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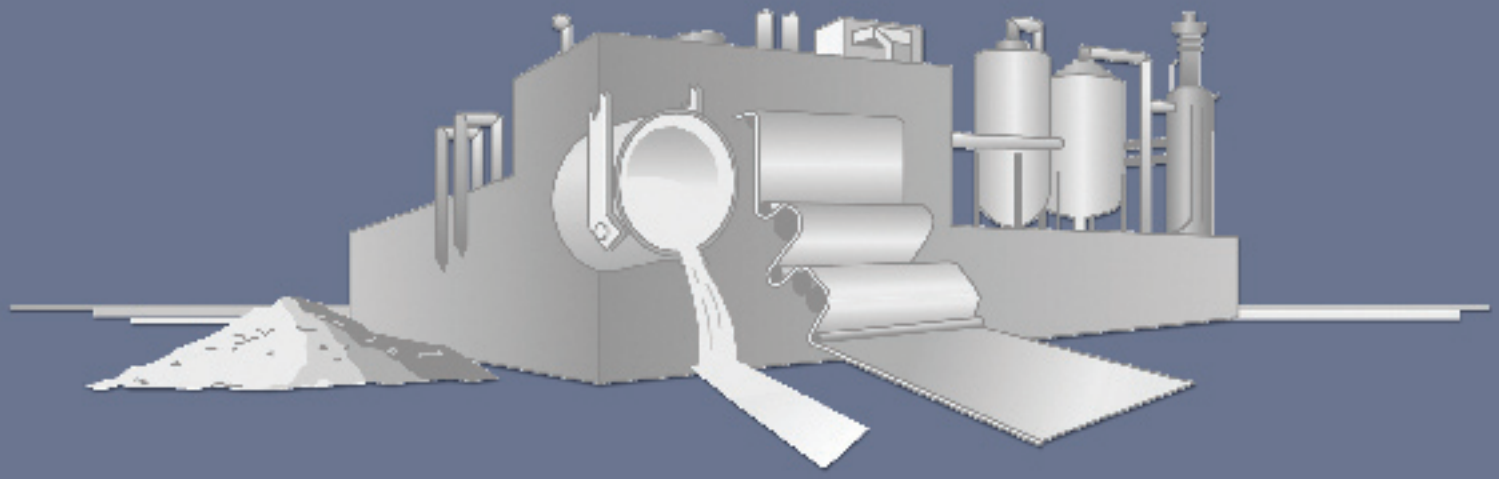
December 2009

Industrial Technologies Program:
Summary of Program Results for CY 2007

Boosting the Productivity and Competitiveness of U.S. Industry



U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

Foreword

Foreword

A robust U.S. industrial sector relies on a secure and affordable energy supply. While all Americans are feeling the pinch of volatile energy prices, project financial-constriction impacts on industry are especially acute. Lack of certainty with energy prices, emission regulations, and available financing not only hurt competitiveness – when combined, they have the potential to push critical U.S. manufacturing operations offshore, costing jobs that are the lifeline for many American families, weakening a sector that serves as the backbone of U.S. gross domestic product.

The Industrial Technologies Program (ITP) is actively working through public-private partnerships to address the enormous energy challenges now facing America and its industrial sector. ITP has an established track record for moving innovative technologies through commercialization and onto the floors of industrial plants, where they are at work saving energy and reducing carbon emissions today. Eight of our newest technologies received the prestigious R&D 100 Award in 2006. Equally notable are the significant savings identified this year through the plant energy assessments we conduct as part of ITP's *Save Energy Now* initiative.

The novel challenges confronting U.S. industry at this time and the rapidly evolving energy picture prompted a reexamination of our strategies for technology development and delivery. We have identified a number of exciting opportunities to build on our strengths, expand into promising new areas, and boost program impacts to support critical national goals. We are proud to be serving our country under the guidance of the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE). We invite you to learn more about our current program and new directions.

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Executive Summary

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Working in partnership with industry, the U.S. Department of Energy's (DOE's) Industrial Technologies Program (ITP) is helping reduce industrial energy use, carbon emissions, and waste while boosting productivity and economic competitiveness. Operating within the Office of Energy Efficiency and Renewable Energy (EERE), ITP conducts research, development, and demonstration (RD&D) and technology transfer that are producing substantial, measureable benefits to industry and helping the nation to address some of its biggest challenges in the areas of energy security and environmental performance. This document summarizes some of the impacts of ITP's programs through CY 2007. The selection of 2007 as the basic timeframe for this report is in recognition of the fact that it takes two years to acquire a full perspective and to total the actual results of commercialization efforts for the technologies and practices at issue.

Industry is the largest and most diverse energy-consuming U.S. sector. In recent years, the industrial sector has used one-third of the energy consumed in the nation, produced about 1,670 MMT of CO_2 per year, contributed 12% to the overall U.S. gross domestic product, and provided nearly 12 million manufacturing jobs. These statistics – combined with the convergence of concerns surrounding energy security, climate change, and global competitiveness – emphasize the strategic role that improved industrial energy efficiency can play in responding to some of the nation's most pressing energy, economic, and environmental challenges.

One of ITP's major efforts is now the *Save Energy Now* LEADER program. This is a new component of *Save Energy Now* – a highly successful national initiative sponsored by ITP beginning in 2006 to drive a 25% reduction in industrial energy intensity in 10 years (25 in 10) through the use of proactive partnerships between government and the private sector. *Save Energy Now* has developed into a robust suite of energy-savings tools and services that ITP provides for partnering with industry to improve energy efficiency. As of September 2009 the *Save Energy Now* initiative has completed over 2,300 assessments. More than 1,500 industrial facilities have implemented the assessment recommendations, achieving $218 million, 35 trillion Btu, and 2.3 MMT of CO_2 savings each year. In 2009, ITP recognized 140 companies for their energy savings. For more information, see http://www1.eere.energy.gov/industry/saveenergynow/recognition.html.

The *Save Energy Now* LEADER program provides a mechanism through which the government actively works with manufacturers to help them identify and implement energy saving technologies and practices that can yield real benefits in real time – benefits that will help save energy, reduce greenhouse gas emissions, and create or preserve jobs. For more information, see http://www1.eere.energy.gov/industry/saveenergynow/leader.html.

ITP is also working with U.S. industry to support the development of an emerging set of energy management standards and a related certification program anchored to a viable business case. Similar to environmental or quality management systems in industry, much energy efficiency in industry is achieved through changes in how energy is managed in a facility. A new energy management standard, ISO 50001, will provide a method for integrating energy efficiency into existing industrial or commercial management systems for continuous improvement. Once completed, ISO 50001 promises to create a framework for all of industry to manage energy and improve cost savings. At issue is the forthcoming industry-designed American National Standards Institute (ANSI)-accredited plant certification program called Superior Energy Performance, which will include conforming to ANSI's Management System for Energy (MSE) standard, or ANSI/MSE 2008, and eventually the more far-reaching international ISO 50001 standard, as well as achieving a defined level of energy intensity performance improvement. A total of 35 countries are participating in developing this international standard. The International Organization for Standardization is estimated to release ISO 50001 in 2011. The energy management standard and certification program will serve as powerful new tools in the arsenal of the broader *Save Energy Now* LEADER program that will assist U.S. industry in continually improving energy efficiency in an accelerated manner.

An additional product of the *Save Energy Now* initiative is an effort by ITP to help drive progress on energy efficiency more aggressively throughout the supply chain. As supply chains for companies have grown increasingly complex, understanding and managing energy waste within them represent a way to reduce energy prices or regulatory risk and increase competitive advantage. Not only can it add to security in a company's operations, it can enhance their suppliers' businesses, as well as provide mentoring and support for these suppliers' energy and emissions management systems.

Many energy-intensive industries, including aluminum and steel, are limited in the choice of fuels and feedstocks required in their processes. As a result, many opportunities for energy-efficiency improvements are very process-specific to one industry. However, because some important energy applications, such as motor drives, boilers, and compressed air systems, are common across the industrial sector, crosscutting energy-efficiency opportunities also exist.

Executive Summary

Over the past 30 years, ITP has supported more than 600 separate RD&D projects that have produced over 200 technologies. In 2007 alone, 107 successfully commercialized technologies saved 83.6 trillion Btu in measured savings. 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. Also, many ITP-supported projects have significantly expanded knowledge about complex industrial processes and have laid the foundation for developing future energy-efficient technologies.

Industrial Distributed Energy, a cross-cutting activity within ITP, builds on activities conducted by DOE's Office of Industrial Technologies during the 1980s and 1990s and the DOE Distributed Energy Resources program since 2000. Since 1990, the use of distributed energy within the United States, primarily combined heat and power (CHP), has increased significantly. CHP capacity additions between 1990 and 2007 totaled 56.1 GW, according to the CHP Installation Database maintained by ICF International for DOE through a contract with Oak Ridge National Laboratory (ORNL). According to a report prepared by ORNL, if CHP capacity were to reach 20% of U.S. electricity production by 2030, more than 5.3 quad of energy would be saved, and CO_2 emissions would be reduced by 848 MMT. This represents 60% of the projected greenhouse gas emissions production from 2006 to 2030.

Through current and expanded funding from the *American Reinvestment and Recovery Act*, ITP is advancing CHP as one of the more promising efficient energy solutions that can help to revitalize the American economy, enhance the nation's energy security, and reduce carbon pollution. CHP can achieve efficiencies of as much as 80% compared with roughly 45% for conventional heat and power production.

One of ITP's primary roles is to invest in high-risk, high-value RD&D that will reduce industry's energy requirements while stimulating economic productivity and growth. Because energy is an important input for many of the nation's key manufacturing industries, reducing energy requirements will also reduce energy costs, greenhouse gases, and other emissions and will improve productivity per unit of output. As a federal program, ITP invests in advanced technologies that are anticipated to produce dramatic energy and environmental benefits for the nation. Investments focus on technologies and practices that will provide clear public benefit but have market barriers preventing adequate private-sector investment. ITP partners with manufacturers to help them overcome these barriers so that the benefits of energy-efficient innovation can be unleashed.

ITP has developed a ten-part strategy to achieve its goals:

1) Investigate cross-cutting R&D to save energy in the top energy-consuming processes used across industry.

2) Exploit fuel and feedstock flexibility to give manufacturers options for responding to energy price and supply pressures.

3) Invest in "next-generation" technologies that are adaptable to processes throughout industry and that could dramatically change the way products are manufactured. For more information, see www1.eere.energy.gov/industry/bestpractices/energymatters/pdfs/energy_matters_fall_2009.pdf.

4) Strengthen planning and analysis to identify opportunities with the greatest potential for energy savings and develop a robust market transformation strategy.

5) Institute rigorous stage-gate project and portfolio management procedures to ensure sound project management and funding decisions.

6) Emphasize commercialization planning throughout the R&D life cycle.

7) Encourage private investment in energy efficiency through new partnerships and strategies to reach industry. For information on state partnerships, see www1.eere.energy.gov/industry/states/state_activities/main_map.asp.

8) Drive ambitious reductions in industrial energy intensity through *Save Energy Now* and its related LEADER program. For information on companies that have signed to be *Save Energy Now* leaders, see www1.eere.energy.gov/industry/saveenergynow/leader_companies.html.

9) Promote energy-efficiency improvements throughout the supply chain.

10) Help drive the development of energy management standards and the Superior Energy Performance certification program to provide a clear roadmap for continual improvement in energy efficiency. For information on the U.S. Council for Energy-Efficient Manufacturing, see www.superiorenergyperformance.net.

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In addition to tracking energy savings, ITP monitors energy savings as well as other benefits associated with the successfully commercialized technologies resulting from its research partnerships. These benefits include current and cumulative energy savings and cumulative reductions of various air pollutants including particulates, volatile organic compounds, nitrogen oxides, sulfur oxides, carbon, and most recently jobs created or saved. In 2007, ITP programs were instrumental in saving industry 734 trillion Btu, equivalent to the 2007 energy consumption for the entire state of Nevada, and $6.73 billion. Over ITP's entire history, these cumulative net benefits are about 8.50 quadrillion Btu, equivalent to 2007 energy consumption for all of California or roughly $67.75 billion (in 2007 dollars).

The bulk of this document consists of seven appendixes. Appendix 1 describes the 107 technologies currently available commercially and their applications and benefits. Appendix 2 describes the 126 ITP-supported emerging technologies likely to be commercialized within two or three years. Appendix 3 describes 111 ITP-sponsored technologies used in past commercial applications, the current benefits of which are no longer counted in this report. Appendixes 4 and 5 summarize the benefits of two ITP technical assistance activities: the Industrial Assessment Centers and Best Practices. Appendix 6 summarizes the benefits of CHP systems attributed to DOE activities. Finally, Appendix 7 describes the methodology used to assess and track ITP-supported technologies.

Summary of ITP Program Impacts

Industrial Energy Use

Industry is the largest and most diverse energy-consuming U.S. sector. In recent years, the industrial sector has used one-third of the energy consumed in the nation, produced about 1,670 MMT of CO_2 per year, contributed 12% to the overall U.S. gross domestic product (GDP), and provided nearly 12 million manufacturing jobs. These statistics – combined with the convergence of concerns surrounding energy security, climate change, and global competitiveness – emphasize the strategic role that improved industrial energy efficiency can play in responding to some of the nation's most pressing energy, economic, and environmental challenges.

In 2007, the industrial sector used 32.30 quad of all types of energy including electricity losses of 7.45 quad (see Figure 1). Petroleum (9.53 quad), natural gas (8.00 quad), and electricity (3.43 quad delivered) are the three fuels most used by industry, with coal and biomass providing another 3.89 quad combined. The industrial sector consumed a total of 24.85 quad, of which 19.50 quad were consumed by manufacturing industries. Of that 19.50 quad, energy-intensive industries consumed 15.37 quad. The non-energy-intensive industries (4.13 quad) and non-manufacturing industries (agriculture, mining, and construction – 5.35 quad combined) accounted for the remaining energy consumption. Industry uses nearly 6.76 quad of the fossil fuels for feedstocks – raw materials for plastics and chemicals – rather than as fuels. Energy expenditures in the manufacturing sector are approximately $104 billion annually.

Energy-intensive industries such as forest products, chemicals, petroleum refining, nonmetallic minerals (glass and cement, especially), and primary metals account for about 79% of all manufacturing energy use (see Figure 2).

Many of the energy-intensive industries are limited in their choice of fuels because the technologies currently used in specific processes require a certain fuel. For example, aluminum production requires large amounts of electricity to reduce the alumina to metal. Paper pulping leaves a large residual of wood lignin that can be reprocessed for its chemical content and consequently supplies the industry with half of its primary energy. Therefore, the wide variety of fuels (and feedstocks) used in the industrial sector partially

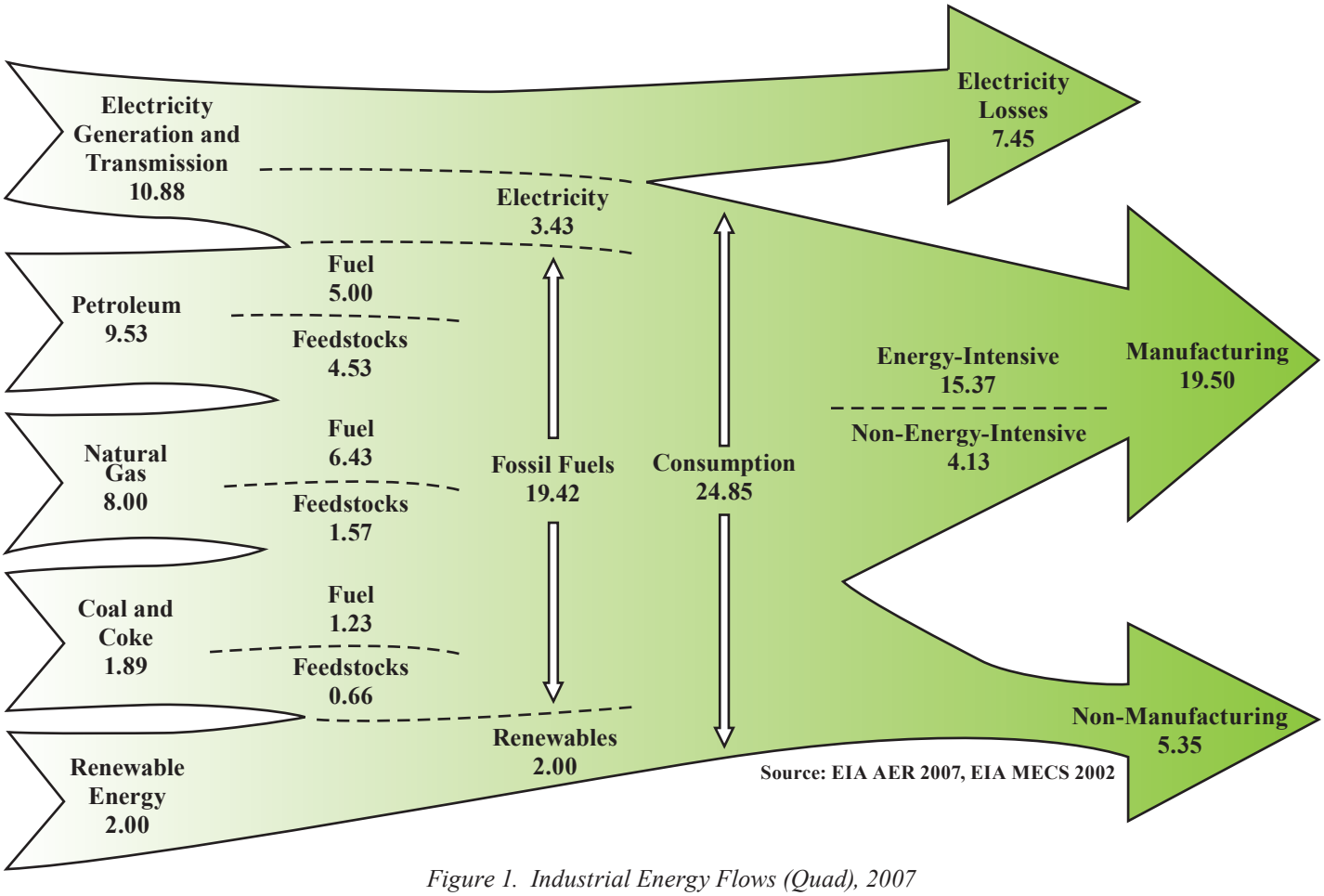

Figure 1. Industrial Energy Flows (Quad), 2007

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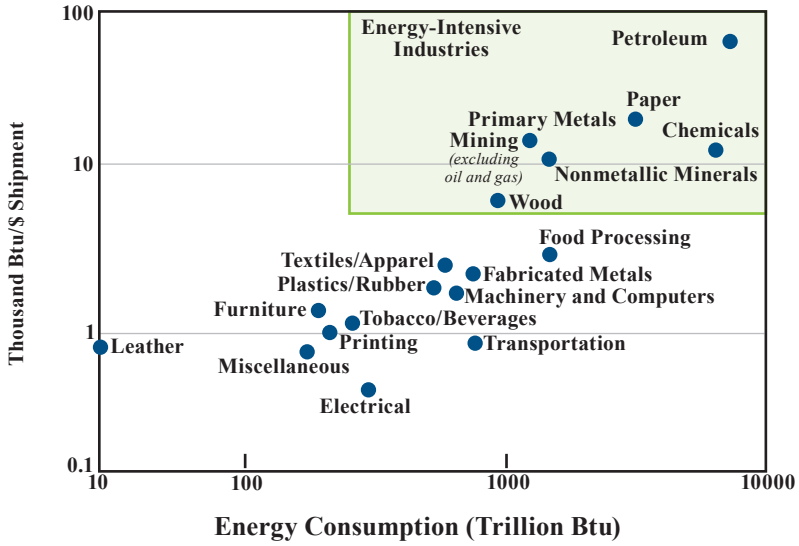
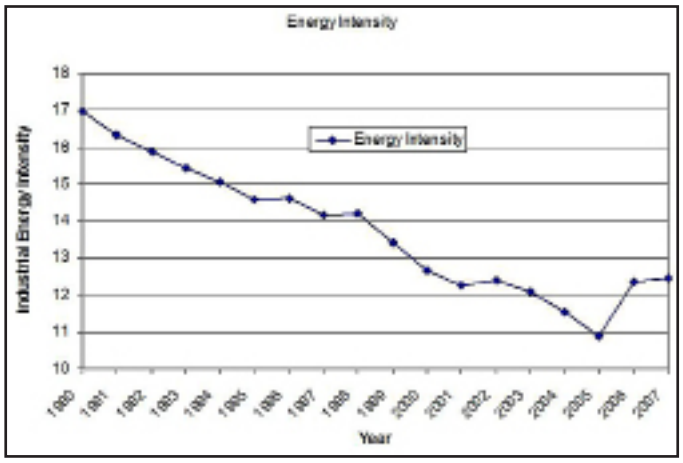


Sources: EIA MECS 2002, Bureau of Economic Analysis

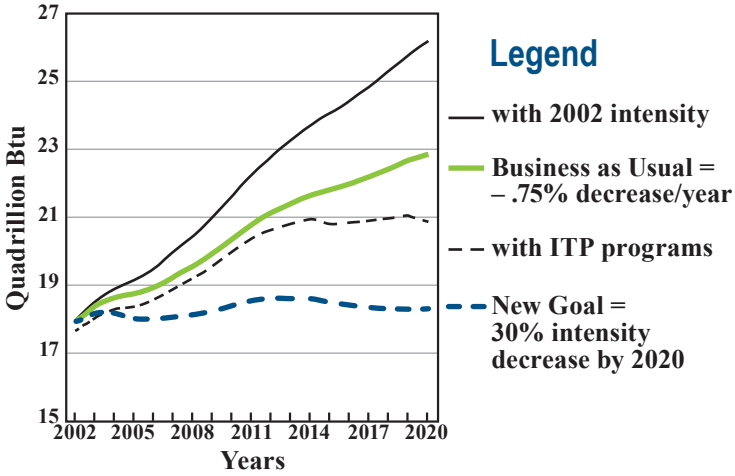
Figure 2. Energy Intensity of Manufacturing Industries

reflects the specific requirements of the processes used to make specific goods or commodities. Because of specific energy requirements, the industrial sector offers a wide variety of opportunities for energy-efficiency improvements that are specific to particular industries and that crosscut many industries (i.e., are common to many industries or are needed by many process-specific technologies).

The energy intensity of the industrial sector has been declining over the past decade, in part because of investments in the development of energy-efficient technologies by the Industrial Technologies Program (ITP), previously the Office of Industrial Technologies (OIT). Since its peak in 1992, industrial sector energy intensity has declined from 17,137 Btu/dollar of industrial GDP to 12,453 Btu/dollar of real industrial sector GDP in 2007 (see Figure 3). These reductions are expected to continue into the future, as is implied by the slower growth of energy use with ITP programs (see Figure 3).



Sources: EIA Annual Energy Review, 2007, Table 2.1d and BEA, Value Added for Industry, 1990-2003, *(Constant $2000)*



Sources: EIA AEO 2004, EIA MECS 2001, ITP

Figure 3. Historical Industrial Energy Intensity and Projected Energy Use

Summary of ITP Program Impacts

The Industrial Technologies Program Office

ITP leads the federal government's efforts to improve industrial energy efficiency and environmental performance. The program is part of the Office of Energy Efficiency and Renewable Energy (EERE) and contributes to its efforts to provide reliable, affordable, and environmentally sound energy for the nation's future.

Large opportunities to save energy still exist in U.S. industry. Putting current knowledge to use and continuing research can make a difference. American industry can increase the nation's resilience in the face of current and future energy challenges. Advances in energy efficiency, fuel flexibility, and innovative technologies can enhance energy security, economic growth, and environmental quality. Good starting points for reducing industry's energy consumption and reliance on oil and natural gas include the following:

- **More Efficient Operating and Maintenance Practices.** Improved and more energy-efficient operating practices can be adopted rapidly at negligible cost to enhance near- to mid-term operating efficiency in manufacturing facilities.

- **Increased Adoption of State-of-the-Art Technology.** Energy efficiency can be improved in the near- and mid-term by increasing industries' adoption of currently available advanced technologies. For example, waste heat recovery, combined heat and power (CHP), and advanced boiler technologies offer huge energy-saving opportunities.

- **Increased Fuel and Feedstock Flexibility.** Manufacturers need the flexibility to adapt to dynamic energy prices and supply issues. Much of industry's natural gas is used for boilers and process heaters, which present primary fuel switching opportunities.

- **Development of Next-Generation Technology.** Progress toward long-term national goals for energy and the environment rely on continuous technology innovation. The technologies required to address today's challenges can take a decade or more to progress from basic science to commercialization.

National energy security will require widespread industry adoption of innovative technologies and practices that reduce energy demand. ITP leads federal efforts to expedite novel technology research and accelerate market introduction of dramatically more efficient industrial technologies and practices. Over the next few years, ITP will build on accumulated knowledge and strategic partnerships to take full advantage of new opportunities to accelerate and broaden impacts on industrial energy use. New challenges call for innovative solutions. The development of energy-efficient technologies ready to enter the market in the near term must be accelerated; at the same time, groundbreaking research must be conducted on revolutionary technologies for the future. ITP's focus on applied research and development (R&D) effectively turns knowledge and concepts initiated by others into real-world energy solutions. In addition, novel strategies to expand ITP's partner base will boost program impacts by expediting technology commercialization and adoption of efficient energy management practices. ITP is currently evaluating a number of opportunities to help industry respond to energy challenges today and tomorrow. ITP is exploring 10 new strategies to help industry stay competitive today while preparing for future challenges:

- Investigate cross-cutting R&D to save energy in the top energy-consuming processes used across industry. ITP is focusing on a small number of widely used technology areas that could achieve large energy benefits throughout the manufacturing supply chain.

- Exploit fuel and feedstock flexibility to give manufacturers options for responding to energy price and supply pressures. ITP is seeking to develop alternative fuel and feedstock technologies to replace oil and natural gas in the long term while supporting near-term deployment activities to reduce the impacts of fuel price hikes. By increasing the range of fuel options available to industry, ITP will foster energy independence and economic resilience.

- Invest in "next-generation" technologies that are adaptable to processes throughout industry and that could dramatically change the way products are manufactured. ITP is funding research in mass-scale nano manufacturing, process-integrated predictive tools, and wireless real-time sensor systems that are just a few of the technologies that could bring new, cost-competitive options to American industry, see www1.eere.energy.gov/industry/bestpractices/energymatters/pdfs/energy_matters_fall_2009.pdf.

- Strengthen planning and analysis to identify opportunities with the greatest potential for energy savings and develop a robust market transformation strategy. ITP is conducting a thorough analysis of industry market barriers and challenges that will allow more effective investment decisions with higher impacts.

- Institute rigorous stage-gate project and portfolio management procedures to ensure sound project management and funding decisions. ITP has developed its own program management guidelines based on the conventional Stage-Gate Management™ concept of R.G. Cooper and Associates (see Figure 4). ITP is examining

projects at critical gates throughout the R&D cycle based on carefully defined technical and business criteria. This program management tool provides ITP managers with a straightforward pathway for evaluating progress and imposes discipline in project management, raising the potential for commercial success of ITP's R&D portfolio.

- Emphasize commercialization planning throughout the R&D life cycle. ITP will work with its R&D partners to develop robust commercialization strategies and provide other support to ensure the market success of promising new technologies.

- Encourage private investment in energy efficiency through new partnerships and strategies to reach industry. ITP will expand its alliance with equipment manufacturers who are well positioned to drive new technology to the market and publicize it to their customers. Private industry will also be challenged to increase their investment in advanced technologies, energy management and best operating practices, and the replacement of older, inefficient equipment, see www1.eere.energy.gov/industry/states/state_activities/main_map.asp.

- Drive ambitious reductions in industrial energy intensity through *Save Energy Now* and its related LEADER program. For information on companies that have signed to be *Save Energy Now* leaders, see www1.eere.energy.gov/industry/saveenergynow/leader_companies.html.

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In addition to these strategies, ITP partners with other program areas within EERE and performs ongoing program evaluation, including assessing past programs and the benefits that have accrued from investments.

ITP's website (http://www.eere.energy.gov/industry) provides a wealth of information about the program, and the EERE Information Center (1-877-337-3463, eereic@ee. doe.gov) fields questions and facilitates access to ITP resources for industrial customers.

One of ITP's major efforts is now the *Save Energy Now* LEADER program. This is a new component of *Save Energy Now* – a highly successful national initiative sponsored by ITP beginning in 2006 to drive a 25% reduction in industrial energy intensity in 10 years (25 in 10) through the use of proactive partnerships between government and the private sector. *Save Energy Now* has developed into a robust suite of energy-savings tools and services that ITP provides for partnering with industry to improve energy efficiency. As of September 2009 the *Save Energy Now* initiative has completed over 2,300 assessments. More than 1,500 industrial facilities have implemented the assessment recommendations, achieving $218 million, 35 trillion Btu, and 2.3 MMT of CO_2 savings each year. In 2009, ITP recognized 140 companies for their energy savings. For more information, see http://www1.eere.energy.gov/industry/saveenergynow/recognition.html.

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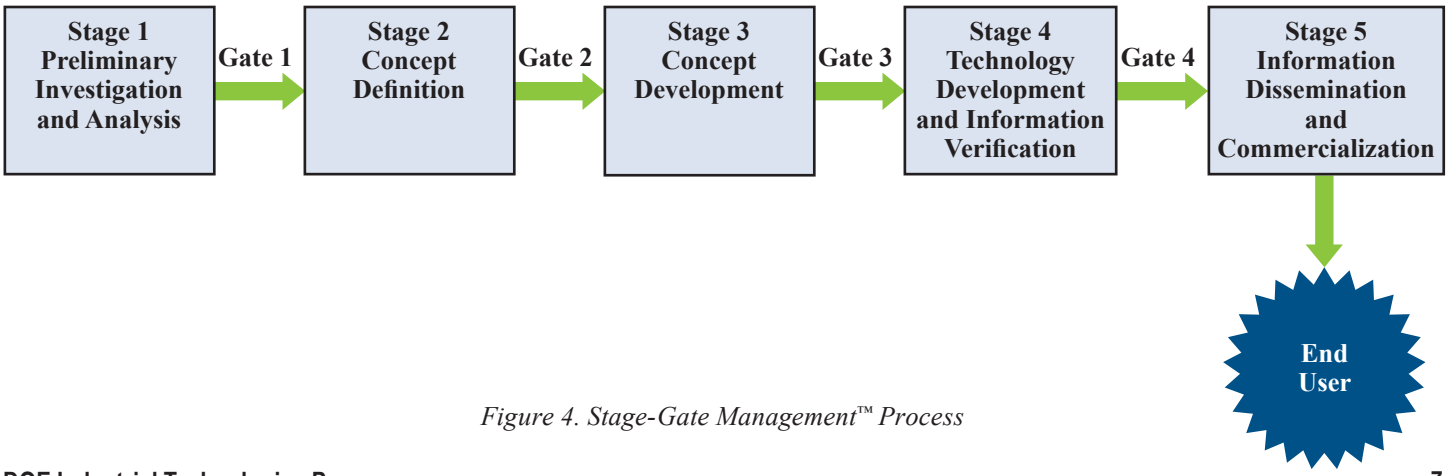

Figure 4. Stage-Gate Management™ Process

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This report also quantifies the benefits of projects in the EERE portfolio now managed through other program offices but initiated in ITP. For example, partnerships with an emerging bio-based products industry, now managed through the Biomass Program, bring expertise and technology from several industries – agriculture, forest products, and chemicals – to create plastics, chemicals, and composite materials from renewable resources. Also, the Inventions and Innovation (I&I) Program provided grants to individual inventors and small companies for conducting early development through to prototyping for innovative energy-saving ideas. In addition, projects are included that were funded by the discontinued NICE[3] (National Industrial Competitiveness through Energy, Environment, and Economics) Program that developed and demonstrated advances in energy efficiency and clean production technologies.

Tracking Program Impacts

ITP has assessed the progress of the technologies supported by its research programs for more than 20 years. ITP program managers recognize the importance of developing accurate data on the impacts of their programs. Such data are essential for assessing ITP's past performance and guiding the direction of future research programs.

Pacific Northwest National Laboratory (PNNL) estimates energy savings associated with specific technologies using a rigorous process for tracking and managing data. When a technology's full-scale commercial unit is operational in a commercial setting, that technology is considered commercially successful and is placed on the active tracking list. When a commercially successful technology unit has been in operation for about 10 years, that particular unit is then considered a mature technology and typically is no longer actively tracked. The active tracking process involves collecting technical and market data on each commercially successful technology, including details on the following:

- 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
- Environmental benefits
- Improvements in quality and productivity achieved
- Other impacts, such as employment and effects on health and safety
- Marketing issues and barriers.

Information on technologies is gathered through direct contact with either the technology's vendors or end users. These contacts provide the data needed to calculate the technology's unit energy savings, as well as the number of operating units. Therefore, unit energy savings are calculated in a unique way for each 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 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.

The cumulative energy savings measure includes the accumulated energy saved for all units actively tracked. These energy savings include the earlier savings from now mature and decommissioned units.

Once cumulative energy savings have been determined, long-term impacts on the environment are calculated by estimating the associated reduction of air pollutants. This calculation is based on the type of fuel saved and the pollutants typically associated with combustion of that fuel and uses assumed average emission factors.

Several factors make the tracking task challenging. Personnel turnover at developing organizations and 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 that are derivative of the developed technology.

Program benefits documented by PNNL are conservative estimates based on technology users' and developers' testimonies. These estimates do not include either derivative effects, resulting from other new technologies that spin off of ITP technologies, or the secondary benefits of the energy and cost savings accrued in the basic manufacturing industries downstream of the new technologies. Therefore, actual benefits are likely to be much higher than the numbers reported here. Nonetheless, the benefits-tracking process provides a wealth of information on the program's successes. The process of tracking these benefits is shown in Figure 5.

Over the past 30 years, ITP has supported more than 600 separate R&D projects that have produced over 200 technologies in commercial use. In 2007, there were 107 technologies that were in commercial use and yielding benefits. Appendix 1 presents fact sheets on these 107 technologies. 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. Table 1, on pages 11 and 12, provides information on the 107 currently tracked technologies. This table shows energy savings in 2007, as well as cumulative energy savings and pollution reductions. Note that for some technologies, energy savings values are unavailable, very small, or too difficult to quantify. The 107 commercial technologies saved 83.6 trillion Btu in 2007 and have cumulatively saved 1,225 trillion Btu.

Technologies that are likely to be commercialized within two or three years are identified in Appendix 2. Some of these 126 emerging technologies have already yielded scientific information that has improved current industrial processes.

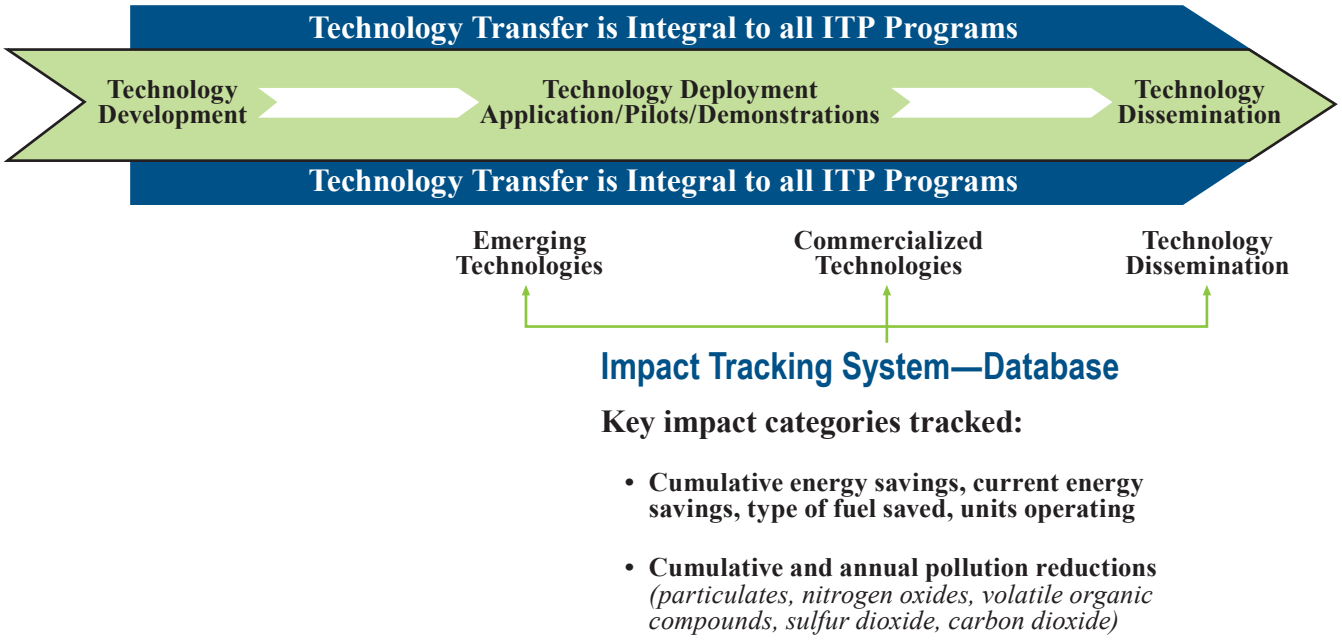

Figure 5. Technology Tracking Process

Summary of ITP Program Impacts

After a commercial technology has contributed to energy and cost savings for about ten years, the technology is considered historical and presumed to be supplanted by newer, more effective technologies. Appendix 3 describes the 111 historical 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 in Table 1. The 111 historical technologies cumulatively saved 2.33 quad.

The method of calculating the results for the Industrial Assessment Centers (IACs) and the resulting benefits are described in Appendix 4. As Table 1 shows, the centers saved 224 trillion Btu in 2007 and cumulatively saved 1,714 trillion Btu since the activity's inception in 1977. The method of calculating the results for the BestPractices strategy and the resulting benefits are described in Appendix 5. As shown in Table 1, BestPractices saved 225 trillion Btu in 2007 and has cumulatively saved 901 trillion Btu since its inception in 1998. The method of calculating the results attributable to DOE's combined heat and power (CHP) activities and the resulting benefits are described in Appendix 6. As shown in Table 1, CHP activities saved 201 trillion Btu in 2007 and have cumulatively saved 2,330 trillion Btu since 1990.

The determination of the net economic benefits of ITP programs is discussed in Appendix 7. Using the energy savings from the technologies as well as the IACs, BestPractices, and CHP activities, the cost savings are determined annually for the fuels saved. The annual energy savings by fuel type is multiplied by the fuel's price, with prices adjusted to reflect the fuel's current costs. The sum of all energy saved times the average energy price yields an estimate of the annual savings in that particular year. To arrive at the net economic benefits, the cumulative energy savings are reduced by the appropriation allocated by the government for ITP programs and by the cost of the industry of adopting the new technologies. Details of this methodology are provided in Appendix 7. In 2007, ITP programs were instrumental in saving industry 734 trillion Btu, equivalent to the 2007 energy consumption for the entire state of Nevada, and $6.73 billion. Over ITP's entire history, these cumulative net benefits are about 8.50 quad, equivalent to 2007 energy consumption for all of California or roughly $67.75 billion (in 2007 dollars). In addition, the ITP programs have cumulatively reduced emissions of carbon by 189 million tons, of nitrogen oxides by 1.61 million tons, and of sulfur dioxides by 3.43 million tons, as Table 1 shows.

Table 1. Technology Program Impacts

Technologies Commercially Available	Cumulative Energy Savings (10^{12} Btu)	2007 Energy Savings (10^{12} Btu)	Cumulative Pollution Reductions (Thousand Tons)				
			Particulates	VOCs	SO_x	NO_x	Carbon
ALUMINUM							
Aluminum Reclaimer for Foundry Applications	0.003	0.001	-	0.000	-	0.000	0.040
Aluminum Scrap Sorting	1.71	0.338	0.008	0.006	0.369	0.275	33.6
Isothermal Melting	0.010	-	0.000	0.000	0.002	0.002	0.203
Oxygen-Enhanced Combustion for Recycled Aluminum	0.025	-	-	0.000	-	0.003	0.400
CHEMICALS							
Cavity-Enhanced Gas Analyzer for Process Control	-	-	-	-	-	-	-
DryWash®	0.063	0.011	0.000	0.000	0.010	0.009	1.176
Hollow-Fiber Membrane Compressed Air Drying System	0.006	0.003	0.000	0.000	0.001	0.001	0.113
Improved Methods for the Production of Polyurethane Foam	0.106	0.082	0.000	0.000	0.011	0.015	1.88
Low-Cost, Robust Ceramic Membranes for Gas Separation	0.019	0.008	-	0.000	-	0.002	0.302
Low-Frequency Sonic Mixing Technology	-	-	-	-	-	-	-
Membranes for Reverse-Organic Air Separations	0.004	0.004	0.000	0.000	0.002	0.001	0.082
Micell Dry-Cleaning Technology	0.030	0.003	0.000	0.000	0.005	0.004	0.560
Mixed Solvent Electrolyte Model	-	-	-	-	-	-	-
No-VOC Coating Products	0.007	0.001	-	0.000	-	0.001	0.111
Nylon Carpet Recycling	-	-	-	-	-	-	-
Pressure Swing Adsorption for Product Recovery	0.404	0.111	-	0.001	-	0.047	6.41
Process Heater for Stoichiometric Combustion Control	1.46	0.338	0.001	0.005	0.086	0.180	24.2
Supercritical Purification of Compounds for Combinatorial Chemical Analysis	3.77	1.080	0.017	0.013	0.814	0.607	74.1
Total Cost Assessment Tool	-	-	-	-	-	-	-
TruePeak Process Laser Analyzer	-	-	-	-	-	-	-
FOREST PRODUCTS							
Advanced Quality Control (AQC) Solution for Thermo-Mechanical Pulping	0.923	0.154	0.004	0.003	0.199	0.149	18.1
Borate Autocausticizing	0.020	0.020	-	0.032	-	1.053	142.9
Continuous Digester Control Technology	9.00	-	-	0.032	-	1.05	143
Detection and Control of Deposition on Pendant Tubes in Kraft Chemical Recovery Boilers	3.85	1.39	0.029	0.017	2.237	0.595	83.8
METHANE de-NOX® Reburn Process	1.34	0.159	0.004	0.004	0.194	0.208	25.1
MultiWave™ Automated Sorting System for Efficient Recycling	-	-	-	-	-	-	-
Pressurized Ozone/Ultrafiltration Membrane System	1.26	0.315	-	0.004	-	0.147	20.0
Screenable Pressure-Sensitive Adhesives	-	-	-	-	-	-	-
Thermodyne™ Evaporator – A Molded Pulp Products Dryer	0.341	0.068	-	0.001	-	0.040	5.41
GLASS							
Advanced Temperature Measurement System	-	-	-	-	-	-	-
High Luminosity, Low-NO_x Burner	-	-	-	-	-	-	-
Process for Converting Waste Glass Fiber into Value-Added Products	0.140	0.070	-	0.000	-	0.016	2.22
METAL CASTING							
Ceramic Composite Die for Metal Casting	-	-	-	-	-	-	-
CFD Modeling for Lost Foam White Side	-	-	-	-	-	-	-
Die Casting Copper Motor Rotors	0.112	0.062	0.001	0.000	0.024	0.018	2.21
Improved Magnesium Molding Process (Thixomolding)	0.074	0.069	-	0.000	-	0.009	1.175
Improvement of the Lost Foam Casting Process	1.96	0.489	0.004	0.007	0.182	0.266	34.2
Low Permeability Components for Aluminum Melting and Casting	-	-	-	-	-	-	-
Rapid Heat Treatment of Cast Aluminum Parts	-	-	-	-	-	-	-
Simple Visualization Tools for Part and Die Design	-	-	-	-	-	-	-
Titanium Matrix Composite Tooling Material for Aluminum Die Castings	0.034	0.015	-	0.000	-	0.004	0.535
MINING							
Belt Vision Inspection System	-	-	-	-	-	-	-
Fibrous Monoliths as Wear-Resistant Components	-	-	-	-	-	-	-
Horizon Sensor™	0.230	0.020	0.001	0.001	0.050	0.037	4.53
Imaging Ahead of Mining	5.38	1.05	0.024	0.019	1.163	0.867	105.8
Lower-pH Copper Flotation Reagent System	2.92	0.973	0.013	0.010	0.631	0.470	57.4
Wireless Telemetry for Mine Monitoring and Emergency Communications	-	-	-	-	-	-	-
STEEL							
Aluminum Bronze Alloys to Improve Furnace Component Life	0.066	0.033	-	0.000	-	0.008	1.045
Automated Steel Cleanliness Analysis Tool (ASCAT)	-	-	-	-	-	-	-
Dilute Oxygen Combustion System	21.6	7.17	-	0.075	-	2.52	342
Electrochemical Dezincing of Steel Scrap	0.268	0.073	0.003	0.000	0.168	0.075	7.49
H-Series Cast Austenitic Stainless Steels	0.000	0.000	-	0.000	-	0.000	0.00
HotEye® Steel Surface Inspection System	6.12	2.04	-	0.021	-	0.716	97.1
Laser Contouring System for Refractory Lining Measurements	-	-	-	-	-	-	-
Life Improvement of Pot Hardware in Continuous Hot Dipping Processes	-	-	-	-	-	-	-
Low-Temperature Colossal Supersaturation of Stainless Steels	-	-	-	-	-	-	-
Microstructure Engineering for Hot Strip Mills	-	-	-	-	-	-	-
Shorter Spherodizing Annealing Time for Tube/Pipe Manufacturing	0.121	0.008	-	0.000	-	0.014	1.93
Transfer Rolls for Steel Production	0.138	0.035	-	0.000	-	0.016	2.19
Vanadium Carbide Coating Process	0.000	-	-	0.000	-	0.000	0.000

Table 1. Technology Program Impacts

IMPACTS

Technologies Commercially Available	Cumulative Energy Savings (10^{12} Btu)	2007 Energy Savings (10^{12} Btu)	Cumulative Pollution Reductions (Thousand Tons)				
			Particulates	VOCs	SO_X	NO_X	Carbon
CROSSCUTTING							
Adjustable-Speed Drives for 500 to 4000 Horsepower Industrial Applications	0.645	0.303	0.003	0.002	0.139	0.104	12.68
Advanced Aerodynamic Technologies for Improving Fuel Economy in Ground Vehicles	0.000	0.000	0.000	0.000	0.000	0.000	0.009
Aerogel-Based Insulation for Industrial Steam Distribution Systems	0.007	0.006	-	0.000	-	0.001	0.104
Autotherm® Energy Recovery System	0.067	0.025	0.001	0.000	0.039	0.010	1.465
Callidus Ultra-Blue (CUB) Burner	46.8	17.3	-	0.164	-	5.47	743
Catalytic Combustion	-	-	-	-	-	-	-
Composite-Reinforced Aluminum Conductor	-	-	-	-	-	-	-
Cromer Cycle Air Conditioner	0.299	0.208	0.001	0.001	0.065	0.048	5.88
Dual-Pressure Euler Turbine for Industrial and Building Applications	0.113	0.048	-	0.000	-	0.013	1.80
Electrochromic Windows - Advanced Processing Technology	0.000	0.000	0.000	0.000	0.000	0.000	0.006
Energy-Conserving Tool for Combustion-Dependent Industries	0.011	0.003	0.000	0.000	0.002	0.002	0.225
Fiber-Optic Sensor for Industrial Process Measurement and Control	-	-	-	-	-	-	-
Fiber Sizing Sensor and Controller	-	-	-	-	-	-	-
Foamed Recyclables	-	-	-	-	-	-	-
Forced Internal Recirculation Burner	-	-	-	-	-	-	-
Freight Wing™ Aerodynamic Fairings	0.058	0.037	0.000	0.000	0.034	0.009	1.267
Functionally Graded Materials for Manufacturing Tools and Dies	-	-	-	-	-	-	-
Ice Bear® Storage Module	0.001	0.001	0.000	0.000	0.000	0.000	0.021
Improved Diesel Engines	1,107	47.0	8.30	4.98	643	171	24,100
In-Situ, Real Time Measurement of Elemental Constituents	0.926	0.222	-	0.003	-	0.108	14.7
Materials and Process Design for High-Temperature Carburizing	-	-	-	-	-	-	-
Mobile Zone Optimized Control System for Ultra-Efficient Surface-Coating	0.045	0.007	0.000	0.000	0.004	0.006	0.780
Portable Parallel Beam X-Ray Diffraction System	-	-	-	-	-	-	-
PowerRim™ High Wattage Energy Saving CFL Adaptor for Recessed Down Lights	0.330	0.077	0.001	0.001	0.071	0.053	6.48
Predicting Corrosion of Advanced Materials and Fabricated Components	-	-	-	-	-	-	-
Process Particle Counter	-	-	-	-	-	-	-
Pulsed Laser Imager for Detecting Hydrocarbon and VOC Emissions	1.020	0.574	-	0.004	-	0.119	16.19
Radiation-Stabilized Burner	0.254	0.066	-	0.001	-	0.030	4.03
Simple Control for Single-Phase AC Induction Motors	-	-	-	-	-	-	-
Solid-State Sensors for Monitoring Hydrogen	-	-	-	-	-	-	-
SpyroCor™ Radiant Tube Heater Inserts	3.39	1.47	-	0.012	-	0.397	53.8
SuperDrive – A Hydrostatic Continuously Variable Transmission (CVT)	0.006	0.002	0.000	0.000	0.004	0.001	0.134
Three-Phase Rotary Separator Turbine	0.034	0.001	0.000	0.000	0.007	0.006	0.675
Ultra-Low NO_X Premixed Industrial Burner	-	-	-	-	-	-	-
Uniform Droplet Process for Production of Alloy Spheres	-	-	-	-	-	-	-
Uniformly Drying Materials Using Microwave Energy	0.162	0.024	0.000	0.001	0.006	0.020	2.69
Vibration Power Harvesting	-	-	-	-	-	-	-
Wear Resistant Composite Structure of Vitreous Carbon Containing Convoluted Fibers	0.003	0.002	0.000	0.000	0.002	0.000	0.060
Wireless Sensors for Process Stream Sampling and Analysis	-	-	-	-	-	-	-
OTHER INDUSTRIES							
Advanced Membrane Devices for Natural Gas Cleaning	-	-	-	-	-	-	-
Deep Discharge Zinc-Bromine Battery Module	-	-	-	-	-	-	-
Energy-Efficient Food Blanching	0.011	0.001	0.000	0.000	0.003	0.001	0.203
Irrigation Valve Solenoid Energy Saver	0.017	0.001	0.000	0.000	0.004	0.003	0.329
Long Wavelength Catalytic Infrared Drying System	0.006	0.003	-	0.000	-	0.001	0.092
Plant Phenotype Characterization System	-	-	-	-	-	-	-
Plastics or Fibers from Bio-Based Polymers	0.088	0.018	0.001	0.000	0.051	0.014	1.90
Textile Finishing Process	0.204	0.023	0.000	0.001	0.019	0.028	3.58
Commercial Technologies Total	1,225	83.6	8.42	5.40	650	186	26,100
IAC Total	1,714	224	8.32	6.26	549	264	34,100
BestPractices Total	901	225	4.41	3.33	294	138	18,000
CHP Total	2,330	201	29.9	2.61	1,460	643	64,800
Historical Technologies Total	2,330	N/A	9.20	17.1	476	380	46,000
GRAND TOTAL	**8,500**	**734**	**60.3**	**34.66**	**3,430**	**1,610**	**189,000**

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Aluminum

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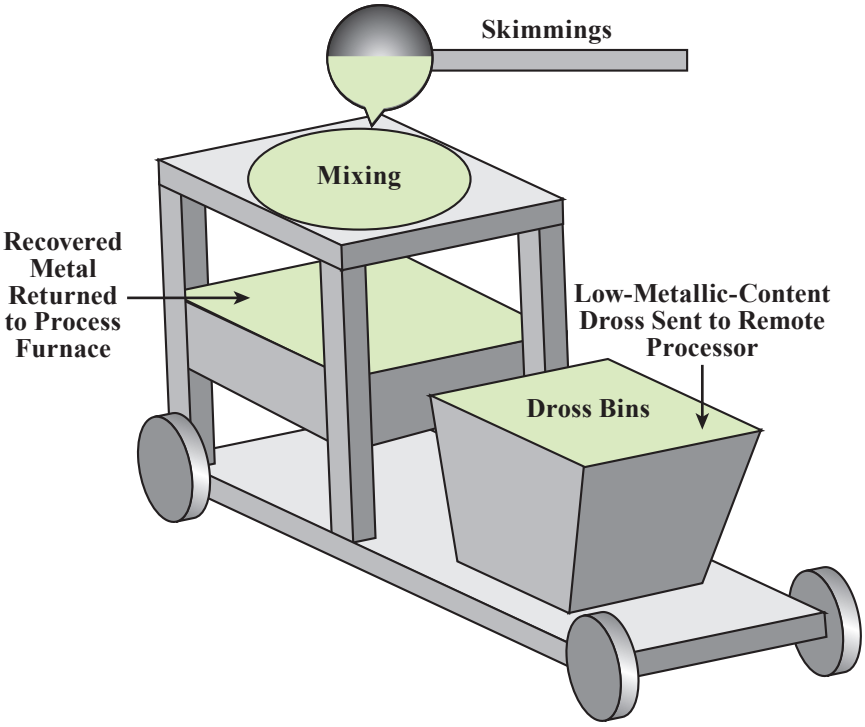
Aluminum Reclaimer for Foundry Applications

Affordable Metallic Recovery System Saves Energy and Reduces Landfill Waste Streams

Aluminum foundries and melters typically generate rich metallic skimmings and drosses during industrial processes. While equipment is commercially available to recover a portion of the contained metallics from skimmings and drosses, the capital investment for the previous equipment has precluded its application with smaller melting units such as crucible or reverb melters. With assistance from ITP, Q.C. Designs, Inc., developed an improved reclaiming process specifically to recover the metallics from small quantities of dross and skim. Recent advances in the technology permit an increase in the quantity of drosses being processed and allow the recovered metal to be returned to the generating furnace in molten form, in some cases. The process has recovered as much as 80% of the contained metal at the point of generation.

