of 500 billion Btu.

Waste Energy Recovery

Two waste-to-energy plants were constructed, one in Honolulu, Hawaii and one in Tacoma, Washington, that burn the combustible portion of municipal solid waste (MSW). The combustible MSW materials are burned to produce steam, which in turn, is used to power a conventional steam turbine/generator to produce electricity. These plants reduce the amount of electricity that must be produced by fossil fuels, as well as the amount of MSW that must be disposed of in landfills. These two installations have yielded more than 35 trillion Btu of energy since being commercialized.

Appendix 4:

Methodology for Technology Tracking and Assessment of Benefits

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Technology Tracking

For over 22 years, the Office of Industrial Technologies (OIT) has been tracking and recording information on technologies developed through cost-shared R&D projects with industry. The tracking process considers technologies that can be classified as commercially successful, mature, or emerging.

When full-scale commercial units of a technology are operational in private industry, that technology is considered commercially successful and is on the active tracking list. When a commercially successful technology unit has been in operation for approximately 10 years, that particular unit is then considered a mature technology and is usually no longer actively tracked.

Emerging technologies are those in the late development or early commercialization stage of the technology life cycle (roughly within one to two years of commercialization). While preliminary information is collected on emerging technologies, they are not usually placed on the active tracking list until they are commercially available to industry.

The active tracking process involves collecting technical and market data on each commercially successful technology, including details on the:

- ◇ Number of units sold, installed, and operating in the United States and abroad (including size and location)
- ◇ Units decommissioned since the previous year
- ◇ Energy saved by the technology
- ◇ Environmental benefits from the technology
- ◇ Improvements in quality and productivity achieved through use of the technology
- ◇ Impacts of the technology on employment
- ◇ Marketing issues and barriers.

Information on technologies is gathered through direct contact with either vendors or end users of the technology. These contacts provide the data needed to calculate the unit energy savings associated with an individual technology, as well as the number of operating units.

Unit energy savings are unique to each individual technology. Technology manufacturers or end users usually provide unit energy savings, or at least enough data for a typical unit energy savings to be calculated. The total number of operating units is simply equal to the number of units installed minus the number of units decommissioned or classified as mature in a given year—information usually determined from sales data or end-user input. Operating units and unit energy savings can then be used to calculate total annual energy savings for the technology.

On the other hand, the cumulative energy savings represents the accumulated energy saved for all units for the total time the technology has been in operation (including previous savings from now-mature units as well as decommissioned units).

Once cumulative energy savings have been determined, long-term impacts on the environment are calculated in terms of the associated reduction of air pollutants. This calculation is straightforward, based on the type of fuel saved and the pollutants typically associated with combustion of that fuel. For example, for every million Btu of coal combusted, approximately 2.5 pounds of sulfur oxides (known acid rain precursors) are emitted to the atmosphere. Thus, every million-Btu reduction in coal use results in the elimination of 2.5 pounds of polluting sulfur oxides.

The results for annual and cumulative energy savings, as well as cumulative pollutant emission reductions for actively tracked technologies, are shown in the Technology Program Impacts chart on pages 8 and 9.

Methodology for Technology Tracking and Assessment of Benefits

Impacts

Deriving the OIT Cost/Benefit Curve

The Cumulative Production Cost Savings minus Cumulative Appropriations curve on page 6 provides an estimate of the direct net economic benefit of the OIT program since its inception. The method used to compute net economic benefits is based on several factors:

- ◆ Cumulative energy savings—the accumulated energy savings (Btu) produced by OIT-supported technologies that have been commercialized and tracked since the program began. As of FY 1997, this figure was 1001 trillion Btu.
- ◆ OIT appropriations—cumulative R&D dollars provided by OIT for commercialized and tracked technologies since the program began. As of FY 1997, this number was \$1,459,154,000.
- ◆ Weighted average cost of industrial energy—the average fuel price (dollars/Btu) that would have been paid to purchase energy, usually an average of industrial energy prices over the last 10 to 20 years, weighted by the mix of industrial fuels saved by OIT commercialized and tracked technologies. For 1997, the weighted average cost of industrial energy was about \$3.54 per million Btu.
- ◆ Levelized cost of industrial energy efficiency—the average “efficiency” fuel price (dollars/Btu) that was paid based on a 1988 study of 43 OIT-supported technologies. This estimate considers differences between the OIT technologies and the technologies they replace.

For each technology, differences in annualized capital costs, operating and maintenance costs, and non-energy production costs are summed and then divided by the annual energy savings to yield a net “price” per million Btu of energy benefits. This net levelized cost for each technology is then multiplied by the cumulative energy savings for that technology to yield cost savings per year. The sum of these cost savings for all 43 technologies, divided by the cumulative energy savings for all 43 technologies, then provides the final levelized cost of industrial energy efficiency, which is \$0.71 per million Btu.

To increase confidence in the cost estimates to over 90%, given the variability in estimates, and to ensure that cost savings are conservative, the cost-benefit analysis doubles the levelized cost to \$1.42 per million Btu.

- ◆ Average energy cost savings rate—the difference between the weighted average cost of industrial energy and the levelized cost of industrial energy efficiency. Thus, for 1997, the average energy cost savings rate was \$3.54 minus \$1.42 per million Btu, or \$2.12 per million Btu.

To develop the Program Benefit/Cost curve, the cumulative production cost savings minus appropriations must be calculated beginning in 1976. Cumulative production cost savings are calculated by multiplying the cumulative energy savings times the average energy cost savings rate. The net economic benefit is then the difference between cumulative production cost savings and cumulative OIT appropriations, or:

$$\begin{array}{r} \text{Cumulative Production Cost Savings} \\ - \quad \text{Cumulative OIT Appropriations} \\ \hline = \quad \text{Net Economic Benefit} \end{array}$$

For 1997, this calculation yielded a net economic benefit of \$662,966,000, calculated as follows:

$$\begin{array}{r} (\$2.12 \text{ per million Btu}) \times (1001 \text{ trillion Btu}) \\ - \quad (\$1,459,154,000) \\ \hline = \quad \$662,966,000 \text{ in Net Economic Benefit} \end{array}$$

The net economic benefit is then plotted on a graph as a function of the fiscal year from FY 1976 to the present.

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