In operation, the process may be run either manually, with power-assisted stirring, or with a fully automatic programmed cycle. All operations are environmentally friendly, reducing the amount of smoke and fumes normally associated with dross processing and furnace cleaning. Foundries reduce their melting losses by the in-plant recovery of drosses and their contained metals, which can then be reused directly without realloying.



Portable Aluminum Reclaimer

Overview

- Available from Q.C. Designs, Inc. (www.qcdesignsinc.com)
- Commercialized in 2001
- Fourteen units installed in the United States

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.003	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.011

Applications

In-plant aluminum foundry dross and skimming recovery

Capabilities

- Processes hot dross in quantities from 10 to 500 lb.
- Allows automatic processing or manual operation.
- Features sizes for applications in different foundry installations.

Benefits

Productivity

Contributes directly to profits by decreasing melting losses. Typical compensation for dross materials from outside processors is 10% to 20% of true value because the generating foundry has to bear the costs of transportation, remelt and processing, landfill of the waste, and return of the recovered material. In-plant processing eliminates a large portion of these costs.

Waste Reduction

Minimizes the volume of material requiring landfilling and recovers a higher percentage (up to 80%) of metallics than current methods.

IMPACTS

Effective Scrap Sorting Provides Large Energy Benefits

Huron Valley Steel (HVS) Corporation has developed scrap sorting technologies, and with support from ITP, they demonstrated that aluminum scrap from aluminum-intensive vehicles can be recycled. The HVS technology assesses the composition and material recovery from the sorting steps required to produce alloy-sorted aluminum from mixed-alloy scrap. A proprietary HVS technology is used for wrought-cast separation. After the wrought fraction is tint-etched, color sorting groups the wrought iron alloys. Laser induced breakdown spectroscopy is used for real-time, remote chemical analysis of each scrap particle and allows the sorting line to separate individual alloys.

This particle-sorting technology focuses on demonstrating the capability to sort nonferrous metal scrap from the reusable materials from aluminum-intensive vehicles. The process includes physical property sorting and chemical composition sorting and is capable of real-time, piece-by-piece batching of specific alloy compositions from the analyzed scrap. This process will help improve the melt composition of recycled materials and is more efficient and less energy intensive than existing chlorination, fractional solidification, and electro-refining processes.

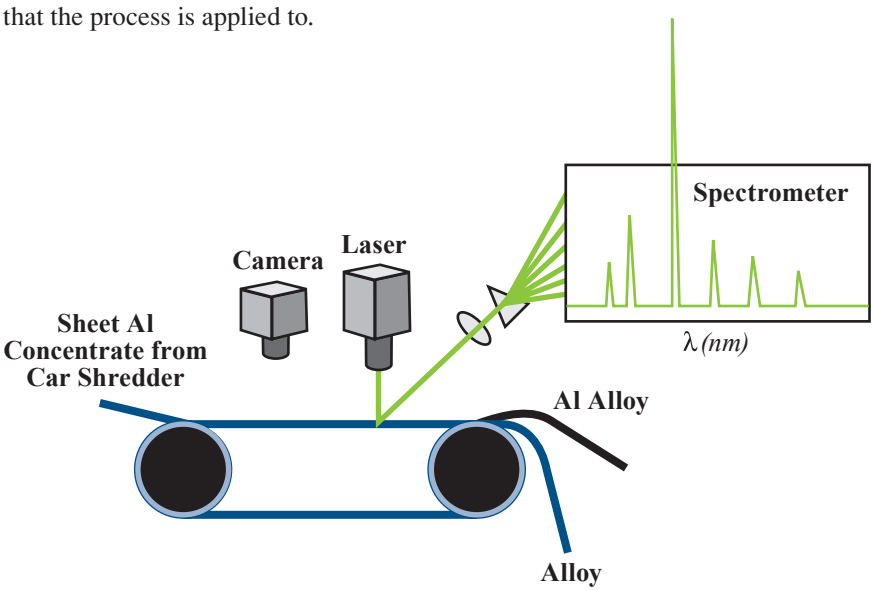
Benefits

Environmental

Decreases the production of primary metal by using aluminum that otherwise would have been scrapped and thereby reduces greenhouse gas emissions.

Use of Raw Materials/Feedstocks

Can eliminate a portion of raw aluminum production and any other alloys that the process is applied to.



Aluminum Scrap Sorting System

Overview

- Developed by Huron Valley Steel Corporation (www.hvsc.net)
- 7500 tons of sorted product processed in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.71	0.338

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.002	0.073	0.054	6.63

Applications

Can be used in sorting of mixed aluminum scrap streams and vehicle and other equipment scrap streams

Capabilities

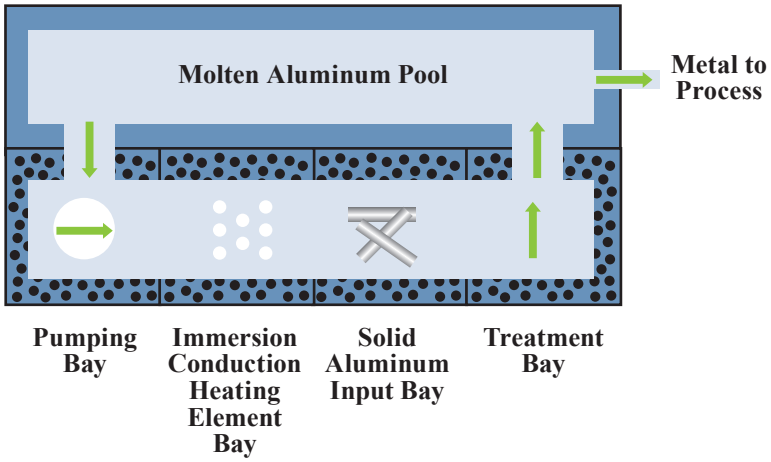
- Improves sorting of mixed aluminum scrap streams.
- Allows aluminum from scrapped motor vehicles to be separated and used as high-value aluminum alloys.
- Separates cast aluminum from wrought, groups aluminum into alloy families, and differentiates between wrought alloys.

Isothermal Melting

New Energy-Efficient Melting Process Saves Energy and Reduces Production Losses

Aluminum melting is an energy-intensive process that exhibits a 2% to 3% loss rate due to the generally open heating method for melting. A new emersion heating process, isothermal melting (ITM), has been developed by Apogee Technology, Inc., with support from ITP. The system uses immersion heaters in multiple bays. Each bay contributes to an efficiency improvement. The pumping bay provides good circulation in the isothermal systems. This circulation promotes better mixing for purifying and alloying and more uniform temperature profiles throughout the molten pool. The heating bay is the major source of efficiency gain, where electricity is converted into heat through the immersion heaters and conducted directly to the molten metal. The heating bay raises the molten metal temperature (typically less than 90°F) just high enough to melt the solid metal being charged into the pool. The charging bay and treatment bay provide more compact areas to control and introduce solid charge or alloying and purifying elements compared with opening a hearth door and exposing the entire surface of the pool and refractory to the plant environment.

The challenge to developing the ITM system was the creation of immersion heaters that could provide the high heat flux and the chemical, thermal, and mechanical robustness required in an industrial molten aluminum environment. Apogee Technology's research program developed new materials, fabrication techniques, and quality control systems to build immersion heaters with high heat flux (approximately 70,000 Btu/hr-ft^2), approximately 5 to 10 times more than commercially available heaters. These new heater designs are based on highly thermally conductive, impact resistant ceramic coating on a metallic sheath and a highly conductive dielectric integral coupling medium between the sheath and the heat producing element. This allows heat transfer by conduction to be the dominant mode, rather than particle to particle radiation heat transfer that prevails in conventional processes. The composite refractory coating is resistant to corrosive attack by the molten aluminum, yet sufficiently thin enough to provide a high heat flux.



The Isothermal Melting System

Overview

- Developed by Apogee Technology, Inc. (www.apogeetechinc.com)
- Installed at one plant in Ohio

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.010	0.00

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.0

Applications

Can be used in aluminum melting processes and other metal melting processes

Capabilities

- Can be retrofitted to existing furnaces.
- Applies to multiple types of molten metal heating operations.

Benefits

Cost Savings

Reduces metal lost to oxidation to <1%.

Environmental Emissions Reductions

Produces zero in-plant emissions compared with natural gas process heating.

Oxygen-Enhanced Combustion for Recycled Aluminum

IMPACTS

New Metal Melting System Results in Low NO_X Emissions, Reduced Energy Use, and Increased Productivity

With ITP support, Air Products & Chemicals, Inc., in cooperation with Argonne National Laboratory, Wabash Alloys, L.L.C., and Brigham Young University, developed and demonstrated a low-NO_X combustion burner integrated with an onsite vacuum-swing-absorption (VSA) oxygen-generation system. This new burner, operated at the Wabash Alloy recycled aluminum furnace, used controlled mixing of fuel, air, and high-purity oxygen streams to lower emissions and improve flame quality.

The VSA system uses a patented high-efficiency molecular sieve to remove nitrogen from the air. Conventional VSA plants are sized for peak demand, and the excess oxygen is vented to the air during off-peak operation. In this application, the oxygen VSA system is improved to operate with a sieve-filled storage vessel that stores oxygen produced when demand is below the average oxygen requirement. The sieve-filled vessel provides 2.5 times the oxygen storage capacity of an empty tank of equal volume. The integration of the new burner with the VSA system greatly reduces NO_X emissions while reducing energy usage and increasing melting productivity.

Benefits

Cost Savings

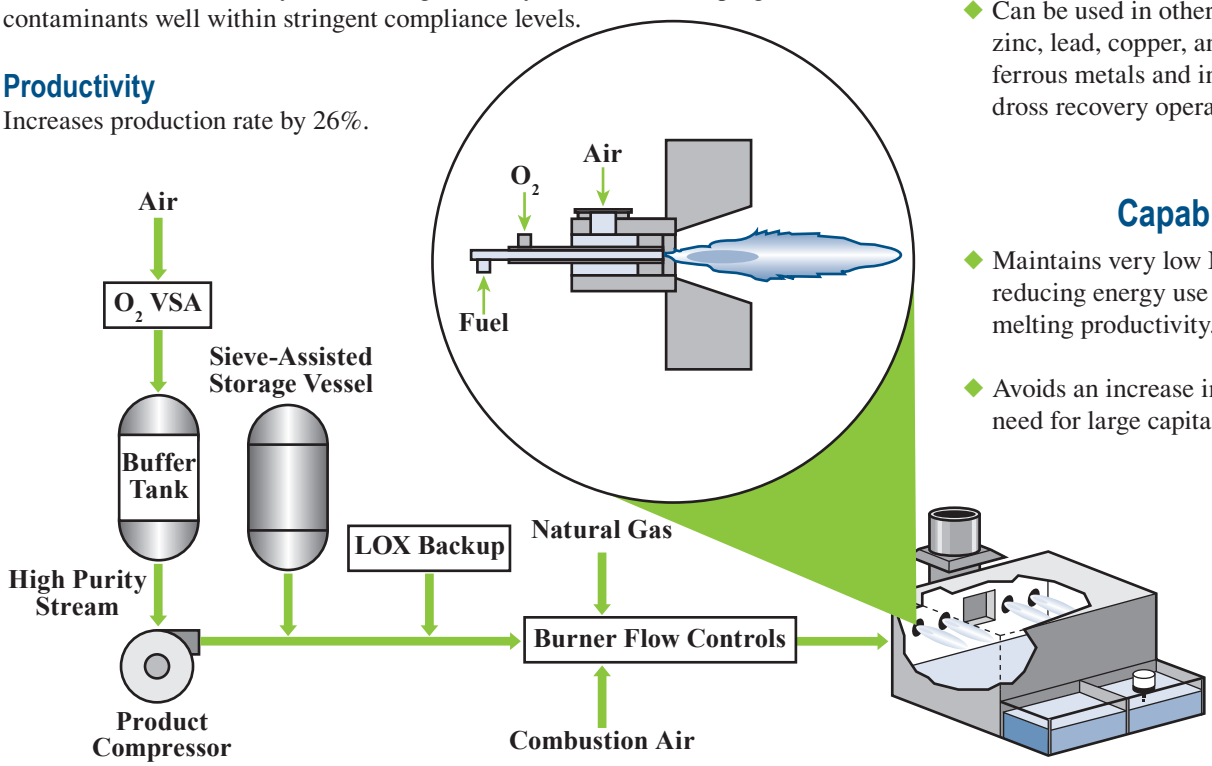
Reduces the overall oxygen consumption and costs by 33% compared with the previously installed burner.

Environmental Quality

Reduces NO_X emissions by 80% and significantly reduces CO, keeping both contaminants well within stringent compliance levels.

Productivity

Increases production rate by 26%.



Oxygen-Enhanced Combustion

Overview

- Developed by Air Products & Chemicals, Inc. (www.airproducts.com)
- Demonstrated at Wabash Alloys in East Syracuse, NY
- Commercialized in 1999

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.025	0.0

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.0

Applications

- Can be used to retrofit reverberatory furnaces commonly used to melt recycled aluminum
- Can be used in other metal melters for zinc, lead, copper, and nonferrous and ferrous metals and in metal tolling and dross recovery operations

Capabilities

- Maintains very low NO_X levels while reducing energy use and increasing melting productivity.
- Avoids an increase in melting costs or the need for large capital expenditures.

Chemicals

IMPACTS

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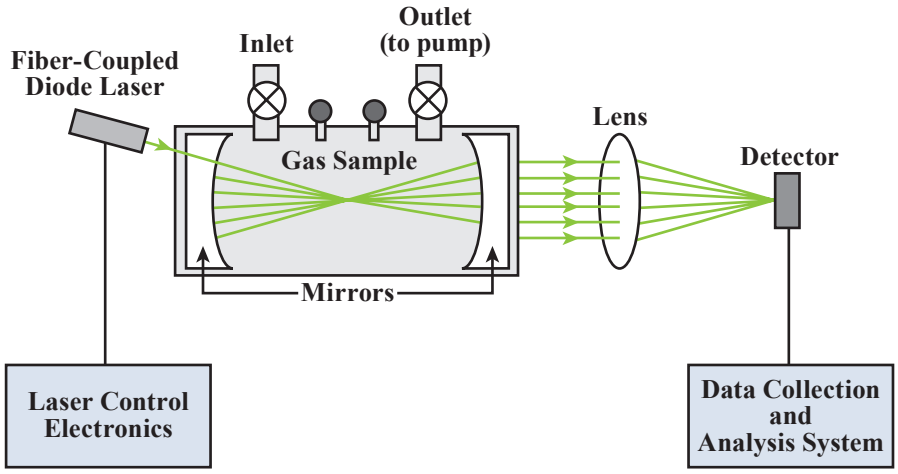
Cavity-Enhanced Gas Analyzer for Process Control

Ultrasensitive Analyzer Provides Real-Time Quantification of Acetylene and Reduces Operating Costs

Ethylene is the largest volume, largest revenue-generating organic chemical produced. Ethylene finds widespread use, serving as the building block for 50% of all organic chemicals and polymers. However, manufacturers who produce polymer-grade ethylene must constantly monitor, and if necessary, hydrogenate any acetylene that may be present in ethylene flows. Such measures are imperative because too high an increase in acetylene concentration has the potential to contaminate both the catalytic bed and the stored finished product, and if left unchecked, acetylene contamination can cost a chemical manufacturer more than $200,000 in losses per event. As a result, the ability to quickly and accurately monitor trace levels of acetylene is a critical need for ethylene manufacturers.

Los Gatos Research, in partnership with Dow Chemical and Analytical Specialties, Inc., has developed an industrial gas process control monitor that can replace gas chromatography. Through support funding provided by DOE's SBIR program, the new gas analyzer uses a patented technology having a variation of absorption spectroscopy. The new technology increases the path-length up to several kilometers of effective path using two highly reflective mirrors in the sample cavity and a diode laser that is not sensitive to alignment. The compact robust technology, Off-Axis ICOS (Integrated Cavity Output Spectroscopy), retains the sensitivity of older detection methods, while providing an absolute, accurate measurement of acetylene contamination that is fifty times faster and one-third less expensive than traditional gas chromatography.

The Off-Axis ICOS technology can be completely integrated into gas handling and computing subsystems. The analyzer is field serviceable to permit long-term deployment in the gas processing environment. Additionally, the highly reflective mirrors can be periodically replaced without any need for realignment or adjustment, which further increases the instrument's lifetime.



Cavity-Enhanced Gas Analyzer System

Overview

- Developed by Los Gatos Research in partnership with Dow Chemical Co., and Analytical Specialties, Inc. (www.lgrinc.com)
- Commercialized in 2006 with five units in operation

Applications

Can be used to measure trace acetylene concentrations in ethylene gas flows, providing a real-time measurement of potential contamination.

Capabilities

- Provides measurements 50 times faster than conventional gas chromatography.
- Reduces the capital cost for analytical support technologies.
- Allows for the optimization of the hydrogenation reactor and minimizes product contamination.

Benefits

Applicability

Integrates into complete gas handling, sampling, and computing systems with a compact, robust design.

Product Quality

Minimizes off-specification ethylene product quality through improved process control.

Profitability

Improves raw material conversion to finished product and minimizes reprocessing and potential system contamination due to excess acetylene in the gas.

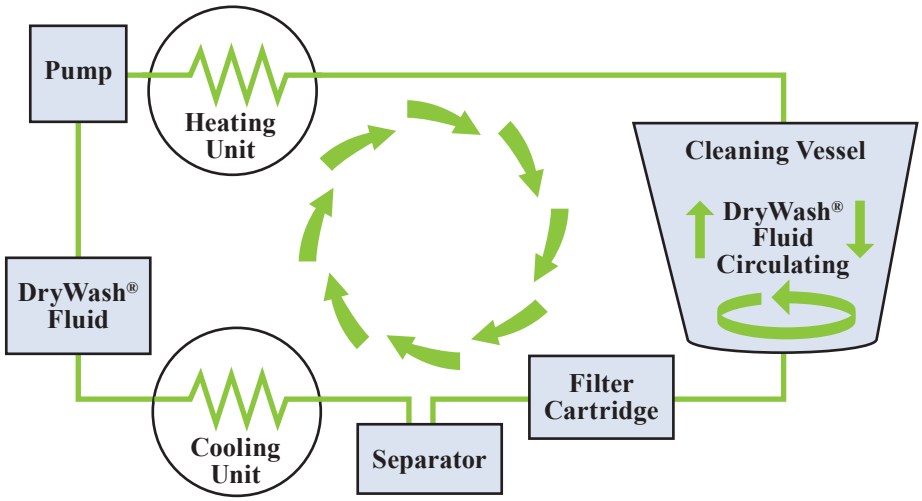
IMPACTS

A New Generation of Chemicals for Cleaning Applications

With ITP support, Raytheon Technologies, Inc. (formerly Hughes Environmental), and Los Alamos National Laboratory used defense-related expertise in supercritical fluids to develop DryWash, an entirely new CO_2-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 have significant environmental impacts. Based on the desirable characteristics of CO_2– it is inert, stable, noncorrosive, and nonflammable – the DryWash system introduces a new generation of technology to the dry cleaning industry.

DryWash uses liquid CO_2-based fluid (not generic CO_2) 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 CO_2-filled tub at a pressure of 700 to 750 pounds per square inch and 54°F to 58°F. The load is agitated; at the end of the cycle, the dirt and oily residue drop out and CO_2 pressure is lowered, allowing for the efficient recycling of CO_2.

Global Technologies, LLC, began introducing the DryWash system in Europe in the fall of 1998 and started marketing it in the United States in mid-1999. Commercial systems are now being sold by Alliance Laundry Systems LLC and SailStar USA.



Drywash Process

Overview

- Developed by Raytheon Technologies, Inc., and commercialized by Global Technologies, LLC (www.sailstarusa.com)
- Commercialized in Europe in 1998 and the United States in 2000 with over 75 machines in operation in the United States

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.063	0.011

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.002	0.002	0.213

Applications

Can be used to replace conventional dry-cleaning systems that use perchlorethylene or petroleum-based solvents

Capabilities

- Uses an environmentally benign solvent (CO_2-based fluid) 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

Profitability

Reduces cycle time by 50% and lowers operating costs.

Quality Improvement

Decreases dirt redeposition and dye transfer and has better performance in oily, particulate soil, and stain removal. Reduces shrinkage and has better color retention.

Hollow-Fiber Membrane Compressed Air Drying System

New Membrane Allows Drying of Compressed Air at Lower Energy and Higher Productivity

With the support of a NICE[3] grant, a new hollow-fiber membrane for dehydrating gases has been developed by Air Products and Chemicals, Inc. The membrane has 5 times higher water vapor permeation coefficient and 25 times higher water vapor/air selectivity compared with first-generation membrane dryers. The membrane produces higher flow capacity and lower purge loss in compressed air drying, which enables high productivity and low energy consumption in drying compressed air. The membrane module contains a bundle of hollow-fiber membranes in a plastic shell with aluminum end caps. The feed air flows through the fiber bores; selective permeation of water vapor produces dry nonpermeate gas, a fraction of which is metered via a flow restrictor such as an orifice to provide a low-pressure purge gas that carries away the permeated moisture.

Compressed air is widely used as a utility in many industries and most often must be dried to avoid condensation or freezing in lines and to meet the needs of many processes. Whereas refrigerant dryers are used at pressure dew points of 35°F and desiccant dryers are used at dew points of -40°F, membranes can be used to cover the range between 35°F and -40°F. The membrane can achieve the necessary degree of drying while requiring less purge air and therefore achieves lower energy consumption than a heatless desiccant dryer. Modular membrane dryer systems with large flow capacity can be used to produce pressure dew points between 35°F and -40°F, consuming less energy than that of desiccants. Unlike desiccant systems, membrane operation is continuous, requiring only one control valve versus at least 5 valves for flow diversion/de-pressurization in the desiccant system.

Benefits

Cost Savings
Provides purge control for additional power and cost savings.

Environmental
Reduces solid waste production.

Operation and Maintenance
Operates without valves or moving parts and is maintenance-free. Requires no electrical wiring or external power and operates silently.

Overview

- Developed by Air Products and Chemicals, Inc. (www.airproducts.com)
- Commercialized in 2004
- 3630 units operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.006	0.003

U.S. Emissions Reductions

(Thousand Tons, 2007)

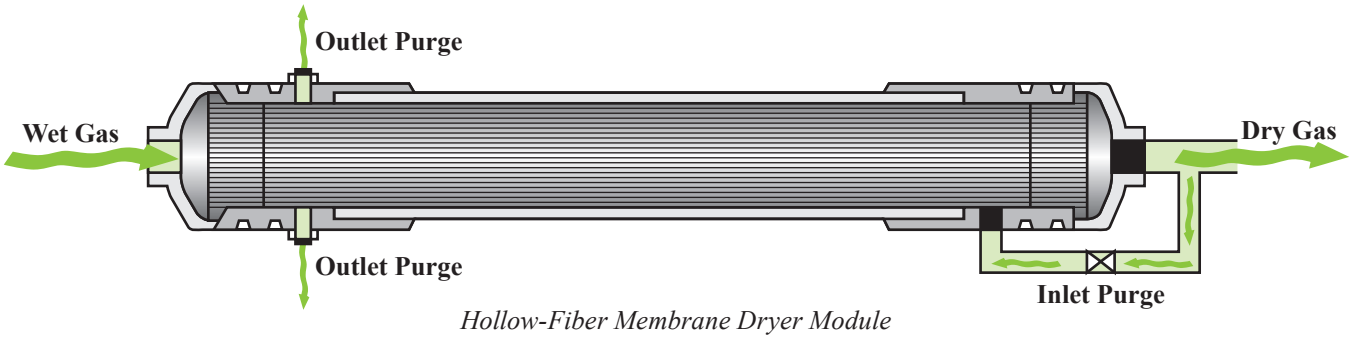
Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.001	0.068

Applications

Can be used by manufacturing industries that use compressed air

Capabilities

- Is compact and lighter in weight than heatless desiccants, allowing flexibility in packaging the unit into a compressed air system.
- Is rated for operation up to 150°F and 200 psig.
- Provides excellent turndown capability, all the way down to zero feed.



Hollow-Fiber Membrane Dryer Module

Improved Methods for the Production of Polyurethane Foam

IMPACTS

New Surfactants Result in a More Environmentally Benign Production Process

Methylene chloride, a toxic chemical that contributes to air pollution, was recently eliminated from use in the U.S. polyurethane industry. This mandated elimination did not permit production of as large a range of foam grades as was possible using methylene chloride, thus placing U.S. industry at a competitive disadvantage. Air Products and Chemicals, Inc., with financial assistance from ITP, developed new silicone surfactants enabling the efficient production of the full range of foam grades using a more environmentally benign CO_2 blowing agent. In addition to lowering toxicity, the new process uses less energy and reduces the net release of CO_2, which is implicated in global warming.

The challenges in using liquid CO_2 as a blowing agent include rapid vaporization, rapid bubble nucleation, and difficulty in maintaining fine cell structure in the foam. The new surfactants address these challenges by emulsifying the blowing agent, thereby maintaining fine cells during foaming. The silicone surfactants have achieved superior performance, resulting in finer cell structure (better yield), higher bun heights (better yield), better top to bottom physical property gradient (product consistency), and better compatibility with flame retardants.

Benefits

Productivity
Increases yield through finer foam cell structure, higher bun heights, and improved top to bottom physical property gradients.

Safety
Improves compatibility with flame retardants.

Waste Reduction
Reduces the toxicity of the process and uses the CO_2 blowing agent more effectively for reduced CO_2 release to the atmosphere.

Overview

- Developed by Air Products and Chemicals, Inc., and being used in seven plants in the United States (www.airproducts.com)
- Commercialized in 2006

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.106	0.082

U.S. Emissions Reductions

(Thousand Tons, 2007)

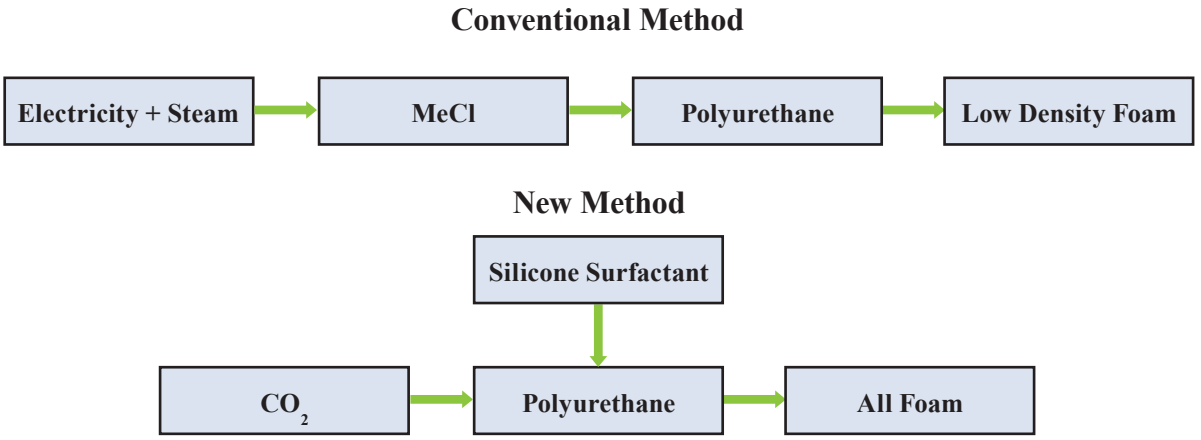
Particulates	SO_x	NO_x	Carbon
0.0	0.009	0.011	1.45

Applications

Can be used in polyurethane foam production

Capabilities

- Eliminates use of toxic methylene chloride.
- Increases foam yield through finer foam structure.
- Improves compatibility with flame retardants.



Polyurethane Foam Production

Low-Cost, Robust Ceramic Membranes for Gas Separation

Innovative Ceramic Membrane Reduces Energy and Cost of Industrial Gas Separation

Ceramic membranes offer great potential for industrial gas separation. Without a ceramic membrane, gases must be cooled before separation. Unfortunately, even though ceramic membranes can improve the productivity for many reactions and separations in the chemicals and refining industries, they are costly.

Media and Process Technology, Inc., with ITP support and industrial partners Gas Control Engineering Corporation, Southern California Gas, and the University of Southern California, developed a new technology that has overcome the cost barrier by using a low-cost, robust ceramic membrane. This membrane separates gases and vapors at temperatures up to 600°C. Significant energy savings are possible because cooling prior to gas separation can be eliminated and valuable components removed from the gas stream can be recycled.

Applications are targeted toward hydrogen production, water and energy recovery from flue gas, and CO_2 removal in natural gas processing. In addition, this low-cost membrane is currently under consideration as substrate for a wide range of thin films capable of industrial gas separations and is being used commercially without the gas separating layer for a wide range of liquid phase separations.

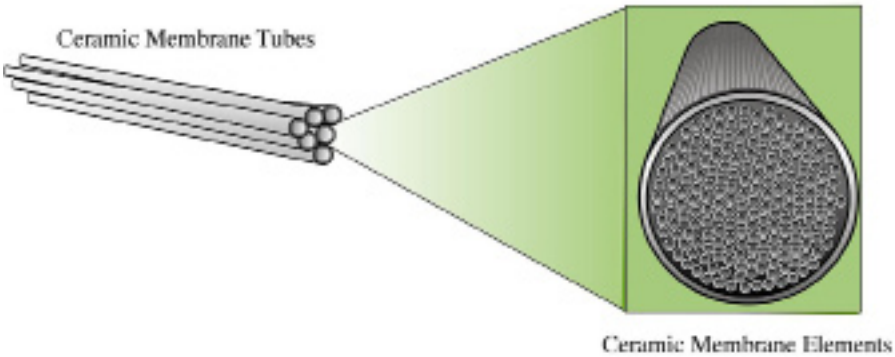
Benefits

Energy Savings

Allows gas separation at higher temperatures, eliminating the need to cool gases beforehand and therefore saving cooling energy.

Profitability and Productivity

Offers a low-cost material that reduces time and money spent for gas separation and allows valuable chemicals to be recycled rather than being disposed of.



Media and Process Technology's Ceramic Membrane Tubes and Elements

Overview

- Developed in joint venture among Media and Process Technology, Inc., Gas Control Engineering Corporation (GCE), Southern California Gas, and the University of Southern California (www.mediaandprocess.com)
- Commercialized in 2005 and being marketed by Cleaver Brooks, Inc. (www.cleaver-brooks.com)
- Installed in two U.S. locations for recovery of water vapor and energy, with a third installation scheduled in 2008

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.019	0.008

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.001	0.127

Applications

Can be used in natural gas processing, landfill gas recovery, hydrogen production, and water and energy recovery. Liquid phase separations are also possible without the gas separating layer. Can be used as low cost substrates for deposition of various membrane layers.

Capabilities

- Separates gases and vapors at temperatures up to 600°C.
- Simplifies chemical production processes.
- Enhances conversion of chemical reactions.

IMPACTS

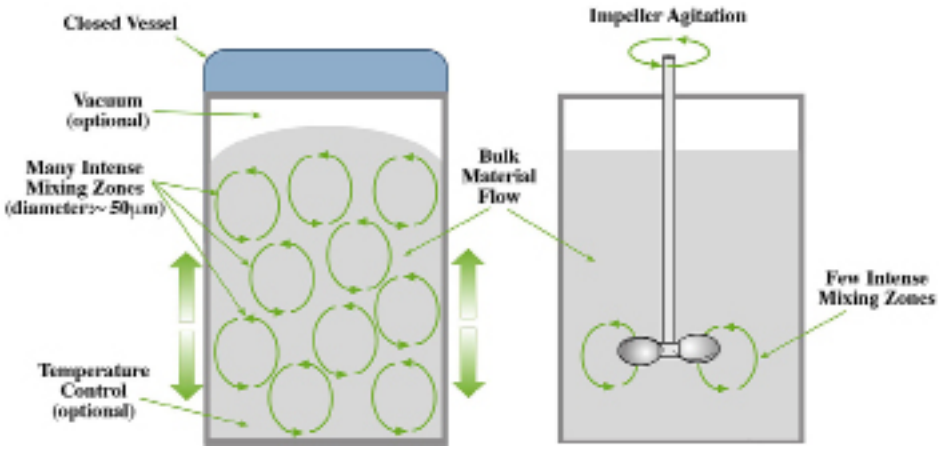
New Acoustic Mixing Technology Improves Productivity Using Low-Frequency, High-Intensity Sound Energy

Typical mixing technology uses a drive mechanism—usually an electric, hydraulic, or pneumatic motor—to rotate a shaft with one or more impellers. While many other mixer designs are available, including static mixers that do not use motors, the motor-driven mixer is the most prevalent mixing method.

Resodyn Corporation's ResonantAcoustics® mixing (RAM) technology, developed with the aid of a grant from DOE's Inventions and Innovation Program, is an improved approach to solving mixing and dispersion problems associated with conventional impeller agitation and ultrasonic mixing. Rather than mix by inducing bulk fluid flow, such as impeller agitation, RAM agitation mixes by inducing microscale turbulence through propagating acoustic waves throughout the medium. The RAM system has a lower frequency of acoustic energy and larger scale of mixing than ultrasonic agitation. Another distinct difference from ultrasonic technology is that the RAM devices are simple, mechanically driven agitators that can be made large enough to perform industrial-scale tasks at reasonable cost.

RAM introduces acoustic vibrations into liquids and slurries via the resonant vibration of a mechanical system. The impedance of the vibrating system is matched to that of the load, i.e., the process fluid. The entire system vibrates in resonance, which allows efficient energy transport to the fluid, creating small-scale eddies. Although the eddies are microscale, the entire reactor is well mixed in an extremely short time because the acoustic streaming, generated by the acoustic field, causes the microscale vortices to be distributed uniformly throughout the fluid. Multiple mixing regimes are possible by using the RAM system and the controls developed exclusively for it.

Since the commercialization of the technology, Resodyn has sold tens of laboratory-scale mixers to both U.S. and international customers and has extended the product line by adding 5-gallon and 55-gallon capacity mixers for production applications. Industries that use mixers in their production process are extremely receptive to new mixing technologies that could help improve efficiency and lower their manufacturing costs.



Resonant/Acoustics® Mixing vs. Impeller Mixing

Overview

- Developed by Montec Research, Inc.
- Commercialized in 2007
- Marketed by Resodyn Acoustic Mixers, Inc. (www.resodynmixers.com)

Applications

Can be used in a number of industries, including agriculture, chemical manufacturing and processing, food, mining, municipal waste treatment, petroleum, pharmaceutical, pulp and paper, aerospace, microelectronics, and water treatment.

Capabilities

- Uses acoustic energy rather than impellers to mix gases, liquids, and slurries.
- Mixes a wide viscosity range (1cP to 100+million cP).
- Can mix in a shipping container using a LabRAM 500 ml mixer.

Benefits

Productivity

Enhances mass transport and improves reaction rates on both macro- and micro-mixing levels. Can easily tune to different frequencies, making them suitable for multiple applications, such as heat- or mass-transfer limited systems, those that expend inordinate mixing energy, or those that require mixing uniformity.

Profitability

Reduces mixing time up to 62% and competes with current mixer prices in many applications.

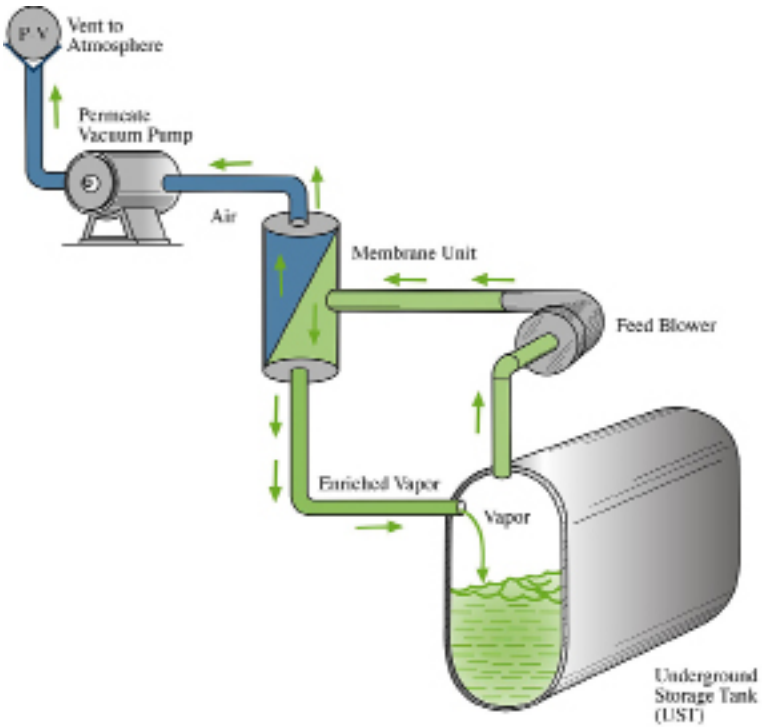
Membranes for Reverse-Organic Air Separations

New Membranes Use Reverse Separation to Reduce Pollutant Emissions

Many industrial applications need a process to separate pollutants known as volatile organic compounds (VOCs) from air in order to protect the environment and save energy. One such application is the venting of vapor from underground storage tanks (UST) used in gasoline storage and dispensing. These vapors, which can build up and create high pressure within the UST, contribute to ground-level ozone and smog upon release.

Traditional separation of VOCs uses rubber-based polymer membranes; however, these membranes are inadequate for applications requiring pressure relief by venting or low-pressure condensation of VOCs because they permeate VOCs more rapidly than air. To address this shortcoming, Compact Membrane Systems, Inc., in conjunction with project partners and support from DOE's SBIR program, has developed a novel reverse separation membrane that can be used to discharge clean air at low to slightly negative pressure, while leaving the VOCs fully contained in the fuel storage tank.

In addition to recovering the fugitive emissions from storage tanks, the system enables the UST and associated piping to operate under negative pressure while providing continuous diagnostics of the refueling system, such as storage tank structural integrity. Maintaining a slight vacuum on the UST ensures that any potential leaks within the system are contained within the tank and are not accidentally released to the environment. Continuing research and development are focused on applications where robust membranes are deployed in gas separation from both vapor and liquid streams.



Compact Membrane Systems' Vapor Recovery System

Overview

- Invented by Compact Membrane Systems, Inc. (www.compactmembrane.com)
- Commercialized in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.004	0.004

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.00	0.002	0.001	0.082

Applications

Can be used by gasoline storage and dispensing facilities, pharmaceutical processes, and fuel oil tank farms engaged in preventing the unintended release of VOCs from storage tanks.

Capabilities

- Reduces VOC emissions below the California Air Resources Board limit of 0.38 lb/month/1000 gallon capacity.
- Enables continuous monitoring of storage tank internal conditions, structural integrity, and leak-checking.

Benefits

Energy Savings

Prevents fuel vapor escape from a gasoline storage tank, thereby potentially saving 180 million gallons of gasoline per year domestically.

Envionmental

Decreases VOC emissions to the atmosphere by limiting gasoline tank leakage.

IMPACTS

New Cleaning Method Eliminates Use of Harmful Chemicals while Saving Energy

Micell Technologies developed a new dry cleaning technology using patents and know-how that is based on ITP-sponsored research on CO_2 surfactant technology performed by the Pacific Northwest National Laboratory. The Micell CO_2 dry cleaning technology is called the Micare™ system. Micell Technologies was the parent company of Hangers Cleaners, who offers franchises incorporating the Micare dry cleaning technology.

The heart of the Micare system is the specially designed $MICO_2$ machine with a 60-pound capacity and ability to hold liquid CO_2. Garments to be cleaned are placed inside a large rotating basket in the $MICO_2$ machine and the door is closed, sealing the system. Carbon dioxide is added from the storage tank along with the Micare detergent package. This patented detergent system enhances the cleaning ability of the liquid CO_2, allowing it to remove dirt from the garments. After the cleaning cycle, the machine pulls the solution of liquid CO_2 and cleaning detergents away from the clothes and then cleans and recycles the CO_2. Most (98%) of the CO_2 is recycled, while a small amount of CO_2 gas is then vented to the atmosphere. The cleaned garments are then removed from the wash tank after a cycle time of 35-45 minutes.

Benefits

Energy Savings
Eliminates the energy-intensive drying cycle used by conventional dry-cleaning systems.

Productivity
Reduces operating time and costs less to operate than conventional systems.

Quality
Cleans effectively with no unpleasant odors, treats garments gently, and eliminates the chance of heat-related damage or setting of stains, because the drying cycle is eliminated.

Waste Reduction
Eliminates harmful releases of perchlorethylene or other petroleum solvents to both the air and groundwater.

Overview

- Commercialized in 1999 by Micell Technologies
- In 2007, there were 23 Micare machines serving U.S. Hangers Cleaners stores. (www.coolclean.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.030	0.003

U.S. Emissions Reductions

(Thousand Tons, 2007)

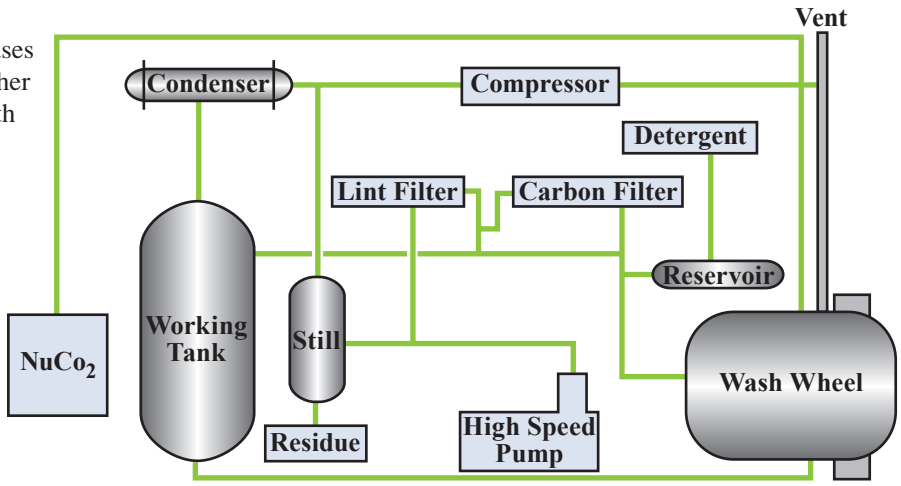
Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.001	0.063

Applications

Can be used to replace perchlorethylene or petroleum-based solvents used by conventional dry-cleaning systems

Capabilities

- Cleans equal to or better than conventional systems; is similar to conventional front-load, mechanical action machines and features gentle wash and extract cycles.
- Requires only 35 to 45 minutes to clean a 60-pound load.



Micell Dry-Cleaning Process

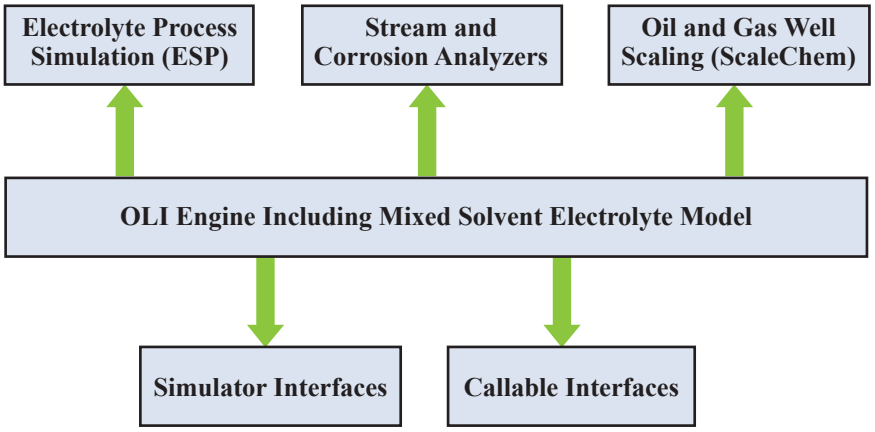
Mixed Solvent Electrolyte Model

Software Tool to Predict Solubility of Solids and Other Thermophysical Properties

With assistance from ITP, OLI Systems, Inc., developed the mixed-solvent electrolyte model, a comprehensive physical property package that can predict the properties of electrolyte systems ranging from dilute solutions to fused salts in water, nonaqueous, or mixed solvents. The model accurately predicts the solubility of solids in complex multicomponent systems, thus providing a tool for designing crystallization processes. In addition, the model predicts other properties such as vapor-liquid and liquid-liquid equilibria, densities, heat effects, viscosity, electrical conductivity, and diffusivity.

The model incorporates chemical equilibria to account for chemical speciation in multiphase, multicomponent systems. For this purpose, the model combines standard-state thermochemical properties of solution species with an expression for the excess Gibbs energy. The model can accurately reproduce various types of experimental data for systems of aqueous electrolyte solutions. Separate formulations have been developed for predicting transport properties in the same range of temperature and compositions.

The model has been implemented in OLI Systems' commercial software, including the Electrolyte Simulation Program (a flowsheet simulator), StreamAnalyzer (a desktop chemical laboratory), CorrosionAnalyzer (a tool for predicting the tendency of metals to corrode), and selected interfaces to third-party process simulation programs. In its various implementations, the mixed-solvent electrolyte model is already used by more than 50 chemical process companies that lease OLI's software.



Integration of the Mixed Solvent Electrolyte Model with OLI Software

Overview

- Developed and marketed by OLI Systems, Inc. (www.olisystems.com)
- Commercialized in 2005
- Sold 64 U.S. licenses and 96 non-U.S. licenses

Applications

Can be used to optimize crystallization and other separation processes throughout the chemical and pharmaceutical industry

Capabilities

- Predicts crystallization and other separation processes.
- Predicts solubility of solids and other thermophysical properties.

Benefits

Efficiency

Improves process control, filterability, and mixing efficiency.

Energy Savings

Substitutes crystallization for more energy-intensive process units.

Product Quality

Improves process control and product quality and minimizes lab and plant testing costs and risks (by using simulations).

IMPACTS

New Water-Based Coating Products Reduce Drying Time and Environmental Impacts

A major concern of the coatings industry is the emission of volatile organic compounds (VOCs), which react with sunlight to create photochemical ozone or smog. VOC-containing solvents used in conventional liquid coatings evaporate during application, curing, and clean-up operations. With help from a NICE[3] grant, Sierra Performance Coatings has developed new waterborne coatings that reduce or eliminate VOC emissions during formulation and application. The production of these new coatings requires lower processing temperatures, which reduces their energy impact. The coatings' quick-drying characteristics save additional energy by avoiding heating and ventilation in the drying process.

Waterborne non-VOC coatings substitute water for a portion of the solvent used as the resin retainer in typical organic coating formulations. These new coatings can be applied to many surfaces, including metal products. The quick-drying formulation reduces energy needs for drying and eliminates installation problems associated with harmful vapors. Many of these new products dry far more quickly than other products, so multiple coats can be applied in one day rather than two or three. This dramatically cuts labor costs and returns the facility to use much sooner. Similarly, the corrosion resistance of Sierra's coatings are superior to any solvent-based coatings on the market.

Benefits

Energy Savings
Reduces or eliminates the energy needed for drying in-line production processes.

Emissions Reductions
Reduces environmental impact and increases compliance with regulations and environmental requirements.

Productivity
Speeds drying and uses simple water clean-up, thereby reducing downtime between coats and at the end of jobs. Reduced emissions also reduce ventilation equipment and labor.

Safety
Eliminates skin irritation from solvent contact and reduces exposure to harmful vapors, the need for ventilation, and the risk of fire from organic vapors, resulting in safer installation.

Overview

- Developed by Sierra Performance Coatings and being marketed by RPM International, Inc. (www.rpminc.com)
- Commercialized in 1998
- 787,371 gallons produced and applied through 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.007	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.020

Applications

Can be used as components of exterior opaque stains, exterior and interior semitransparent stains, waterproofing sealers, clear wood finishes, varnishes, and sanding sealers

Capabilities

- Provides equal protection and material-covering characteristics such as longevity and toughness with improved drying times and easier installation.
- Allows for quicker installation with none of the noxious fume problems associated with standard products.
- Reduces drying time and environmental impacts.

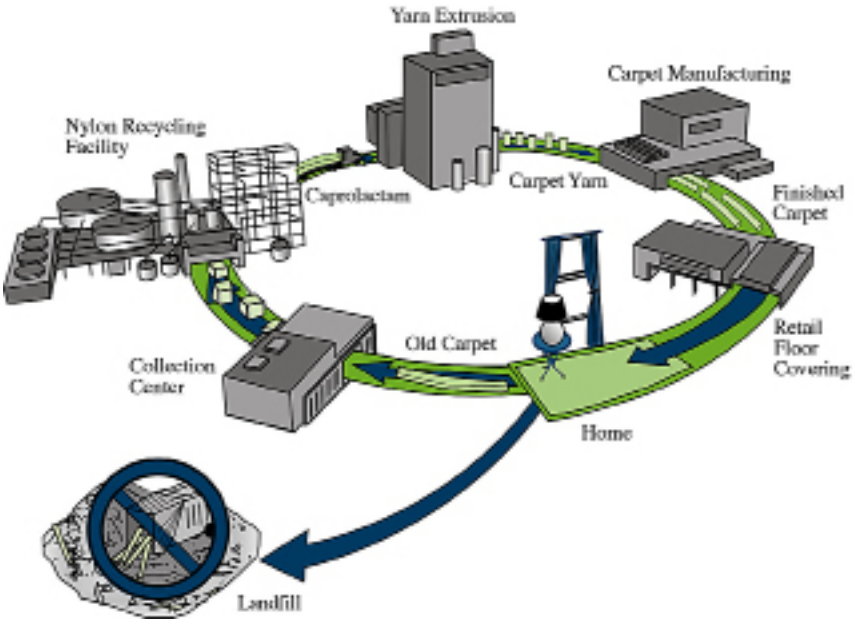
Nylon Carpet Recycling

New Process Recovers and Reuses Nylon from Waste Carpeting Saving Energy and Costs

With a desire to keep materials out of the landfill, Shaw Industries, Inc., has incorporated a novel process developed by Honeywell International, Inc., and DSM Chemicals North America, Inc., into the largest Nylon-6 carpet recycling facility in the United States. The recovery process not only reduces the amount of carpet-based material destined for landfill, but produces virgin quality caprolactam, the monomer building block of Nylon-6 resin used to make carpet fiber.

With proof-of-principal financial assistance provided by ITP, the closed-loop depolymerization and purification process allows Nylon-6 recyclers to recover and reuse a significant percentage of the raw materials used to make carpeting while consuming less total energy compared with the conventional production of caprolactam. In addition to caprolactam recovery, the process can reclaim calcium carbonate used for carpet backing and other polymers used in carpet manufacturing for future use.

Shaw Industries' Evergreen Nylon Recycling (ENR) facility is the largest commercial-scale Nylon-6 recycling plant in the world. With the plant currently in operation, ENR is drawing from over 40 carpet collection facilities across the nation and has collectively kept over 165 million pounds of carpet out of landfills. The Cradle to Cradle™ process recovers approximately 25 million pounds of caprolactam and 35 million pounds of calcium carbonate filler and recovers up to 300 billion Btu each year.



Shaw Industries' Nylon Carpet Recycling Loop

Overview

- Developed by Honeywell International, Inc., and DSM Chemicals North America, Inc.
- Evergreen Nylon Recycling facility in Augusta, GA, is owned and operated by Shaw Industries, Inc. (www.shawinc.com)
- Recycled over 165 million pounds of post-consumer carpeting since re-opening of the facility in 2007
- Produced in excess of 25 million pounds of virgin quality caprolactam in 2007

Applications

Can be used to recover and reuse the primary constituents of reclaimed carpeting and carpet fibers including caprolactam, calcium carbonate, and other polymers

Capabilities

- Produces virgin quality pure caprolactam using the closed-loop depolymerization and purification system.
- Enables processing of whole Nylon-6 carpets and eliminates mechanical separation.
- Enables reuse of recovered raw materials in Nylon-6 as carpeting, fibers, and resins.

Benefits

Energy

Reduces energy consumption in the production of Nylon-6 resin and carpet fiber.

Environmental

Reduces landfilling of nylon waste carpets and other Nylon-6-based materials and reduces raw material demand for the production of Nylon-6.

Pressure Swing Adsorption for Product Recovery

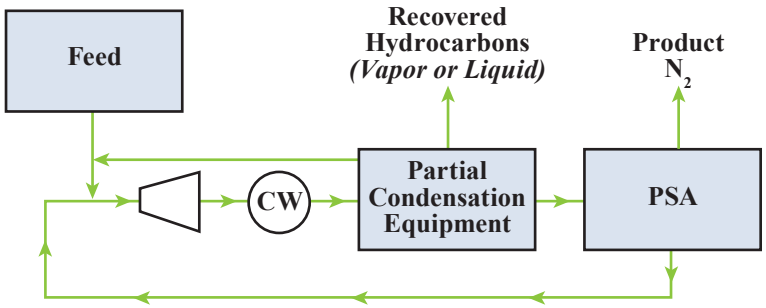
IMPACTS

Highly Selective Pressure Swing Adsorption Technology Recovers Valuable Components from Waste Streams

Many polyolefin plant designs use a polymer degassing step to remove unreacted monomer, solvents, and additives from the product polymer fluff before it is processed in downstream pelletizing operations. When nitrogen is used as the stripping gas, the operation produces a low-pressure gas stream that typically contains nitrogen and valued hydrocarbons that can be recovered and recycled to the plant. If the gas is not processed for recovery, it is typically flared. The flaring step results in volatile organic compounds, NO_X, and CO_2 emissions. Flaring can also be costly, roughly equal to the value of the purchased nitrogen.

With assistance from ITP, Air Products and Chemicals has developed a single unit operation to recover these gases. Pressure swing adsorption (PSA) is combined with partial condensation to essentially recover 100% of the hydrocarbons from the vent gas. In addition, PSA produces a high purity N_2 stream, with nearly 100% recovery of nitrogen. The recovered nitrogen can be recycled to the stripping operation or used elsewhere in the facility. Air Products' high recovery system eliminates waste streams and therefore emissions.

In this new process, the vapor stream from the partial condensation section flows into a PSA unit. Within the PSA, specially selected adsorbent materials extract hydrocarbons, thereby refining the nitrogen to a high purity with minimal pressure drop. Over time the adsorbent material in the bed becomes saturated and must be regenerated. Lowering the pressure in the saturated bed desorbs the hydrocarbon components from the adsorbent material in the PSA. The hydrocarbons are released and recovered in a low-pressure tail gas, which is recycled back to the compressor suction so the hydrocarbons are not lost. This technology provides a significant opportunity for energy and cost savings and reduced waste.



Pressure Swing Adsorption Recovery

Overview

- Developed by Air Products and Chemicals (www.airproducts.com)
- Commercialized in 2003
- Installed in three locations in Texas

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.404	0.111

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.013	1.76

Applications

Can be used by chemical and refining industries, including polyethylene and polypropylene production processes that use N_2 for degassing the polymer fluff and for treating refinery off-gas streams. Could be adapted to recover valuable products from other waste streams throughout the industry.

Capabilities

- Recovers hydrogen, nitrogen, and hydrocarbons for reuse.
- Is flexible enough to operate using an external refrigeration source.

Benefits

Pollution Reduction

Can collect and separate for reuse exit streams from certain processes, eliminating the emissions and need for disposal. Can save energy and costs by eliminating flaring of waste streams, which is typically part of disposal.

Profitability and Productivity

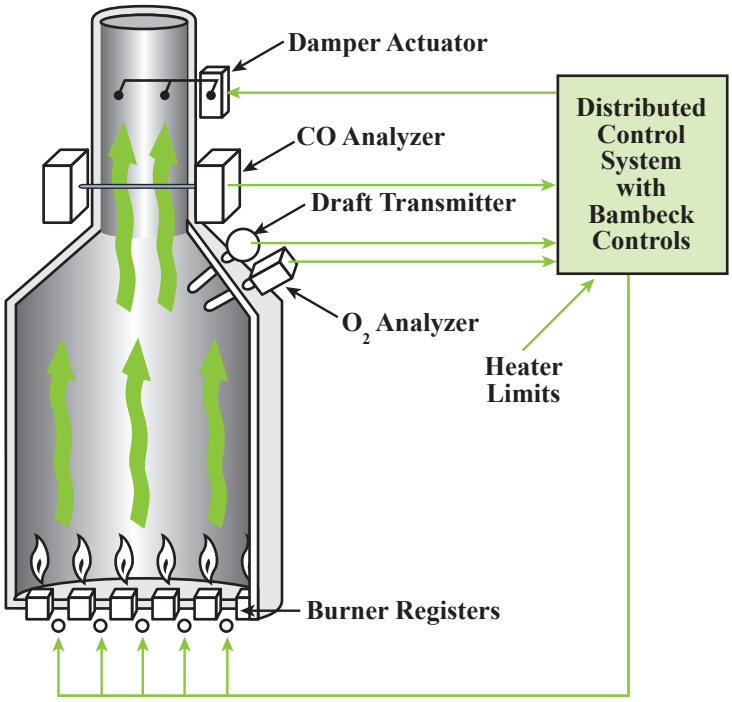
Reduces operating and emission costs by eliminating flaring and increases productivity by reusing products in the feed streams.

Process Heater for Stoichiometric Combustion Control

An Enhanced, CO-Based, Low Excess Air Control System Saves Energy While Reducing Emissions

To heat liquids and induce chemical reactions during production processing, the refining and chemicals industries rely on process heaters and boilers that consume large amounts of fuel. Bambeck Systems and Valero Energy received a grant from ITP to demonstrate how fuel can be saved by fully automating the available air to the three types of heaters typical to a refinery. Using a Bambeck fast CO analyzer to monitor the heater flue gas, a control scheme is installed to reduce the oxygen until a small amount of CO is produced. Using this parameter in the control scheme optimizes the air needed for combustion, thereby not wasting fuel to heat unneeded air.

The three requirements to successfully implement this technology are the fast CO analyzer, a new control strategy, and operator education. The analyzer provides CO data to the existing heater control system. The current control strategy is then modified to reduce the air to the heater via the controllable entrances, including stack dampers, fans, and burner registers. When a small amount of CO is generated, the control system automatically maintains that point, changing the controllable entrances as more or less air is required as indicated by the CO analyzer. Since fuel Btu content can change rapidly, the fast CO analyzer responds to the change in demand for O_2 and, through the control system, sends commands to the dampers, fans, and registers to open or close. Because operators historically used an O_2 monitor to ensure that the combustion process has excess air, the operators need to be educated to feel comfortable seeing very low O_2 readings. The heater is safer because CO is a precursor to a combustible condition and O_2 is not. In addition, reducing the excess O_2 also reduces both NO_x and CO_2 (greenhouse gas).



Bambeck Ultra-Low Excess Air Control System

Overview

- Developed and being marketed by Bambeck Systems, Inc. (www.bambecksystems.com)
- Commercialized in 2002 with over 700 of the original technology installed
- Seven enhanced ultra-low versions installed

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.46	0.338

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.020	0.042	5.60

Applications

Can be used by the chemicals, petrochemicals, and refining industries

Capabilities

Monitors the unburned fuel gases and controls the amount of air available for the combustion process, providing the minimum amount needed.

Benefits

Reduced Emissions

Reduces NO_x emissions from 30% to 45% and CO_2 in proportion to the size of the heater.

Safety

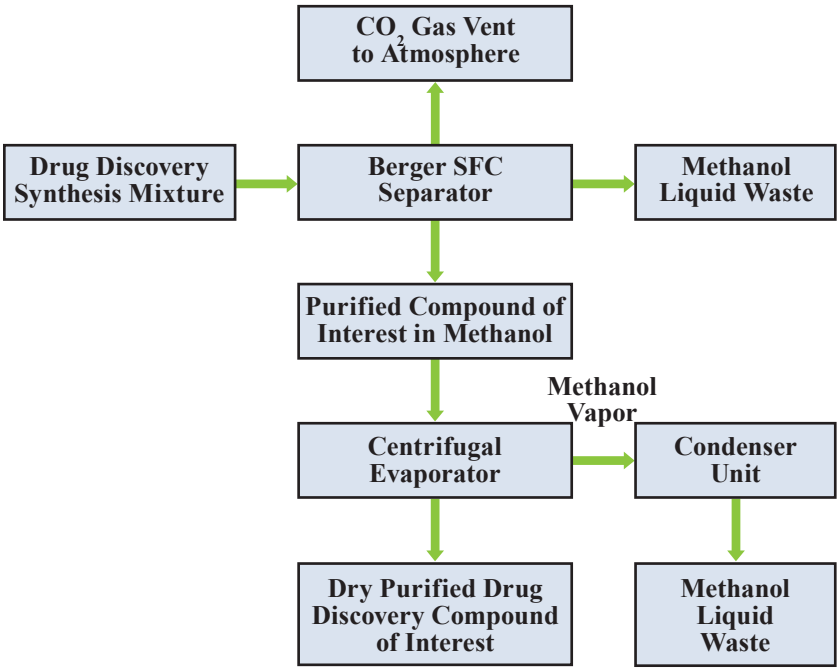
Eliminates the possibility of any dangerous combustible conditions developing in the heater.

Supercritical Purification of Compounds for Combinatorial Chemical Analysis

Innovative Purification Method Reduces Energy Use and Chemical Waste

With the support of a NICE[3] grant, Berger Instruments, Inc., developed and demonstrated an innovative approach to combinatorial chemistry for the drug discovery industry called supercritical fluid chromatography (SFC). Conventional liquid chromatography (LC) systems are capable of purifying only 5 to 10 compounds per day. In addition, because of the wide variation in the number of complex chemical compounds that need to be tested, the LC process requires several manual operations, two to three trial runs, and up to 48 hours to remove organic/aqueous waste and water from the purified products. This time-consuming work poses a bottleneck for the pharmaceutical industry, which depends on high levels of throughput and purity.

Using the new SFC process, samples can be purified and dried 20 to 100 times faster than by conventional LC systems. SFC, a packed column analysis technique similar to LC, uses compressed gases such as CO_2 rather than liquid solvents as the primary component of the mobile phase. The high diffusivity and low viscosity of CO_2 results in greater speed and resolution than possible with LC. Additionally, the SFC technology provides a solute purity of 95% or greater, very rapid fraction collection with full automation, and no need for manual intervention. This new process also significantly reduces energy consumption and liquid-solvent waste generation.



Supercritical Fluid Purification System

Overview

- Developed by Berger Instruments, Inc., and marketed by Thar Instruments, Inc. (www.tharsfc.com)
- Commercialized in 2000
- 153 units operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
3.77	1.08

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.005	0.233	0.174	21.2

Applications

Can be used in the pharmaceutical, chemical, and drug discovery industries

Capabilities

- Processes samples at higher speed with high purity.
- Approaches full automation without the need for manual intervention.

Benefits

Energy Savings

Uses 2% of the energy required by conventional LC technology.

Productivity

Processes samples 20 to 100 times faster while producing a purity of 95% or greater.

Waste Reduction

Reduces liquid chemical waste by 95% for each processed compound.

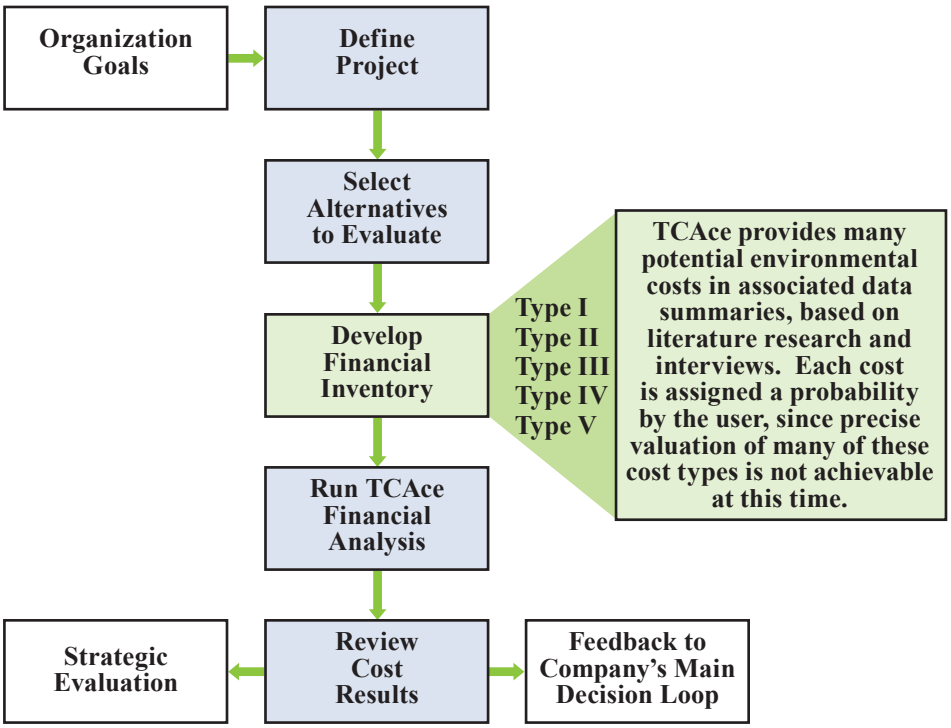
Total Cost Assessment Tool

New Decision-Making Software Integrates Costs into Environmental Decisions and Life Cycle Assessments

The Total Cost Assessment (TCA) methodology enables industry to include all environmental, health, and safety costs in decision-making. In particular, TCA includes contingent liabilities such as fines and cleanup costs and intangible costs such as damage to corporate or brand image and reduced employee morale. External costs, such as costs to society, can also be included in the TCA methodology. In traditional industry decision-making, environmental health and safety (EHS) assessments have been conducted separately from life cycle cost analyses. This customary separation has limited the influence and relevance of life cycle assessment for decision-making and has left uncharacterized the important relationships and tradeoffs between the economic and environmental performance of alternative decisions.

The TCA methodology was developed by an industry collaboration of ten companies led by the American Institute of Chemical Engineers (AIChE) Center for Waste Reduction Technologies (CWRT) with support from ITP and the National Business Roundtable Industrial Pollution Prevention Council.

The Total Cost Assessment Tool (TCAce), developed and sold by Sylvatica, manages the TCA process by enabling the company to use sliding ranges and probabilities to reflect the true nature of contingencies. TCAce integrates scenario case studies and sensitivity/uncertainty/risk analysis into a company's existing economic evaluation framework to enable sound decisions. It identifies all conventional, hidden, human health, and environmental impact costs, both internal and external. TCAce requires an operating system of Windows 98 or better and recommends at least a 24MB hard drive.



The Total Cost Assessment Process

Overview

- Software developed by Sylvatica of North Berwick, Maine (www.earthshift.com)
- Has sold 9 units to date: 3 in the United States and 6 internationally
- Commercialized in 2005

Applications

Can be used throughout industry in considering all the environmental and health costs associated with a business decision, such as process, project, or corporate-level investment alternatives. The software performs and addresses the following activities: estimating baseline costs, benchmarking, process development, product mix, waste management decisions, pollution prevention alternatives, remediation alternatives, environmental management, research budget allocations, materials/supplier selection, facility location/layout, outbound logistics, market-based environmental options, and public relations/lobbying.

Capabilities

- Identifies best environmental and economic options in business decision-making.
- Aligns environmental goals with good business strategies.
- Integrates internal costs and externalities into a single assessment process.

Benefits

Environmental Benefits

Selects waste management investment decisions that are environmentally sound and reduces long-term liabilities.

Profitability

Reduces manufacturing costs by integrating life cycle assessment with life cycle cost analysis and facilitating collaborative scenario planning.

IMPACTS

In-Situ Sensors Provide Real-Time Measurements Enabling Better Control and Process Optimization

Current chemical process controls use few in-situ sensors, relying instead on analytic techniques that require sample conditioning and transport, and significant turnaround time. With few exceptions, these techniques lack speed of measurement, accuracy of measurement, sensitivity of measurement, and economical measurement. In-situ sensors can provide real-time measurements, enabling better understanding and control of the process and improving process optimization, product quality, and plant economics. Supported with a grant from ITP, Analytical Specialties, Inc., has developed a system of in-situ sensing for more efficient process operation.

The system, called TruePeak, is a tunable diode laser analyzer that directly measures the concentration of O_2, H_2O, and potentially several other gasses. TruePeak measures across an infrared absorbance region, which makes it useable in high dust and corrosive environments and provides a true interference-free analysis. The system is characterized by rapid measurement (as fast as 1 second), high process pressure capability (up to 20 bar), high temperature (up to 1500°C), and no contact with the process. The system operates at the required process conditions (pressure, temperature, etc.), provides real-time or near real-time data, and significantly reduces installation and operational costs compared with currently available products.

Appropriate applications for TruePeak include combustion oxygen analysis of process heaters, furnaces, and incineration operations. The technology is also applicable to processes where reducing errors in oxygen concentration measurements can reduce plant process shutdown. The need for this technology and its measurements are driven by advances in process control systems and the need to "close the loop" in modern control systems. This rugged unit can be used in a variety of chemical process applications and can provide real-time, accurate measurements in harsh environments, which can improve process efficiency, reliability, and productivity.

Overview

- Developed by Analytical Specialties, Inc. (www.analyzer.com)
- Commercialized in 2004

Applications

Can be used for gas sensing in chemical processes

Capabilities

- Provides in-situ analysis, eliminating errors and costs associated with extractive analyzers.
- Can be used in harsh environments.

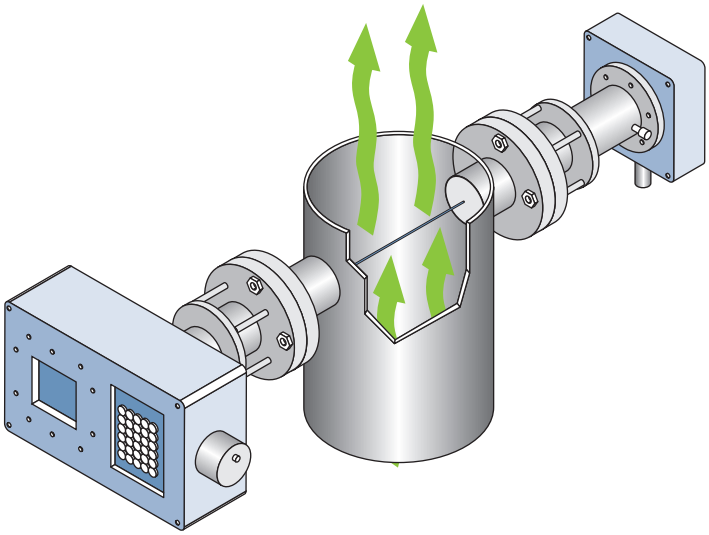
Benefits

Applicability

Operates with processes up to 1500°C and 20 bar and virtually interference-free.

Productivity

Reduces downtime for maintenance and provides near real-time measurements with improved accuracy for better control.



TruePeak Process Laser Analyzer

Forest Products

IMPACTS

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- Detection and Control of Deposition on Pendant Tubes in Kraft Chemical Recovery Boilers 47
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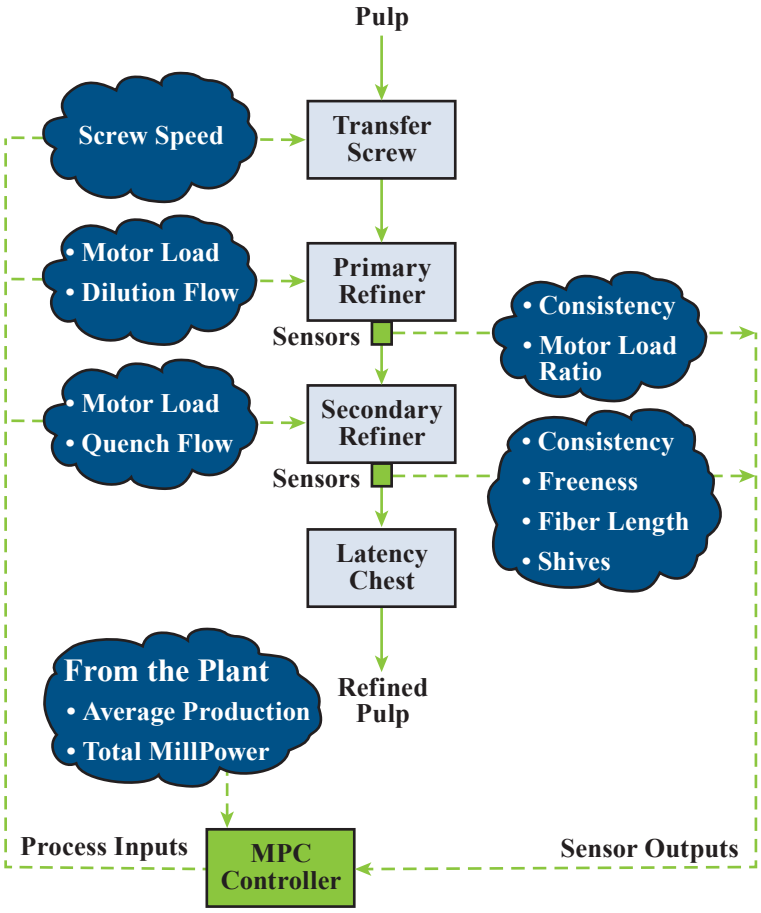
Advanced Quality Control (AQC) Solution for Thermo-Mechanical Pulping

Optimal Pulping Using an Advanced Control System and Sensors

Thermo-mechanical pulping (TMP) has become the pulping method of choice for many pulp and paper mills. Electrical energy accounts for 23% of the total production cost, with over 70% of that dedicated to the TMP process. In 2001, with financial and technical support provided by ITP, Pacific Simulation assessed and implemented their AQC model-predictive controls in a TMP plant. In this demonstration, the plant realized gains in three key areas: reduced peak and specific energy consumption, reduced production line transition times, and improved freeness targets.

Commercial implementation of AQC involves coordinating advanced quality control in multiple areas of the paper mill: mainline refiners, reject refiners, screen room, and pulp quality. Sensors are used to measure controlled variable outputs for freeness, consistency, shive content, fiber length, motor load, screw speed, refiner temperature and pressure, and reject rate. The heart of the AQC system is the multivariable predictive controller (MPC) and associated software that compares "current" data against "historical" data to determine the predictive model. The MPC, coupling pulp line output with plant productivity and power consumption, can make real-time optimization changes to manipulated variables to efficiently manage pulp and finished paper quality and production capabilities while reducing specific energy consumption. The AQC Solution has been implemented on over 72 refiners in the United States, Canada, Sweden, Norway, New Zealand, and Chile.



AQC System Schematic for Pulp Refining

Overview

- Developed and commercialized by Metso Automation's Pacific Simulation in 1995
- Expanded under DOE grant in 2001
- Purchased and marketed by Metso Automation in 2004 (www.metso.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.923	0.154

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.001	0.033	0.025	3.02

Applications

Can be used to link final product quality with the thermo-mechanical pulping process optimizing production, quality, and cost.

Capabilities

- Reduces peak and specific energy demand by matching real-time pricing from local electrical utilities.
- Reduces raw material costs by limiting the required amount of purchased Kraft pulp.
- Improves final pulp quality by optimizing refiner operation and output.

Benefits

Energy Savings

Reduces specific peak energy from 8 MW to 6.5 MW; uses an average of 125 horsepower days/ton in the plant down from 145 horsepower days/ton.

Production

Uses stock blending quality control to optimize the blend of feedstock quality and final paper grade to allow mills to match pulp quality production to the exact requirements of the paper machine on a grade basis.

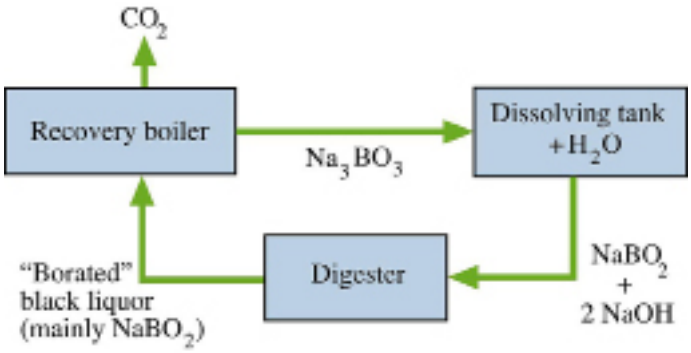
IMPACTS

New Technology Increases Energy Efficiency of Kraft Chemical Recovery Process and Causticizing

Boron-based autocausticizing is a new, cost-effective technology to recover kraft pulping chemicals. Conceptually, the technology can be used to supply part or all of the sodium hydroxide requirements of the kraft process, supplementing or replacing the lime cycle. Because the de-carbonating reactions take place directly in the recovery boiler, instead of the lime kiln, this process reduces energy consumption and increases causticizing and calcining capacities.

The technology uses sodium metaborate to react with sodium carbonate in the kraft furnace. Once the reacted salts are dissolved in the green-liquor dissolving tank, sodium hydroxide is formed, and the sodium metaborate is regenerated. The technology provides more energy-efficient hydroxide production, increases the causticizing equilibrium, and, when used in conjunction with the conventional lime cycle, increases the causticizing/calcining capacity.

Rio Tinto Minerals, with ITP support, has developed partial borate autocausticizing, which is being implemented in pulp mills worldwide to supplement conventional lime causticizing with almost no capital investment. The one U.S. application is in the P.H. Gladfelter Co. mill in Spring Grove, Pennsylvania, where it increased production by roughly 5% in 2007.



Borate Autocausticizing Process

Overview

- Developed by U.S. Borax/Rio Tinto Minerals
- Commercialized in 2004
- Being used in one U.S. plant and in four international plants.

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.020	0.020

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.012	0.003	0.440

Applications

Can be used to replace all or part of the kraft causticizing-calcining process, therefore providing supplemental lime kiln and causticizing capacities

Capabilities

- Reduces the load on lime causticizing plants, improving the performance of clarifiers or filters and reducing the extra alkali circulated in the weak wash (weak white liquor) stream.
- Reduces fresh lime usage and lime mud disposal associated with lime kiln production constraints.

Benefits

Cost Savings

Decreases the load on causticizing and lime reburning to reduce either lime purchases or kiln energy and maintenance costs.

Productivity

Increases the causticizing capacity of the mill to increase pulp production without investment in lime kilns or recausticizing equipment.

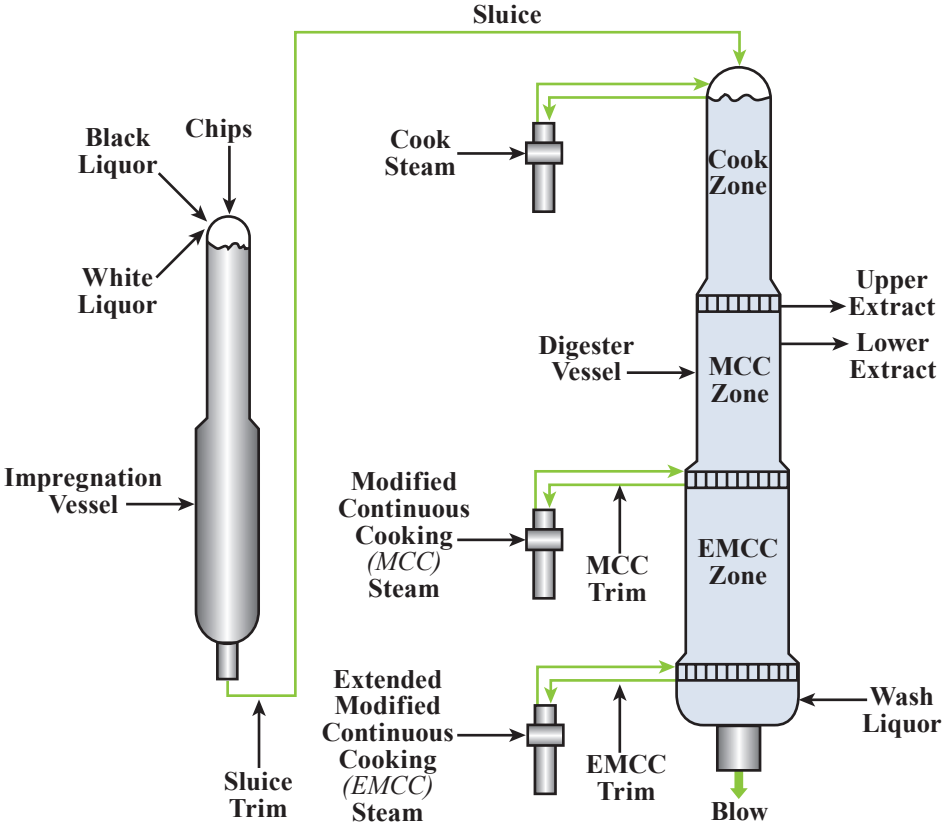
Continuous Digester Control Technology

Pulp Process Model Identifies Improvements that Save Energy and Improve Productivity

The pulp digester is known as the bottleneck unit in the pulp mill flow sheet because it can require 5% to 50% of typical on-line operation time, making this component of the pulping process very capital intensive. Improving digester performance can significantly reduce production losses, operating costs, and negative environmental effects while increasing paper quantity and quality. Using a computer-based model and control system for continuous digesters could regulate the pulping process, thereby minimizing mill downtime caused by digester problems and fostering continuous operation and pulp production.

Previous work conducted at the University of Delaware (UD) indicated that fundamental computer models could manage the internal conditions within the digester. The UD resolved the major challenge to designing such a model by developing a fundamental digester model that manages production rate changes and grade swings between hardwood and softwood feedstocks.

The digester's fundamental process model integrates physical and chemical properties as system "states" (i.e., points in the digester process) to track grade transitions. This model allows appropriate material, energy balance, and diffusion simulations to be calculated as various-origin chips pass through the digester. The observation and tracking of these data help identify process improvements. The model's first commercial application in a Texas mill allowed the temperature to be reduced in part of the pulping process, thereby saving 1% of the process energy.



Dual Vessel EMCC Continuous Digester

Overview

- Developed at the University of Delaware
- Commercialized in 2003
- Being marketed by IETEK (www.ietek.net)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
9.00	0.0

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.0

Applications

Can be used in all types of pulp digesters and provides the basis for developing more model-based methods of soft sensing, diagnostics, and control

Capabilities

- Uses a computer model to evaluate the pulping process.
- Provides operational data through the model to identify process improvements.

Benefits

Environmental Impact

Minimizes the amount of chemicals used.

Productivity

Improves operator control, thus raising productivity and process reliability. Also improves system operability through rate and grade transitions.

Product Quality

Reduces pulp and paper quality variations.

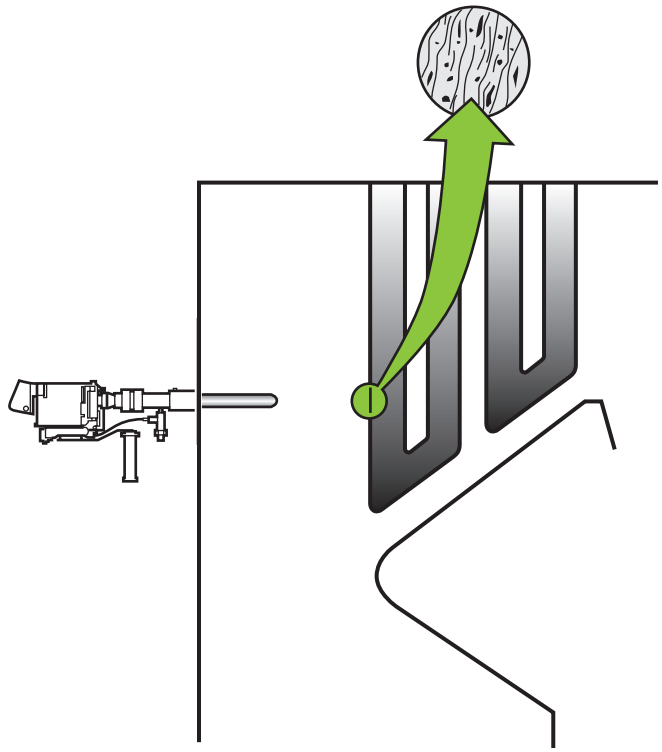
Detection and Control of Deposition on Pendant Tubes in Kraft Chemical Recovery Boilers

Advanced Imaging System Improves Boiler Efficiency, Reduces Sootblowing Costs, and Improves Operational Safety

The kraft chemical recovery boilers used for pulp processing are large and expensive and can be the limiting factor for mill capacity. Improvements in boiler efficiency with better control of deposits on heat transfer surfaces (e.g. pendant tubes) and reductions in boiler downtime (due to pluggage or slag impact) can improve boiler capacity and reduce operating costs.

With assistance from DOE's Inventions and Innovation Program, Enertechnix, Inc., has developed a hand-held infrared inspection system. Using the inspection system technology, they have also established the feasibility of and are developing a continuous integrated monitoring sootblower control system to detect and control buildup of deposits. The early detection of deposits can extend the intervals between boiler shutdowns. The resulting improved boiler operation and reduced maintenance provide energy savings and productivity improvements to the pulp processing industry.

Sootblowers use steam to clean the soot from heat exchanger pendant tube surfaces. The hand-held inspection system has demonstrated reductions in sootblower steam use of up to 20% because the frequency of sootblower operation is reduced, sootblowers can be repositioned based on data obtained from the inspection, and sootblower malfunction can be detected. Reduced pluggage and deposition in the boiler have also led to improved heat transfer rates. The integrated observation camera and sootblower control system (under development) are expected to reduce sootblower steam usage by 30-35% and improve heat transfer efficiency by 20%.



Hand-Held Inspection System on a Kraft Recovery Boiler

Overview

- Developed by Enertechnix, Inc. (www.enertechnix.com)
- Commercialized a hand-held device in 2002
- 126 units in use in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
3.85	1.39

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.010	0.805	0.214	30.2

Applications

Can be used by kraft recovery boilers in the pulp and paper industry and also for boilers in the coal power, cement, steel, and glass industries

Capabilities

- Produces clear video images of boiler interiors despite highly particle-laden environments.
- Produces images at distances up to 100 feet, enabling inspection anywhere in the combustion chamber including the convection pass and economizer.

Benefits

Productivity

Reduces boiler downtime through early detection of defective fixtures (tube leaks or damaged sootblower). Without shutting down the boiler, also detects slag formation at an early stage, preventing impact damage and enabling cleaning before deposits harden.

Safety

Enables early detection and elimination of sizable slag deposits on boiler internals, which can lead to severe damage and potential injury.

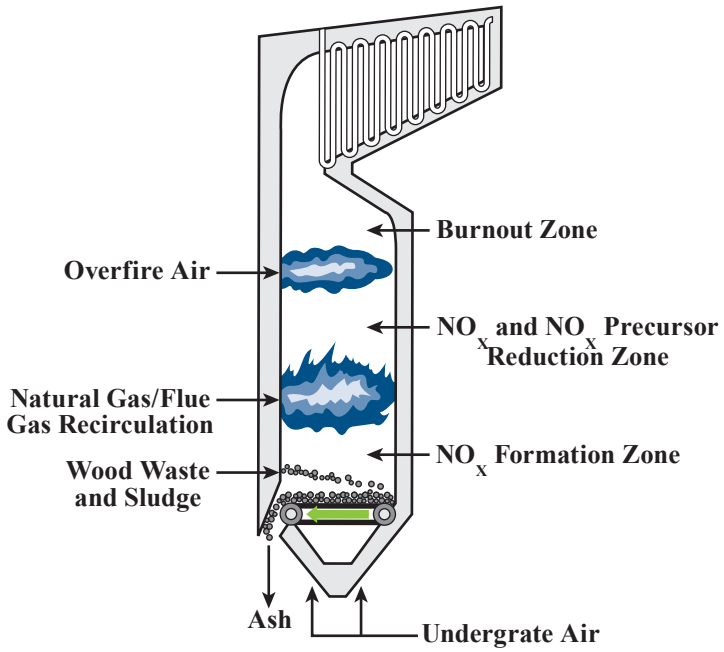
METHANE de-NOX® Reburn Process

METHANE de-NOX Reburn Process Uses Waste Wood for Biomass-Fired Stoker Boilers

The METHANE de-NOX process is a reburn technology using 5% to 25% natural gas heat input for improving combustion of solid waste fuels and for controlling emissions of NO_X and CO. The METHANE de-NOX process injects natural gas above the grate and uses flue gas recirculation to enhance mixing and create an oxygen-deficient atmosphere that retards NO_X formation. Overfire air is injected higher in the furnace to burn out the combustibles. The technology has been successfully demonstrated in commercial power plants using municipal solid waste and coal as fuel. In these demonstrations, the combustion systems operated more efficiently, required less maintenance, and reduced emissions of NO_X, CO, and VOCs.

With assistance from ITP, the Gas Technology Institute (formerly the Institute of Gas Technology) demonstrated the METHANE de-NOX reburn technology in the forest products industry. The project involved a field demonstration on a 300 million Btu/hr stoker-fired boiler fueled with waste wood and paper sludge at Boise Paper Solutions' paper mill in International Falls, Minnesota. After the boiler was retrofitted, performance tests confirmed that the added heat released from natural gas combustion above the stoker grate stabilized the firing of solid fuel, permitted uniform heat release, reduced localized peak temperature, and permitted greater load flexibility including low load operation, thus improving combustion of difficult-to-burn waste fuels.

Commercial implementation of the technology provides the forest products industry with a means to use (rather than landfill) more waste wood solids and sludges, reduce natural gas consumption and NO_X emissions, and improve boiler thermal efficiency.



METHANE de-NOX Process

Overview

- Developed by the Gas Technology Institute (www.gastechnology.org)
- Commercialized in 1998, with three units operating at paper mills and 26 units on coal-fired cogeneration boilers

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.34	0.159

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.023	0.024	2.96

Applications

Can be used by a wide range of wastewood and sludge-fired stoker boilers in the forest products industry and by coal-fired boilers

Capabilities

- Improves grate combustion of difficult-to-burn fuel such as high-moisture-content waste wood.
- Substantially reduces NO_X emissions and natural gas input while increasing sludge firing rates and thermal efficiency.
- Provides a cost-effective means to use abundant waste wood solids and sludges for energy generation rather than landfilling them.

Benefits

Ease of Operation

Allows cleaner gas to pass through the furnace with less fouling and unburned carbon and fly ash at the bottom.

Productivity

Increases sludge firing from 1.2 up to 5 tons/hour and boiler thermal efficiency by 1% to 2%, resulting in greater steam production capacity.

MultiWave™ Automated Sorting System for Efficient Recycling

IMPACTS

Advanced Sensor Detects Paper's Unique Spectral Signature at High Speed

The primary challenge in recycling paper has been to obtain raw material with the highest purity. Ideally, creating a paper stream sorted by purity would facilitate a high-quality end product, thereby saving processing chemicals and energy. Unfortunately, previous manual sorting techniques were not effective in meeting this challenge. With financial assistance from ITP, North Carolina State University, Weyerhaeuser, and MSS Corporation developed sensors for automatically sorting grades of paper from a mixed stream at high speed for more efficient recycling. Using technology developed by North Carolina State University, MSS commercialized the MultiWave™ sensor in 2006, providing proprietary full spectrum color and near infrared (NIR) spectroscopy in one compact module at scanning speeds that are more than double those of other NIR sensor systems. The new sensor also provides gloss and lignin identification.

The new sensor provides manual recycling facilities, as well as paper and plastics processors, with a solution for automated optical separation at levels not possible before. At up to 15 tons/hr, the incoming stream is uniformly fed in a single layer on high-speed conveyors at velocities of 1,200 ft/min (6 meters/sec). Besides increased speed, the sensor works in machine widths of up to 96" (2440 mm), which allows significantly higher throughput rates to be processed than any other sorting module available on the market – more than 160 ft^2 per second (15 m^2/sec).

The sensor starts the process by analyzing all items and classifying them according to specific "signatures." Then, the master computer processes the signals and fires compressed air jets. Depending on the setup, the targeted materials can be ejected together into one chute (upwards) or separately into two chutes (one upward, one downward). An auto-calibration feature ensures consistently high sorting accuracy. The result is a paper stream that is sorted by purity, thereby meeting the original challenge and reducing landfill waste.

Overview

- Developed by North Carolina State University
- Commercialized and marketed by MSS Corporation in 2006 (www.magsep.com)

Applications

Can be used for high-speed sorting of mixed recycled paper streams and gloss and lignin identification

Capabilities

- Works in machine widths up to 96 inches, up to 15 tons per hour.
- Analyzes and classifies paper type at 1,200 feet per minute.

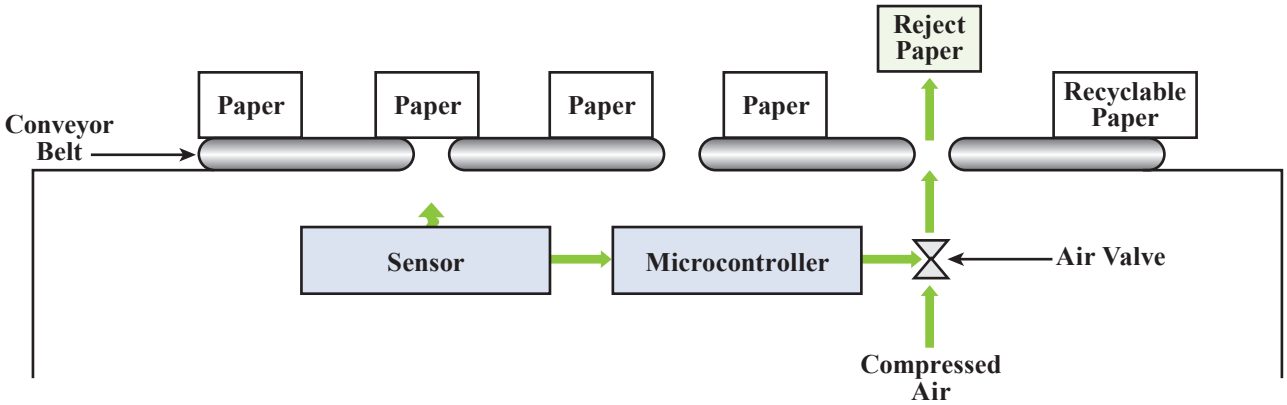
Benefits

Profitability

Sorts recycled paper using a high-speed machine instead of hand sorting.

Waste Reduction

Reduces rejected recycled pulp up to 5%.



Paper Recycling Using the MultiWave Sensor System

Pressurized Ozone/Ultrafiltration Membrane System

Novel Process Dramatically Reduces Energy Use, Improves Process Water Quality, and Reduces Effluent Discharge

With the support of a NICE[3] grant, LINPAC, Inc., demonstrated a novel technology for closed-loop systems that uses pressurized ozone with dissolved air flotation and an ultrafiltration membrane in series. This system allows total dissolved solids (TDS) in process water to be readily converted to total suspended solids for efficient removal. Contaminated mill process water thereby can be continually and cost effectively cleaned to the high-quality process water standards required for reuse in the mill. After passing through the new system, process water is far cleaner and of higher quality than water from other processes and requires far less energy for reheating than fresh water. The system reduces the production problems associated with buildup of TDS in paper mill operations and provides operational benefits such as reduced energy needs and fewer chemicals and additives. The system also results in production and quality gains because of the higher-quality process water. Because the environmentally friendly system allows paper mills (and other water-intensive manufacturing mills) to operate in a closed loop, effluent discharge to rivers and waterways is eliminated or drastically reduced. This new system substantially reduces both effluent discharge and the need for fresh water.

Benefits

Environmental

Removes TDS in mill process water, thereby allowing mills to eliminate or reduce effluent discharge. Eliminates CO_2 discharges of up to 815 tons a year for a typical plant operation. Potentially reduces landfill waste by 50% and use of processing chemicals by $5/ton of paper produced.

Productivity

Allows production gains of 5% to 15%, saves energy costs due to heating and drying, reduces chemical additive use, and potentially reduces downtime in mill process water treatment systems.

Overview

- Developed by LINPAC, Inc., and Cellulose Products and Services LLC
- Commercialized in 2004 and marketed by Cellulose Products and Services LLC
- Currently installed and operating in a LINPAC paper plant

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.26	0.315

U.S. Emissions Reductions

(Thousand Tons, 2007)

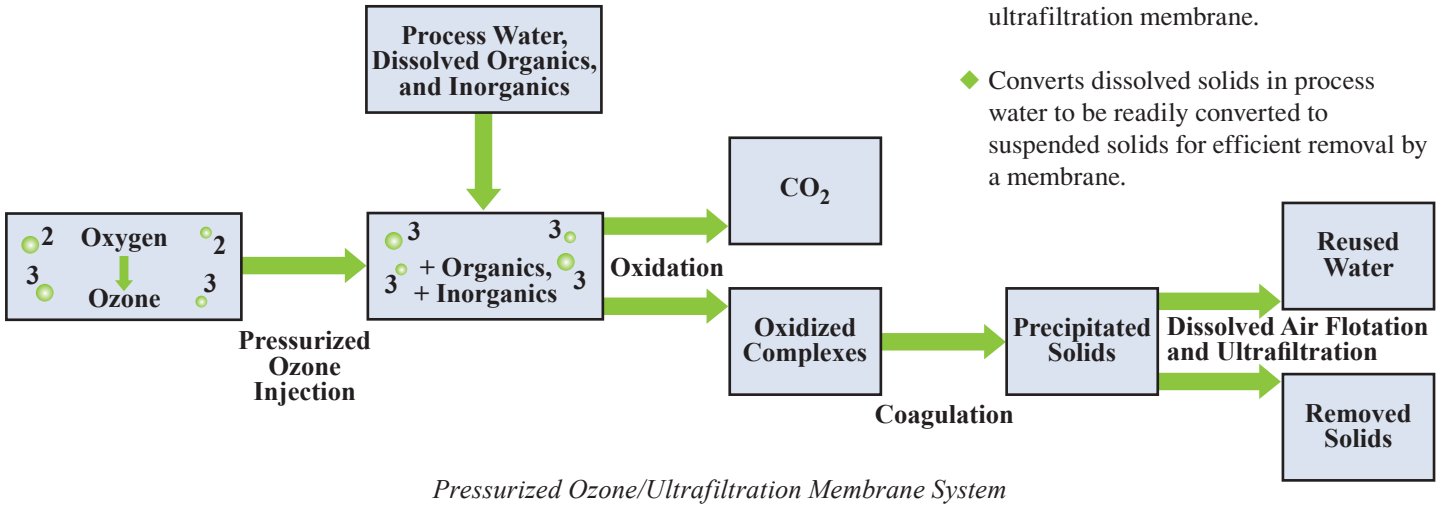
Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.037	5.0

Applications

Can be used in the pulp and paper industry and in other processes such as the food industry, which require filtration technology

Capabilities

- Uses a series combination of pressurized ozone, dissolved air flotation, and an ultrafiltration membrane.
- Converts dissolved solids in process water to be readily converted to suspended solids for efficient removal by a membrane.



Pressurized Ozone/Ultrafiltration Membrane System

IMPACTS

Improving Recycled Paper Production Energy Efficiency

Pressure-sensitive adhesives (PSAs) in recycled paper create a number of problems for the recycling process, including lost production and diminished product quality. Unlike conventional PSAs, a new adhesive material was developed at the University of Minnesota, with the assistance of ITP funding, that is effectively removed from the papermaking process during the furnish screening process. The new adhesive possesses properties that enhance its removal without impacting its performance in PSA products.

To develop the new adhesive materials, new screenable PSAs were synthesized and characterized, and performance measures were created. In addition, modified adhesive substrates were tested, and test methods were designed to gauge disintegration inhibition of adhesive labels and relative removal efficiencies of developed polymers. The new adhesives break down into larger, harder, nontacky particles that are more easily removed through conventional screening, and the cross linking reactions may be controlled through external stimuli allowing the reactions to be initiated during recycling.

The technology was commercialized in 2006 and is the industry's first 100% recyclable label. Currently, the Pinnacle Label Company is selling a portion of their labels under their recyclable label brand utilizing this technology. Using 100% recycled paper stock and a recyclable permanent adhesive, Pinnacle now has an environmentally friendly product. Pinnacle Label supplies the needs of its national customer base from its headquarters and production facility in Buffalo, New York, and other distribution centers around the nation.

Overview

- Developed by Dr. Steven Severtson of the University of Minnesota in 2000
- Commercialized in 2006 and being marketed by H. B. Fuller Company (www.hbfuller.com)

Applications

Can be use for all press-on type labels and sticker products

Capabilities

- Allows easier adhesive removal in paper recycling.
- Reduces machine downtime by reducing jams due to adhesives and reduces process chemical needs.

Benefits

Energy Savings

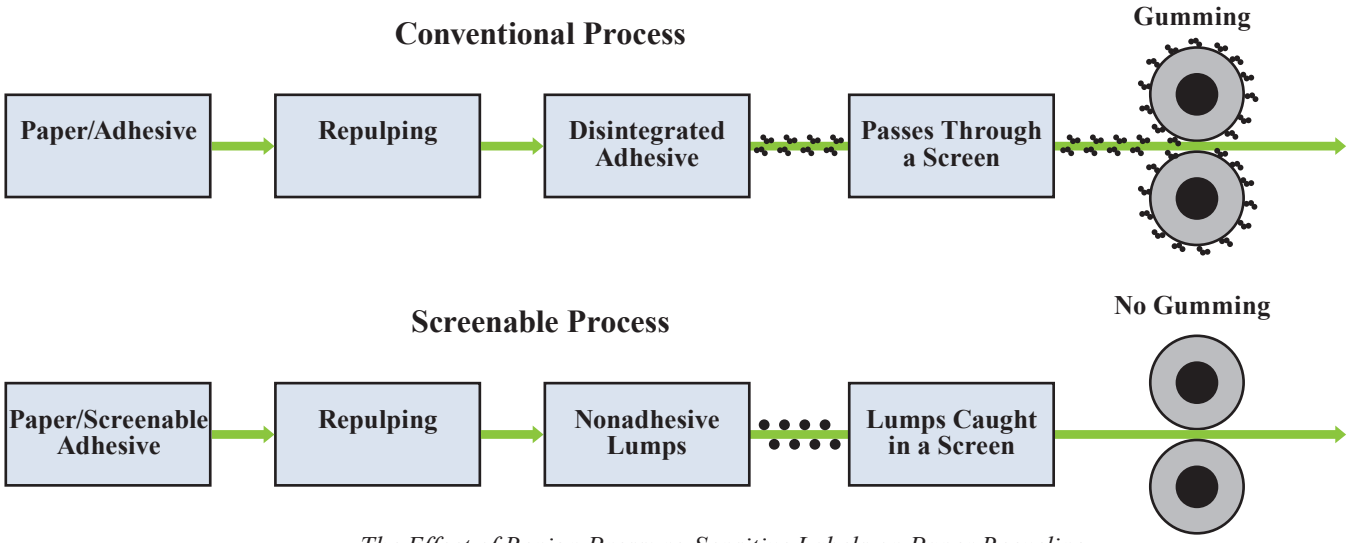
Improves the energy efficiency of recycled paper production.

Productivity

Reduces paper recycling re-manufacture processing downtime and lowers fiber loss.

Waste Reduction

Allows for the recycling of more post-consumer paper trash and reduces process chemical needs.



The Effect of Benign Pressure-Sensitive Labels on Paper Recycling

Thermodyne™ Evaporator – A Molded Pulp Products Dryer

Thermodyne Evaporator–A Substantially Improved Molded Pulp Products Dryer

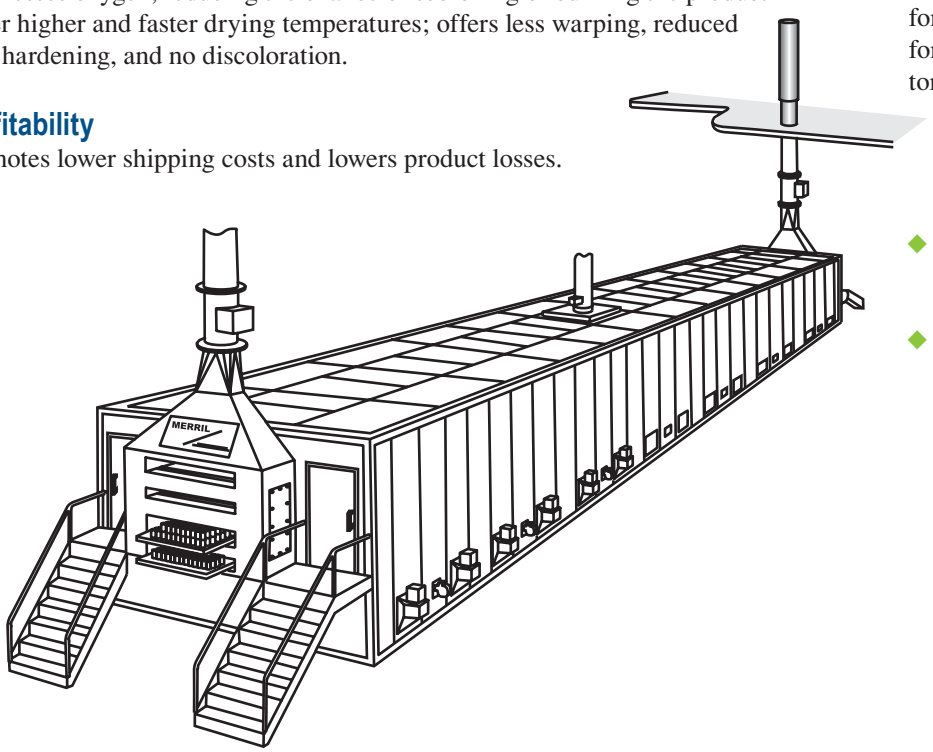
With assistance from DOE's Inventions and Innovation Program, Merrill Air Engineers demonstrated that its Thermodyne dryer outperforms conventional molded pulp dryers. Unlike other dryers, the Thermodyne dryer reheats water vapor released from the product being dried to create superheated steam that 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. Fires are prevalent with standard dryers, but lower oxygen levels in a Thermodyne dryer eliminates this hazard. 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 dryer's condensate, substantially reducing the amount released into the atmosphere.

Benefits

Productivity
Promotes easier stacking and wrapping.

Product Quality
Suppresses oxygen, reducing the chance of scorching or burning the product under higher and faster drying temperatures; offers less warping, reduced case hardening, and no discoloration.

Profitability
Promotes lower shipping costs and lowers product losses.



Thermodyne Evaporator–A Molded Pulp Products Dryer

Overview

- Developed by Merrill Air Engineers (www.merrillengineering.com)
- Commercialized in 1997
- Two units in service in the U.S., one in Ireland, and one in Columbia

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.341	0.068

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.008	1.071

Applications

Can be used by the forest products industry for manufacturing molded fiber articles and for drying pulp, wood, cotton, cellulose, or torrefied wood and wood veneers

Capabilities

- Can replace conventional drying systems in the forest products industry.
- Handles a wide variety of forest products and can be applied to agricultural applications.

Glass

IMPACTS

- Advanced Temperature Measurement System 54
- High Luminosity, Low-NO_x Burner 55
- Process for Converting Waste Glass Fiber into Value-Added Products 56

Advanced Temperature Measurement System

New Material Leads to Development of Improved Monitoring Equipment

Self-validating sensor technology, developed by Accutru with support from ITP, is based on the ability to measure multiple, mutually exclusive thermoelectric properties of thermally sensitive materials contained in the tip of the sensor probe. The sensor probe is constructed like a thermocouple but is specially designed so that the thermal response of each element of the sensor can be monitored using independent combinations with multiple other elements. The signal conditioner/transmitter multiplexes these measurements and monitors the health of each individual thermo-element using at least two of its electrical properties.

This concept makes it possible to continuously monitor and "validate" each of the measuring elements inside the sensor while it is in service so that no element can drift without detection. If an individual element begins to drift or de-calibrate for any reason, the system eliminates the data for that element while still providing an accurate, traceable temperature with the remaining "healthy" elements. Using information about the number of "healthy" elements in the sensor, the transmitter then provides the operator or control system with sensor health status and notifies of impending loss of sensor validation before it occurs. Therefore, an accurate and reliable temperature is reported for the life of the sensor.

This technology has many features:

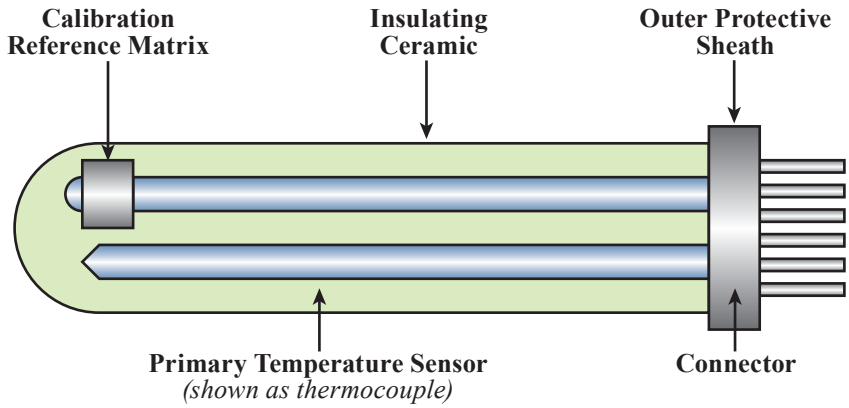
1) Uses a new concept of monitoring multiple independent measurements of the system temperature and individual element health

2) Continuously validates and reports the system temperature

3) Reports a temperature traceable to a NIST standard for the life of the sensor

4) Reports the health of the sensor

5) Warns in advance of deterioration of any of the sensor elements.



AccuTru Self-Verifying Temperature Sensor

Overview

- Developed by AccuTru International, Kingwood, Texas
- Commercialized and marketed by AccuTru (www.accutru.com)
- 46 units currently operating in the United States

Applications

Can be used in any thermochemical process where accurate and repeatable temperature read out is important: glass melters and delivery systems, chemical reactors, heat treating, and gas turbines

Capabilities

- Offers reliable temperature range: -200°C to 1750°C.
- Is self-validating while in service for the life of the sensor.
- Provides warning on the onset of decalibration, predictive maintenance.

Benefits

Optimizing Process Yield

Offers improved fuel efficiency, enhanced safety, and extended equipment life.

Productivity

Reduces failures by 90% and increases annual yields by 10%.

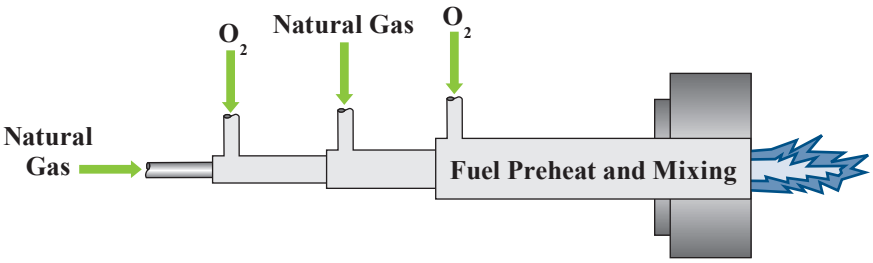
IMPACTS

High-Efficiency Burner Lowers Costs and Emissions in Oxy-Fuel Glass Melters

Glass melters use combustion systems to produce molten glass. While significant progress has been made in developing oxy-fuel combustion systems, current technologies provide low flame luminosity and generate relatively high NO_X emissions in the presence of even small mounts of nitrogen in the combustion process.

With the help of a grant from ITP, Combustion Tec Inc., now Eclipse, Inc., has developed an innovative burner that increases luminosity and radiant heat transfer in high-temperature glass furnaces. The burner improves performance by modifying the fuel prior to combustion and then forming and burning soot in the flame. The burner increases heat transfer rates while decreasing flame temperatures to improve furnace production rates and thermal efficiency.

The high-luminosity, low-NO_X burner combines a preheating zone with two combustion zones. First, a small fraction of the natural gas is burned. The products of this combustion are then mixed with the main supply of natural gas, resulting in hydrocarbon soot precursors generated in an oxygen-free heating environment. Next, the preheated natural gas enters the first, fuel-rich combustion zone in which soot forms in the flame. However, most of the combustion occurs in the second, fuel-lean combustion zone. The burning soot particles create a highly luminous flame that is more thermally efficient and cooler than a typical oxy-fuel flame.



High Luminosity, Low-NO_X Burner Design

Overview

- Developed and marketed by Eclipse, Inc. (www.combustiontec.com)
- Commercialized in 2002
- Operating in five U.S. plants in 2007

Applications

Can be used in existing and new oxy-fuel glass melters, with the largest demand currently existing in the container, fiber, and specialty glass sectors of the glass industry

Capabilities

- Can be used on new furnaces or retrofit to older ones.
- Improves furnace production rates as a result of a more than 12% increase in heat transfer rates.

Benefits

Energy Saving and Pollution Reduction

Reduces NO_X emissions from glass melters up to 50% and improves thermal efficiency up to 20% over traditional oxygen fuel burners.

Productivity

Allows cost-effective compliance with emissions regulations and provides flexibility for compliance in existing furnaces without major modifications.

Reliability

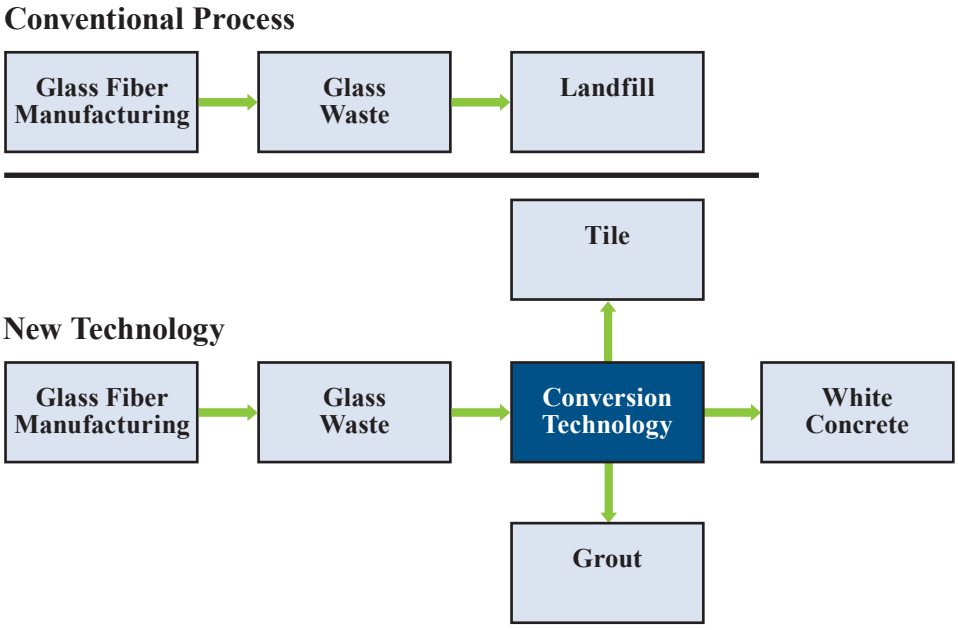
Produces a lower flame temperature and lower exit temperatures, which could extend the furnace life.

Process for Converting Waste Glass Fiber into Value-Added Products

New Process Reduces Glass Fiber Waste Stream to Landfills

Solid wastes are generated at glass fiber manufacturing facilities. With the help of a grant from DOE's Inventions and Innovation Program, Albacem, LLC, developed a new process that converts these waste streams into VCAS™ (vitrified calcium alumino-silicate) pozzolans that can be used in cement and concrete applications. This technology can help divert up to 250,000 tons per year of discarded glass fiber manufacturing wastes for use in the concrete construction industry. This technology can also be used for processing glass fiber waste materials reclaimed from existing landfills at manufacturing facilities. Both sources can help supply over 500,000 tons per year of glass fiber waste for processing into value-added products.

In the new process, waste glass fiber is ground to a fine powder that effectively functions as a reactive pozzolanic admixture for use in Portland-cement-based building materials and products, such as concrete, mortars, terrazzo, tile, and grouts. Because the waste fiber from the glass manufacturing industry is vitreous, clean, and low in iron and alkalis, the resulting pozzolan is white and highly consistent in chemical composition. This white pozzolan is especially suited for white concrete applications, providing increased long-term strength and improved long-term durability. This new pozzolan is being manufactured and marketed by Vitro Minerals, Inc. While this additive is targeted towards white concrete applications, it can also be applied to other concrete applications where environmental benefits are desired.



Glass Waste Conversion Process

Overview

- Developed by Albacem, LLC
- Commercialized and marketed by Vitro Minerals in 2006 (www.vitrominerals.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.140	0.070

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.008	1.11

Applications

Can be used for waste streams in the glass fiber industry and to replace part of the cement used in concrete

Capabilities

- Decreases water used to cure concrete.
- Imparts white color to concrete.

Benefits

Energy Savings

Decreases the amount of cement used in concrete and the amount of water needed to cure concrete while imparting white color to the concrete.

Environmental

Reduces the carbon footprint of a product when used as a cement additive.

Waste Reduction

Reduces the waste stream from current glass fiber manufacturing and reclaims glass fiber waste from old landfills.

Metal Casting

IMPACTS

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Ceramic Composite Die for Metal Casting

New Ceramic Composite Materials to Produce Superior, Low Cost Dies

Metalcasting, a major U.S. industry, has long been hampered by the high cost and short life of casting dies. Steel dies often fail prematurely due to metal fatigue cracking, corrosion, erosion, oxidation, heat checking, and soldering when the dies are exposed to molten metals while operating under cyclic-mechanical and thermal loading.

For some applications, coatings are applied to protect the die from the damage inflicted by molten metals. However, these coatings can fail prematurely and tend to interfere with the welding and polishing operations needed during reworking and correcting damages in the die.

With assistance from DOE's Inventions and Innovation Program, the Materials and Electrochemical Research Corporation has developed ceramic composite materials as an alternative to conventional material used in forming casting dies. Ceramic composites can deliver proven stability to molten metals and are resistant to corrosion, erosion, oxidation, thermal fatigue, and cracking. In addition, lower-cost hybrid composites in the nitride/nitride carbide family have the potential to last up to ten times longer than coated steel dies with significantly lower weight. These new composites are expected to reduce the cost of many products fabricated in the United States and create stronger competitiveness in the domestic metalcasting industry.

Benefits

Productivity

Weighs approximately one-third less than traditional tool steel dies, saving time in production by eliminating some of the mechanical moving equipment.

Waste Reduction

Reduces the amount of waste produced by failed tool steel casting dies and produces fewer casting rejections, reducing the energy needed to recycle the rejected castings.

Overview

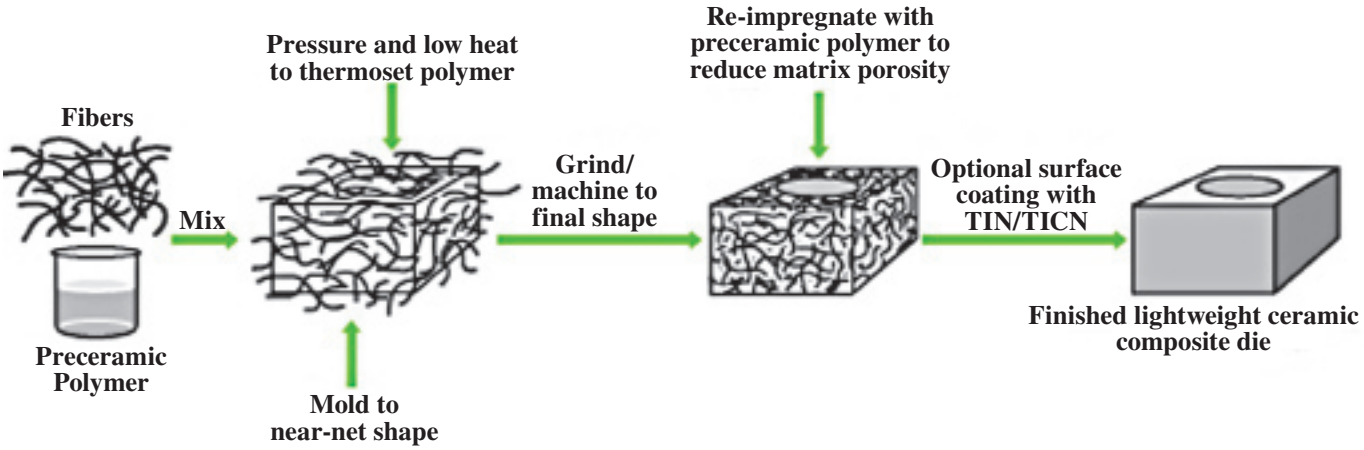
- Invented by the Materials and Electrochemical Research Corporation (www.mercorp.com)
- Commercialized in 2002
- Installed in several U.S. locations

Applications

Can be used as dies for metal casting, including replacement dies that are currently tool steel

Capabilities

- Offers resistance to corrosion, erosion, oxidation, thermal fatigue, and cracking, thus improving product quality.
- Provides stability when exposed to molten metals.
- Two to five times harder than tool steels, resulting in five to ten times longer useful die life.



Ceramic Composite Die Forming Process

CFD Modeling for Lost Foam White Side

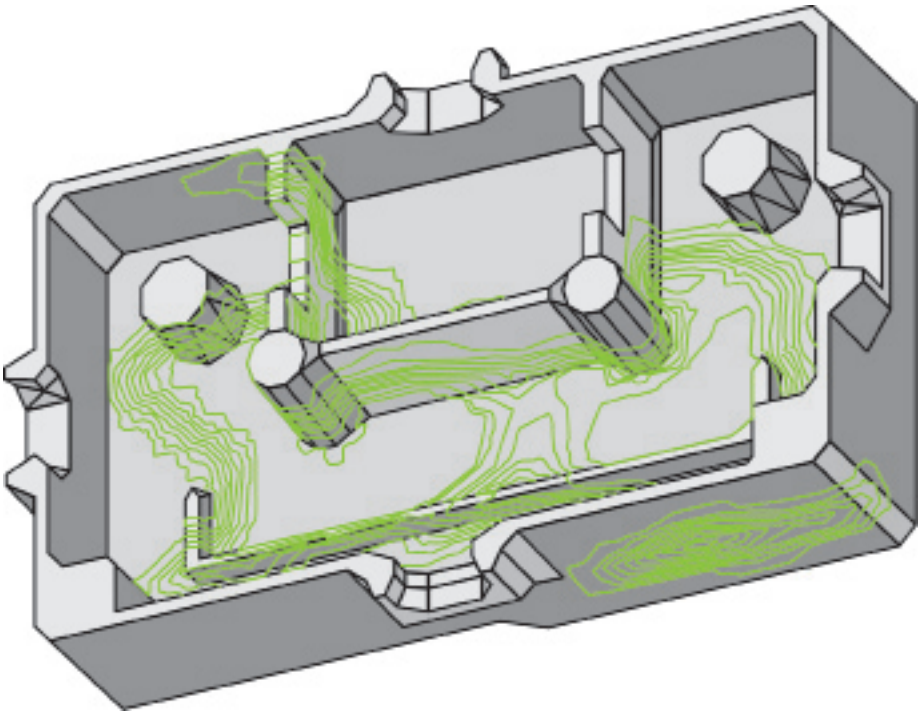
IMPACTS

New Modeling Program Provides Higher Quality Lost Foam Molds

The lost foam casting process produces clean, high-quality castings with close tolerances. The most important advantage is that no cores (with binders) are required. One challenge in lost foam casting is maintaining the uniformity and quality of the expandable polystyrene (EPS) pattern. This has often been the cause of defects in casting. An estimated 80% or more of lost foam defects can be attributed to the pattern, or the so-called white side. Foam molds are complex, and beads must flow through complex passages to completely fill the mold. The process is further complicated by the expansion of the beads.

General Motors Powertrain and others in the metal casting industry have successfully used advanced computational fluid dynamics (CFD) tools to improve foundry processes. These efforts have yielded significant cost savings and improvements in the casting processes. The industry has recognized that mathematics-based tools are needed to design and build consistent, quality EPS patterns for lost foam casting.

Arena-flow, LLC, in conjunction with the American Foundry Society, ITP, and the metal casting industry, have extended existing flow modeling software to simulate the air-driven blowing of pre-expanded beads into a mold and the subsequent steaming (expansion) of beads as they form a lost foam pattern. They developed a CFD tool for improving design and development of EPS patterns for lost foam castings.



Expandable Polystyrene Pattern Volume Fraction During Filling of a General Motors Test Box

Overview

- Invented by Arena-flow, LLC, and marketed by CPFD Software, LLC (www.cpfd-software.com)
- Being used by 2 U.S. manufacturers in 3 locations

Applications

- Can be used in modeling fluid/particle applications for mold creation in the lost foam casting industry
- Can be used in analysis of other industrial fluid/particle processes, including cyclones or fluidized bed reactors

Capabilities

- Provides visualization of the mold by using CFD modeling prior to the mold creation.
- Optimizes pattern quality as affected by fill guns, beads, and tool venting.

Benefits

Productivity

Results in fewer casting defects, requires no cores, and produces higher-quality castings.

Waste Reduction

Reduces casting defects on the white side, caused by pattern difficulties.

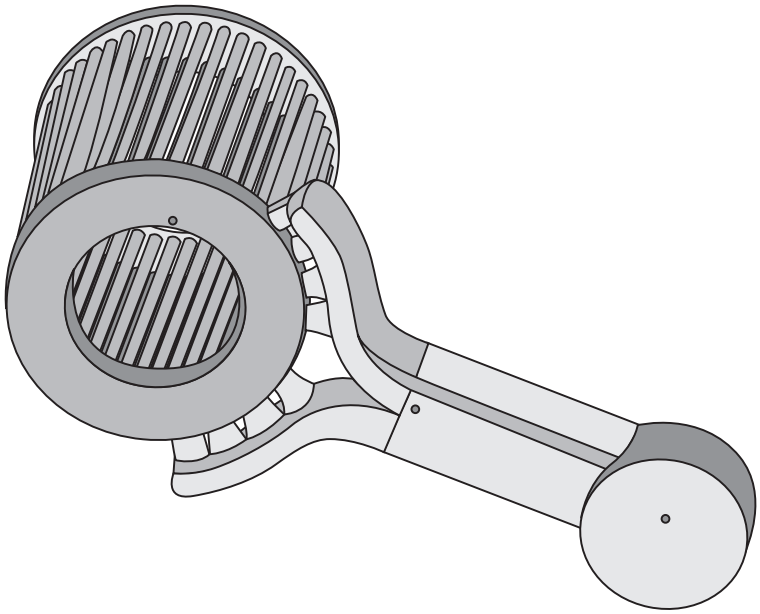
Die Casting Copper Motor Rotors

Die Casting Copper Technique Improves Energy Efficiency of Electric Motors

Though it conducts electricity less efficiently than copper, aluminum is the industry's preferred fabrication material in electric induction motor rotors. Traditional tool steel casting molds suffer thermal shock, shortening mold life and increasing operating costs when used for die casting copper rotors. ThermoTrex Corporation, with the assistance of a NICE[3] grant, proposed a process for copper die casting using molds from high-temperature, thermal shock-resistant materials. The copper industry successfully tested these mold materials for copper die casting at higher temperatures (copper melts at 1083°C, aluminum at 660°C).

The copper die-casting technology developed by the copper industry is now in commercial use. The process replaces the tool steel molds used for the aluminum die casting with molds made from high-temperature die materials. In addition, the new process preheats the die inserts, reduces the temperature differential between the mold surface and the cooler interior, and avoids mold failure from thermal shock and thermal fatigue.

In 2003, SEW Eurodrive of Bruchsal, Germany, was the first company, worldwide, to bring the technology to market. A line of high-efficiency gear motors (1.1-5.5 kW) use copper rotors at a competitive price. Although traditional high-efficiency motors are larger than standard motors, gear boxes using copper rotor technology provide efficiency without increasing motor size. In 2004, FAVI S.A., a major French supplier of copper and copper alloy die castings, began offering custom-designed, copper-based rotors for squirrel-cage electric motors in sizes ranging from fractional to 100 hp. Siemens Corporation began commercial production and sales domestically in 2006 in the 1 to 20 hp range.



Squirrel-Cage Motor with Die Cast Copper Rotors

Overview

- Invented by the ThermoTrex Corporation and commercialized by the Copper Development Association (www.copper-motor-rotor.org)
- Marketed by SEW Eurodrive, FAVI S.A, and Siemens Corp. with more than 110,000 in use in the U.S. in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.112	0.062

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.013	0.010	1.21

Applications

Can be used in electric motors throughout U.S. industry, which account for more than 60% of all electricity use in the nation.

Capabilities

- Reduces electric motor total energy loss by 15% to 20%.
- Decreases operating costs compared with conventional motors.

Benefits

Productivity

Reduces production time and hand labor compared with former methods of producing copper motor rotors.

Profitability

Decreases operating costs compared with conventional motors.

Improved Magnesium Molding Process (Thixomolding)

IMPACTS

Improved Die Casting Process Substantially Reduces Energy, Waste, and Operating Costs

Traditionally, die-cast molding results in product yields of 50% and creates waste – scrap, slag, and dross. The Thixomolding process, developed and demonstrated by Thixomat, Inc., with the help of a NICE[3] grant, improves product yields to 90% while eliminating waste and loss of product to melting. The process is worker and environmentally friendly and can be integrated into automated manufacturing processes to produce metal and metal/plastic assemblies.

In Thixomolding, room-temperature magnesium chips are fed through a volumetric feeder into the back end of a heated barrel that contains an argon atmosphere to prevent oxidation. Within the barrel, a rotating screw propels the material forward as the screw retracts. Resistance heaters on the outside of the barrel, arranged in 10 separately controlled zones, heat the material to the semi-solid region (approximately 560°C to 630°C). Once the magnesium is heated, the screw rotation provides the necessary shearing force to divide the dendrites from the root solid particles. This action creates a thixotropic slurry consisting of spherical solid particles in a continuous liquid matrix. The slurry is forced through a non-return valve and into the accumulation zone. When the proper amount of slurry is in front of the non-return valve, the screw proceeds forward at a speed of 1 to 5 m/s, forcing the metal into a preheated metal mold to produce a net or near-net shape part requiring few, if any, secondary operations. The process offers numerous cost advantages over other production methods, including higher yield, increased die life, lower utility costs, consistency of process, tighter dimensional tolerances, and improved manufacturing agility.

Benefits

Cost Savings
Reduces operating costs by 20%.

Environmental
Significantly reduces pollutant emissions and eliminates the use of sulfur hexafluoride. Eliminates slag and dross and their disposal problems.

Waste Reduction
Reduces scrap that must be recycled and subsequently reheated by 50%.

Overview

- Developed by Thixomat, Inc. (www.thixomat.com)
- More than 40 Thixomolding machines in use in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.074	0.069

U.S. Emissions Reductions

(Thousand Tons, 2007)

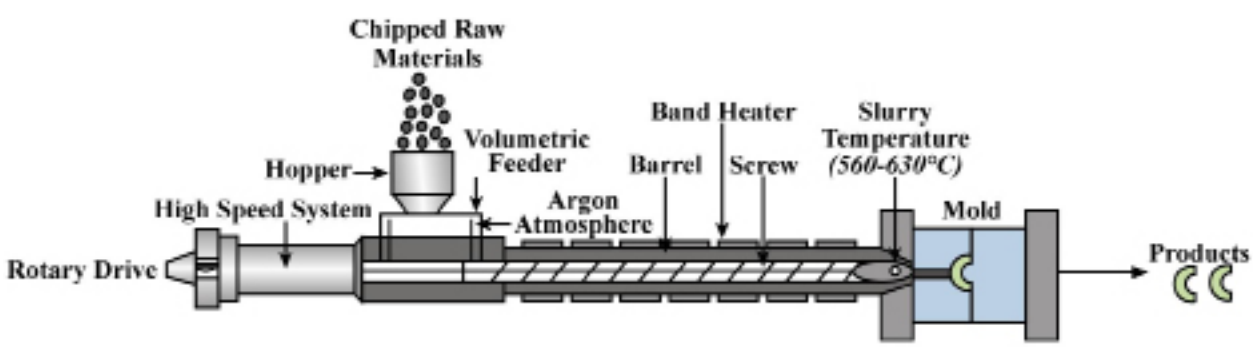
Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.008	1.095

Applications

Can be used in automotive, electronics, communications, and hand tool industries

Capabilities

- Produces thinner, lighter, and stronger parts than possible with engineered plastics.
- Provides excellent dimensional stability (0.001 mm/mm), low porosity, tighter part tolerances, minimum shrinkage (0.5%), low residual stress, and virtually no component distortion.



Thixomolding Process

Improvement of the Lost Foam Casting Process

Improved Process Reduces Energy Use, Waste and Emissions, While Lowering Product Defects and Costs

Casting is an energy-intensive manufacturing process within the metal casting and aluminum industries, requiring natural gas to melt aluminum and electricity to run equipment. The higher-than-acceptable faults and scrap rates in the lost foam casting process for the complex L61 engine previously resulted from the inability to control and measure refractory coating thickness and to control particle size and the shape of the unbonded sand. Remelting defective castings adds to overall energy costs, emissions, and use of resources.

The lost foam casting process starts with a foam pattern of the desired end-product made out of polystyrene beads. The foam pattern is coated with a thin refractory film and placed into dry, unbonded sand that is compacted by vibration. Molten metal, poured into the sand casting, evaporates and replaces the foam, producing a metal casting that is nearly identical to the foam pattern. The foam vapor passes through the pores in the refractory coating and the sand. This process enables the joining of several components within a single casting, thereby reducing downstream machining and assembly.

With the assistance of a NICE[3] grant and the New York State Energy Research and Development Authority, General Motors Corporation has developed tools to precisely measure dried coating thickness and pore size distribution, more accurately measure the size and shape of sand used in casting, and better understand the rheology of coatings. Rheology affects both coating thickness and uniformity on foam patterns. Coating thickness controls the permeability of gaseous expanded polystyrene by-products, which is directly related to casting defects such as porosity and folds. Therefore, measuring the rheological properties of the lost foam coating is critical to minimizing casting defects.

Benefits

Cost Savings

Reduces costs for polystyrene beads, glue, coating, sand, aluminum, cleaning media, and labor by $900,000 to $1.5 million annually.

Environmental

Reduces harmful incinerator emissions and sand waste by 2.2 to 3.5 tons annually.

Product Quality

Improves product quality 5% to 8% over conventional lost foam casting and significantly reduces scrap rates.

Overview

- Developed by General Motors Corporation (www.gm.com)
- Commercialized in 2004
- Employed at 3 General Motors casting facilities

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.96	0.489

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.001	0.045	0.066	8.56

Applications

Can be used in metal casting and aluminum industries

Capabilities

Significantly reduces aluminum and sand scrap rates during production of the complex General Motors L61 engine.

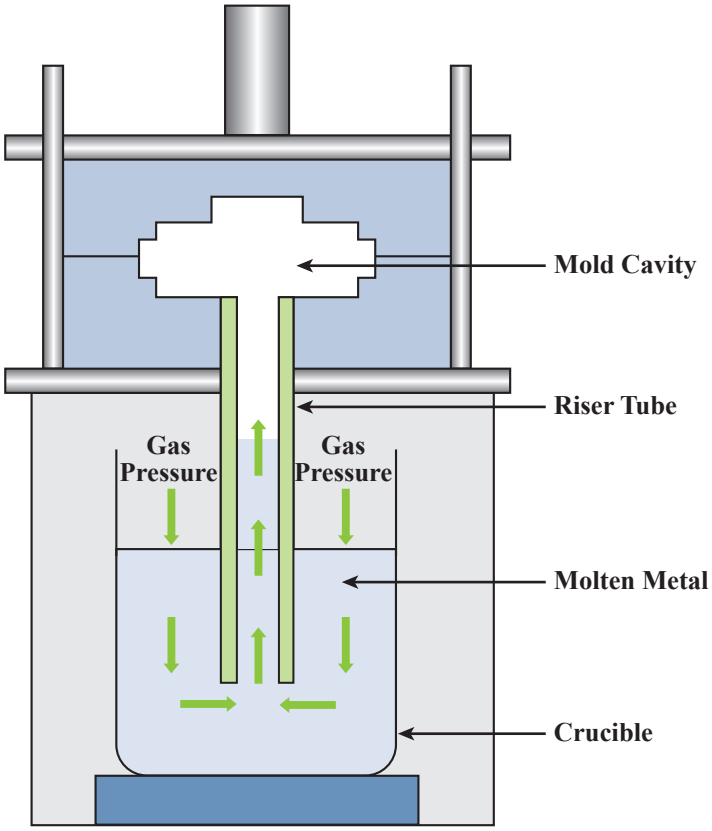
Low Permeability Components for Aluminum Melting and Casting

IMPACTS

New Low Permeability Coating Improves Durability and Life of Aluminum Casting Components

Materials for low-pressure casting operations typically have limited lifetimes. New, optimized coatings for ceramics and refractory components have been developed by Pyrotek, Inc., Oak Ridge National Laboratory, and the University of Missouri with support from ITP. The new materials exhibit low permeability to gases for applications involving low-pressure casting and contact with molten aluminum. The products treated with this new technology will have improved coatings, functionally graded materials, and monolithics that will hold gas pressure.

The new materials include enhanced combinations of properties, including resistance to thermal shock, erosion, corrosion, and wetting. As these materials are successfully deployed in aluminum smelting and casting operations, their superior performance and durability will achieve marked improvements in uptime, defect reduction, scrap/rework costs, and overall energy savings. Initial applications of this technology, labeled "XL" glaze, include riser tubes in low-pressure die casting of aluminum products. The reduced porosity of the new ceramic coating material improves the component's air tightness, which reduces tube failures. Testing shows that the improved tube coatings increase the life of the component 3-4 times the standard, depending on the application and coating material. Additional work is underway on a castable material system that will incorporate the benefits of the "XL" coating in the cast material itself. This product is expected to increase component life by up to 7 times the standard.



Aluminum Casting Riser Tube with Pyrotek's Low-Permeability Coating

Overview

- Developed by Pyrotek, Inc. (www.pyrotek-inc.com)
- Commercialized in 2005

Applications

Can be used in aluminum casting and chemical reaction processes where riser tube and other material flow components are subject to extreme temperatures or caustic chemical streams and replacement of process components is costly and time-consuming

Capabilities

- Extends tube component life 3-4 times.
- Increases component reliability.

Benefits

Energy Savings

Eliminates reheating energy by reducing waste.

Productivity

Reduces production downtime because components have longer lifetimes.

Product Quality

Increases the life of process components.

Rapid Heat Treatment of Cast Aluminum Parts

Automated In-Line Fluidized Bed Aluminum Heat Treatment System Improves Efficiency and Reduces Pollution

Arizotah Global Enterprises, LLC, in conjunction with the NICE[3] Program and the Minnesota Office of Environmental Assistance, has developed a system that reduces the time and energy required to heat treat cast aluminum components by up to 90%.

Unlike existing technologies where components are stacked in baskets and placed in a convection or vacuum furnace, this process uses a fluidized bed in a continuous process mode. Because each component is individually heated in the fluidized bed, the components reside in the bed only as long as necessary, thus reducing the process time.

The technology offers additional benefits by using microprocessor-controlled pulse-fired burners, which allow for precise temperature control that reduces rejection rates and increases product consistency. The fluidized bed also allows the casting sand that is traditionally disposed of to be captured and recycled in the fluidized bed and removed for use in new castings.

Benefits

Energy Savings

Substantially increases energy efficiency, reducing heat treating energy use by up to 90%.

Process Productivity

Reduces the number of personnel required for loading, unloading, and transfer and eliminates the disposal of sand contaminated with binders.

Product Quality

Reduces component rejection rates and improves product performance, while simultaneously reducing the amount of aluminum needed to achieve performance standards. Eliminates problems of media dispersion into the facility and volatility in the heat chamber.

Overview

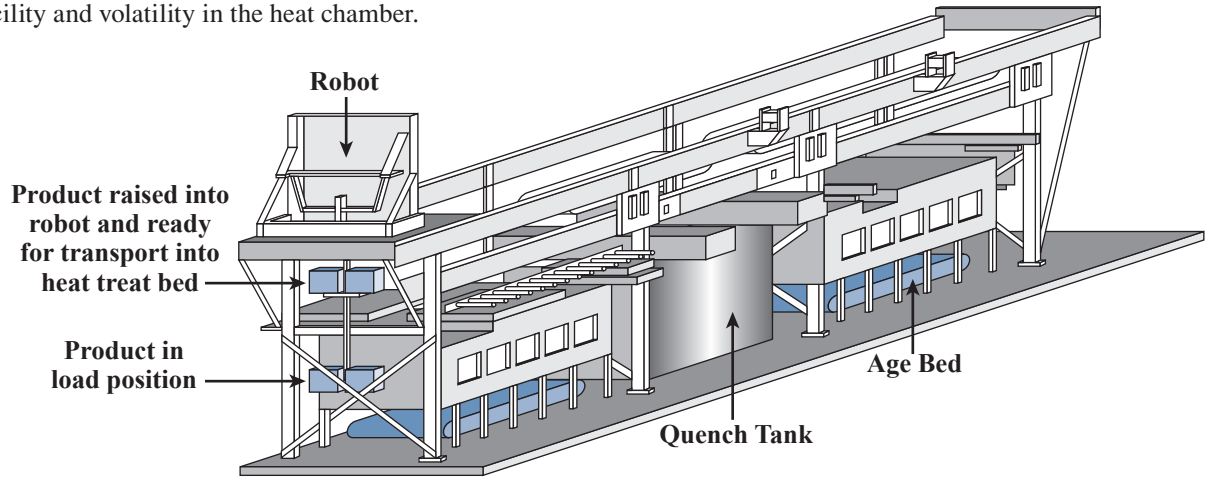
- Developed and commercialized by Arizotah Global Enterprises, LLC (www.rapidheattreat.com)
- Commercialized in 2006
- 9 units operating in the United States in 2007

Applications

Can be used in the wrought and cast aluminum heat treatment industry

Capabilities

- Allows for short-cycle heat treating of aluminum castings and forgings.
- Brings the heat treating process into the production flow with the forming operation.



Automated Fluidized Bed Heat Treatment System

Simple Visualization Tools for Part and Die Design

IMPACTS

New Software Program Helps Detect Potential Design Problems in Die Casting

With funding from ITP and the North American Die Casting Association (NADCA), a software program has been developed that offers a simple qualitative method to visualize potential design problems in die casting. CastView™ is a PC-based modeling program for die casting flow simulation. It is based on a qualitative analysis of part geometry that yields extremely fast analysis times. The program uses imported STL files so a solid model does not have to be constructed. The user can select gate sizes and locations, and the program provides a visualization of how the die cavity fills. A typical analysis can be made in a matter of minutes, making multiple iterations quick and manageable. A "thickness" feature allows the user to find the thickest and thinnest sections of the casting geometry quickly and visualize the first and last area to solidify.

Using a standard computer interface and intuitive viewing controls, CastView points casting and die designers to the potential problem areas they may want to focus on using a more detailed, mathematically-based simulation program. CastView is an excellent front-end complement to the commercially available, mathematically-based computer modeling programs.

Benefits

Energy and Environmental Savings

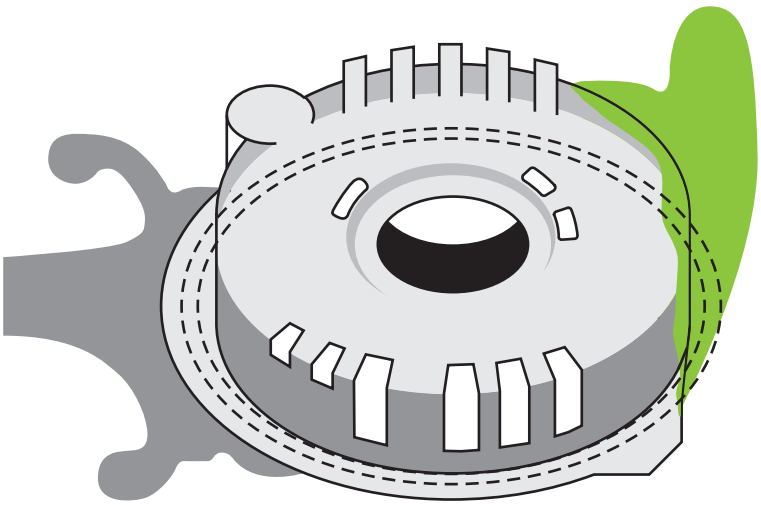
Can reduce process scrap by 20% or more, increasing yield and saving the energy formerly wasted producing defective parts.

Productivity

Can significantly reduce part development lead-time and tryout/setup time by promoting compatibility between die casting part and die design.

Profitability

Enables the die caster to negotiate a modification of the part geometry with the part designer to achieve a more castable part.



CastView Pattern

Overview

- Commercialized by the North American Die Casting Association (www.diecasting.org)
- Commercialized in 1999
- 161 units sold to date

Applications

Can be used in the die casting industry by both designers and die casters to visualize, identify, and resolve potential die casting design problems while still in the design stage

Capabilities

- Improves communications between die casters and designers.
- Allows quick evaluations of a large number of design alternatives.
- Locates and displays thick and thin sections in the die.
- Minimizes flow-related filling problems.
- Minimizes thermal problems in the casting die.
- Minimizes solidification-related defects in the cast part.
- Allows more and easier-to-use controls for the rotation of the part for all views.
- Provides functions to test for bad STL files, thus eliminating many problems associated with bad data.
- Includes print and save functions so that the analysis results can be recorded as bitmaps for use in other programs and documents.
- Includes an expanded animation function that includes slice mode animation, allowing operator to automatically produce a sequence of slices through the part.

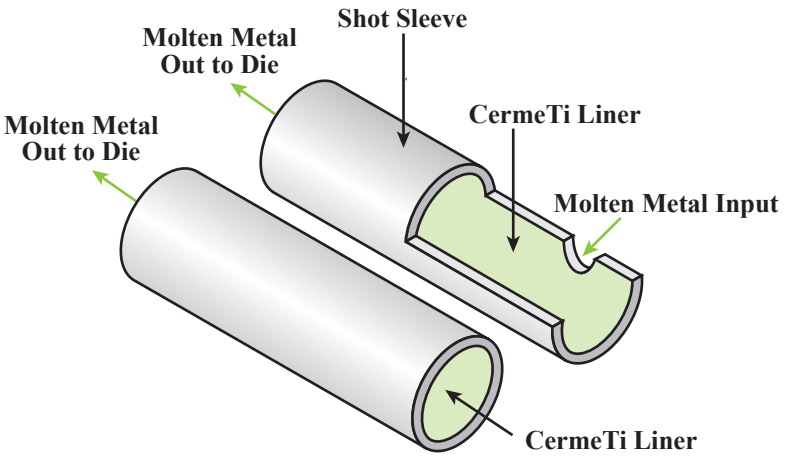
Titanium Matrix Composite Tooling Material for Aluminum Die Castings

Innovative Material Saves Energy and Extends Product Life In Aluminum Die-Casting Components

In aluminum die-casting, molten aluminum is forced under high pressure into a die cavity. First a "shot" of molten aluminum is ladled into a shot sleeve and the shot of molten aluminum is forced by a plunger through the shot sleeve into the die cavity. Shot sleeves are subject to severe conditions. For example, impingement of the shot can cause erosion at the surface across from the pour hole, and delivering and then expelling the shot can subject the shot sleeve to cyclical heating.

Currently, H-13 tool steel is used to fabricate shot sleeves and other aluminum die-casting components. However, the useful life of H-13 is limited because molten aluminum adheres (called "aluminum soldering") to the surface of the steel, eventually causing the sleeve to fail. Also, H-13 has poor resistance to heat checking, thermal fatigue, erosion, and distortion. The poor performance of H-13 results in frequent shot sleeve replacements.

With the help of a NICE[3] grant, Dynamet Technology, Inc., developed CermeTi®, a titanium-alloy metal matrix composite material that is used as a liner inserted into an H-13 shot sleeve. This new technology has significant advantages over the conventional technology, especially in its resistance to aluminum soldering and erosion. In addition, the reduced thermal conductivity of the CermeTi liner reduces heat loss during the injection phase of the casting process. Slower cooling permits the use of lower pouring temperatures (less preheat energy) or slower plunger-tip speeds (less turbulence or surface impingement problems within the die). As a result, the useful life of the shot sleeve is dramatically improved, reducing downtime, improving product quality, and saving energy.



Aluminum Die-Casting Shot Sleeves with CermeTi® Liners

Overview

- Developed by Dynamet Technology, Inc. (www.dynamettechnology.com)
- Commercialized in 2005 and being used by 31 die-cast machines in the U.S.

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.034	0.015

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.002	0.241

Applications

Can be used in metal casting applications currently using H-13 shot sleeves, including squeeze casting, conventional die-casting, and semi-solid processing

Capabilities

- Enhances thermal shock resistance through excellent resistance to aluminum soldering and lower thermal conductivity than H-13 steel.
- Reduces the tendency of premature metal solidification that impedes the flow of molten metal needed to feed the casting properly.

Benefits

Cost Savings

Reduces total process costs by 3%.

Productivity

Extends sleeve life by 4 to 10 times over H-13 steel, reduces downtime as a result of fewer shot sleeve changeovers, and enables longer plunger tip life.

Mining

IMPACTS

- Belt Vision Inspection System 68
- Fibrous Monoliths as Wear-Resistant Components 69
- Horizon Sensor™ 70
- Imaging Ahead of Mining 71
- Lower-pH Copper Flotation Reagent System 72
- Wireless Telemetry for Mine Monitoring and Emergency Communications 73

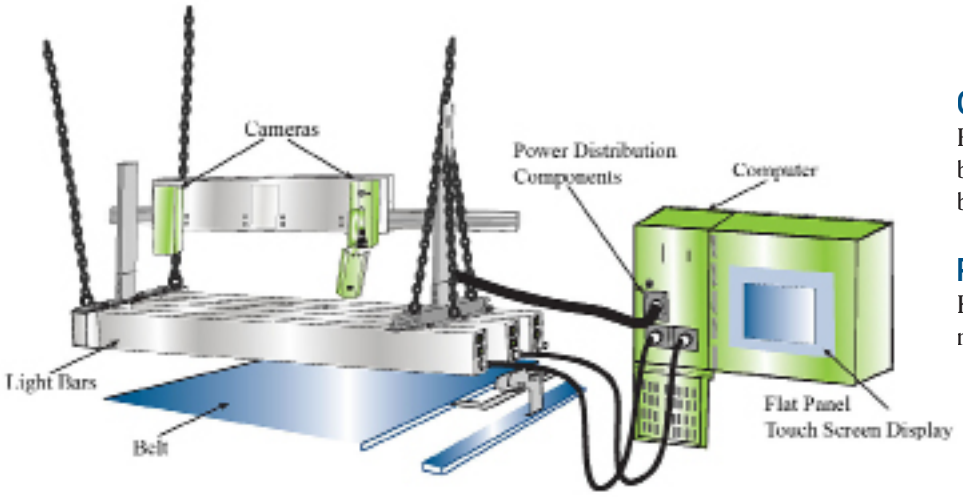
Belt Vision Inspection System

Low-Cost System Identifies Defects in Mining Conveyor Belts, Reducing Unscheduled Maintenance and Downtime

Mining operations rely on conveyor belts to move mined material from the working face of the mine to a processing plant. When a conveyor belt breaks or stops for unscheduled maintenance, production generally halts because the belt is the only way to carry material away from the mining unit and stockpiling is typically not available at the point of extraction. Longwall mining operations can produce revenue at $1000/minute; a mainline belt break will stop production for a minimum of four hours, resulting in $240,000 of lost revenue.

The Belt Vision system, developed by the Beitzel Corporation and Carnegie Mellon University's National Robotics Engineering Consortium, with support from ITP, uses high-speed line scanning cameras and a computer system to monitor mechanical splice deterioration in moving conveyer belts. The computer system, located on the belt or a remote desktop, digitizes and records continuous imaging of the belt and splices. Mine personnel can review live or historical images several times a day with minimal effort and take action before belt splices fail. The Belt Vision system helps eliminate costly repairs to conveyor belts, keeps production running, and helps reduce costs.

The Belt Vision system's hardware consists of cameras for imaging the belt, lighting for illuminating the belt, a computer for digitizing and analyzing the camera image, a flat panel touch screen display for a local user interface, and components for power distribution. Mines using the system can measure cost savings from avoided downtime, plan maintenance effectively, review the real time splice status of beltlines more easily, and plan action items for a splice. More than 10 systems were in use in U.S. coal mines in 2007.



Components of Beitzel's Belt Vision System

Overview

- Developed by the Beitzel Corporation (www.beitzelcorp.com)
- Marketed by Pillar Innovations, LLC (www.pillarinnovations.com)
- Commercialized in 2007

Applications

Can be used to provide images of the belt splices to mine personnel, who evaluate these images and take action before the belt splice fails

Capabilities

- Allows mine personnel to monitor deterioration in operating conveyor belts in underground and surface mines.
- Reduces deterioration in mining conveyance systems.
- Provides a user interface for belt inspection at installation points using software that controls the cameras, collects encoder data, and captures images.
- Stores images in a database and distributes them to a web server that can be accessed on a remote computer.

Benefits

Cost Savings

Helps eliminate costly repairs to conveyor belts by finding potential problem points before the belt fails.

Productivity

Keeps production running and allows better maintenance planning.

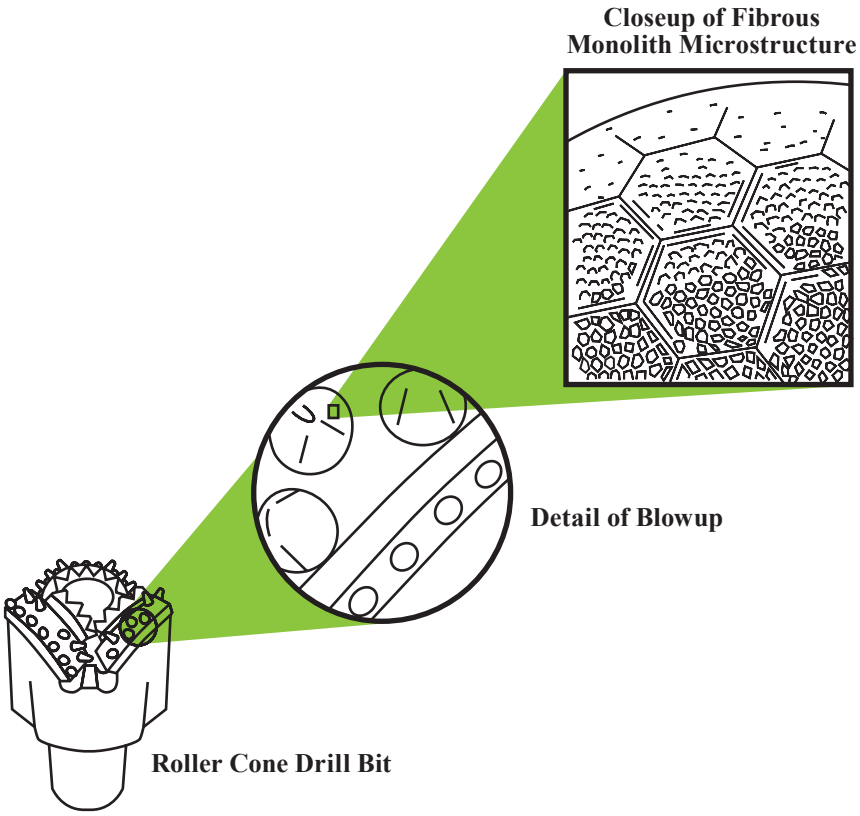
Fibrous Monoliths as Wear-Resistant Components

IMPACTS

New Composite Material Improves the Cost/Performance Ratio of Drill Bits

Advanced Ceramics Research (ACR) led a collaborative effort of component manufacturers, end users, a national laboratory, and universities to develop fibrous monoliths (FMs) for mining applications. ACR licensed the technology to Smith Bits of Houston, Texas, one of the world's largest oil and drill bit manufacturers. Smith Bits demonstrated nearly a 3 to 1 oil drilling performance increase using FM technology compared with state-of-the-art diamond-coated drill bits. ACR also started a joint commercialization program with Kyocera Corporation to apply FM technology to industrial cutting tools.

Smith Bits uses the FM composites in Cellular Diamond™ inserts for drilling and high-impact applications. FMs are produced using a simple process in which sets of inexpensive, thermodynamically compatible ceramic and/or metal powders are blended with thermoplastic polymer binders and then co-extruded to form a green fiber. The green composite fiber is extruded and thermoformed into the shape of the desired component, pyrolyzed to remove the polymer binder, and consolidated at ultra-high pressure and temperature to obtain the final FM product. The new FM manufacturing process produces ultra-hard inserts for roller cone bits.



Roller Cone Drill Bit with Fibrous Monolith Inserts

Overview

- Collaboratively developed by a national laboratory, universities, and private companies led by Advanced Ceramics Research, Inc.
- Currently licensed to Smith Bits, a subsidiary of Smith International, Inc., for use on drill bits (www.smithbits.com)

Applications

Can be used for wear-resistant components for drilling

Capabilities

Offers very high fracture energies, damage tolerance, and graceful failure.

Benefits

Energy Savings

Reduces energy consumption by more efficient use of the drill machinery and less downtime.

Productivity

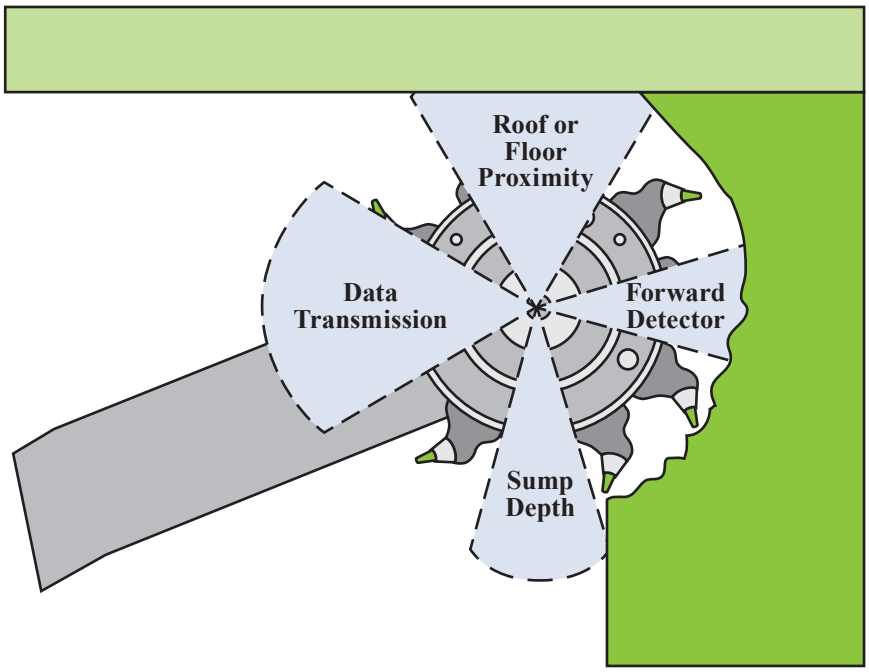
Increases the cost/performance ratio of wear materials and components and increases employee output.

Horizon Sensor™

Remote Sensing Cuts Coal and Other Minerals More Efficiently

Future mining will be from deeper and thinner seams; profiles of deep coal seams reveal multiple levels of coal and sediment strata or layers. Some of these layers contain greater levels of pollutants than others, which results in more effort to clean the coal once it is removed from the ground and more emissions when it is burned for fuel.

With the aid of ITP, Stolar Horizon, Inc., developed the Horizon Sensor to distinguish between the different layers of coal. Miners can use this technology at remote locations to cut only the clean coal, resulting in a much more efficient overall process. The sensor, located inches from the cutting bits, is based on the physics principle of resonant microstrip patch antenna (RMPA). When it is in proximity of the rock-coal interface, the RMPA impedance varies depending on the thickness of uncut coal. The impedance is measured by the computer-controlled electronics and then is sent by radio waves to the mining machine. The worker at the machine can read the data via a graphical user interface, which displays a color-coded image of the coal being cut, and can direct the machine appropriately.



Functions Performed by the Horizon Sensor Mounted on the Cutting Edge of a Continuous Mining Machine

Overview

- Developed by Stolar Horizon, Inc. (www.stolarhorizon.com)
- Commercialized in 2002
- Used in 10 different U.S. mines

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.230	0.020

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.004	0.003	0.403

Applications

Can be used in both underground and surface mining operations. Primarily used in the coal industry but is also used to mine trona and potash.

Capabilities

- Improves the quality of coal extracted from mines.
- Allows for deeper mining.
- Is used remotely for miner safety.

Benefits

Productivity

Increases productivity by reducing or eliminating the cleaning step after extraction. Allows for deeper mining, resulting in more material obtained from one location and results in longer bit life keeping the cutting bits out of rock.

Safety

Allows workers to operate the machinery away from the hazards of cutting coal, including noise, dust and gases, and coal and rock splintering and outbursts.

IMPACTS

Radio-Imaging Method (RIM™) Improves Mine Planning and Products

Coal mining is becoming more difficult as machines must extract the coal from deeper, thinner, and more geologically complex coal beds. This type of mining also includes the need to reduce risk and costs.

To address these mining issues, Stolar Horizon, with support from ITP, redesigned and improved a technology developed twenty years ago. The Radio-Imaging Method (RIM) uses wireless synchronization between a transmitter and remote imaging receiver to detect geologic formations up to 1,800 feet ahead.

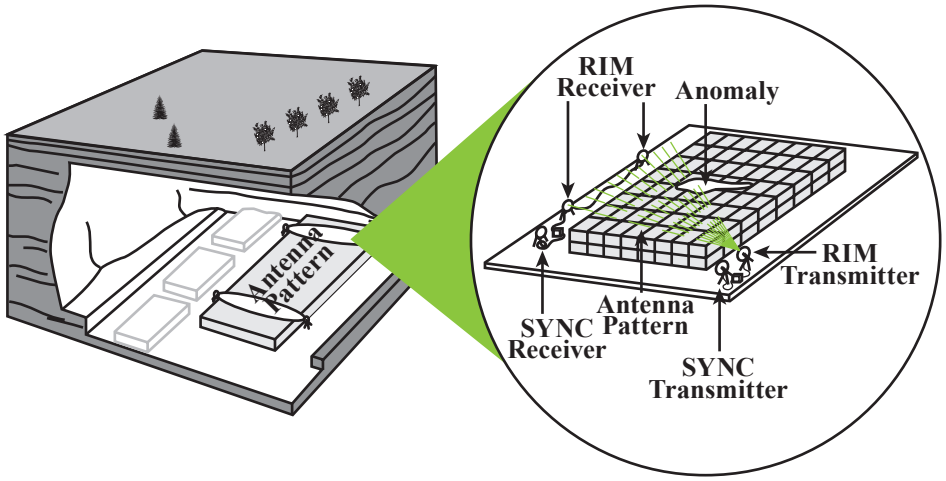
In layered sedimentary geology, a natural coal seam waveguide occurs because of the 10:1 contrast in conductivities between coal and surrounding materials. The electromagnetic wave sent by RIM through the rock reacts to these properties with a detectable change in magnitude because it is very sensitive to changes in the waveguide geology.

The information from RIM can be used to produce an image that maps out the dikes, faults, and paleochannels for more targeted mining. Areas of high signal loss represent geologic anomalies and can be imaged to high resolution using tomographic reconstructions similar to CAT scans.

Benefits

Productivity and Profitability

Reduces the risk of interrupting production because of adverse geologic conditions. When RIM is integrated into the planning of underground mining, forecasting production can improve 10 percent, which in turn increases profits.



In-Mine RIM Detection System

Overview

- Developed by Stolar Horizon, Inc. (www.stolarhorizon.com)
- Commercialized in 2002
- Used in 18 different mines in the United States through 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2006	2007
5.38	1.05

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.005	0.227	0.170	20.7

Applications

Can be used in both underground and surface mining operations. Primarily used in the coal industry but has also been used for metalliferous mining, environmental research, and civil engineering applications. Also has been used to confirm the location of old and abandoned mine works and the integrity of barrier pillars.

Capabilities

- Detects ore seams and geologic anomalies.
- Delineates ore bodies, monitors heap leaches, and detects voids in coal seams.
- Detects voids and confirms geologic anomalies.

Lower-pH Copper Flotation Reagent System

New Reagent System Improves Recovery, Reducing Energy Use and Air Emissions in the Mining Industry

In the mining industry, flotation is a process that concentrates minerals from their ores prior to metal recovery. Current practice uses slurry pHs in excess of 10, achieved by adding burnt lime (CaO). However, lime production is an energy-intensive process that releases large quantities of carbon dioxide into the atmosphere. Furthermore, lime has several undesirable properties once it is in the flotation circuit. Lime produces scaling in piping and equipment, requiring the use of descaling reagents. It flocculates fine material and may occlude fine copper-sulfide particles. Lime increases the viscosity of the mineral slurry and tends to hinder aeration, slowing flotation kinetics. In addition, the calcium ion also has been shown to decrease recoveries of lead and molybdenum-sulfides and to reduce the recovery of free gold.

A new reagent system, developed by Versitech, Inc., with assistance from DOE's Inventions and Innovation Program, recovers copper minerals at a much lower pH than conventional reagents and avoids floating pyrite. The process reduces or even eliminates both the lime used in copper flotation and the accompanying carbon dioxide. The result is immediate cost, energy, and environmental savings along with improved recovery of copper and other minerals.

Benefits

Cost Savings

Reduces annual operating costs in a 50,000 ton per day plant by $1.3 million.

Productivity

Improves mineral recovery in the mill flotation processes and decreases the amount of waste rock.

Overview

- Developed by Versitech, Inc.
- Commercialized in 2005

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
2.92	0.973

U.S. Emissions Reductions

(Thousand Tons, 2007)

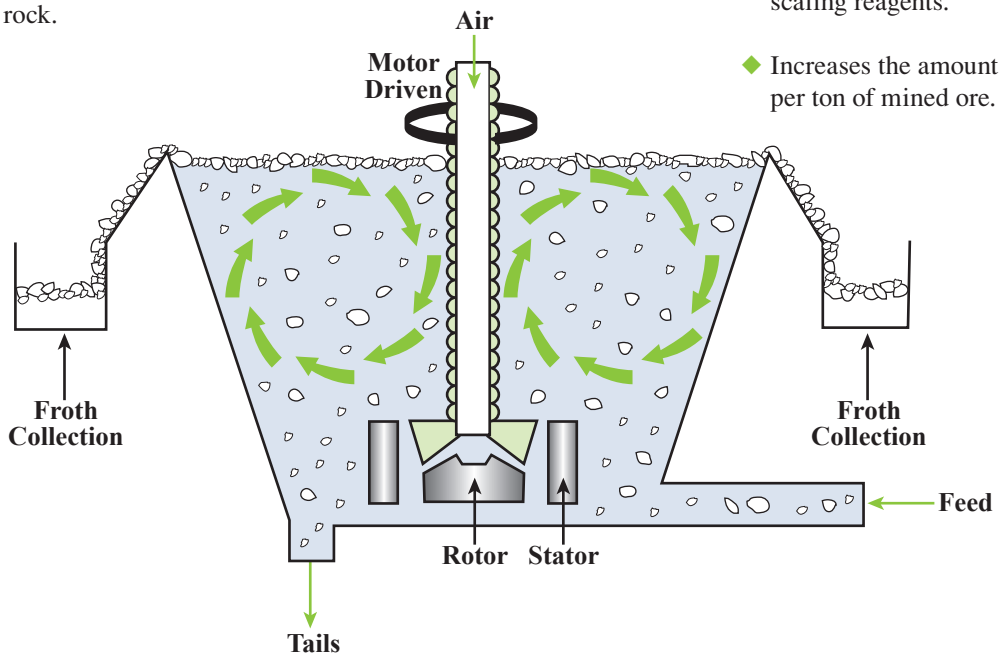
Particulates	SO_x	NO_x	Carbon
0.004	0.210	0.157	19.1

Applications

Can be used in mining processes using a lime additive in the separation process

Capabilities

- Reduces or eliminates lime and de-scaling reagents.
- Increases the amount of copper recovered per ton of mined ore.



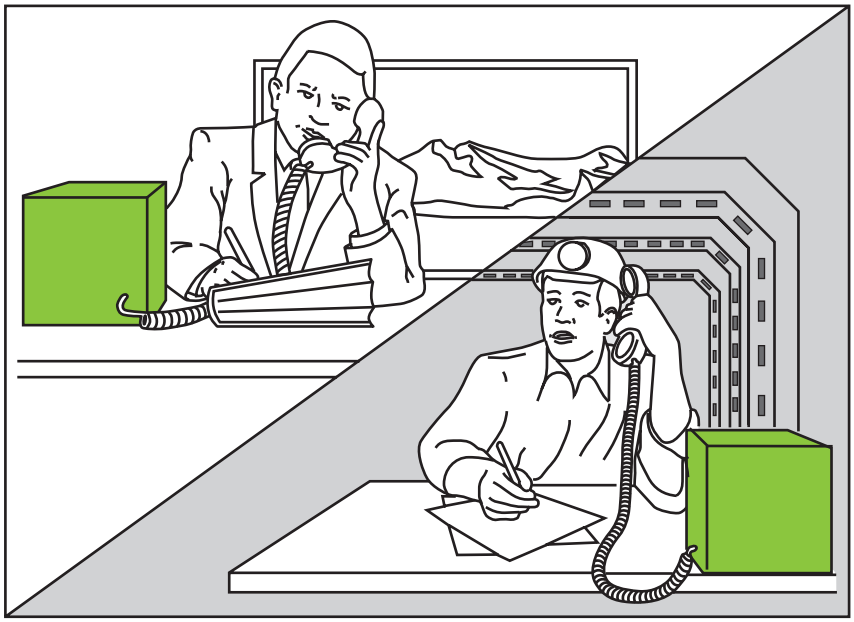
Copper Flotation Reagent System

Wireless Telemetry for Mine Monitoring and Emergency Communications

Replacing Communication Cables Improves Safety, Efficiency, and Cost of Mining

The hard-wired systems currently used in mining to transmit production data, environmental monitoring data, and voice signals to the surface are not reliable in emergency situations because of shifting debris or other hazards. To solve these critical problems, a wireless, through-the-earth telemetry prototype system, TeleMag, was developed with the assistance of DOE's Inventions and Innovation Program. The TeleMag system eliminates the need for wire connections between the surface and mining sites underground.

Additional funding was provided by a grant from ITP to develop a multiple repeater system, ComCell, which provides coverage for handheld wireless radios throughout an underground mine, tunnel, large building, parking garage, or other structure where radio communication is difficult to maintain. The system is easily wired. Multi-mode interface provides optional connections to computer networks, telephones systems, the Internet, security systems, etc. The master control module provides central control and automatically directs all functions of the system. ComCell can be wired to the surface or interfaced with the TeleMag system. Feedback from installations indicates that the technology is a significant source of cost and maintenance savings.



Wireless Telemetry Communication System

Overview

- Invented by Transtek, Inc. (www.transtekcorp.com)
- Commercialized in 1998
- As of December 2007 four customers are using 30 units in non-coal U.S. mines

Applications

- ComCell is applicable to steel-reinforced buildings, tunnels, transit systems and limestone mines
- TeleMag is a prototype system still in development

Capabilities

- ComCell increases communication capabilities among personnel underground, providing greater flexibility and mobility.
- ComCell is not limited by line-of-sight transmission patterns.
- ComCell relays signals throughout the covered area, penetrating around corners. The UHF frequency band offers excellent signal strength

Benefits

Cost Savings

Reduces costs by up to 25% by eliminating the need to purchase, install, and maintain communication cables. Reduces unplanned downtime, thereby also saving costs.

Worker Safety and Health

Increases the safety and acceptability of coal mining as an energy source, thereby augmenting the energy supply. Improves safety by the system's ability to provide uninterrupted communications.

Steel

IMPACTS

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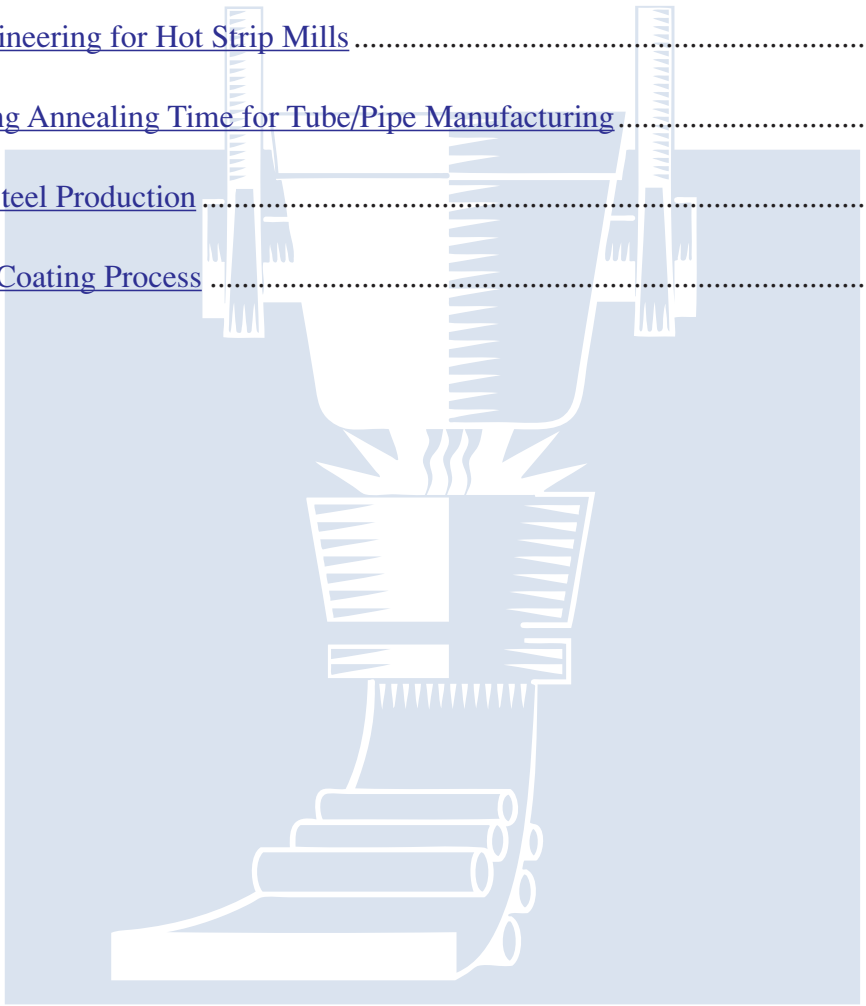


Aluminum Bronze Alloys to Improve Furnace Component Life

Improved System Increases Steelmaking Furnace Efficiency, Safety, and Productivity

Hoods, roofs, and sidewall systems in basic oxygen furnaces (BOFs) and electric arc furnaces (EAFs) enable effluent gasses in excess of 3000°F to be properly captured, cooled, and processed prior to delivery to the environmental control equipment. Traditionally, these carbon steel components have been considered standard "repair and replace" items by the industry. During the steelmaking process, large amounts of waste heat, particulates, and waste gases are generated in the furnace. The interaction of these waste streams with the carbon steel components of the furnace can result in metal failure from erosion, corrosion, and thermal stress cracking.

With ITP support, the Energy Industries of Ohio, Oak Ridge National Laboratory, Republic Engineered Products, and Amerifab, Inc., developed and installed several components of a BOF with aluminum bronze alloy material. Replacing carbon steel components with those manufactured from aluminum bronze alloy reduces metal failure, increases productivity, improves operating safety, and reduces energy consumption in the steel making process. Additionally, slag from the steel making process does not adhere to the aluminum bronze alloy, which eliminates all cleaning time, equipment damage, and operational difficulties associated with the accumulation of slag on the skirt.

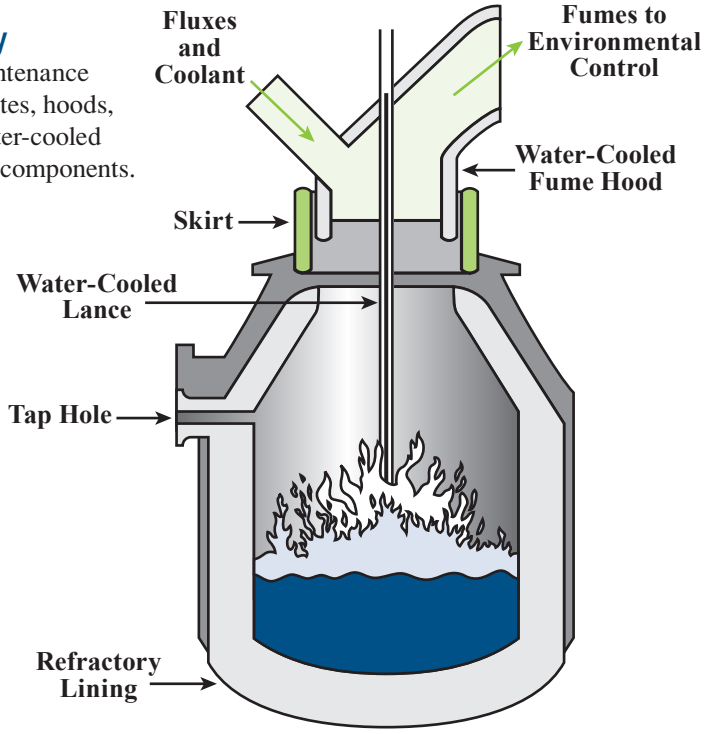
Benefits

Environmental

Reduces chance of air permit violations associated with improper skirt positioning in suppressed combustion furnaces, thereby optimizing primary capture of vessel emissions.

Productivity

Reduces maintenance on skirts, chutes, hoods, and other water-cooled steel furnace components.



Basic Oxygen Furnace Components

Overview

- Developed by AmeriFab, Inc., in 2002 (www.amerifabinc.com)
- Commercialized in 2004
- Components being used on two furnaces in Ohio and Illinois

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.066	0.033

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.004	0.528

Applications

Can be used for BOF/EAF hood, roof, and side wall systems that are exposed to aggressive heat, particulate, and corrosive waste gas from the steelmaking process.

Capabilities

- Provides superior performance compared with industry standard carbon, chrome-moly, and weld overlayed steels.
- Improves production throughput and limits energy consumption by reducing forced outages and downtime due to thermal fatigue, particulate erosion, and chemical corrosion.
- Reduces issues related to slag buildup.

Automated Steel Cleanliness Analysis Tool (ASCAT)

IMPACTS

New Microscopy System Improves Steel Mill Performance and Allows Production of Higher Quality Steel

Inclusions are particles of insoluble impurities formed during steelmaking and casting operations that are entrapped during solidification of metal. Characterizing inclusions is important because of an increasing demand for cleaner steels with low inclusion (defect) content. The composition, and therefore the properties, of the inclusions can be controlled through the chemistries of the metal and slag. Controlling the properties of the inclusions allows higher quality steel to be made. However, despite the major advances in inclusion control, no rapid and accurate method is available to determine the type, size, and number of inclusions present in steel samples.

RJ Lee Group, Inc., with ITP and steel industry support, has developed the ASCAT, an inclusion analysis tool based on a highly capable scanning electron microscope combined with specially developed hardware and software. The ASCAT provides a way to understand the complicated effects of inclusions in the steel making process and on the resulting properties of steel. The instrument uses an innovative state-of-the art silicon drift detector to acquire x-ray composition information that is about an order of magnitude faster than previously used equipment. The ultimate goal is to develop the system so that analysis time is reduced to 10-15 minutes, which would enable the ASCAT to be used as an "on-line" analysis tool. The ASCAT uses "intelligent" software to emulate specialized knowledge that can be used to evaluate causes of clogging/erosion, slag treatment practices, castability, degasser circulation optimization, and slab disposition. One ASCAT system is now in use at the U.S. Steel Munhall Research and Technology Center.

Benefits

Energy Savings
Improves energy efficiency by minimizing steel rejection and subsequent remelting of the rejected steel.

Productivity
Increases production and reduces downgrades, with significant cost savings.

Product Quality
Allows for the increased production of high-grade steels and alloys.

Overview

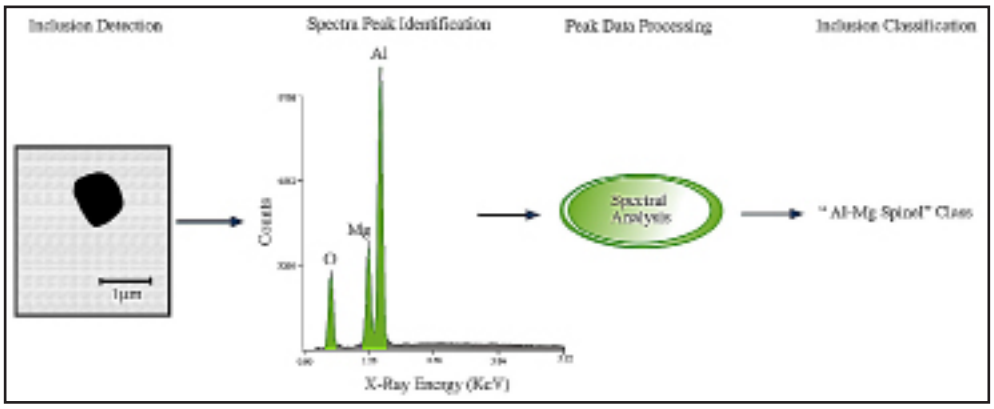
- Developed and being marketed by the RJ Lee Group, Inc. (www.rjlg.com)
- Commercialized in 2007
- Employed at the U. S. Steel Munhall Research and Technology Center

Applications

Can be used in the steel manufacturing process, including in castability of calcium treated steel; interstitial free degasser grade slag conditioning practice; tundish clogging and erosion minimization; degasser circulation and optimization; quality assessment/steel cleanliness; slab, billet, or bloom disposition; and alloy development.

Capabilities

- Collects statistically meaningful data on inclusions in a steel sample and addresses a market need to monitor the effects of inclusions in the steel making process.
- Uses fast inclusion identification software with advanced statistical algorithms to automatically sort inclusions into meaningful classifications.
- Provides intuitive graphics-based output, which can be integrated to plant control rooms and computer databases.



Classification of Steel Inclusions Using ASCAT

Dilute Oxygen Combustion System

Dilute Oxygen Combustion Improves Reheat Furnace Performance and Provides Very Low NO_x Emissions

The Dilute Oxygen Combustion (DOC) system provides competitive rolling mill operators with higher productivity reheat furnaces without high capital and operating costs or increased NO_x emissions. By replacing combustion air with oxygen, the DOC system needs less fuel to heat steel and also gives lower flue gas temperatures. These features allow a reheat furnace to operate economically at higher production rates. The DOC system injects the fuel gas and oxygen into the furnace as distinct, separate high-velocity jets rather than through a single burner. The jets mix with the hot furnace gases before reacting with each other. This dilution effect prevents the high peak flame temperatures that are responsible for NO_x generation, providing low NO_x levels even with high nitrogen levels for the furnace. Because the flue gas is recirculated aerodynamically within the furnace, the DOC system is simpler and less expensive to install then conventional flue gas recirculation systems. In addition, the wide, diffuse flame from the DOC system provides exceptionally uniform heating of the steel, leading to better rolling mill performance and lower reject rates.

Benefits

Energy Savings

Results in fuel savings of up to 50% over air-fuel combustion for reheat furnaces.

Productivity and Profitability

Increases productivity 10% to 30% over air-fuel combustion with the simple, low-maintenance combustion system. Improves heating uniformity, giving better quality and fewer rejects in rolled products.

Overview

- Commercialized by Praxair, Inc. (www.praxair.com)
- 14 burners operating at two locations in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
21.6	7.17

U.S. Emissions Reductions

(Thousand Tons, 2007)

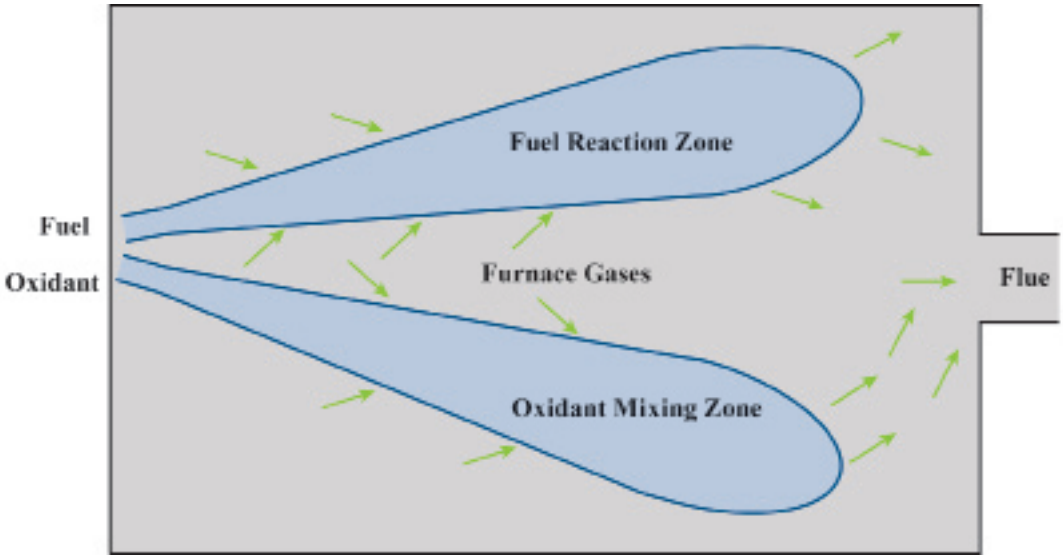
Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.839	114

Applications

Can be used in the steel and glass industries and on most furnace systems

Capabilities

- Increase furnace capacity up to 30%.
- Can be used on continuous or batch reheat furnaces.



Dilute Oxygen Combustion

IMPACTS

Dezincing of Steel Scrap Reduces Concerns of Recyclability and Waste Streams

Half of the steel produced in the United States is derived from scrap. With zinc-coated prompt scrap increasing fivefold since 1980, steelmakers are feeling the effect of increased contaminant loads on their operations. The greatest concerns are the cost of treatment before disposal of waste dusts and the water associated with remelting zinc-coated scrap.

With financial assistance from ITP, Argonne National Laboratory with Metal Recovery Technologies, Inc., and Meretec Corporation have developed a technology that separates steel scrap into dezinced steel scrap and metallic zinc. The removal of zinc from steel scrap increases the recyclability of the underlying steel, decreases steelmaking dust, and decreases zinc in wastewater streams.

The process consists of two stages: dissolving the zinc coating from scrap in a hot, caustic solution and recovering the zinc from the solution electrolytically. Through a galvanic process, the zinc is removed from the steel and is in solution as sodium zincate ions rather than zinc dust. The steel is then rinsed with water and ready for reuse. Impurities are removed from the zinc solution, and then a voltage is applied in order to grow metallic zinc via an oxidation-reduction reaction. All waste streams in this process are reused.

Benefits

Pollution Reduction

Decreases steelmaking dust released to the air as well as pollutants in wastewater streams. The process itself does not consume any chemicals, other than drag-out losses, and produces only a small amount of waste.

Productivity

Removing zinc prior to processing of scrap saves time and money in disposal of waste dusts and water. Without the zinc, this high-quality scrap does not require extra handling, blending, or sorting for remelting in steelmaking furnaces.

Overview

- Developed by Argonne National Laboratory
- Commercialized in 2003 by Meretec Corp. (www.cmacorp.net)
- Steel scrap sold to several dealers, steemakers, and foundries after dezincing

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.268	0.073

U.S. Emissions Reductions

(Thousand Tons, 2007)

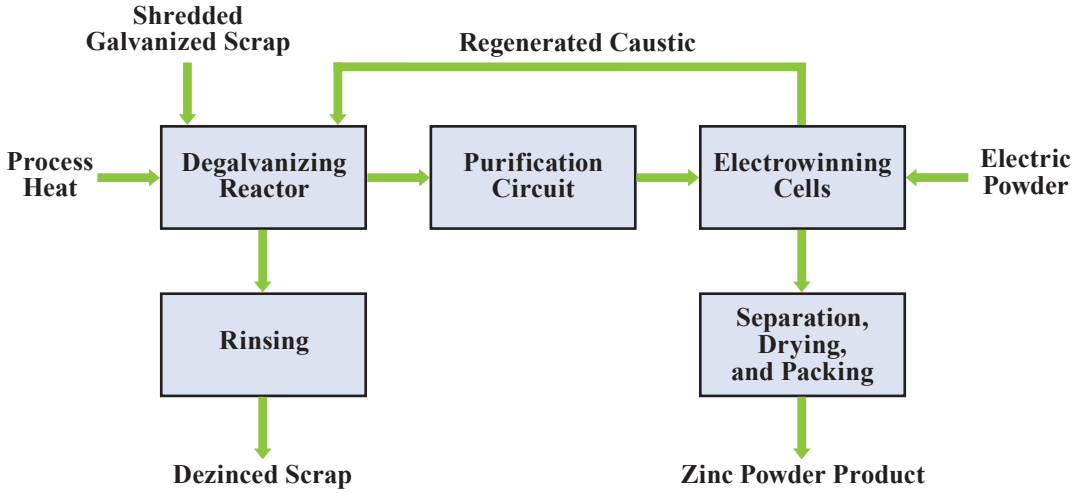
Particulates	SO_x	NO_x	Carbon
0.001	0.046	0.020	2.05

Applications

Can be used primarily in the steel and foundry industries.

Capabilities

- Improves quality of steel scrap that steelmakers can use.
- Produces 99.8% pure zinc for resale.



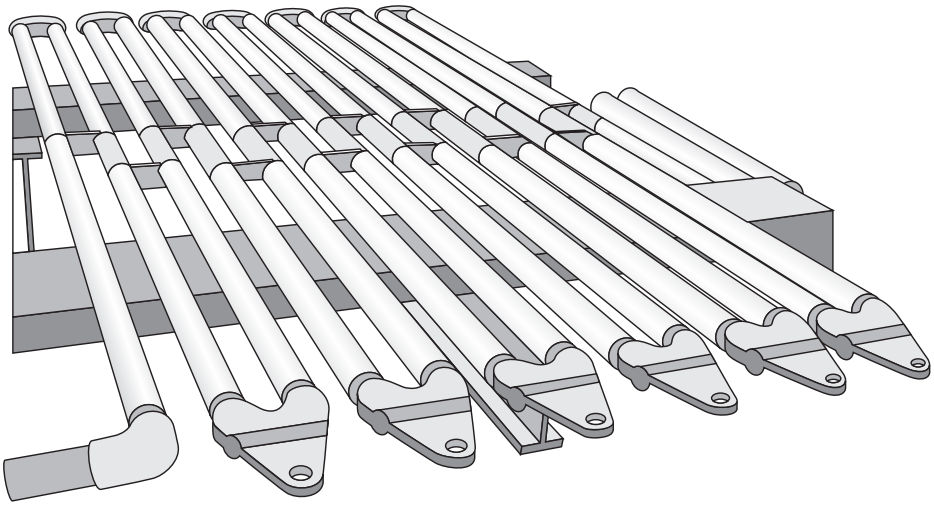
Electrochemical Dezincing of Galvanized Steel Scrap

H-Series Cast Austenitic Stainless Steels

Scientific Design Methodology Used to Develop Stronger Stainless Steels for High-Temperature Applications

Cast H-Series austenitic steels are used extensively in several industries for a broad range of high-temperature applications. The H-Series stainless steels have evolved over many years of complex alloy development that added various alloying elements by trial-and-error methods. The native microstructure established in these austenitic alloys consists of dendritic structures of austenite matrix with finer dispersions of carbides. With the support of a grant from ITP, a combination of thermodynamic modeling, developed at the Oak Ridge National Laboratory, micro-structural characterization, and mechanical property measurements was used to derive composition-structure-property relationships for this class of alloys. With these relationships, Duraloy Technologies, Inc., successfully developed new alloy compositions with improved properties at higher temperatures.

The combined approach of micro-characterization of phases and computational phase prediction permits rapid improvement of a current class of alloy compositions and allows alloys to be customized across steel grades for specific applications. The results of this work increased the high-temperature creep strength and the upper-use temperature range of H-Series stainless steel material, including HP and HK alloys. Application of these new products is best suited to radiant burner tubes for annealing furnaces in the steel heat treating industry, tubes for the chemical industry, and transfer rolls and kilns for various high-temperature furnace operations. Other applications in other industries would apply where high-temperature operations are required.



Chemical Processing Coils Composed of H-Series Stainless Steel

Overview

- Developed by Duraloy Technologies, Inc. (www.duraloy.com)
- Commercialized in 2003
- As of 2007, 179 U.S. applications were operating in 10 processing plants

Applications

Can be used in the chemicals, forest products, heat treating, petrochemical, and steel industries, including burner tubes for heat-treating furnaces, transfer rolls for heat-treating furnaces, coiler drums and rolls for Steckel mills, and tubes for ethylene cracking and other processes

Capabilities

- Offers superior toughness over standard H-series steel.
- Applies to multiple heating processes.

Benefits

Energy Savings

Could save an estimated 35 trillion Btu/year and $185M/year by 2020.

Productivity

Improved process efficiencies from higher operating temperatures reduces downtime of the production equipment, reduces replacement of components, and increases productivity with reduced rejection.

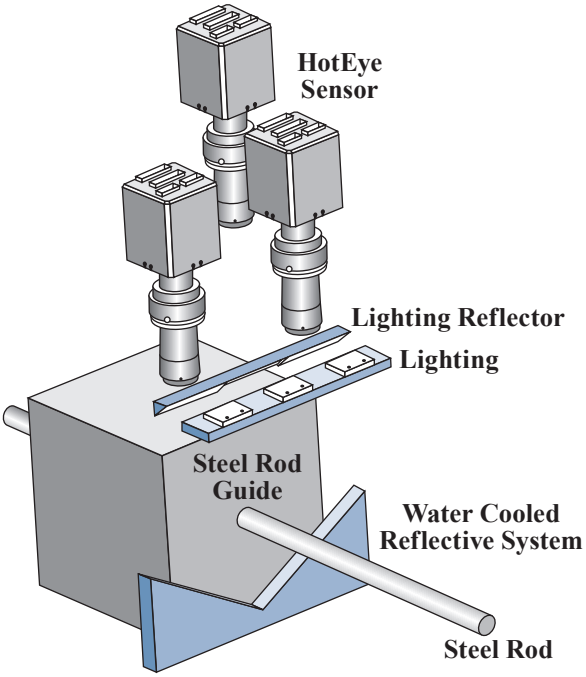
HotEye® Steel Surface Inspection System

IMPACTS

Unique Measurement System Enhances Process Control, Cuts Scrap by Half, and Saves Energy

A new inspection system, the HotEye® Rolled Steel Bar (RSB) System, has been developed and demonstrated by OG Technologies (OGT) Inc., with the help of both a NICE[3] grant and a project under the ITP Sensors and Automation Program. The HotEye RSB System is based on OGT's HotEye System and integrates it with a dynamic control plan (DCP) for hot steel processes. The HotEye System accurately and reliably measures a part's dimensions and detects its surface features, including defects, while it is still red hot, i.e., at temperatures of up to 1550°C. Current measurement systems cannot be used until the parts cool down, which results in higher scrap rates once defects are detected. The DCP classifies some defects from production and identifies their root causes and corrective actions. The DCP's effectiveness depends on instruments that can detect quantitative quality information in real-time in a hostile operating environment. The HotEye RSB System provides real-time process control to increase yields 2.5% in continuous casting and hot rolling steel mills, saving energy, improving quality, and increasing productivity.

The HotEye RSB System consists of three HotEye imaging sensors, four powerful PCs, modulating devices for the lighting system, proprietary image processing software, the software version of the steel rolling DCP, and an enclosure to protect the hardware and software from the effects of the harsh operating environment in a steel mill. The HotEye RSB System will automatically (1) inspect 100% of the surface of the product in-line; (2) identify defects as small as 0.025 mm; (3) analyze and record the size, nature, and location of the defects; (4) measure 100% of the dimensions of the product; and (5) generate process correction advice based on the DCP, while the product is at a temperature up to 1550°C and moving at a speed up to 100 m/second.



Design of the HotEye RSB Sensor System

Overview

- Developed by OG Technologies, Inc. (www.ogtechnologies.com)
- Commercialized in 2004
- Operating in four U.S. and multiple foreign steel mills in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
6.12	2.04

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.239	32.4

Applications

Can be used in steel hot rolling mills and continued casting processes

Capabilities

- Inspects 100% of product surface on-line.
- Identifies defects as small as 0.025 mm.
- Performs inspections while the product is at temperatures of up to 1550°C and moving at 100 m/second.

Benefits

Employee Safety

Allows the inspection of parts at temperatures of up to 1550°C remotely, reducing employee burns.

Profitability and Productivity

Detects and identifies production flaws quickly and reduces the scrap rate from the process by 50%.

Laser Contouring System for Refractory Lining Measurements

Optical Sensor Provides Real-Time Process Control, Resulting in Reduced Costs and Improved Performance

A suite of new robust sensors and control systems for base oxygen furnace (BOF) and molten steel transfer ladles makes possible dynamic process control and rapid assessment of the effectiveness of operations. With ITP support, Process Metrix and the American Iron and Steel Institute developed the Laser Contouring System (LCS) now being sold by Process Metrix. The LCS is a high-speed, laser-based technology that measures the refractory lining thickness of furnace vessels for manufacturing steel, copper, and aluminum. With a laser scan rate of over 8,000 points per second, the LCS provides exceptionally detailed contour resolution and accurate bath height determination. Moreover, measurement time ranges between 1 to 6 minutes or ten times faster than prior units. Quick on-line feedback eliminates downtime costs due to off-line inspection and unnecessary relining, increases equipment life, and ensures operational safety.

Contour maps of both vessel wall and bottom clearly illustrate lining thickness over the entire vessel interior. Thickness values are displayed both numerically and by color key, immediately revealing regions that might require attention. The report generator automatically prints all of the views and screens needed by the mill to make informed process decisions. New software releases, that include upgrades and feature requests from customers, are made twice annually.

Two principle objectives are emphasized in the mobile platform design: speed and simplicity. Fast measurement times are achieved using a laser-based navigation system. Working from three reflectors mounted on the building structure behind the cart, this system automatically measures the cart position relative to the BOF and reports position information directly to the LCS computer. The navigation system is completely automatic and updates 8 times per second. Process Metrix has also implemented a radio frequency (RF) link that continuously broadcasts the vessel tilt to a receiver located in the cart. The RF-link incorporates 2.4 gigahertz spread-spectrum technology for interference-free transmission. During the measurement, the RF receiver automatically reports the vessel tilt to the LCS computer. Together, the laser navigation system and RF link enable fast, error-free measurement of the vessel lining thickness. Single measurements can be made in 20-30 seconds. An entire map of the vessel interior, consisting of 4-6 measurements and 500,000+ data points, can be completed in less than 6 minutes.

Fixed position installation is available for converter and ladle applications. This type of installation, coupled with the high measurement speed of the LCS, enables measurements after every heat with little or no loss of process time.

Overview

- Commercialized in 2001 by Process Metrix (www.processmetrix.com)
- Seven units in operation at five U.S. installations in 2007 and additional units in use overseas

Applications

Can be used for rapid measurements of vessel wall and bottom lining thickness in the steel furnace or ladle environments

Capabilities

- Is available as a mobile platform or a fixed position installation.
- Maps the entire vessel interior in less than 6 minutes.
- Provides detailed contour resolution and vessel lining thickness with over 500,000 individual contour measurements.

Benefits

Cost Savings

Saves up to $1 million per year for manufacturers.

Energy Savings

Reduces energy usage via rapid real-time measurements for process control and with no loss of process time.

Productivity

Reduces maintenance on BOF refractory via automated furnace inspection.

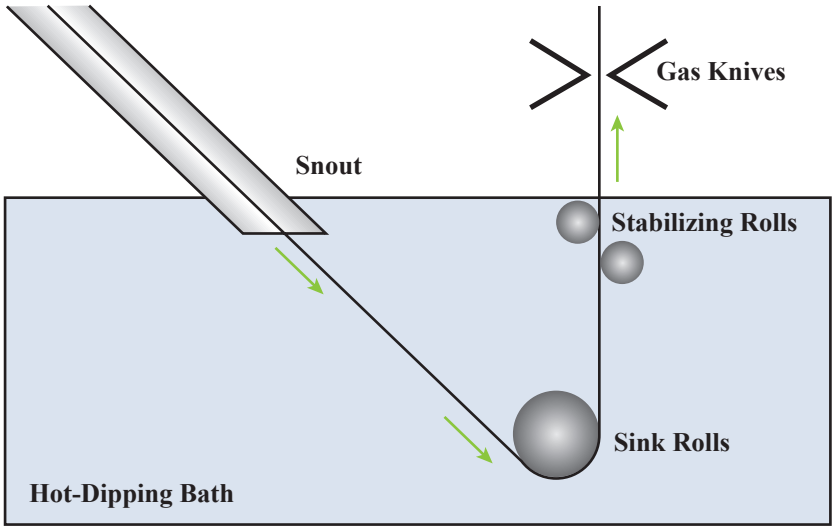
Life Improvement of Pot Hardware in Continuous Hot Dipping Processes

Improved Galvanizing Bath Hardware and Materials Result in Energy and Cost Savings

Flat-rolled surface-coated steel, including galvanized and aluminized sheet, is one of the fastest growing, most profitable sectors of the U.S. steel industry. Coating steel sheets by continuous hot dipping in a molten metal bath of zinc and aluminum is an efficient and economical method of protecting most steel sheet compositions from corrosion. However, corrosion, wear, and dross buildup on bath hardware such as bearings, sink rolls, and stabilizing rolls can lead to frequent downtime of production lines and can significantly reduce energy efficiency.

West Virginia University, with support from ITP and numerous private sectors partners, developed a new generation of bath hardware components. The components are made with several entirely new materials, such as an iron-aluminum-cobalt alloy, which provide 10 times the corrosion and wear resistance in the Zn/Al bath compared with baseline materials. The advanced bath hardware and materials provide longer life in the corrosive galvanizing bath by minimizing crystal growth, corrosion attack, and bearing surface degradation, all of which can lead to surface impurities on the final product, lowering the market value of the finished galvanized steel.

Delivering new roll and bearing designs, along with bath hardware materials developed with these new alloys, has extended component life by an order of magnitude, while remaining cost effective at only 10% to 15% higher than comparable components.



Steel Sheet Manufacturing Process

Overview

- Developed by West Virginia University in partnership with numerous steel manufacturing support companies
- Commercialized in 2006 by Pyrotek, Inc. (www.pyrotek-inc.com)

Applications

Can be used to improve the life of pot hardware, which applies to the 57 continuous hot dipping process lines in the U.S.

Capabilities

- Provides up to 10 times the corrosion and wear resistance compared with baseline materials.
- Reduces the potential for bearing instability due to improved hardware alloys.
- Improves surface characteristics of sheet steel from reduced dross formation.

Benefits

Cost Savings

Reduces waste and process scrap volume by limiting the frequency of downtime in the galvanizing process.

Environmental

Reduces emissions from sheet steel manufacturing plants.

Productivity

Limits the formation of surface imperfections on the finished sheet steel.

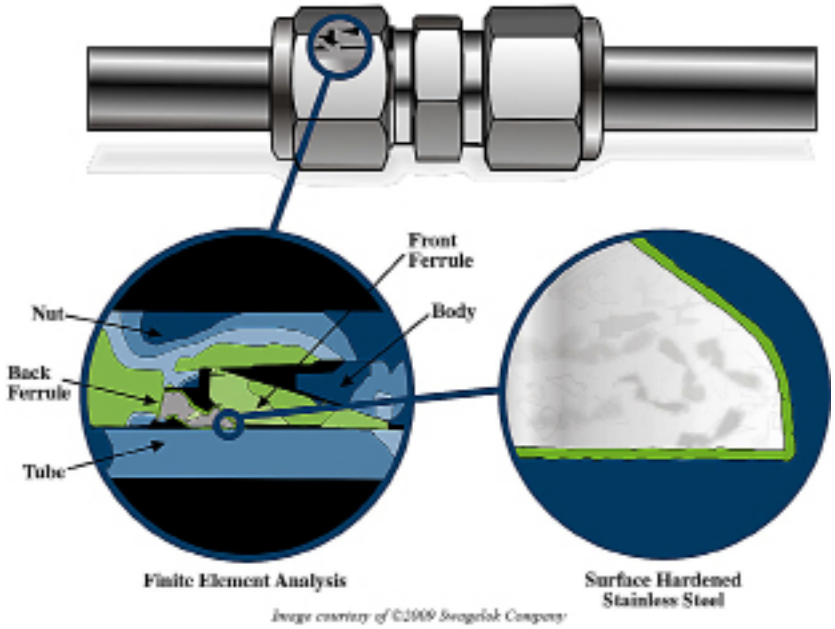
Low-Temperature Colossal Supersaturation of Stainless Steels

New Process Improves Hardness and Corrosion Resistance of Stainless Steel Components

Austenitic stainless steels in the 300 Series are the primary materials used for a very broad range of applications when corrosion resistance is needed in aqueous solutions at ambient temperatures. While austenitic stainless steels have excellent corrosion-resistance properties, they possess low hardness values and cannot be heat-treated to increase their hardness. In materials science, it has been generally understood that carbon atoms cannot be introduced into austenitic stainless steel through heat treatment without the formation of chromium carbides, which compromise the corrosion-resistant properties of the alloy. Until now, hardness and corrosion resistance have been typically regarded as tradeoffs.

With assistance from ITP and the Ohio Department of Development, Swagelok Company contributed to research using its patented heat treating process known as low-temperature colossal supersaturation (LTCSS). This process dramatically improves surface hardness without losing corrosion resistance. By contrast, the traditional methods of heat treating stainless steel promote the formation of chromium carbides that compromise the corrosion-resistant properties of the alloy. LTCSS introduces carbon atoms into the austenitic, or face-centered-cubic, crystal structure without the formation of chromium carbides. Testing has shown the carbon absorption to be about 80,000 times greater than thermodynamics and kinetics would suggest being possible. At the same time, there is evidence of improved corrosion resistance, wear resistance, and increased fatigue strength.

Swagelok Company launched their LTCSS business by forming a subsidiary, Swagelok Technology Services Co., to treat steel parts supplied by their customers. Swagelok is pursuing individual licensing of the technology.



An Application of Swagelok's LTCSS to Tube Fittings

Overview

- Developed by Swagelok Company (www.swagelok.com)
- Research performed in conjunction with Case Western University, Energy Industries of Ohio, Oak Ridge National Laboratory, and Spirax Sarco, Inc.
- Used by Swagelok since 1999 and commercialized to the public in 2007
- Used by the U.S. Naval Research Lab for treating stainless steel components

Applications

Can be used anywhere stainless steel parts are used, e.g., pump and circulation equipment, industrial components, and medical devices

Capabilities

- Imparts higher hardness to stainless steel components.
- Provides nickel-like corrosion resistance for a part that will cost less than an expensive high-nickel alloy.
- Allows sheet metal to be treated and still retain its ductility.
- Treats finished components without distortion or change of dimension.
- Avoids carbide formation.

Benefits

Durability

Increases the corrosion/erosion resistance of stainless steel components to levels previously attainable only by expensive high-nickel or high-molybdenum alloys.

Product Quality

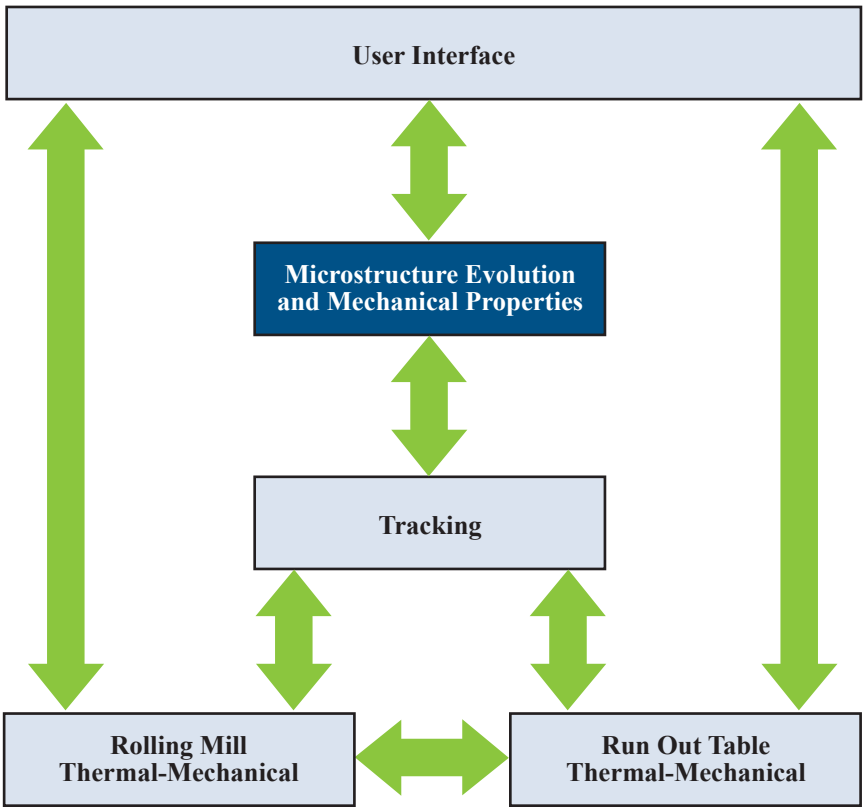
Allows ordinary stainless steels to adopt performance characteristics of more expensive alloys.

IMPACTS

Innovative Model Provides a More Detailed Insight into Mill Operations to Reduce Costs and Improve Quality

Many hot rolled products must achieve strict strength and toughness requirements, making control of the microstructure critical. This causes these products to be difficult to make and requires many costly full production trials before the range of both chemical composition and hot strip mill processing parameters can be defined. The Hot Strip Mill Model (HSMM) is an invaluable tool to cost effectively assist in determining the optimum processing conditions to achieve the desired product properties. This model runs in an off-line mode, thereby saving many tons of wasted product that might be scrapped in trying to identify the proper mill set-up.

The HSMM also provides additional savings in grade consolidation, control optimization for new grades, and improvement of mechanical and microstructure properties for downstream processing. The model can consolidate grades by allowing the user to develop different processing setups for the same steel grade that will then achieve the various mechanical properties needed for the different finished products. The HSMM can improve on-line control optimization for new grades by using what is learned from the HSMM to help set up the on-line models so they learn faster how to optimize the processing of the new grade. And finally, processing the steel to achieve the optimum or specific microstructure attributes further improves processing of the product in downstream operations.



Components of the HSMM

Overview

- Developed by The American Iron and Steel Institute as part of its Advanced Process Control Program
- Marketed and sold by INTEG Process Group, Inc. (www.integpg.com)
- Acquired by 21 companies or universities around the world, including four U.S. steel companies

Applications

Can be used in any hot rolling mill that produces sheet or plate products (flat rolled material). The model can handle a variety of rolling mill configurations, including roughing mills, coil boxes, finishing mills, run out tables, and coilers

Capabilities

- Allows the user to easily modify the mill configuration or processing parameters to see its impact on the end results of the product being rolled (simulated).
- Can be used as a training tool, allowing operators to see the end result for different processing conditions or grades of steel.

Benefits

Competitiveness

Improves industrial competitiveness through product optimization and cost savings.

Productivity

Decreases product variability through the development of a predictive tool, which can quantitatively link the properties of hot rolled product to the operating parameters of the hot strip mills.

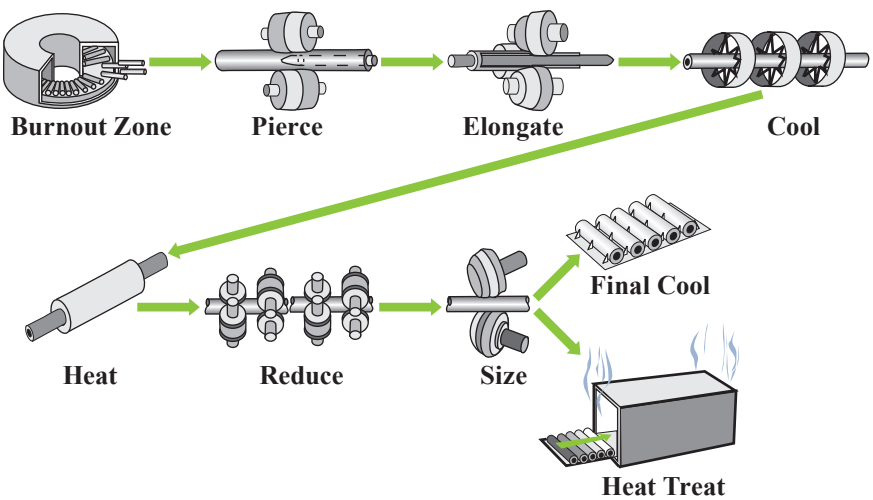
Shorter Spherodizing Annealing Time for Tube/Pipe Manufacturing

New Process Results in Productivity Improvements and Energy Savings

The steel industry is working to improve the manufacturing of tubes and pipes while maintaining key steel parameters and reducing the amount of energy used in the process. The Timken Company developed an enhanced spherodized annealing cycle for through-hardened steel. This technology is a by-product of a larger ITP-sponsored project, the "Controlled Thermo-Mechanical Processing (CTMP) of Tubes and Pipes for Enhanced Manufacturing and Performance."

The spherodized annealing process changes the hard, elongated carbide particles in the steel to be spherical with a preferred diameter. The size and shape of the original elongated carbides produced by the previous hotworking process influence the ability to spherodize the carbides. The spherodized annealing process consists of heating the carbide particles to temperatures at which they form spherical shapes. This entire heating and holding cycle takes 20 to 50 hours. Various combinations of temperatures and times can be used to achieve the desired shape and distribution of the carbide spheres. In this ITP-sponsored project, experimentation was conducted to characterize the effect of the original elongated carbides and the annealing times and temperatures on the resulting spheroid size and distribution.

The experimental results helped the Timken Company shorten the annealing cycle time by 20% and condense the number of plant trials to achieve that. The result was an optimized cycle that reduced energy consumption and improved productivity while generating a quality product with the desirable metallurgical properties for forming and machining.



Tube Making Process

Overview

- Developed by The Timken Company (www.timken.com)
- Used at one U.S. steel plant in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.121	0.008

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.001	0.133

Applications

Can be used by steel tube and pipe manufacturers and specialty metal manufacturers.

Capabilities

Shortens annealing cycles and saves energy.

Benefits

Energy Savings

Reduces fuel requirements by reducing annealing cycle time by 20%.

Productivity

Increases productivity approximately 10% due to the reduced cycle time.

Product Quality

Provides the end user with steel that is easily formed and machined with the same desirable metallurgical properties.

IMPACTS

New Nickel Aluminum Transfer Rolls for High-Temperature Applications

A nickel aluminum alloy developed by Oak Ridge National Laboratory (ORNL), in conjunction with ITP, has the potential to transform the steel heat-treating industry. Nickel aluminide is a strong, hard, inter-metallic material that resists wear, deformation, and fatigue from repeated stress or high temperatures. Because the alloy becomes stronger and harder at high temperatures, nickel aluminide transfer rolls are well suited to replace steel transfer rolls in heat-treat roller hearth furnaces.

In the annealing furnace at Bethlehem Steel Burns Harbor Plate Division (now Arcelor Mittal Burns Harbor Plate Inc.), nickel aluminide inter-metallic alloy rolls provide greater high-temperature strength and wear resistance compared with the conventional H-series cast austenitic alloys currently used in the industry. ORNL and Bethlehem (Arcelor Mittal) partnered with ITP to demonstrate and evaluate the nickel aluminide inter-metallic alloy rolls as part of an updated, energy-efficient, large, commercial annealing furnace system.

The project involved developing welding procedures for joining nickel aluminide inter-metallic alloys with H-series austenitic alloys and developing commercial cast roll manufacturing specifications. Several commercial suppliers helped produce a quantity of high quality, reproducible nickel aluminide rolls for a large steel industrial annealing furnace. The capabilities of the rolls in this furnace were then demonstrated and trials were performed to evaluate the benefits of new equipment and processes.

Straight-through plate processing is now possible because of the nickel aluminide rolls, which also improved the quality of the plate product surface to allow the additional processing of surface critical material. Benefits also include associated large reductions in maintenance, reduction in spare rolls and associated component costs, and potential for greater throughput and productivity. Estimated project fuel cost reductions alone for processing 100,000 tons/yr through this furnace are $100,000/yr from straight-through processing, assuming natural gas prices of $6.00/MMBtu.

Benefits

Productivity

Reduces furnace shutdowns to replace worn components, resulting in increased production. Decreases maintenance and furnace shutdowns from weekly to quarterly. Reduces damage to steel during heat-treating, resulting in less steel scrap.

Product Quality

Offers two to three times the strength of conventional steel roll assemblies. Increases strength at temperatures greater than 1475°F. The high aluminum content resists oxidation and carburization at high temperatures without adhering to steel.

Profitability

Extends transfer roll life three to five times and reduces life cycle costs by 75% compared with steel rolls. Produces steel plates with greater, more consistent quality.

Overview

- Nickel aluminide developed by Oak Ridge National Laboratory
- Being marketed by Duraloy Technologies, Inc. (www.duraloy.com)
- Nickel aluminide transfer rolls technology commercialized in 1993

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.138	0.035

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.004	0.559

Applications

Can be used to move steel plates through the heat treatment process in heat-treat roller hearth furnaces

Capabilities

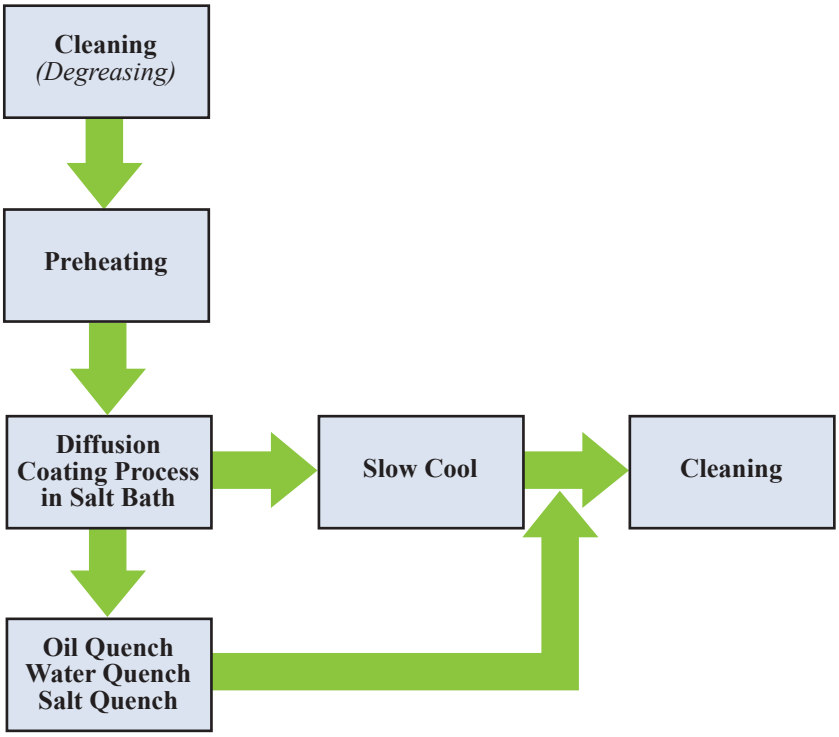
Can operate in temperatures as high as 2100°F.

Vanadium Carbide Coating Process

Innovative Process Enhances Wear Resistance of Metals, Saving Energy, Waste, and Costs

Traditional methods of coating steel surfaces with a layer of hard metal carbide require large capital investment, produce toxic and hazardous gases, are costly to operate, and require multiple heat-treatment steps during processing. Vanadium carbide (VC) coating technology provides a superior protective coating for steel surfaces and eliminates the need for multiple heat-treatment steps during processing, thereby eliminating harmful gas emissions.

The coating system, developed by Metlab-Potero with assistance from the NICE[3] program, is based on a thermal diffusion technology, which forms a VC surface layer that can be made up to 15 microns thick in 12 hours. Process steps include cleaning, preheating, coating, cooling, or quenching, and subsequent tempering as required. Cleaned parts are preheated and then immersed in an environmentally benign fused salt bath in an 800°C to 1200°C furnace at ambient pressure until the required coating thickness is achieved. The work piece is then removed from the furnace for quenching, slow cooling, or additional hardening and tempering. The process protects steel surfaces with a thick, well-controlled layer of VC while eliminating the need for multiple heat-treatment steps that increase energy use and the chance of production defects. Reducing the number of processing steps eliminates emissions, vacuum vessels, and the associated electrical heating system components.



Vanadium Carbide Coating Process

Overview

- Developed by Metlab-Potero (www.metlabheattreat.com)
- Commercialized in 2005

Applications

Can be used for manufactured tools and dies requiring hardened, wear-resistant surfaces

Capabilities

Increases dimensional accuracy and creates wear-resistant surfaces without multiple heat-treatment steps.

Benefits

Cost Savings

Reduces process costs by 20%.

Environmental

Reduces water usage by 20% to 50% and eliminates harmful gas emissions.

Productivity/Quality

Offers productivity gains of 10% to 30% and increases tool life 5 to 30 times compared with conventional wear-resistance methods.

Crosscutting

IMPACTS

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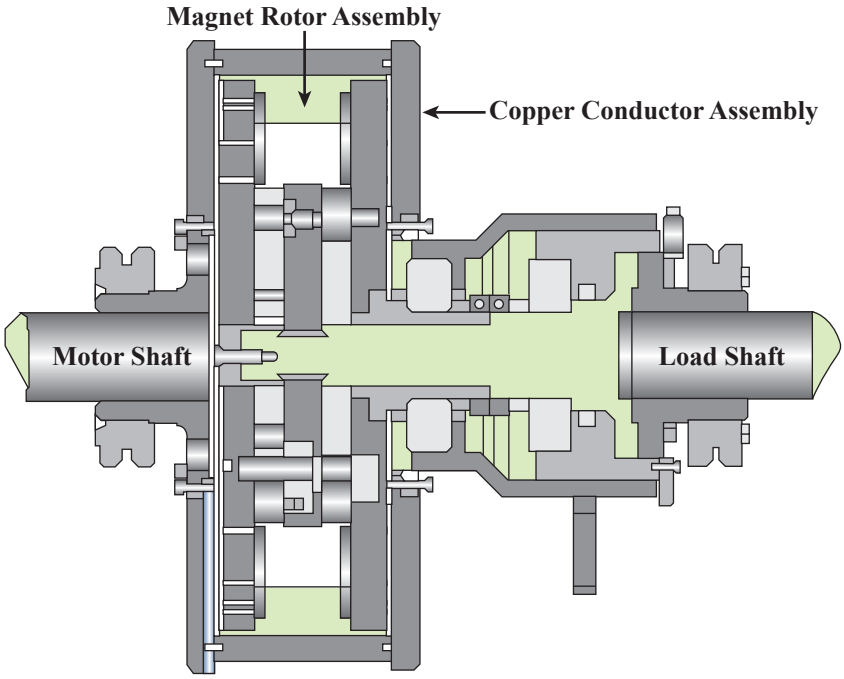
Adjustable-Speed Drives for 500 to 4000 Horsepower Industrial Applications

New Drive System Saves Energy and Extends Variable Speed Control to Larger Motors

MagnaDrive Corporation, with assistance from the NICE[3] program and Washington State University's Cooperative Extension Energy Program, has developed a highly efficient adjustable speed drive (ASD) for various industrial applications. The MagnaDrive ASD has been successfully tested and used in industrial environments with motors up to 4,000 horsepower (hp). Over 5,000 units are currently in use in applications up to 2,500 hp, of which 36 are over 500 hp.

The ASD consists of two major components that never touch: (1) the copper conductor assembly, directly connected to the motor shaft; and (2) the magnet rotor assembly, directly connected to the load shaft. The torque is transmitted across a thin air gap that can be continuously adjusted to control the speed of the load. The actuation components are attached to the magnet rotor assembly on the load side of the ASD. Rare-earth permanent magnets are the key to the system's performance. The magnets are made of neodymium, iron, and boron (NdFeB) and retain their magnetic properties for the life of the system.

The motor is started with the ASD system in a position that places the largest air gap between the magnet rotors and the copper conductors. The motor quickly comes to full speed in an unloaded condition. The magnet rotor is then actuated to adjust the rotors closer to the conductors. As the components approach each other, eddy currents are induced, allowing a smooth transfer of torque across the air gap until the distance between the magnet rotor and the copper assembly closes to about 1/8 inch. At this point the ASD reaches its maximum efficiency of up to 99% of the torque transferred between the motor and the load.



Adjustable-Speed Drive Components

Overview

- Developed by MagnaDrive Corporation (www.magnadrive.com)
- Commercialized in 2003
- 36 large and over 5000 smaller units operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.645	0.303

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.001	0.065	0.049	5.96

Applications

Can be used in motor driven pumps, fans, blowers, and other processing/manufacturing equipment used in industry

Capabilities

- Transfers torque from motors to driven equipment across an air gap without shaft-to-shaft physical connection.
- Permits speed control by varying the air gap spacing, thereby controlling the amount of torque transmitted.
- Eliminates the transmission of vibration across the drive due to the air gap configuration.

Benefits

Productivity

Eliminates vibration, reduces noise, tolerates misalignment, provides overload protection, extends motor and equipment life, and reduces overall maintenance and operations costs.

Product Quality

Improves product quality and optimizes process rates.

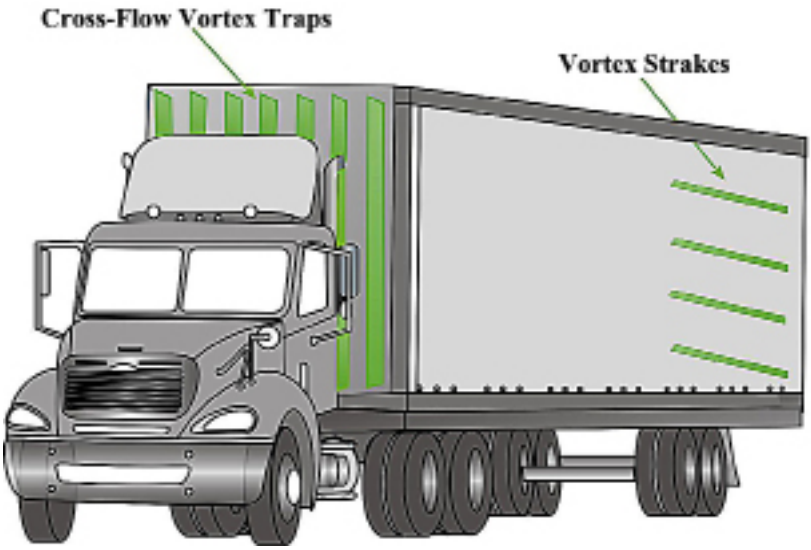
Advanced Aerodynamic Technologies for Improving Fuel Economy in Ground Vehicles

Low-Cost Aerodynamic Drag Reduction Devices for Tractor-Trailer Trucks Reduce Fuel Consumption

Heavy vehicles lose a tremendous amount of energy from wind resistance, braking, and rolling resistance. Such non-engine losses can account for about a 45% decrease in efficiency. The need for technologies to reduce these parasitic losses has gained significant attention as fuel costs have increased. The 21st Century Truck Program, an industry-government collaboration, has established an aerodynamic drag reduction goal of 20% for Class 8 tractor-trailer combinations.

With assistance from DOE's Inventions and Innovation Program, SOLUS Solutions and Technologies LLC has developed several low-cost aerodynamic devices that reduce drag and improve fuel economy for tractor-trailer trucks. In 2007 Silver Eagle Manufacturing Company began to produce and sell the SOLUS drag reduction devices. Wind tunnel and on-road testing demonstrated that these devices can provide a combined fuel savings of about 10% at 60 mph. The expected fuel savings from the inventions for an average tractor-trailer truck will exceed 2,000 gallons per year.

The geometric-based devices can be attached to or integrated into the trailer's front face, sides and top surfaces, and the undercarriage. One device employs "trapped vortex" design technology to eliminate the drag due to flow in the gap region between the tractor and the trailer. The "vortex strakes" create a "boat tail" at the back of the trailer. A boat tail is a tapering protrusion mounted on the rear of a truck that reduces the aerodynamic base drag caused by the lower-pressure effect that occurs in the wake of a vehicle. The industry has known about the benefits of boat tails for decades; however, pre-existing devices for achieving them interfered with rear door access. The location of the vortex strakes (trailer sides and top) does not interfere with door operation. Testing indicates that adding the SOLUS devices to trailers has no negative impact on either operational utility or maintenance requirements.



SOLUS Solutions and Technologies' Vortex Drag Reduction Devices

Overview

- Developed by SOLUS Solutions and Technologies LLC in 2001 (www.solusinc.com)
- Commercialized in 2007
- Currently marketed by Silver Eagle Manufacturing Company (www.silvereaglemfg.com)

Applications

Can be used for all classes of heavy tractor trailers to reduce drag and improve fuel economy

Capabilities

- Improves fuel economy of a tractor-trailer by 10% at 60 mph.
- Improves vehicle stability and handling.
- Reduces drag by up to 25% at all operational speeds.

Benefits

Pollution Reduction

Reduces exhaust emissions as a result of reduced drag and associated fuel savings.

Profitability

Ensures low operation and maintenance costs and a return on investment in less than one year.

Reliability

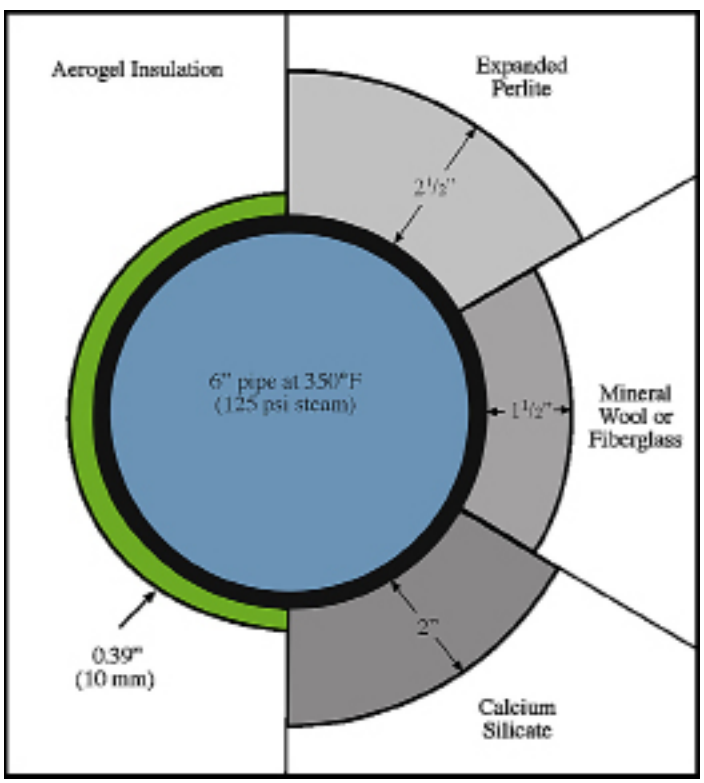
Reduces wear on engine and braking assemblies and wear on the transmission.

Aerogel-Based Insulation for Industrial Steam Distribution Systems

New Efficient Insulation for Pipes Allows for the Use of Less Material with High-Temperature Durability

Thermal loss through industrial steam distribution systems accounts for a large part of total U.S. energy consumption. Traditional pipe insulation employs mineral wool, fiberglass, calcium silicate, perlite, and various foams. Annular shrouds of these materials are tightly wrapped around steam pipes and clad with sheet metal. As a highly efficient insulation material, flexible aerogel blankets can help reduce these losses when wrapped around hot piping, vessels, and equipment. This breakthrough technology provides the equivalent insulating properties of conventional insulation but with two to five times less material. A cost-effective method has been developed by Aspen Aerogels, Inc., with ITP assistance, to manufacture this industrial insulation product that has remarkable thermal performance, physical toughness, and water-resistant properties.

Aerogel has the lowest thermal conductivity of any known material. Recent processing developments allow this once boutique material to be manufactured cheaply in blanket form. The main attraction of aerogel insulation is that it significantly reduces the amount of material needed to achieve the same insulation value as bulkier traditional insulation. Aerogel is still more expensive to produce on a weight basis, but much less material is required, so the improved properties compensate for the difference in cost. Insulation designs and installation protocols were developed to allow for widespread adoption of aerogel-based pipe insulation by all industries that rely on steam distribution systems, with a focus on assemblies that are not currently cost-effectively addressed by aerogel insulation, such as large diameter, complex, and/or high-temperature pipe systems.



Thickness Comparison of Aspen Areogel's Insulation vs. Conventional Insulation with Equivalent Insulation Properties

Overview

- Developed by Aspen Aerogels, Inc., in partnership with Air Liquide USA LLC (www.aerogel.com)
- Commercially available in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.007	0.006

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.000	0.000	0.001	0.092

Applications

Can be used for industrial steam distribution systems, enhancing high-temperature durability up to superheated steam at 1200°F.

Capabilities

- Enhances high-temperature durability of industrial insulation.
- Reduces installation labor.
- Offers long-term water resistance and corrosion protection because of the aerogel's hydrophobic properties.
- Has very low thermal conductivity.

Benefits

Efficiency

Possesses a very low thermal conductivity and thickness compared with conventional insulation materials.

Material Savings

Reduces the amount of material needed to achieve the same insulation value as bulkier traditional insulation.

Autotherm® Energy Recovery System

Innovative Technology Reduces Idling, Fuel Costs, and Emissions on Large Vehicles

Historically, cab interiors are kept warm when a vehicle is stationary in the winter by either installing an expensive fuel-fired heater or idling the vehicle engine to keep hot water circulating to the cab heater. According to Argonne National Laboratory, larger vehicles can consume one gallon per hour of fuel simply to operate the heater. In most vehicles once the motor is turned off, within a few minutes, the vehicle interior is too cold to occupy comfortably because the engine driven pump is no longer recirculating water to the cab heater. With assistance from DOE's Inventions and Innovation Program, Autotherm developed a system that continues to supply heat stored in the engine to a vehicle cab when the engine is turned off. The easy-to-install design allows the vehicle to stay heated for up to several hours when the vehicle is turned off, eliminating both fuel consumption and emissions from the stationary vehicle.

Once the vehicle motor is turned off, the Autotherm system operates the vehicle's existing heater using a dash-mounted system control unit and a small electric recirculating pump, which is attached to the existing engine coolant system. The system is fully automatic and can maintain cab temperature with the driver present or absent from the vehicle. Operation stops automatically when the engine coolant drops to about 95°F. The vehicle can be left securely locked, and if the driver returns within the heating period, the vehicle will be warm and snow-free.

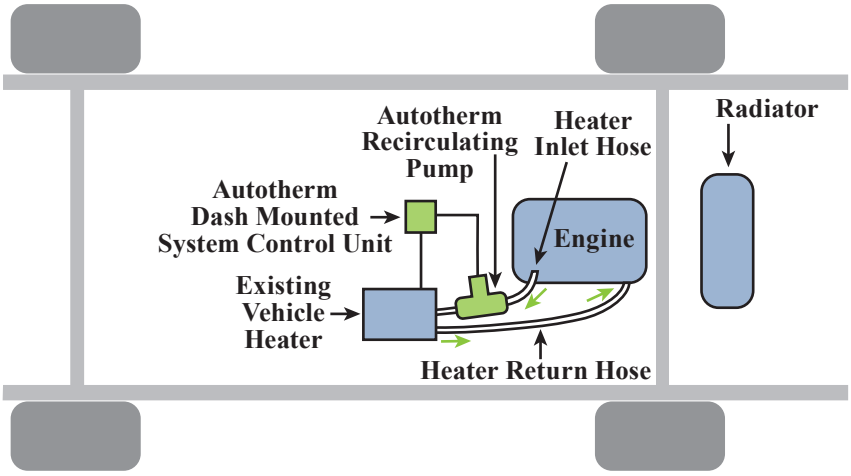
Benefits

Emission Reduction

Reduces 100% of the emissions from an idling vehicle by eliminating the need for the engine to run to maintain cab temperature.

Profitability

Reduces operating costs and has a payback of one heating season.



Autotherm Components

Overview

- Invented by Frank Perhats in 1974 and refined using DOE funding
- Commercialized in 2003 and being marketed by the Autotherm Division of Enthal Systems, Inc. (www.autothermusa.com)
- About 1300 units installed through 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.067	0.025

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.015	0.004	0.552

Applications

Can be used in any vehicle that is prone to idling, including small to large service vehicles and semi-trucks.

Capabilities

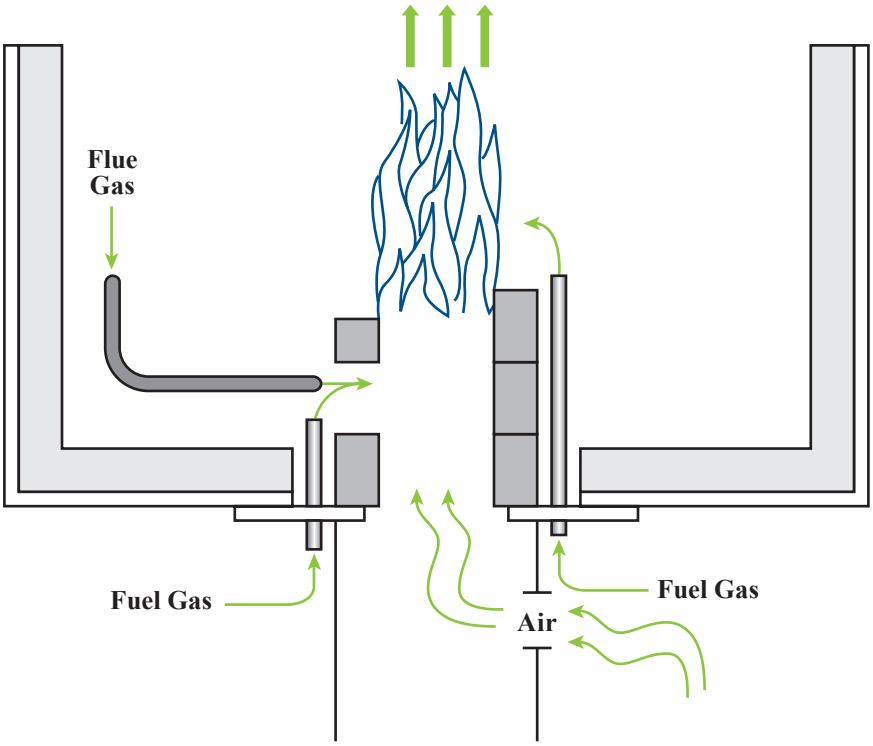
- Maintains a vehicle's interior temperature for several hours when the engine is off by recovering energy stored in the warm engine.
- Automatically turns off when the engine coolant system drops to below 95°F.
- Alerts the driver to an approaching "low battery voltage" condition and shuts down the system before the battery is low.

IMPACTS

A New Generation of Smart, Integrated Burner/Fired-Heater Systems

The refining and chemicals industries rely on process heaters to heat liquids and induce chemical reactions during production processing. Process heaters in these two industries generate over 235,000 tons of NO_X emissions annually. The chemicals and refining industries are facing more stringent environmental regulations to reduce NO_X emissions; for example, the state of Texas has ordered refiners in the Houston area to reduce NO_X emissions by 80+%.

Callidus Technologies, along with funds and resources from ITP, Gas Research Institute (GRI), and Arthur D. Little Company, developed and demonstrated an ultra-low NO_X emissions burner. The burner uses internal flue gas recirculation to reduce 80% of the NO_X emissions, with many applications achieving reductions greater than 90%. Callidus Technologies, with licensing rights from GRI, is manufacturing and marketing the Callidus Ultra-Blue Burner to the chemicals and refining industries, where potential NO_X reductions of 200,000 tons/year are possible.



Callidus Ultra-Blue Burner

Overview

- Developed by Callidus Technologies, Inc. (www.callidus.com)
- Commercialized in 2000
- Over 8000 burner units installed by 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
46.8	17.3

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	2.03	275

Applications

Can be used in the chemicals, petrochemicals, and refining industries

Capabilities

Works with natural or forced-draft operation; refinery fuel gas, natural gas, and high and low hydrogen content; and ambient and preheated air.

Benefits

Emissions Reductions

Reduces thermal NO_X in the combustion zone by 80% to 90%.

Profitability

Eliminates or reduces the need for expensive post-combustion emission-altering equipment.

Other

Is designed to be user-friendly.

Catalytic Combustion

Advanced Catalytic Combustion System Reduces NO_X Emissions

Natural-gas-fired turbine systems currently require complex after-treatment systems to clean the exhaust of harmful emissions. Many of these emissions could be reduced by lower operating temperatures during the combustion process.

With the support and recognition from many organizations, including ITP, the California Air Resources Board, the California Energy Commission, and the U.S. Environmental Protection Agency, Catalytica Energy Systems, Inc., has developed an innovative system to reduce turbine emissions. The Xonon Cool Combustion® System uses a catalytic process instead of a flame to combust the fuel, thereby lowering the combustion temperature and significantly reducing the formation of NO_X.

While maintaining turbine efficiency, the technology has the potential to reduce the cost associated with achieving ultra-low emissions while generating electricity with gas turbines. With the growing need for electricity generation that produces less pollution, Catalytica Energy Systems' solution provides a cost-effective method to meet air pollution control standards through pollution prevention rather than cleanup. In its first commercial installation, the NO_X output was reduced from approximately 20 ppm to well below 3 ppm.

Benefits

Emission Reductions

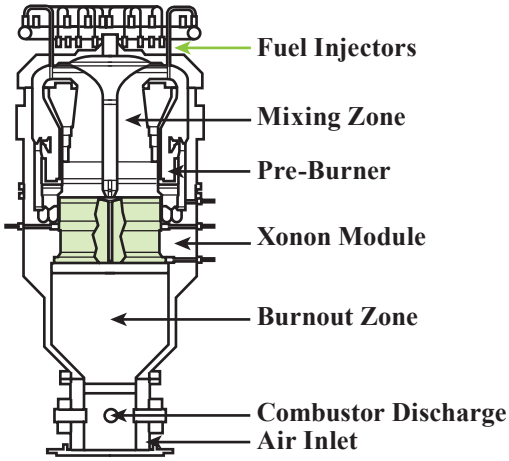
Reduces air pollutant emissions from gas turbine energy generation systems.

Pollution Reduction

Avoids the need for costly or burdensome exhaust cleanup systems that use toxic reagents such as ammonia.

Productivity

Maintains turbine efficiency, demonstrating operating reliability greater than 98%.



Catalytic Combustion

Overview

- Developed by Catalytica Energy Systems, Inc. (www.kawasaki.com)
- Has accumulated over 18,000 hours of operation on the grid in field demonstrations
- First commercialized in 2002
- Commercially available through Kawasaki Gas Turbines-America on its M1A-13X, a 1.4-MW gas turbine as part of the GPB 15X cogeneration system
- Being actively developed in partnership with GE Power Systems for its GE10, a 10-MW gas turbine, and with Solar Turbines for its Taurus 70, a 7.5-MW gas turbine

Applications

- Can be used for power generation turbine systems with low emission requirements or preferences, such as California installations, international systems, and systems with low pollution requirements
- Can also be applied to turbine generation systems with cogeneration to improve energy efficiency

Capabilities

- Can be used in a broad range of turbine sizes and will not reduce the turbine efficiency.
- Achieves emissions less than 3 ppm for NO_X and less than 10 ppm for CO.
- Uses a catalyst rather than a flame to combust fuel.

IMPACTS

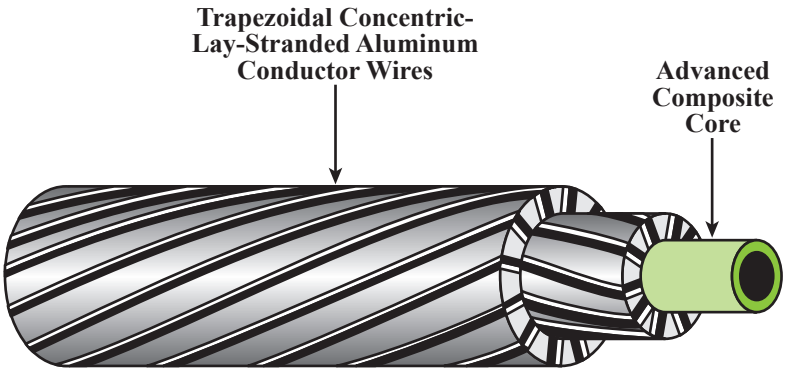
New Aluminum Conductor Composite Core Cable Increases Transmission Efficiency and Installs Easily

After nearly three years of intensive research and development, Composite Technology Corporation, in association with General Cable, introduced a new conductor type known as ACCC (Aluminum Conductor Composite Core). This new conductor uses a lighter-weight, high-strength carbon and glass fiber core embedded in a high-performance thermoset resin matrix, which is produced continuously using an advanced pultrusion process. The hybrid structural core is then helically wound with fully annealed trapezoidal-shaped conductive aluminum wires. Compared with a conventional steel core cable, the new core allows for up to 28% more conductive aluminum to be wrapped within the same outside diameter. The end product is of similar weight to conventional aluminum conductor steel reinforced cable, which allows existing structures to be used without modifications.

While the conductor was designed to perform efficiently at temperatures significantly higher than conventional steel-cored conductors, ACCC actually operates much cooler and more efficiently under equal power flow. Because the power flow capability, or "ampacity," is double that of a conventional conductor, the ACCC's improved efficiency can help reduce power generation costs and greenhouse gas emissions, while mitigating grid bottlenecks and the associated high costs of grid congestion.

The ACCC conductor's higher capacity can also improve grid reliability; if a parallel line fails, it can handle the extra current flow. When operated at higher temperatures (representing higher current flow), a normal conductor would tend to thermally expand and sag beyond safe limits – potentially grounding out to adjacent lines or structures – causing catastrophic outage. The ACCC conductor's reduced coefficient of thermal expansion prevents thermally induced line sag and would prevent that type of occurrence.

In addition to improving the weight and conductivity characteristics of utility transmission and distribution lines, the new ACCC allows for reductions in the number of structures by as much as 16% or more because of its thermal stability and 25% to 40% greater strength. The added aluminum content (~28%) greatly reduces resistance and line losses. One utility reported a reduction in line losses of approximately 35% on one of their ACCC lines, which also helped improve the overall efficiency of the system.



Aluminum Conductor Cable with Composite Core

Overview

- Developed by Composite Technology Corporation (www.compositetechcorp.com)
- Commercialized in 2005
- Over 1.7 million feet of line installed in 9 U.S. states and much more in foreign countries

Applications

Can be used by the power industry to increase transmission efficiency and increased capacity for new and existing pathways. Is available in all the industry standard sizes ranging from 431 to 2727 kcmil.

Capabilities

- Doubles the current carrying capacity of existing transmission and distribution lines.
- Decreases the cost of new installations by reducing the number of structures required and related construction and maintenance costs.
- Resists environmental degradation and improves reliability.

Benefits

Productivity

Uses conventional installation methods and tools, allows the existing transmission and distribution structures to be used without modifications, and reduces construction costs by using fewer support structures.

Product Quality

Virtually eliminates high-temperature cable sag and will not rust or corrode or cause electrolysis with aluminum conductors or other components.

Profitability

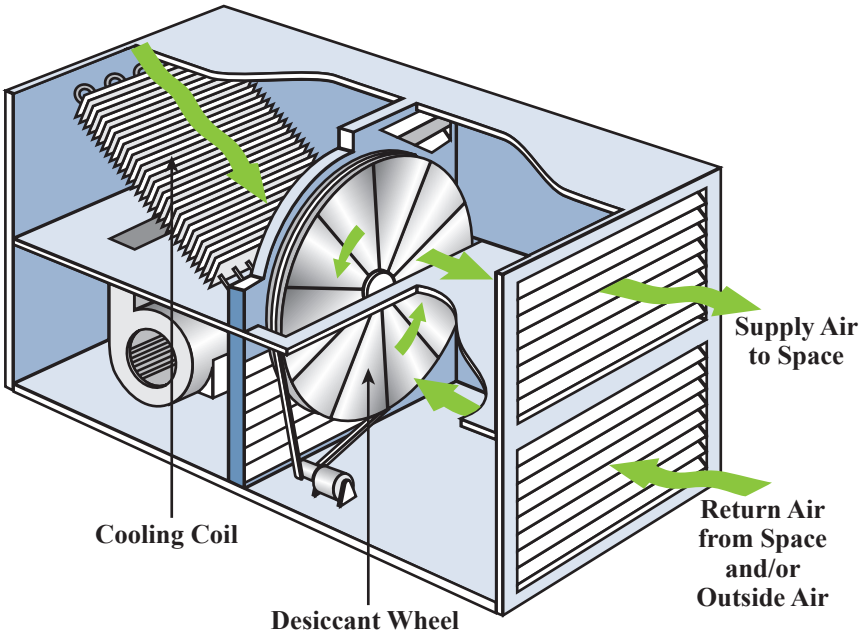
Doubles current-carrying capacity and reduces power generation and transmission costs.

Cromer Cycle Air Conditioner

New Air Conditioning System Uses Desiccant to Transfer Moisture and Increase Efficiency and Capacity

When cooling a space to a comfortable temperature, two types of heat energy must be removed: temperature-associated sensible heat and moisture-associated latent heat. An air-conditioner coil usually operates by performing about 25% moisture removal and 75% cooling. In a typical system, over-cooling must occur to meet the moisture-removal demands. These typical systems inefficiently add heat to the supply air (reheat), which consumes even more energy, to correct for the over-cooling. Latent-heat ratios often become higher than 25% in hot and humid climates, where introducing fresh air brings in significant levels of moisture, upsetting the temperature and moisture balance of interior spaces and reducing comfort levels. Excessive moisture in the air can also contribute to indoor air quality problems in buildings.

With assistance from DOE's Inventions and Innovation Program, the Cromer cycle air conditioner was developed to reduce energy consumption of the air conditioning while increasing the moisture-removal capacity of the air-conditioner coil. In the Cromer cycle air conditioner, a desiccant wheel is used to transfer moisture continuously from the supply air stream to the return air stream before the cooling coil. This transfer enhances dehumidification of the coil without significantly reducing coil temperature, improving the efficiency of the refrigeration cycle. The drier air supplied to interior spaces increases comfort and indoor air quality. Trane incorporated the Cromer cycle into a new system called the Cool Dry Quiet (CDQ™) desiccant dehumidification system. The first CDQ systems were sold in 2005 and by the end of the year 30 units had been installed, primarily in hospitals and museums. In 2006, Trane began to market the CDQ in roof top units and in applications for package units.



Trane Cromer Cycle Air Conditioner

Overview

- Developed by Charles Cromer of the Solar Engineering Co.
- Commercialized in 2005
- Being produced and marketed by Trane (www.trane.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.299	0.208

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.001	0.045	0.033	4.08

Applications

Can be used in commercial, industrial, or residential HVAC systems needing dehumidification down to 25°F dew points

Capabilities

- Reduces the amount of cooling, eliminating reheat used in many systems to dehumidify, and improves the efficiency of the cooling needed by maintaining higher evaporator coil temperatures than standard systems.
- Requires minimal maintenance of the desiccant wheel for the life of the air conditioning system.

Benefits

Productivity/Comfort

Improves humidity control for more comfortable working or living environments, resulting in improved productivity.

Waste Reduction

Avoids the need for stand-alone dehumidification equipment or dedicated outdoor air units; uses return air to regenerate the desiccant versus the high-temperature heat used with other desiccant systems.

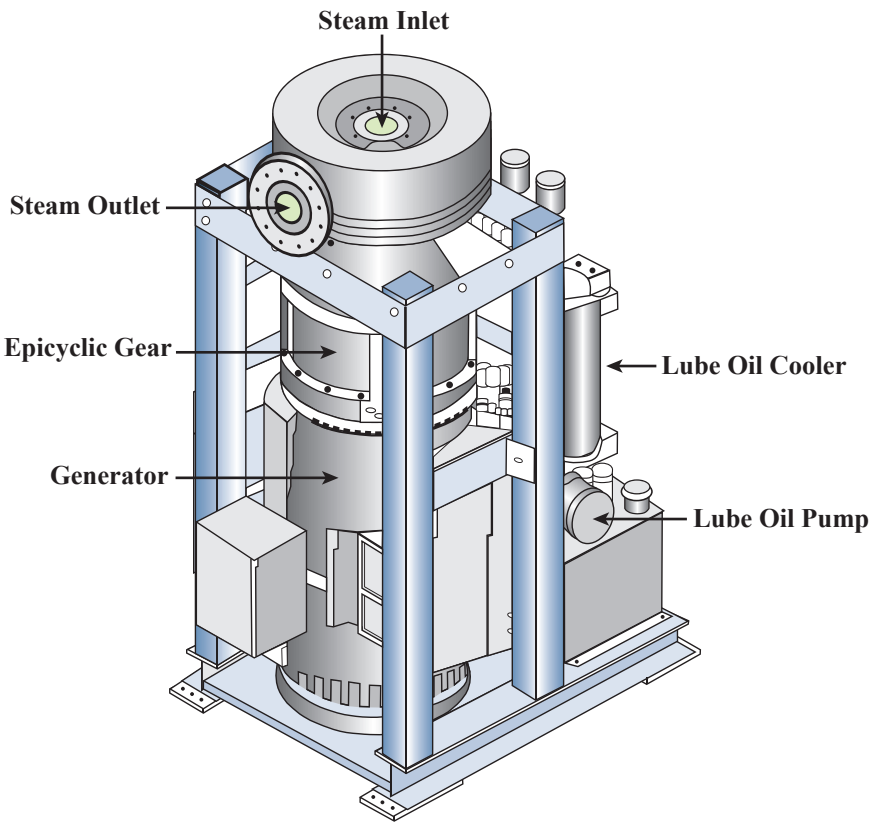
Dual-Pressure Euler Turbine for Industrial and Building Applications

IMPACTS

Innovative Dual-Pressure Euler Turbine Generates Electric Power by Harnessing Previously Wasted Energy

The single-stage steam turbine has been one of the most successful technologies applied in industry. However, because its average efficiency is only 40%, most of the potential energy generated by this "back pressure" system is wasted. Doubling the efficiency reduces by half the steam flow needed to produce the required power output. Such a dramatic change significantly reduces emissions while increasing the number of cost-effective applications for steam generation.

Douglas Energy, with assistance from the NICE[3] Program and a consortium of project partners, has developed a unique turbine system that dramatically improves generation efficiency. The original technology is limited by the extent of the centrifugal pressure rise in the rotor and the resulting velocity created by expansion through the rotor nozzles. The novel dual-pressure Euler turbine increases the reaction and power by lowering the rotor exit pressure. Harnessing this "reaction" energy allows the single-pressure machine to be converted into a two-stage turbine; it becomes a combined impulse and reaction turbine with internal compression. Compared with traditional technology, turbine efficiency can be increased from an average of 40% up to 80%. A vertical shaft saves space in crowded equipment rooms and enables installation through a standard doorway.



Dual Pressure Euler Turbine

Overview

- Developed by Douglas Energy Company Inc. and licensed to Mafi-Trench Company (www.mafi-trench.com)
- Commercialized in 2004
- 6 units operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.113	0.048

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.006	0.757

Applications

Can be used in place of steam system pressure reduction valves (PRVs)

Capabilities

- Uses energy that is normally dissipated by reducing steam pressure in a PRV, converting the wasted energy into electric power.
- Can achieve overall efficiencies up to 80%.

Benefits

Environmental

Reduces CO_2 and NO_x emissions by 50%.

Productivity

Operates with poor quality steam.

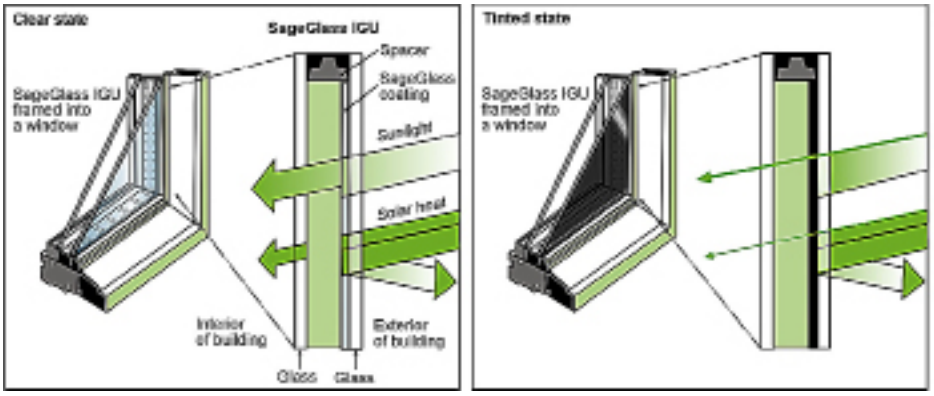
Electrochromic Windows – Advanced Processing Technology

'Smart Glass' Technology Reduces Solar Heat Gain in Buildings

Windows are often the most inefficient part of a building envelope and are responsible for heat loss in cold months and solar heat gain in warm months. Sunlight entering a home can increase cooling loads by up to 20%. In some instances, glare from the sun can make it difficult to see a computer or other LCD screen, requiring the blinds to be pulled, negating the benefits of natural light. Sunlight can also fade furniture, carpets, and drapes, increasing building owners' maintenance costs.

SAGE Electrochromics, Inc., with assistance from DOE's Inventions and Innovation Program, developed SageGlass® product technology to create windows and skylights that switch from clear to dark with the push of a button. Within 5-10 minutes, the electrochromic (EC) glass completely changes, depending on the size and temperature of the pane. The variable tint feature of the glass prevents glare, fading, and heat gain without the loss of a view. Without the drawbacks of traditional glass, this technology allows architects the freedom to design with daylighting, creating well-lit, comfortable buildings.

This EC glass modulates light transmission and solar heat gain by sending an electrical charge through the glass. The glass is made up of five separate layers of ceramic materials; when voltage is introduced, the glass lightens or darkens as needed. The electricity used to operate 1,500 square feet of SageGlass window is less than a 60-watt light bulb. The glass can be altered manually via a wall switch or as part of an integrated building management system so that windows can be programmed to tint depending on input from timers, motion sensors, or similar controls.



SAGE Electrochromics' SageGlass Window Operation

Overview

- Developed by SAGE Electrochromics, Inc. (www.sage-ec.com)
- Commercialized in 2003

Applications

Can be used in any building with windows or skylights, including homes and large public buildings; is particularly appropriate for hospitals, schools, libraries, etc.

Capabilities

- Reduces solar energy by up to 81% in its fully tinted state.
- Prevents sunlight from damaging artwork, furniture, and carpet.
- Reduces glare so windows do not have to be shaded or blocked.

Benefits

Adaptability

Can be configured to operate by a wall switch or as part of a building's automation system and is appropriate for both residential and commercial applications.

Energy Savings

Reduces annual cooling loads in commercial buildings by 20% and peak electricity demand in most of the United States by 19% to 26%.

Energy-Conserving Tool for Combustion-Dependent Industries

IMPACTS

MultiGas™ Analyzer Provides On-Line Feedback Resulting in Lower Energy Use and Emissions

Using a NICE[3] grant, Advanced Fuel Research (AFR), Inc., has developed and demonstrated a new system to improve continuous emissions monitoring (CEM) and on-line process tuning of combustion-dependent systems such as boilers and turbines.

Many existing combustion-monitoring techniques are unable to effectively and efficiently monitor all combustion gases, including difficult-to-separate hydrocarbons such as formaldehyde and emission control reactants such as ammonia. Typical CEM systems monitor a limited number of gases using an expensive collection of single-gas analyzers. These systems require a temperature-controlled room and a substantial ongoing investment to maintain operation and calibration of the facility.

The new multi-gas analyzer technology is portable, low-cost, and energy-efficient and combines advanced Fourier transform infrared spectroscopy with advanced electronics and software. This system provides CEM and on-line feedback for operational tuning of combustion-based industrial processes. The system allows for real-time measurement of criteria emissions and pollutants, including pollutants that are not usually monitored such as formaldehyde and ammonia. The improvements in dependability and efficiency and the lack of need for expansive temperature-controlled space result in lower operations, energy, and labor costs.

Benefits

Environmental

Measures criteria and hazardous air pollutants that are not typically monitored on-site in real-time, such as formaldehyde and ammonia.

Productivity

Reduces maintenance and performance verification time, resulting in labor savings of up to 80%.

Overview

- Developed by Advanced Fuel Research, Inc.
- Commercialized in 2001
- Manufactured and sold by MKS Instruments (www.mksinst.com)
- 44 units operating in the U.S. in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.011	0.003

U.S. Emissions Reductions

(Thousand Tons, 2007)

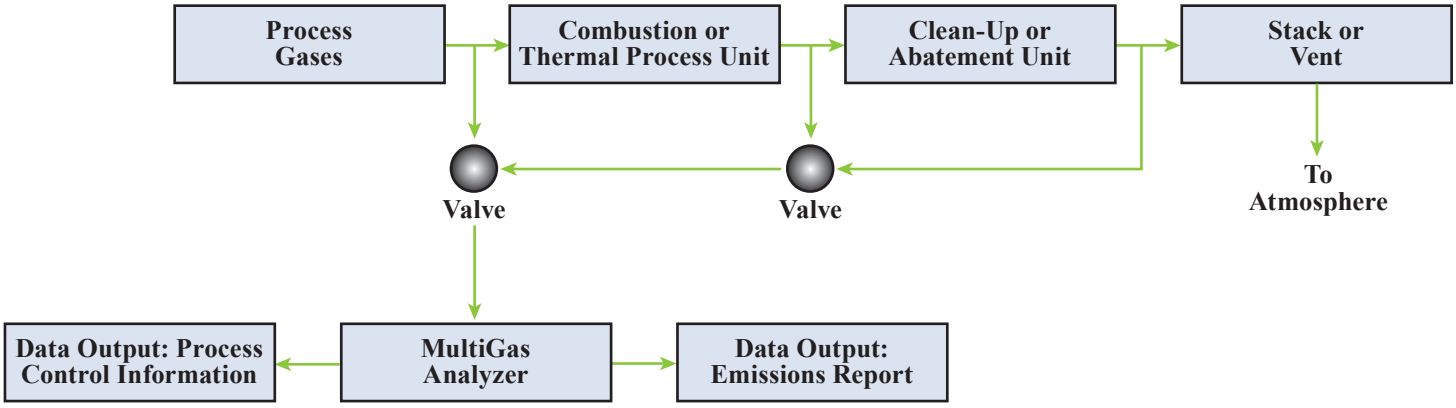
Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.001	0.067

Applications

Can be used in systems and processes requiring combustion of fuels in engines, boilers, incinerators, and turbines

Capabilities

- Achieves higher combustion efficiencies through closely monitored and controlled combustion.
- Reduces emissions through verified efficient operation.



MultiGas Analyzer System

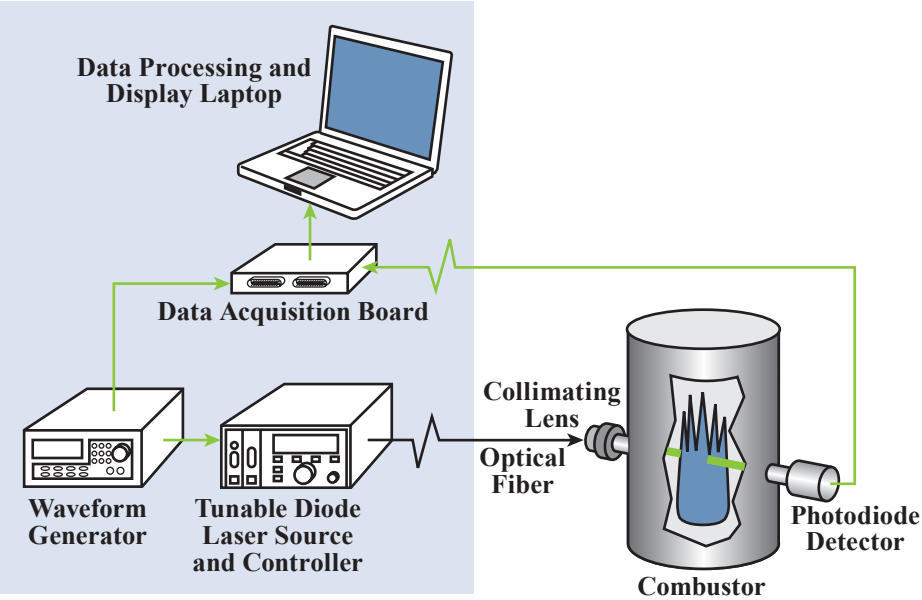
Fiber-Optic Sensor for Industrial Process Measurement and Control

Reliable Advanced Laser Sensor Helps Control High Temperature Gas Combustion

Through a marketing agreement with MetroLaser Inc., Bergmans Mechatronics LLC is offering the LTS-100 sensor to the aerospace and industrial markets. This new sensor will help reduce the cost and improve the performance of traditionally difficult temperature measurements. A separate marketing agreement with LaVision GmbH of Germany has been entered into in which a version of this sensor is marketed to the pharmaceutical industry for leak detection.

Many existing industrial process sensors have limited accuracy in applications involving highly corrosive gases at elevated temperature and pressure because they require extractive sampling systems that introduce variations in the temperature, pressure, and composition of the probed gases. Moreover, sampling systems introduce a lag resulting in >1-10 second response times, require frequent servicing, and may be subject to unexpected failures because of their complexity. Using advanced tunable diode laser absorption spectroscopy (TDLAS) sensors for closed-loop process control affords a direct, quantitative measure of the species concentration in the probed region. In addition, by monitoring two or more transitions, the temperature along the optical path can also be determined.

Near-infrared diode lasers are attractive light sources for sensing applications because they are rapidly tunable, small and lightweight, low-cost, efficient, and robust. They operate at near-ambient temperatures and produce narrow bandwidth radiation over a broad wavelength range. These on-line sensors can be combined with process optimization control strategies to significantly improve plant throughput, increase product quality, and reduce energy consumption and waste.



LTS-100 Processing Unit

Overview

- Developed by MetroLaser Inc., Irvine, CA
- Commercialized in 2003
- Being provided as a service in the United States by MetroLaser (www.metrolaserinc.com)
- Applying a derivative of this technology as a leak detection system for pharmaceutical production lines

Applications

Can be used in coal-fired power plants to achieve accurate real-time temperature measurements, in solid propellant combustion to enhance the capabilities of the next generation of solid-fuel vehicles, and in leak detection for pharmaceutical production

Capabilities

- Monitors high-temperature gas combustion in process control applications.
- Monitors vacuum leaks in pharmaceutical vials using non-intrusive measurements.

Benefits

Profitability

Reduces maintenance costs and minimizes slag buildup heat-transfer losses in coal-fired power plants by precisely controlling furnace temperature and startups.

Reliability

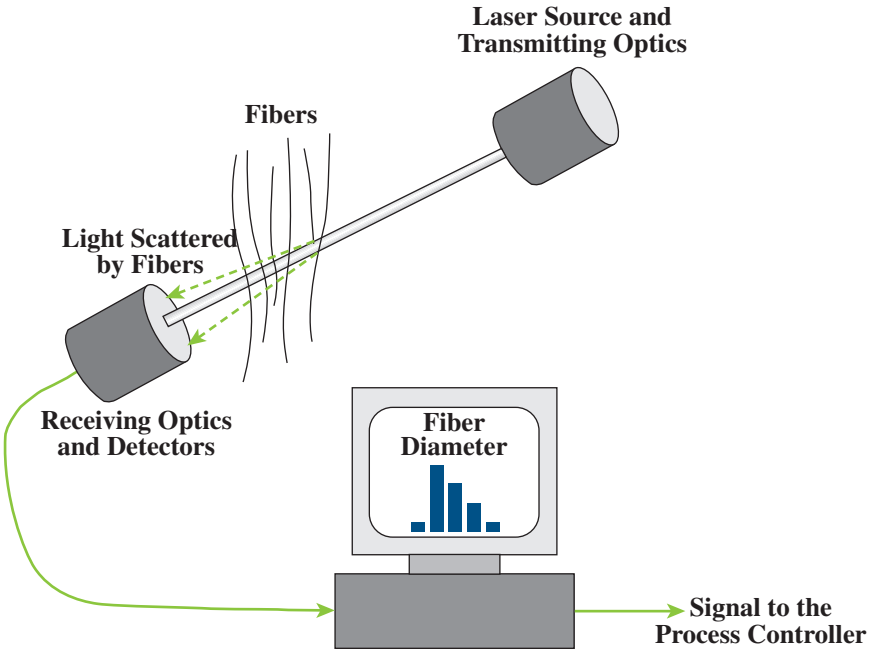
Performs measurements regardless of vibration, flame luminosity, temperature, pressure extremes, and particle interferences.

IMPACTS

Revolutionary Optical Technology Provides Rapid Measurement of Large Samples of Fiber Diameters

Fiber size (or denier) has a significant effect on the performance of fiber-based products, such as filters, insulation, and composites. Fiber samples are generally characterized by optical or electron microscopy. Flow resistance of a sample of fibers (e.g., by the Micronaire™ technique) is also used to estimate the mean fiber size. However, these methods require sampling and are time consuming, and microscopic measurements are usually based on a small number of fibers selected from an image of a collection of fibers and may not be statistically reliable. Rapid measurement of fiber size, based on a large sample, is desirable for quality control of fiber-based products, development of new fiberizing processes, or basic research on fiber generation. With assistance from DOE's Inventions and Innovation Program, Powerscope, Inc., developed FibrSizr™, which provides rapid measurements for both on-line and off-line fiber characterization. The sample size is large and usually consists of hundreds of fibers.

FibrSizr consists of a laser instrument developed for the accurate real-time and in-situ determination of fiber diameter distributions. This device can be used to monitor nonwovens and glass fibers during production and to rapidly measure fiber size distribution in a web sample. This technique is applicable across a wide range of polymers, production methods, and fiber sizes.



Fiber Sizing Sensor/Controller Using Ensemble Laser Diffraction

Overview

- Developed and commercialized by Powerscope, Inc., in 2004 (www.powerscopetech.com)
- Completed sales, lease arrangements, and contract measurements for several major U.S. fiber manufacturers

Applications

Can be used in off-line and on-line process control of fibers on a variety of production/treatment methods such as meltblown, spunbond, meltspun, carded, chemical bonded, needlepunched, spunlaced, stitchbonded, thermal bonded, and rotary fiberizing

Capabilities

- Offers a new model that uses violet laser, instead of red laser, for better resolution of fine fibers as small as 0.7 micron in mean size.
- Provides a detachable transmitter and receiver for applications with limited physical access.
- Covers a wide range of fiber sizes (denier) and fiber densities using adjustable laser power and detector gain.

Benefits

Energy Savings

Eliminates events, such as sudden shutdowns, which result in waste of energy and material, by close monitoring of the process.

Pollution Reduction

Minimizes release of pollutants such as CO_2 from the pertinent combustion processes by operating the fiberizers at near optimal conditions.

Product Quality

Measures and controls fiber size distribution, which is a critical element in producing nearly all value-added fiber products.

Foamed Recyclables

New Process Allows Coal Ash to be Made into Building Material Products

With a grant from DOE's Inventions and Innovation Program, Century-Board USA, a licensee of Ecomat, Inc., has a fully developed process to convert solid wastes into synthetic building materials.

The process consists of mixing up to 85% solid waste into a modified polyester polyurethane resin with special additives. This polymer system is a thick liquid that is poured into discrete molds or continuously cast, as is done with the "plastic" lumber. This thick liquid then forms and fills all the crevices of the mold and produces a lightweight, hard, and tough product. The material does not contain thermoplastics such as polyethylene or PVC, wood, or sawdust unless requested by the customer.

Benefits

Productivity and Profitability

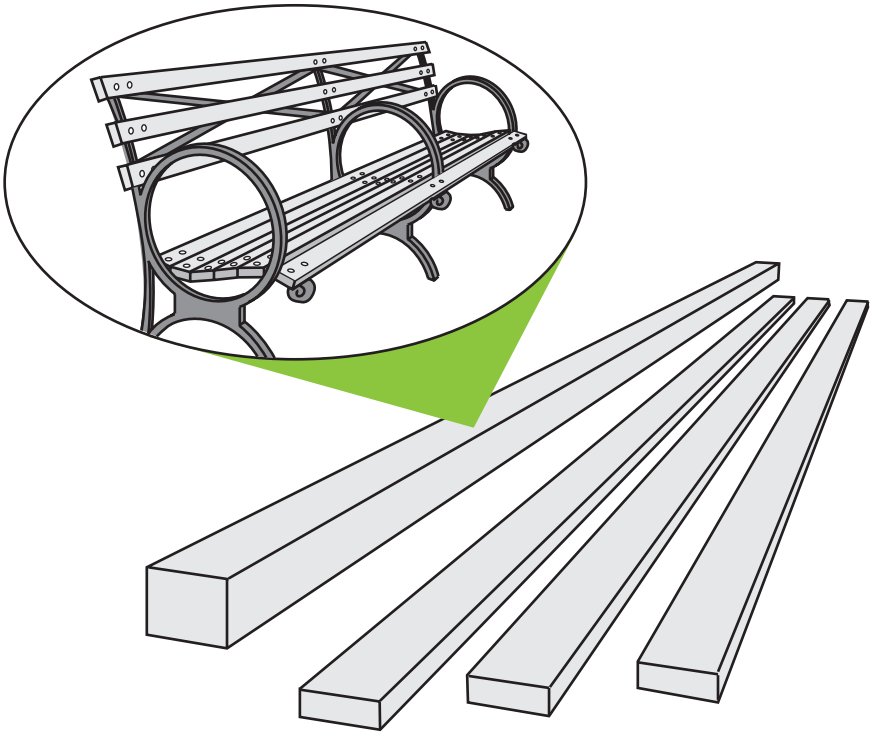
Offers a lower cost than many competitive materials and can be reground and reused in the same process. It is lightweight and can be 1/10th the density of concrete.

Product Quality

The synthetic building material products are maintenance-free, fire and weather resistant, lightweight, and tough.

Waste Reduction

Reduces landfilling of coal ashes from utility power plants.



Foamed Recyclable Building Material

Overview

- Developed by Century-Board USA (www.centuryboardusa.com)
- One U.S. commercial plant operating with the capacity to process 1 ton/hr of coal fly ash to make plastic lumber, siding, and fencing
- A second plant is making synthetic structural lumber in a pilot plant using coal fly ash as the main ingredient

Applications

Can be used to make products such as roof tiles, artificial slate, siding, molding, doors, utility poles, marine and dimensional lumber, picture frames, office partitions, and wallboard

Capabilities

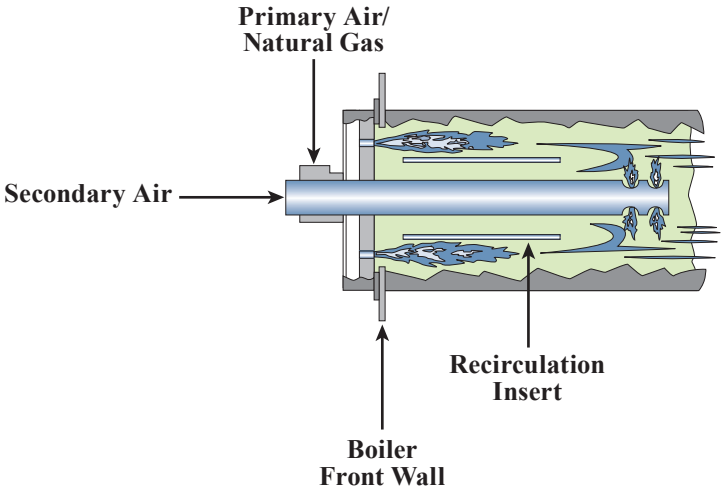
Have successfully tested the following in their process as the major ingredients: waste glass, sand, ashes from wood and municipal waste burning, waste from metal smelting, red mud from aluminum refining, coral dust, granite fines, agricultural plant ashes, waste cotton and polyester fibers, heavy metal contaminated waste, contaminated soil, foundry sand, sewage sludge, and slate dust.

IMPACTS

New Burner Significantly Reduces Emissions Compared with Conventional Technology

The forced internal recirculation (FIR) burner combines several techniques to dramatically reduce NO_X and CO emissions from natural gas combustion without sacrificing boiler efficiency. One technique is premixed substoichiometric combustion and significant internal recirculation of partial combustion products in the first stage to achieve stable, uniform combustion that minimizes peak flame temperatures and high oxygen pockets. Other techniques include enhanced heat transfer from the first stage to reduce combustion temperatures in the second stage and controlled second-stage combustion to further minimize peak flame temperature. As a result, the burner minimizes overall NO_X formed in the combustor.

The FIR burner was developed by the Gas Technology Institite and several sponsors, including ITP. The FIR burner technology is licensed to Johnston Boiler Company (firetube boiler applications), Coen Company, Inc. (packaged watertube boiler applications), and Peabody Engineering Corporation (field-erected boilers in the steel industry). The burner is applicable to a wide range of firetube boilers from 50 to 100 MMBtu/hr. The technology is currently being tested for applications in packaged watertube boilers and multi-fuel burners for the steel industry.



Forced Internal Recirculation Burner

Overview

- Developed by the Gas Technology Institute
- Marketed by Johnston Boiler Company for firetube boilers (www.johnstonboiler.com)
- Operating on 50 boilers in 2007

Applications

Currently used in firetube boilers and being developed for watertube boilers and field-erected boilers for the chemicals, petroleum products, food, and steel industries

Capabilities

- Minimizes thermal and prompt NO_X through staged combustion with internal recirculation of products of partial combustion.
- Is suitable for new or retrofit applications on a wide range of combustion chamber configurations.

Benefits

Emissions Reductions

Results in very low NO_X emissions, less than 9 ppm, without using diluents such as steam, water, or external flue gas recirculation.

Productivity

Increases system efficiency, with operation at less than 15% excess air over the entire turndown range of four to one.

Profitability

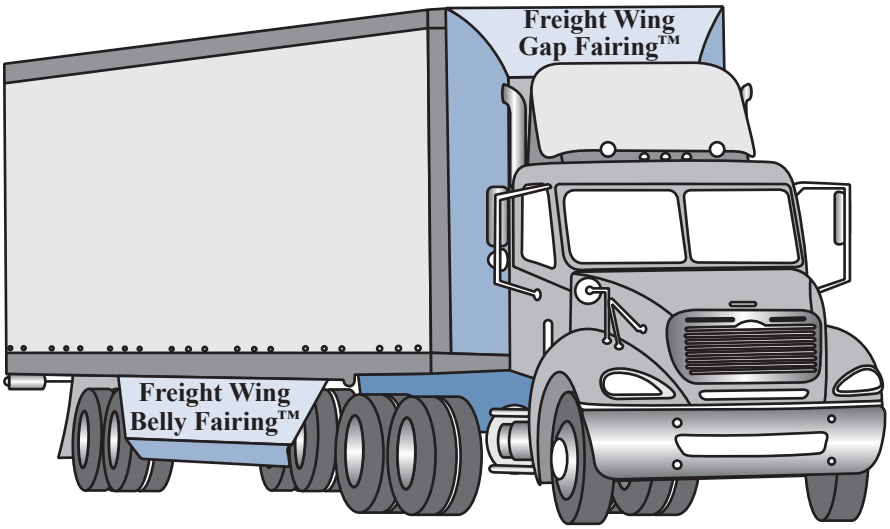
Reduces developmental, operating, maintenance, and capital costs compared with "current generation" low-NO_X burner systems.

Freight Wing™ Aerodynamic Fairings

Innovative Aerodynamic Fairings Minimize Drag on Box-Shaped Semi-Trailers

A great deal of scientific research has demonstrated that streamlining box-shaped semi-trailers can significantly reduce a truck's fuel consumption. However, significant design challenges have prevented past concepts from meeting industry needs. Freight Wing, Inc., was formed to improve the fuel efficiency and profitability of trucking fleets through innovative aerodynamic devices. Freight Wing was initially funded through a grant from DOE's Inventions and Innovation Program to develop rear-fairing technology and has since expanded the company's products to a complete line of aerodynamic solutions. Their initial research focused on developing a practical rear fairing that would not interfere with the truck's operation and on investigating other means to reduce aerodynamic drag on box-shaped semi-trailers. Freight Wing market research soon revealed that the industry was not very interested in the rear fairing because that area is extremely prone to damage and durability is a primary concern. Consequently, the company has since focused on developing designs for front or gap fairings and undercarriage or belly fairings.

Freight Wing generated prototypes of all three fairing designs with their manufacturing partner, ASAP Metal Fabricators, in early 2004. In May 2004, Freight Wing tested all three fairing prototypes at the independently owned Transportation Research Center (TRC) in East Liberty, Ohio. TRC tested the fairings using the industry standard Society of Automotive Engineers/ Technology & Maintenance Council (SAE/TMC) J1321 fuel consumption procedure Type II test. A 7% fuel savings was demonstrated on trailers equipped with all three fairings. The product was marketed starting in the fall of 2004, and soon thereafter the company made its first sale of two belly fairings. Additional research was conducted to develop second-generation designs using different materials and aerodynamic concepts. The resulting second-generation belly fairing product produced a 5.8% fuel savings alone in SAE tests and in fleet operation. In 2007, Freight Wing sold 245 fairings to new and repeat customers, who have provided positive feedback regarding product performance.



Freight Wing Fairings Installed on a Semi-Trailer

Overview

- Developed and marketed by Freight Wing, Inc. (www.freightwing.com)
- Commercialized in 2004
- Currently used by over 65 trucking fleets in the United States and Canada

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.058	0.037

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.022	0.006	0.809

Applications

Can be used on trucks or semi-trailers to reduce the effects of aerodynamic drag

Capabilities

- Reduces aerodynamic drag on semi-trailers.
- Retrofits on existing or new semi-trailers.

Benefits

Energy Savings

Reduces fuel consumption by up to 6% with belly and gap fairings.

Emission Reduction

Reduces emissions of combustion products, including particulates, SO_X, NO_X, and CO_2.

Functionally Graded Materials for Manufacturing Tools and Dies

New Material Processes Improve the Performance and Lifetime of Tools and Dies

Tools, dies, and process equipment currently used in the metal casting, forging, and glass manufacturing industries are generally composed of thick-sectioned monolithic H13 or other tool steels. Although the starting materials are relatively inexpensive, the conventional tool manufacturing process results in low material yields, significant machining time, long lead times, and high overall cost. When the dies contact either hot/molten metals or glass, as appropriate, significant degradation of the surfaces occurs due to soldering, heat checking, and/or physical erosion. Damaged dies lead to part surface imperfections, dimensional tolerance issues, high part reject rates, and die repair downtime.

With assistance from ITP, Carpenter Powder Products, Inc., has developed functionally graded materials (FGM) to produce more robust tools and dies. The techniques of laser powder deposition and solid-state dynamic powder consolidation result in FGM tools and dies with increased wear resistance and superior performance at elevated temperatures.

Functionally graded materials provide many benefits to the industrial process user. The tools and dies perform better, which leads to shorter process cycle times and a reduction in waste scraps from parts manufacturing. In addition, FGM parts have a longer lifetime than traditional tools and dies, which reduce replacement costs.

Benefits

Adaptability
Allows properties of functionally graded tools to be customized to meet the requirements of a particular application.

Cost Savings
Increases tool and die lifetimes, thereby reducing the cost to replace parts.

Waste Reduction
Reduces scrap and waste in tool and die parts manufacturing.

Overview

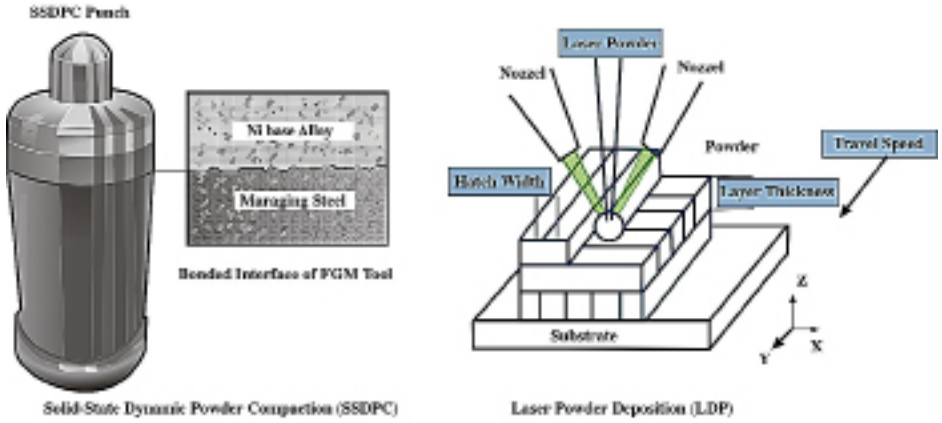
- Developed by Carpenter Powder Products, Inc. (www.cartech.com)
- Commercialized in 2007
- Used by multiple U.S. metal forging and die casting companies in 2007

Applications

Can be used in the aluminum, forging, glass, metal casting, and steel industries

Capabilities

- Improves elevated-temperature properties of tools and dies.
- Reduces die surface degradation.
- Increases wear resistance and dimensional stability of tools and dies.
- Reduces process cycle times.



Two Manufacturing Processes Used to Produce FGM Tools

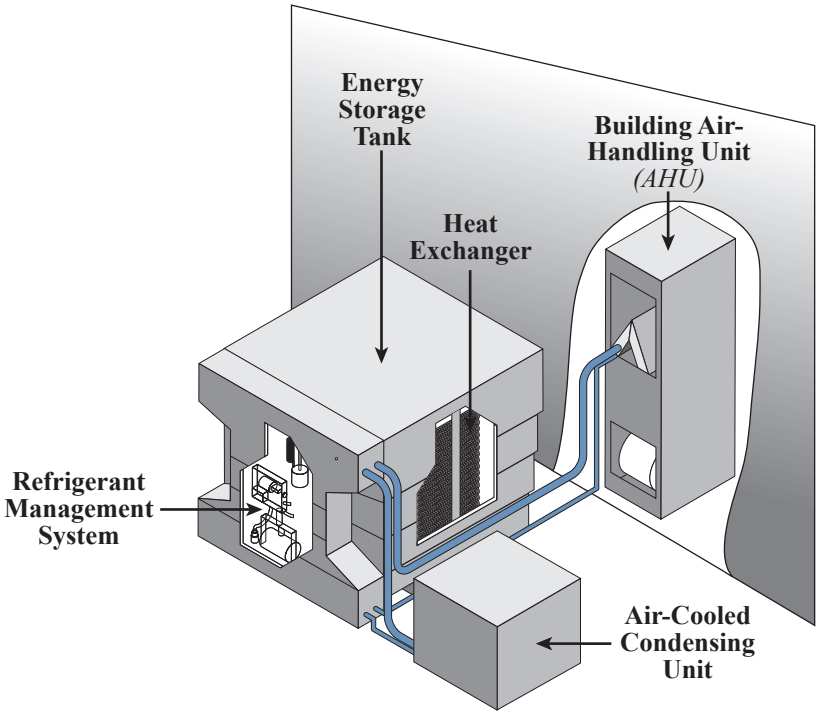
Ice Bear® Storage Module

Thermal Energy Storage for Light Commercial Refrigerant-Based Air Conditioning Units

The Ice Bear® storage technology was initially developed by Powell Energy Products, with assistance from DOE's Inventions and Innovation Program and commercialized by Ice Energy®, Inc. The Ice Bear storage module was engineered to complement new or existing air conditioning (AC) equipment to shift energy use from peak to off-peak periods. The Ice Bear unit is designed for use with rooftop or split system AC equipment. The Ice Bear unit with an air-cooled condensing or rooftop unit operates during off-peak hours to store energy as ice. During peak daytime cooling, the Ice Bear unit functions as the condenser, circulating ice-condensed refrigerant with a low-power refrigerant pump. Total energy use is only 300 watts to provide 7.5 tons of cooling for 6 hours.

The Ice Bear unit consists of a heat exchanger made of helical copper coils placed inside an insulated polyethylene storage tank filled with normal tap water, a patented refrigerant management system, a low-power refrigerant pump, and the CoolData® controller. To provide AC, the Ice Bear uses a low-power pump to circulate refrigerant to the evaporator coil in the air handler. By using the condensing or rooftop unit to produce ice during the night and the refrigerant pump to supply condensed liquid refrigerant to the evaporator coil during the day, the Ice Bear effectively transfers the majority of load requirements to nighttime hours or levels energy loads. In both of these applications, the Ice Bear reduces humidity levels, which helps meet indoor air quality standards.

The Ice Bear unit is designed to meet retrofit, replacement, and new construction requirements in commercial or industrial AC applications.



Ice Bear Storage Module

Overview

- Base technology developed by Powell Energy Products, Inc., and patents acquired by Ice Energy, Inc. in 2003
- Commercialized by Ice Energy, Inc. in 2005 (www.ice-energy.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.001	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.010

Applications

Can be used in conjunction with 3.5-to-20 ton AC units in markets such as small to big-box retail, industrial, data centers, office buildings, restaurants, banks, fire stations, libraries, schools, and community centers

Capabilities

- Shifts 95% of AC load from peak to off-peak periods.
- Offers energy storage capacity of 45-ton/hr, up to 7.5 tons of cooling for 6 hours.

Benefits

Cost Savings

Substantially reduces electrical bills in load-shifting applications where peak and off-peak price differentials exist by reducing demand by 95%.

IMPACTS

Redesigned Diesel Engines Improve Heavy Truck Fuel Economy

The KIVA computer model resulted from the efforts of a diesel engine working group formed in 1979 as part of DOE's Energy Conservation and Utilization Technologies (ECUT) Division's Combustion Technology Program. The goal of this activity was to guide the development and application of diagnostic tools and computer models. Under the guidance of DOE and the Cummins Engine Company, 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 see the effects of alterations to engine geometry without actually building the engine. Cummins Engine Company has used KIVA to make 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 savings in fuel.

Energy savings from this development are based on the number of trucks (class 7 and 8) powered by Cummins engines. This value, multiplied by the savings per mile and the number of miles driven per year, results in the estimated annual energy savings.

Benefits

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

Productivity
Reduces time required from engine design to production.

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

Overview

- Developed by Los Alamos National Laboratory, Sandia National Laboratories, Southwest Research Institute, and others
- Commercialized in 1991
- First used by Cummins Engine Company to redesign diesel engines for improved energy efficiency

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1107	47.0

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.353	27.3	7.26	1020

Applications

Can be used in visualizing the effect of design changes on engine performance, in assessing engine ability to use alternative fuels or reduce emissions, and in optimizing engine operation to reduce emissions

Capabilities

- Simulates precombustion fluid motion, chemical kinetics, flame propagation, and combustion dynamics in engines.
- Investigates airflow and diesel spray characteristics nonintrusively.

In-Situ, Real Time Measurement of Elemental Constituents

New Laser System Provides Real-Time Measurements for Improved Product Quality Control

A probe uses laser-induced breakdown spectroscopy (LIBS) to determine the elemental constituents in ferrous and non-ferrous metals, ceramics, or glass. This probe measures continuously and in-situ at any point in the melt, thus providing spatial and temporal real-time data. The probe uses a pulsed (5-10 ns duration) Nd:YAG laser at 1064 nm that is focused, through a fiber-optic cable. In the molten aluminum application, the probe is immersed into the melt, generating high-temperature plasma consisting of excited neutral atoms, ions, and electrons. Any chemical compounds present in the sample are rapidly separated into their constituent elements. The laser-generated plasma is allowed to cool several microseconds after the laser pulse, and then a spectrometer collects and disperses optical emissions from neutral and ionized atoms. The line radiation signal provides the concentration of each element present.

The probe has several applications in the ferrous and non-ferrous metals, ceramics, or glass industries. For example, the probe can be used for in-line alloying to measure chemical content during a pour and for continuous and semi-continuous furnace operations to minimize the current practice of off-line sampling and measurement. In other applications, the probe can perform in-line monitoring of impurity removal from the melt, such as removing magnesium from molten aluminum, and can provide real-time data to validate computer simulations and model furnaces.

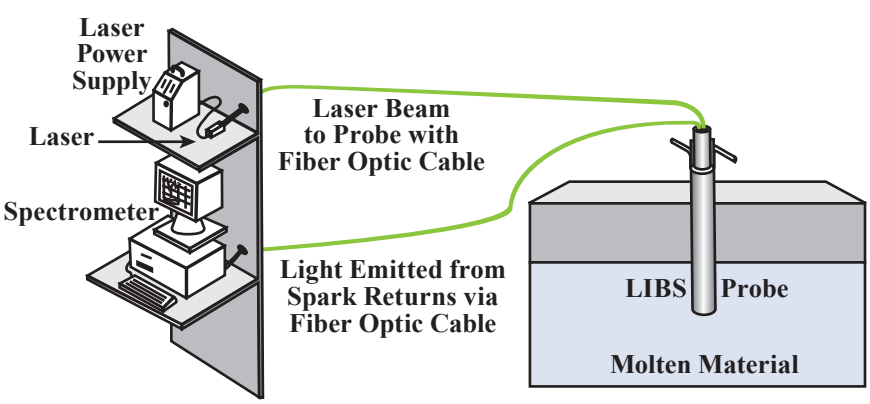
Benefits

Productivity and Profitability

Eliminates the aluminum and steel furnace idle time now required for off-line measurement of melt constituents. The payback has been shown to be less than one year.

Product Quality

Providing data for use in a feedback control loop to control the furnace operation in real time increases product quality.



Example of LIBS System Applied to Molten Material

Overview

- Developed and marketed by Energy Research Company (www.er-co.com)
- Installed in an aluminum plant in 2003
- Installed in a glass plant in 2004

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.926	0.222

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.026	3.53

Applications

Can be used in identify elemental constituents in ferrous and non-ferrous metals, ceramics, and glass melts during the fabrication process; to identify elemental constituents of wet or dry, solid or gaseous raw materials via close non-contact; and to characterize coal sample constituents to determine coal quality

Capabilities

- Measures aluminum melt constituents with 5% accuracy and a 0.002% minimum detection limit.
- Monitors trace alkali metal content in electronic glass compositions.
- Analyzes material being conveyed prior to processing, potentially eliminating energy use and emissions from using "off-spec" material.

Materials and Process Design for High-Temperature Carburizing

IMPACTS

New Class of High-Performance Carburized Steels Saves Energy and Increases Productivity

Various project partners have integrated an optimization of process and materials that will enable a broad usage of high-temperature carburization. The unique capabilities of high-temperature carburizing were exploited to access new levels of steel performance, including the distortion-free, high-performance gear and bearing materials for the transportation sector. Emphasis was placed on creating a new class of thermally stable, ultra-durable, deep case-hardened steels that could ultimately extend case hardening to tool and die steels. Case hardening would enable major productivity gains in the forging, forming, and die casting of aluminum and steel.

With assistance from ITP, a consortium of project partners used their carburization simulation tools and fundamental calibration data to gain reliable control of high-temperature carburizing of their new class of high-performance gear steels. One of the partners, QuesTek, used the technology to successfully commercialize the new gear steels by demonstrating both higher gear performance and acceptably reduced manufacturing variation.

Benefits

Energy Savings
Reduces the U.S. annual energy consumption for carburizing.

Environmental
Reduces greenhouse gases compared with conventional gas carburizing technology.

Productivity
Reduces scrap and eliminates the need for hard chromium plating in many applications; offers increased durability and higher performance when it replaces conventional steel.

Overview

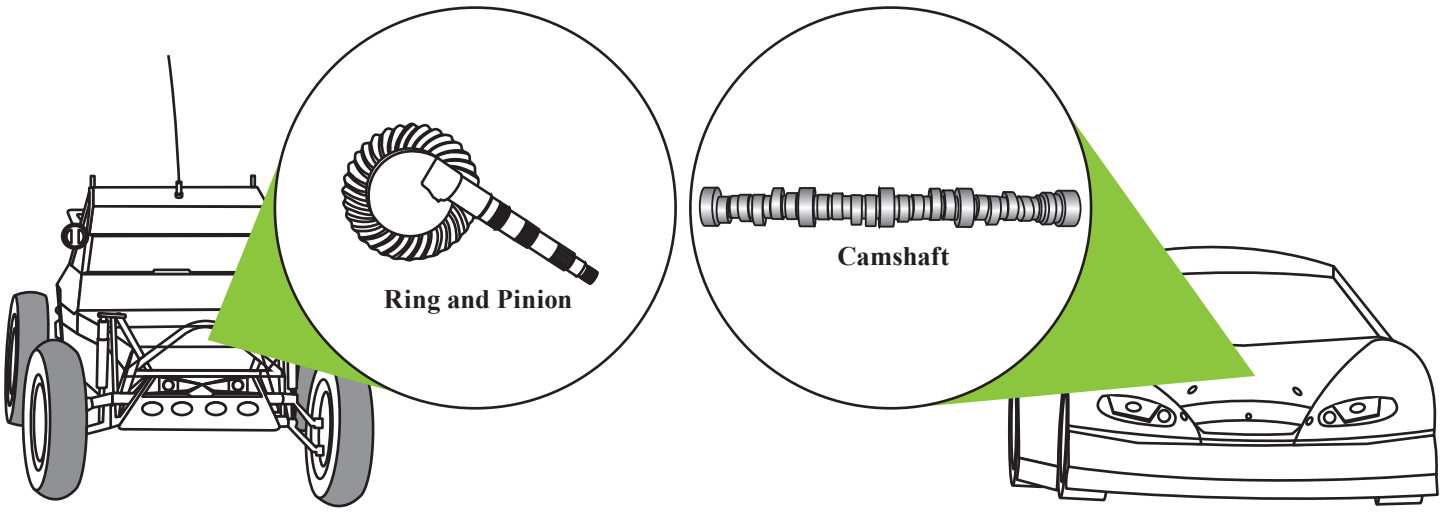
- Developed by a consortium of project partners including the Center for Heat Treating Excellence, Metal Processing Institute – Worcester Polytechnic Institute, Northwestern University, and QuesTek
- Commercialized by QuesTek in 2003 (www.questek.com)

Applications

Can be used in high-performance gear and bearing applications for the transportation sector and in new deep-case applications, include ultra-durable die materials for forging and forming of steel and aluminum and for die casting of aluminum

Capabilities

- Establishes sufficient control of high-temperature carburizing to greatly expand applications.
- Creates a new class of steels with particular emphasis on novel deep-case applications.
- Demonstrates accelerated materials and process development through the emerging technology of computational materials design.



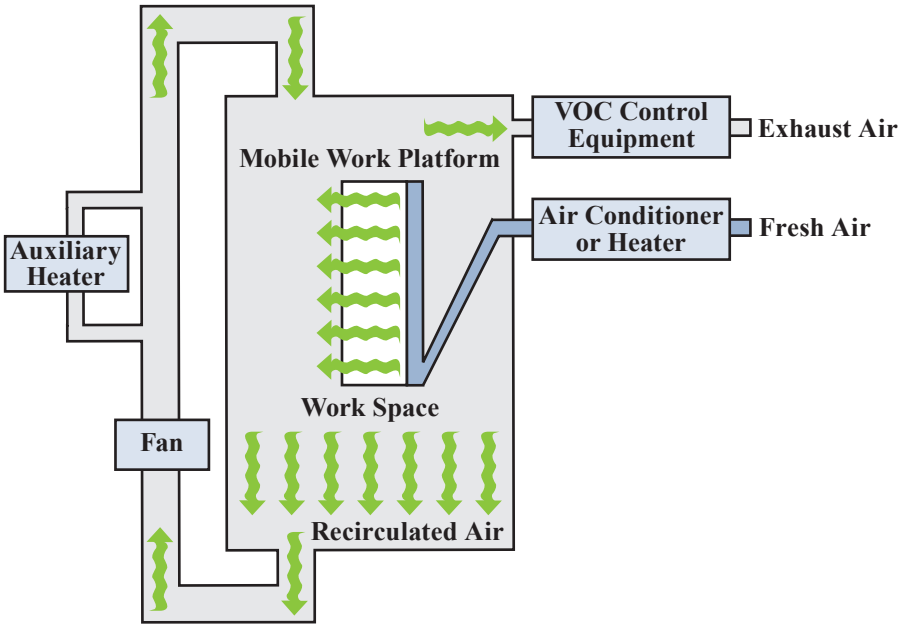
New Gear Steel Products Created Using High-Temperature Carburizing

Mobile Zone Optimized Control System for Ultra-Efficient Surface-Coating

New Surface-Coating Ventilation System Reduces Air Pollution and Energy Use

Volatile organic compounds (VOCs) are released during the application of spray coatings in paint enclosures, exposing workers to toxins, creating air pollution emissions, and creating fire or explosion hazards. To meet safety and environmental regulations, paint booths are usually ventilated with 100% outside air, which is then heated or cooled to maintain useable work temperatures. Ultimately, the amount of ventilating air entering the spray booth (usually expressed as cubic feet per minute) determines the energy usage and scale of the pollution problem.

A new spray booth technology developed by Mobile Zone Associates, with the help of a grant from the EPA and DOE's Inventions and Innovation Program, greatly reduces the amount of energy needed to heat and cool ventilation air during surface coating operations by reducing the quantity of ventilating air consumed. The Mobile Zone system separates the human painter from the contaminated air of the spray booth by providing the painter with a separate, mobile work platform or cab during spray coating operations. The cab is flushed with fresh air, while the rest of the spray booth uses recirculated air. The design meets OSHA regulations and National Fire Protection Association (NFPA) guidelines. Excluding robotic painting operations, the Mobile Zone installation is the only successful example of substantial ventilating air reduction in the United States and possibly the world. It represents superior process containment and is a first step before consideration of air-to-air heat exchange or VOC pollution-control equipment. The technology is currently being used by the U.S. Army at Fort Hood, Texas, for consideration of system wide use.



Air Flow in Paint Spray Booth with Mobile Zone System

Overview

- Developed by Mr. Clyde Smith and Mr. William Brown of Mobile Zone Associates (www.mobilezonepaintbooth.com/aboutus.html)
- One installation operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.045	0.007

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.001	0.120

Applications

Can be used to apply sprayed surface coatings to chairs, tables, motorcycles, tractors, railroad cars, aircraft, and other painted products in either side-draft or down-draft booths

Capabilities

Reduces the ventilation, heating and cooling requirements by directing a sufficient, but small, amount of fresh air to the painter and recirculated air to the remaining unoccupied space within the spray booth. Meets existing OHSA, EPA, and NFPA standards for worker conditions.

Benefits

Profitability

Reduces the size of heating, cooling, and pollution control equipment between 60% and 98%, which offers significant savings in associated capital and energy costs.

Productivity/Product Quality

Maintains or improves production speed and quality.

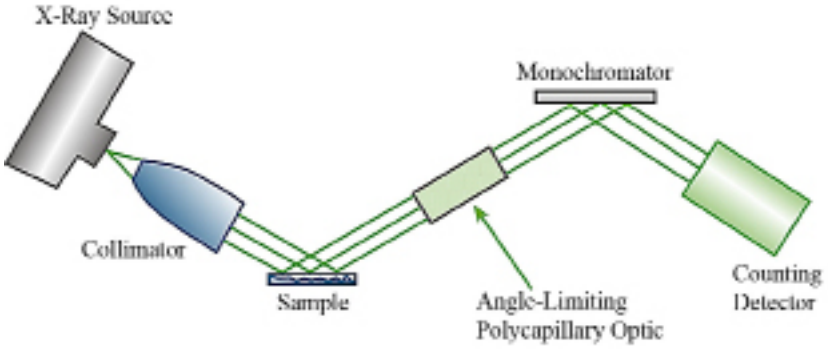
Portable Parallel Beam X-Ray Diffraction System

IMPACTS

New, Low Power System Reduces Energy Consumption and Improves Process Efficiency

Real-time, nondestructive, in-line measurements of material properties are needed for process control in metallurgical manufacturing. With ITP support, X-Ray Optical Systems, Inc., developed the X-Beam®, a portable x-ray diffraction (XRD) system that can be used to identify structural phases, determine grain size, and measure stress and texture of materials in line. XRD is widely used in laboratories to determine these material properties, but conventional XRD techniques usually cannot be used for in-line monitoring because they require sophisticated sample preparation, weigh hundreds of pounds, require water cooling, and consume several kilowatts of power (8 to 24 kW).

The X-Beam provides real-time material characterization capability, is portable, weighs no more than 50 pounds, and uses about 50 watts of power. The X-Beam uses polycapillary x-ray optics to collect x-rays over a large solid angle from a low-power x-ray source and to form an intense quasi-parallel beam. This system eliminates the problem of misalignment and provides significantly more diffraction intensity than current Bragg-Brentano XRD systems. The parallel beam geometry also eliminates the instrument error functions that contribute to asymmetric peak shape broadening: flat specimen, axial divergence, sample displacement, and sample transparency.



X-Ray Optical System's Parallel Beam XRD Process

Overview

- Developed by LTV Steel Technology Center and X-Ray Optical Systems, Inc.
- Commercialized in 2007
- Marketed by X-Ray Optical Systems, Inc., with over 115 units sold worldwide (www.xos.com)

Applications

- Can be used wherever elemental analysis is required, including protein crystallography
- Can be used by industrial sectors, including steel, aluminum, cement, pharmaceutical, and semi-conductor

Capabilities

- Provides continuous in-line monitoring of phase, grain size, grain orientation (texture), and residual stress of steel.
- Provides real-time, nondestructive, in-line measurements of material properties using XRD or x-ray fluorescence.

Benefits

Energy Savings

Uses 90% less energy then the standard rotating anode x-ray system and operates without a water cooling loop.

Portability

Decreases measurement system weight compared with the current XRD systems (from 200 to 1,000 kg to 20 kg) and volume from the current 2 m^3 to 0.04 m^3.

Productivity

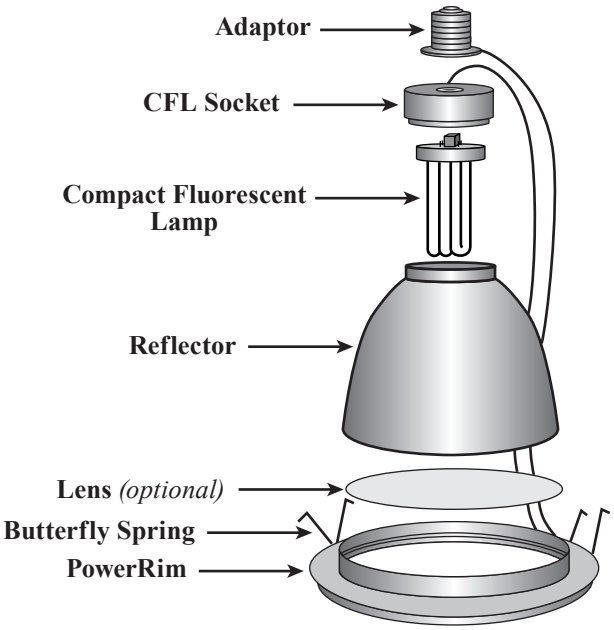
Allows process control in the steel, pharmaceutical, nano-material, and plastics and polymer industries.

PowerRim™ High Wattage Energy Saving Compact Fluorescent Lamp (CFL) Adaptor for Recessed Down Lights

New Innovative Design Allows CFLs to Replace Higher-Wattage Incandescent Down Lights

Compact fluorescent lighting has long been an attractive, energy-efficiency alternative to incandescent lamps. Compact fluorescent lamps (CFLs) use one-fourth the electricity and last nearly 10 to 13 times longer than incandescent bulbs. Many commercial settings – malls, hotels, motels – are excellent sites for CFLs. A few manufacturers have designed down light fixtures specifically for use with CFLs, but these lines continue to be a minor portion of all the recessed down light fixtures produced. Efforts also have been made to develop adaptors for retrofitting incandescent fixtures with CFLs but have been only marginally successful because the adaptors are restricted to lower-wattage applications (e.g., 10-W and 15-W CFLs), which do not produce enough light for the intended application.

PowerLux Corporation, with the aid of a grant from DOE's Inventions and Innovation Program, developed, built, and tested the PowerRim high-wattage CFL adaptor for recessed down lights. PowerRim is a retrofit adaptor kit that allows 100-W to 200-W incandescent lights to be converted to higher-wattage CFLs. The ballast is located at ceiling level keeping it cooler, thus extending ballast life and improving operating efficiency. The use of an optional glare shield placed below the lamp further reduces the operating temperature of the ballast, thus increasing its life and its efficiency. In addition, the glare shield radiates light out from the fixture, using it more efficiently.



Components of the PowerRim Adapter Kit

Overview

- Developed and marketed by PowerLux Corporation (www.powerlux.com)
- Commercialized in 1998 with more than 47,000 installations through 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.330	0.077

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.017	0.012	1.52

Applications

Can be used in down lighting in industrial, commercial, or residential settings such as classrooms, data centers, malls, restaurants, airports, hotels and motels and can be used in retrofit or new construction

Capabilities

- Allows CFL to screw into an incandescent socket of down light.
- Reduces temperature of ballast and allows use of higher-wattage CFL because of the glare shield below the lamp.
- Installs without needing an electrician because the existing fixture is not removed.
- Reduces loss of conditioned air from recessed cans.

Benefits

Operations and Maintenance

Requires less labor to install and lasts longer than other bulbs.

Waste Reduction

Costs less to use than incandescent light bulbs and saves energy.

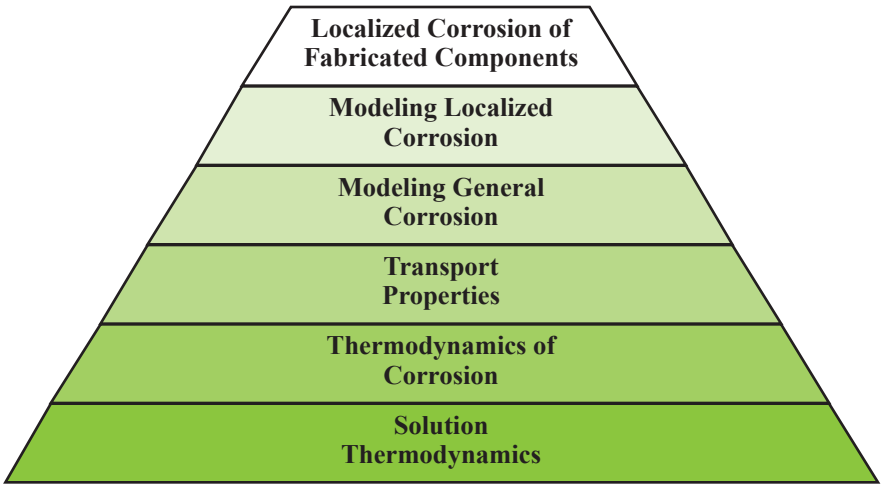
Predicting Corrosion of Advanced Materials and Fabricated Components

Corrosion Prediction Software Tool Facilitates Selection and Development of Corrosion-Resistant Alloys

Based on the fundamental understanding of corrosion phenomena, OLI Systems, Inc., with assistance from ITP, developed the CorrosionAnalyzer, a methodology that simulates the electrochemical reactions and associated physical processes responsible for corrosion at the metal/aqueous solution interface. The simulation methodology predicts the susceptibility of fabricated components to localized corrosion as a function of alloy composition, fabrication procedures, and external environmental conditions.

To predict the occurrence of localized corrosion, the system relies on the computation of the corrosion and repassivation potentials as functions of solution chemistry and temperature. The corrosion potential is calculated from a mixed-potential model that has been verified by calculating corrosion rates in mixed acids and corrosion potential as a function of pH and concentration of oxidizing species. The repassivation potential is calculated from a separate model that quantitatively considers competitive processes at metal/salt film/solution interfaces in the limit of repassivation. This model has been shown to be accurate for reproducing the repassivation potential for mixtures containing both aggressive and inhibitive ions. The combined predictive methodology has been extensively validated for engineering alloys using both laboratory and plant data.

This system combines fundamental understanding of mechanisms of corrosion with focused experimental results to predict the corrosion of advanced, base, or fabricated alloys in "real-world" environments encountered in the chemical industry. Users are able to identify process changes, corrosion inhibition strategies, and other control options before costly shutdowns, energy waste, and environmental releases occur. These innovative corrosion mitigation measures can be tested in a virtual laboratory without risking the plant. The "useful remaining life" can be predicted based on operating experience and projected operating conditions so that catastrophic failures can be avoided and well-planned corrosion control and maintenance actions can be proactively scheduled.



Structure of Corrosion Prediction Model

Overview

- Developed and marketed by OLI Systems, Inc. (www.olisystems.com)
- Commercialized in 2005
- 24 companies leasing the CorrosionAnalyzer in the United States and 41 outside the United States

Applications

Can be used in industries where fabricated components are exposed to corrosive environments, including chemicals, forest products, and petroleum industries

Capabilities

- Predicts the tendency of alloys to corrode as a function of environmental conditions.
- Predicts the tendency for localized corrosion and corrosion damage as a function of time.

Benefits

Efficiency
Reduces waste and environmental damage, and improves risk management.

Energy Savings
Reduces process losses, improves thermal efficiencies due to more optimum design of components, and reduces heat transfer losses attributable to corrosion and corrosion by-products.

Productivity
Improves component life and reduces unscheduled downtimes.

Process Particle Counter

New Particle-Size and Concentration Monitor Leads to Efficient Use of Lower-Quality Fuels

While both gas turbines and power-recovery expanders used in petroleum power generation are efficient energy-conversion devices, fuel quality limits the application of these technologies. Widely available low-cost fuels generally contain more contaminants, which can lead to system fouling and wear as well as downtime for repair and cleaning. Without continuous monitoring for particulate contamination and feedback control, systems must be set for unknown conditions, so the more-efficient gas turbines and power-recovery expanders are not installed or, if installed, operate at lower efficiency.

With assistance from ITP and a grant from DOE's Inventions and Innovation Program, Process Metrix LLC developed a real-time laser-optical process particle counter/sizer (PPC). The PPC can be used as a short-term or automated long-term sensor and control system for dust monitoring of expanders/gas turbines and process stacks. The PPC uses optical technology with fixed alignment to provide a continuous, real-time, robust, standalone particulate monitor that allows expanders and gas turbines to operate closer to optimum conditions. Such conditions improve efficiency while protecting turbines, allowing use of lower-quality fuels.

Benefits

Durability
Protects turbines from high particulate concentrations that lead to blade wear.

Emissions Reductions
Decreases emissions by improving power-generation efficiency.

Energy Savings
Could save 20 billion Btu of natural gas per installation annually.

Productivity
Allows high-efficiency turbines to be installed in more applications and reduces production downtime from failures caused by particulate contamination.

Overview

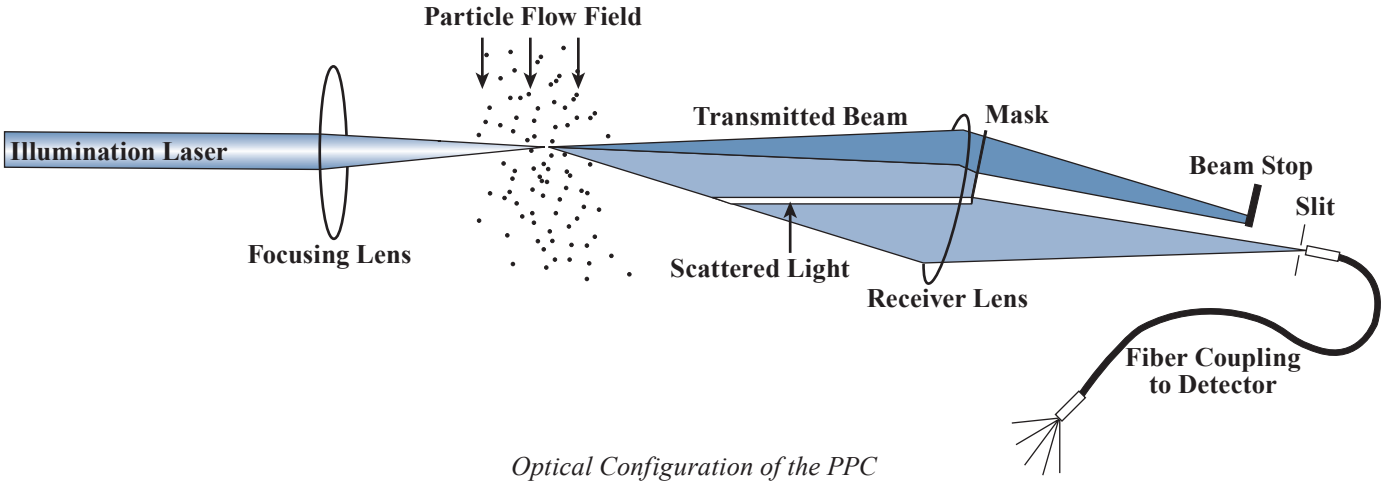
- Developed and being marketed by Process Metrix, LLC (formerly Insitec) (www.processmetrix.com)
- Commercialized in 2004
- Ten units being used in the United States in 2007

Applications

Can be used in petroleum power generation both for existing power-recovery expanders and in situations where power-recovery expanders have not been used because of unreliable fuel quality and return on investment concerns

Capabilities

- Monitors gas-phase particle contamination at low concentration using single particle counting.
- Measures size, concentration, and velocity of gas particles in real-time.
- Operates in-situ at industrial high temperatures/pressures.
- Uses diffraction light scattering with minimum shape and refractive index sensitivity.



Optical Configuration of the PPC

Pulsed Laser Imager for Detecting Hydrocarbon and VOC Emissions

IMPACTS

Advanced System Safely and Effectively Detects Leaks and Emissions Without Requiring an Air Sample

With assistance from DOE's Inventions and Innovation Program, LaSen, Inc., developed the Airborne Lidar Pipeline Inspection System (ALPIS®). ALPIS is a helicopter-based, mid-infrared, Differential Absorption Lidar system that detects leaks in natural gas and hazardous liquids pipelines. The laser beam is transmitted downwards from the sensor to illuminate the area above and around the buried pipeline. When the laser beam passes through an emitted plume of hydrocarbon gas, some of the beam's energy is absorbed (i.e., removed from the beam) by the gas molecules in the plume. As a result, the amount of light reflected from the ground back towards the sensor is diminished. The amount of attenuation is measured by special detectors inside the sensor and can be used to determine the intensity of gas in the beam's path. This basic principle is at the heart of laser-based gas detection systems.

ALPIS is operated at a safe distance of 50 to 150 meters above the inspection site. Once a volatile organic compound (VOC) is detected, the GPS coordinates are recorded and an estimate of the leak size and a high resolution video image of the location are simultaneously recorded and delivered to the customer the day after the inspection flight. This remote capability provides better information for response teams to effectively maintain their pipeline. LaSen is offering ALPIS as a service to U.S. pipeline companies.

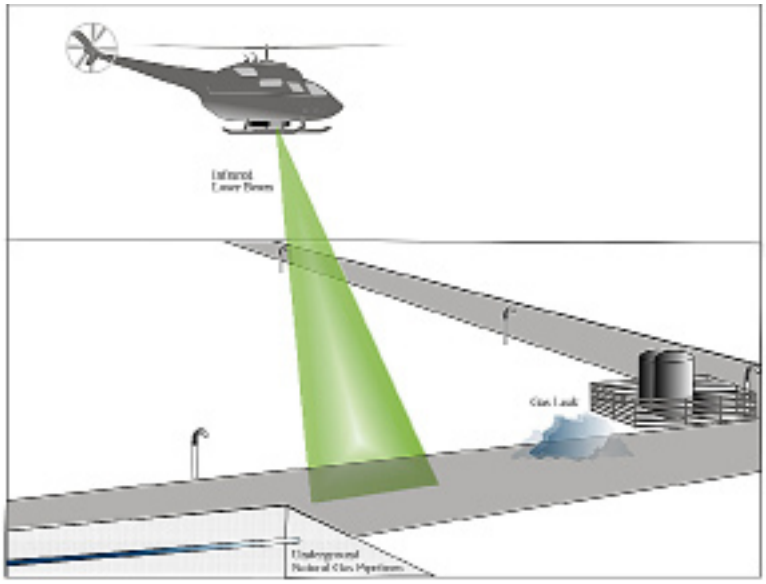
Benefits

Efficiency

Delivers complete survey results on a secure online database, which includes GPS coordinates of the indications, maps, and digital and satellite imagery of the right-of-way within 1 to 12 hours of inspection.

Safety

Offers a safe, fast and reliable remote detection system that eliminates human error and uses an eye safe laser.



LaSen's ALPIS Used to Detect Underground Pipeline Leaks

Overview

- Developed and being offered as a service by LaSen, Inc. (www.laseninc.com)
- Commercialized in 2005
- Currently used by 17 major U.S. oil and gas companies

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
1.02	0.574

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.067	9.11

Applications

Can be used in the oil and gas industry to monitor and maintain the integrity of their pipeline systems from the wellhead to the end user

Capabilities

- Inspects over ten times faster compared with ground surveys.
- Provides high sensitivity in remote hydrocarbon detection.
- Provides easy access to rough terrain and private land.
- Provides high-resolution digital photography of the entire survey route.
- Provides real time detection of benzene, propane and other volatiles.

Radiation-Stabilized Burner

New Burner will Deliver High Efficiency and Low Emissions in Industrial Boilers and Process Heaters

ITP and Alzeta Corporation have developed the Radiation-Stabilized Burner (RSB), an ultra-low NO_X and CO burner for applications in industrial boilers and process heaters. Characteristics of the RSB that improve performance relative to conventional burners include (1) full premixing of fuel and air to the greatest extent possible prior to combustion, (2) surface stabilization through the use of radiant zones and high flux zones on the burner surface, and (3) controlled flame shape above the burner surface. This results in low NO_X and CO emissions without sacrificing thermal efficiency or boiler reliability.

Premixing of the fuel and air before combustion provides a simple method of combusting all fuel at the desired fuel-air ratio and has been demonstrated to be an effective method of providing simultaneous low NO_X and low CO emissions. Excellent flame stability is needed to achieve low emission levels over the broad range in which industrial boilers operate. High-surface heat flux and controlled-flame shape above the burner surface allow for more compact boiler designs and for more rapid cooling of the flame to further reduce NO_X emissions.

Benefits

Emissions Reductions

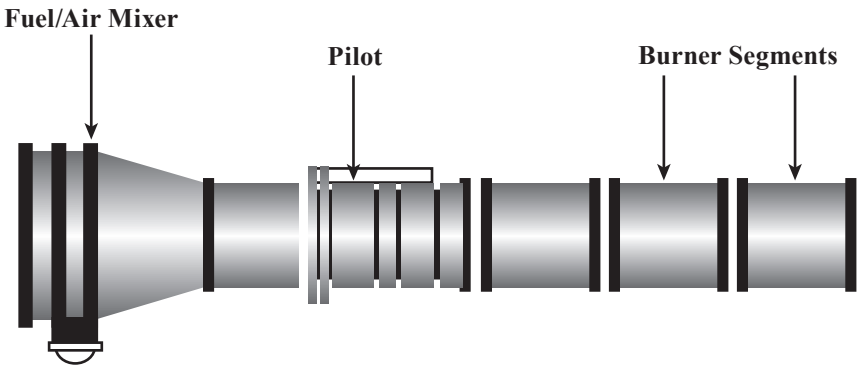
Simultaneously achieves low NO_X, CO, and unburned hydrocarbon emissions due to the fully premixed burner design.

Productivity

Results in little downtime, allowing any problems to be easily repaired.

Profitability

Eliminates the need for "post-combustion" pollution-control devices to reduce the cost of NO_X compliance. Allows for more compact boiler designs due to the uniformly distributed heat flux from the RSB surface.



Radiation-Stabilized Burner

Overview

- Developed by Alzeta Corporation (www.alzeta.com)
- Commercialized in 1999 and being marketed by Power Flame, Inc. (www.powerflame.com)
- Since 1999, over 300 burners have been installed in the United States

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.254	0.066

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.008	1.05

Applications

Can be used in industrial boilers and process heaters with capacity ranging from 2 MMBtu/hr to 150 MMBtu/hr, which are used in refineries, pulp and paper plants, and chemical manufacturing facilities

Capabilities

- Achieves sub-9 ppm NO_X and sub-50 ppm CO emissions.
- Avoids loss in thermal efficiency relative to current 30 ppm burner designs with high efficiency controls option.
- Provides stable operation over a broad range of emission levels, from sub-7.5 ppm NO_X to sub-30 ppm NO_X, with one burner design.

Simple Control for Single-Phase AC Induction Motors

IMPACTS

New Motor Controller Reduces Noise and Increases Efficiency

A new approach to electric motor control removes the need for complex, high-frequency, high-voltage digital controllers that are motor and application specific. With the help of a grant from DOE's Inventions and Innovation Program, Opto Generic Devices, Inc. (OGD), developed an optical programmable encoder and controller combination that offers continually adaptive/variable-speed, optimized commutation, dynamic vector control, real-time feedback, application tuning, and signal enhancement for operating AC motors. Based on this technology, OGD's subsidiary, OGD V-HVAC, Inc., developed a new technology, with the Adaptive Climate Controller (ACC), using optical programming that controls single-phase motors. While this controller has many uses with small motors, its most common applications provide climate control and healthy indoor air quality with energy efficiency, noise reduction, relative humidity control, and moisture control for mold abatement. Air filtration systems function more effectively with gradually changing air flow than with abrupt off-on fan cycling that accelerates harmful particles and organisms through mechanical and electronic filters.

In addition to providing a second, analog input for low DC voltage, the factory-supplied temperature sensor provides feedback for the controller to maintain temperature in the human comfort zone by gently mixing room air to avoid the extremes of cold air near the floor and warm air near the ceiling. If comfort demands suddenly change, such as when additional people enter a classroom or conference room, the ACC ramps up airflow as the mechanical system supplies heated or chilled air at temperatures above or below the human comfort zone, responding quickly to the changing room needs. Gradually ramping up fan speeds, instead of turning fans on fully whenever the thermostat calls for heated or chilled air, conserves energy by using only the electrical and thermal energy necessary to satisfy the demand. In systems such as fan coils, where thermal energy is transferred from heated or chilled coils into the air, the ACC enhances thermal energy exchange from the coils as it gradually ramps down fan speed in response to the actual supply air temperature as it settles into the setpoint temperature even after the thermostat has closed the valve that brings in heated or chilled water. Thus, the coil thermal energy transfer with the room continues even after the water valve has closed, allowing for additional electrical savings in chillers and fuel savings in boilers.

Benefits

Ease of Installation
Allows control upgrades to be easily installed on existing systems within minutes.

Energy Savings
Adaptively varies air flow to only what is needed.

Product Quality
Reduces noise for workers or occupants in businesses, hospitals, hotels, schools, etc.

Overview

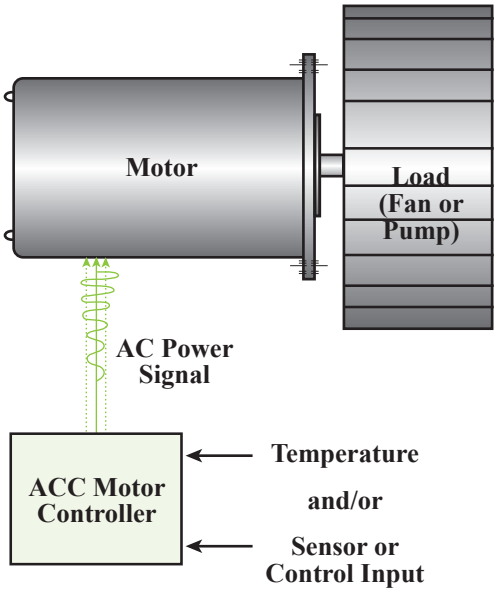
- Developed by Opto Generic Devices, Inc. (www.ogd3.com)
- Commercialized in 2005 with thousands of installed units

Applications

Can be used to control small single-phase motors up to 240 V_{AC} and 10 amps full load, including HVAC and other system motors found in data centers, hospitals, residences, hotels, nursing homes, schools, and other institutions. Also can be used to control fan coils, packaged terminal air conditioners, unit ventilators, and exhaust fans.

Capabilities

- Accepts one or two analog inputs, including, but not limited to, temperature and low DC voltage from a sensor or building management system.
- Adaptively varies motor speed for the discharge air flow across fan coils to control indoor climate.
- Reduces system noise.



OGD Electric Motor Control

Solid-State Sensors for Monitoring Hydrogen

New Sensors Rapidly and Accurately Detect Hydrogen, Improving Industrial Safety and Efficiency

Molecular hydrogen, H_2, is a combustible gas that is produced in large quantities by many industries and has a broad range of applications. When H_2 is an undesirable contaminant, a monitor must be able to detect concentrations on the order of parts per million (ppm). In other cases a monitor must be usable in nearly pure hydrogen. Although gas chromatography and mass spectrometry are widely used for detecting H_2, these methods require bulky, expensive equipment.

Using solid-state technology developed at Sandia National Laboratory, H2scan LLC is now commercializing hydrogen-specific sensing systems that can detect hydrogen against virtually any background gases. These hydrogen-sensing devices can detect hydrogen in 1 to 10 seconds, thus allowing the devices to be used in control systems. Currently, H2scan offers three hydrogen-sensing system configurations: a hand-held portable leak detector, a fixed-area monitoring system, and an in-line real-time concentration analyzer.

The advantages of the H2scan hydrogen sensors are in their operating parameters. The sensors have a low hydrogen sensitivity of about 5 ppm in air and less than 1 ppm in nitrogen. They are hydrogen specific with no cross-sensitivity to other gases. The upper range of the sensor is 100% with an extremely fast speed of response. They operate between -40°C to 150°C, making them attractive for virtually all sensor applications.

Benefits

Energy Savings

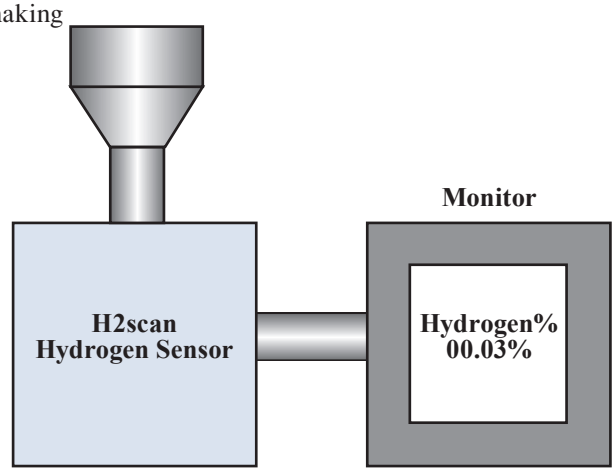
Saves substantial energy by avoiding improper monitoring.

Productivity

Detects hydrogen in 1 to 10 seconds, which is suitable for interfacing to control systems. Using the device to monitor hydrogen in feedstock of a refinery feed hydrogen/carbon monoxide facility could improve overall performance by up to $250,000 per year per plant.

Profitability

Can be mass-produced, making them much less expensive than competing sensors. Small sensor dye produces a system that is much smaller than traditional sensors.



H2scan Hydrogen Monitoring System

Overview

- Developed by Sandia National Laboratory and H2scan LLC (www.h2scan.com)
- Commercialized in 2003
- Over 1600 units sold through 2007

Applications

- Monitoring trace levels of H_2 in high-purity feed gases for chemical processes
- Monitoring hydrogen production from methane and refinery offgases, where hydrogen is often mixed with CO
- Monitoring hydrogen levels in transformer oil to detect when the oil starts breaking down
- Measuring the hydrogen given off from lead acid batteries due to overcharging to stop a buildup of hydrogen and reduce the threat of either a fire or explosion
- Monitoring and control of hydrogen, which are crucial to obtain the correct molecular-weight distributions in the gas-phase polymerization of polyethylene and polypropylene
- Analyzing fugitive hydrogen emissions in ambient plant environments or in materials subjected to high-energy radiolysis, which is crucial for safety in those environments
- Measuring hydrogen levels to control the efficiency of fuel cell reformers

Capabilities

- Can be used over a wide range of hydrogen concentrations with minimal interference from other gases.
- Provides rapid response time of 1 to 10 seconds, allowing the sensors to be used for process control.

SpyroCor™ Radiant Tube Heater Inserts

IMPACTS

Unique Twisted Design of Ceramic Insert Saves Energy for Metal Heat-Treating Furnaces

Radiant tube heaters are typically used in metal heat-treating furnaces. The heaters are long tubes, often in a U shape, which have natural-gas fired burners at one end of the tube (the burner leg) to produce a flame and heated gas that flows through the tube to produce heat for conditioning metals (e.g., strengthening them or otherwise changing some of their properties). In a traditional radiant tube, the burner leg releases 30% more energy than the exhaust leg because of convection and radiation heat transfer in the burner leg.

With the help of a grant from DOE's Inventions and Innovation Program, STORM Development LLC and Sycore, Inc., optimized the SpyroCor, a ceramic (silicon-carbide) insert for the exhaust leg of the tube heater. The patented twisted design of the SpyroCor produces nonturbulent, high convection flow that produces the highest possible rate of uniform heat transfer. As a result, the SpyroCor reduces heat loss and the energy demands of the process or application by 15% to 20%. A typical furnace contains 10 radiant tubes, which use an average of 3 SpyroCors per tube. Through 2007, 409 furnaces have been equipped with SpyroCors for a savings of 3.39 trillion Btu.

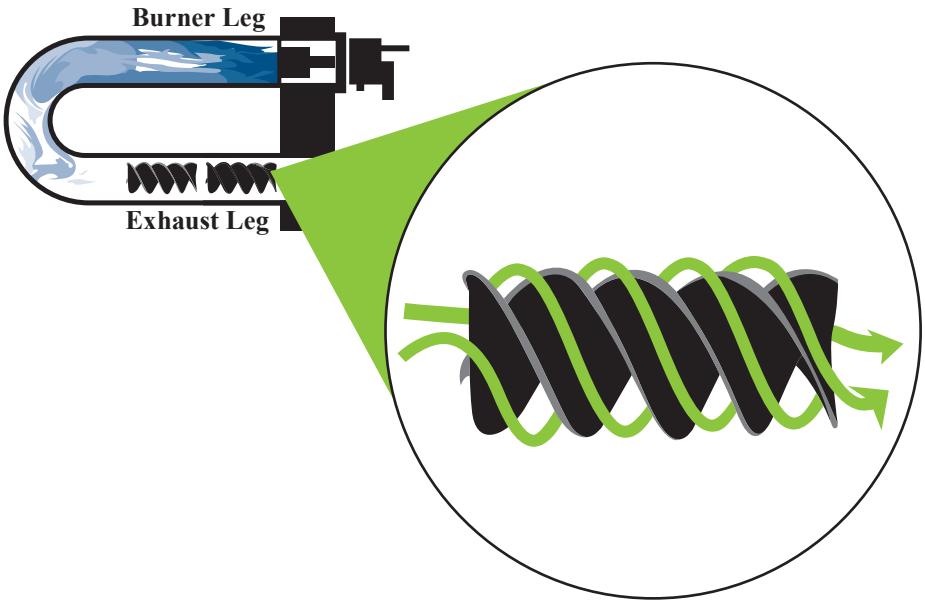
Benefits

Ease of Installation

Can be quickly and easily inserted into existing heater tubes without overhauling the entire furnace.

Productivity

Allows the furnace user to increase the amount of metal treated for the same amount of energy used or to reduce the amount of energy used for the same output.



SpyroCor Installed in a Radiant U-Tube Heater

Overview

- Developed by STORM Development LLC and SyCore, Inc.
- Commercialized and being marketed by Spinworks LLC (www.spin-works.com)
- Sold more than 11,300 units through 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
3.39	1.47

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.172	23.3

Applications

Can be used in radiant tube heaters typical in metal heat-treating furnaces that use natural gas burners or in industrial radiant tube space heaters

Capabilities

- Produces nonturbulent, high convection flow in the radiant tube.
- Doubles the amount of surface area available for heat transfer.
- Balances the heat transfer throughout the radiant tube, allowing more energy to be available to the load.

SuperDrive – A Hydrostatic Continuously Variable Transmission (CVT)

Innovative Approach to Fuel Economy in Heavy-Duty Vehicles

The heavy-duty truck (class 7 and 8) market is dominated by standard-geared transmissions. Standard transmissions are so efficient that little interest has been shown in exploring even greater efficiencies using other types of transmissions. With assistance from DOE's Inventions and Innovation Program, SuperDrive, Inc., addressed increased efficiency by developing a hydraulic transmission system to uncouple engine rpm from wheel speed. This design allows the electronic control module to seek the lowest rpm at which sufficient torque is available to maintain the desired speed.

The patented SuperDrive system uses an axial piston, variable hydraulic pump that is coupled to the crankshaft at the rear of the engine. The pump drives axial-piston variable motors connected to the drive shaft. With an electronic control module, SuperDrive maintains the lowest rpm possible to produce sufficient torque to maintain required pump output. If demand increases, the fuel flow to the engine increases to meet demand, but engine speed is increased only as a last resort. This method allows the vehicle to maintain a constant speed over varying terrain with little or no increase in engine rpm. Because this is a closed-loop hydraulic system incorporating variable pumps and motors, it has the capacity for hydraulic braking by activating a flow control valve. The improved fuel efficiency, an average of 25% to 40%, more than offsets the reduction in transmission efficiency for heavy-duty trucks.

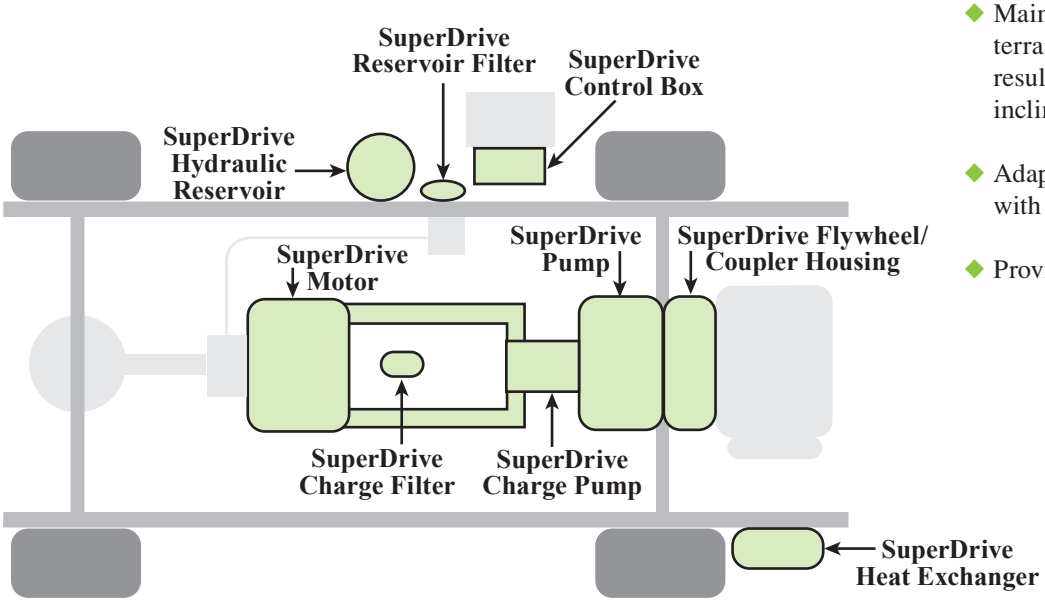
Benefits

Environmental

Reduces emissions by up to 35% over conventional long haul operations.

Productivity

Reduces driver fatigue and the need for drivers skilled in using multi-gear standard transmissions.



SuperDrive Components

Overview

- Developed and marketed by SuperDrive, Inc. (www.superdriveinc.com)
- Commercialized in 2004
- Currently installed on three transit buses in Piqua, OH

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.006	0.002

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.0	0.037

Applications

Can be used in heavy-duty truck and bus engines in long-haul and fleet applications

Capabilities

- Maintains constant speed over varying terrain with minimal increase in rpm, resulting in minimal energy increase on inclines.
- Adapts to unique characteristics or trucks with different engines and transmissions.
- Provides hydraulic braking.

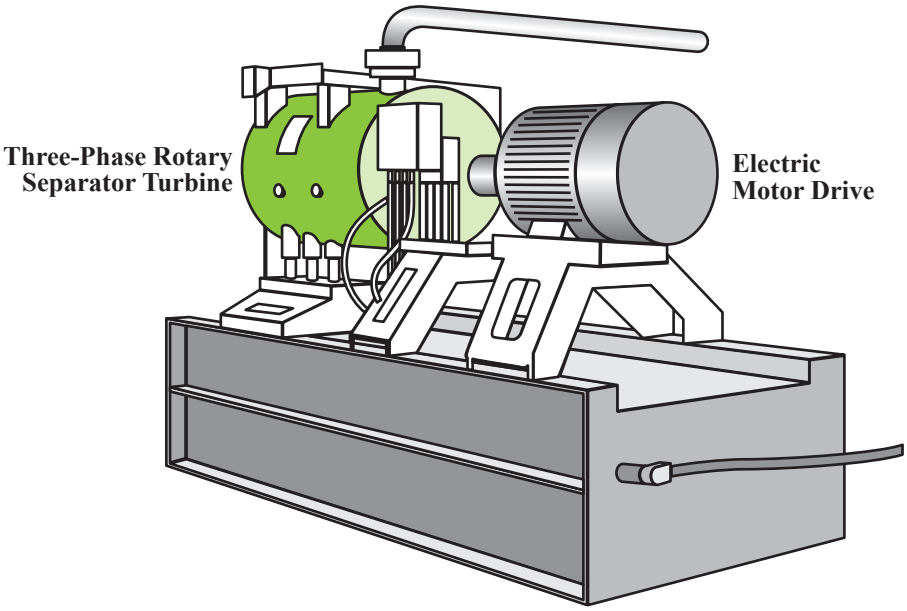
IMPACTS

New Turbine Efficiently Separates Gas, Oil, and Water While Generating Electricity from Waste Energy

Using a NICE[3] grant, Douglas Energy Company and Multiphase Power and Processing Technologies (MPPT) demonstrated a three-phase rotary separator turbine (RST3) at a land-based production field and on an offshore production platform. The device introduces a highly efficient and compact method for separating gas, oil, and water during production operations, while generating substantial power from previously wasted process energy.

Traditional oil and petroleum separator systems use a centrifuge or gravity separator. The centrifuge system requires outside energy to power the motors that propel a centrifugal drum, where oil and water are separated. After separation occurs, solids remain inside the drums and require costly periodic cleaning. The gravity separators use huge vessels that rely on gravity to perform the separations. However, the separations are often incomplete and require secondary energy-consuming systems.

The RST3 effectively separates solid waste, oil, gas and water, while harnessing expansion energy from the pressure reduction that occurs after the oil, gas, and water mixture is brought to the surface from offshore wells. This creates a clean power source that accelerates the rotating portion of the RST3 unit, where the mixture is separated more efficiently than by traditional methods. The new process often creates net energy for other offshore oil platform operations, reducing the need for electricity produced from natural gas turbine generators.



Three-Phase Rotary Separator Turbine

Overview

- Developed by Douglas Energy Company Inc.
- Commercialized in 2003 and marketed by Dressor-Rand Group, Inc. (www.dresser-rand.com)
- Two units operating in the United States in 2007

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.034	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.029

Applications

Can be used to replace traditional separation technologies used in petroleum and chemical industries

Capabilities

- Creates its own source of clean shaft power, reducing electrical input requirements.
- Weighs 10 times less than a typical gravity three-phase separator and has a much smaller footprint.

Benefits

Cost Savings

Substantially reduces the size and cost required for offshore platforms, enabling a low-cost production system for marginal oil and gas fields and increasing supply.

Environmental

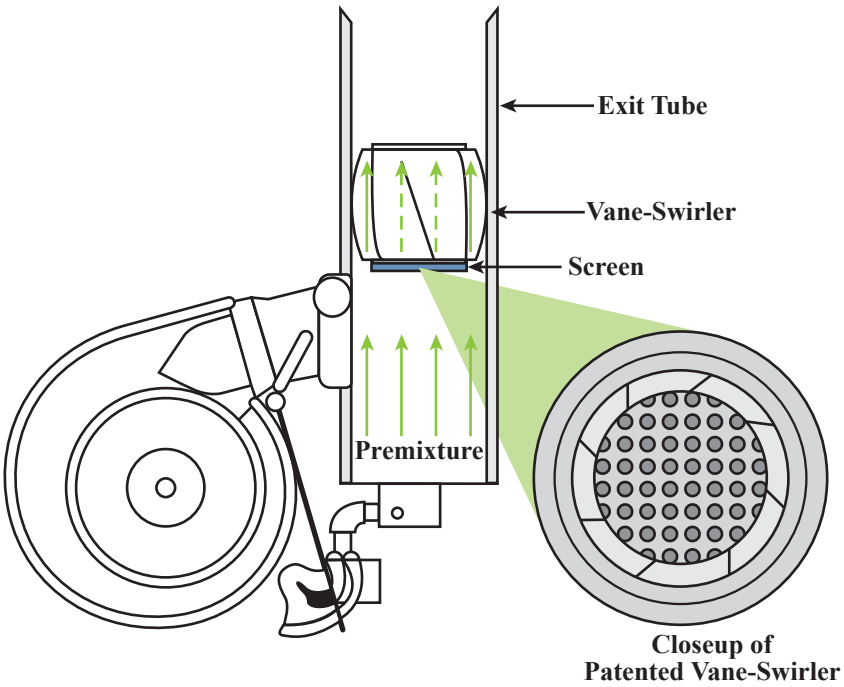
Purifies the process water without adding harmful chemicals commonly used in traditional separators.

Ultra-Low NO_x Premixed Industrial Burner

Reduction of Burner NO_x Production with Premixed Combustion

Industries that are dependant on combustion processes are faced with more stringent environmental regulations to reduce NO_x emissions. Some states require NO_x emissions reductions as great as 90% for chemical and refining industries. The recently developed M-PAKT™ Ultra-Low NO_x Burner uses lean premixed combustion gases and low swirl flow of combustion gases to achieve NO_x emissions levels <10 ppm (an NO_x reduction of 80% to 90%).

The research for this technology originated at Lawrence Berkeley National Laboratory with funding from the DOE Office of Science Experimental Program and ITP. This new burner's distinct characteristic is a detached flame that is lifted above the burner, providing the capability for more complete combustion with less emissions. This burner concept can be applied to a wide range of combustion systems including furnace and boiler applications, gas turbines, and liquid process heaters for the chemical and refining industries. The burner can be operated with natural gas, biomass gas, and pre-vaporized liquid fuels. The burner is scalable and simple in design with no need for costly materials for manufacturing and installation. Maxon Corporation has licensed the technology for industrial process heaters used in many industrial baking and drying ovens. Applications have also been successfully tested in smaller-diameter domestic heater units.



M-PAKT Ultra-Low NO_x Burner Installation

Overview

- Developed by LBNL with two patents issued
- Installed in the U.S. and overseas
- Technology licensed to Maxon Corporation and sold as the M-PAKT burner (www.maxoncorp.com)
- Over 1000 burners estimated to reduce NO_x by over 1.13 million pounds in 2007

Applications

Can be used on a wide range of combustion systems: furnaces and boilers, chemical and refining industry process heaters, and gas turbines

Capabilities

Reduces thermal NO_x in the combustion zone.

Benefits

Adaptability

Burns different gaseous fuel types and blends. Can be scaled to different sizes of units and adapted to different orientations and sizes of various flue configurations.

Low Cost

Offers low cost for manufacturing compared with traditional low NO_x solutions because the components are simple and are made from conventional materials.

Pollution Reduction and Energy Efficiency

Typically reduces NO_x to less than 10 ppm without compromising energy efficiency.

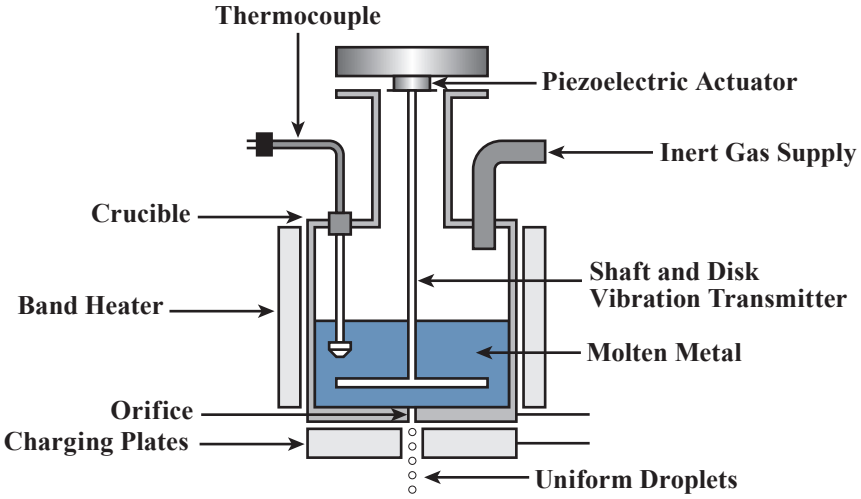
Uniform Droplet Process for Production of Alloy Spheres

IMPACTS

New Process Allows High-Quality Production of Uniform Alloy Droplets

The Uniform Droplet Spray (UDS) process is a nongas atomization process that uses the concept of controlled breakup of a laminar jet to produce uniform alloy droplets with identical thermal histories. This controlled breakup is similar to that used in ink-jet printing technology and produces monosized droplets. The droplets are solidified along a path that produces a desired microstructure. Unlike other methods for producing thermal sprays, the spray parameters in this process are fully decoupled and, therefore, permit materials processing under conditions inaccessible by conventional thermal spray processes.

With support from ITP, Oak Ridge National Laboratory, the Massachusetts Institute of Technology, and Northeastern University have developed this process that is now being commercialized for various applications. With appropriate engineering, novel particulate materials can be produced at reasonably high production rates and low capital and operating costs. Currently, the major commercial use is to produce micro-solder balls for Ball-Grid Array electronics packaging; the balls are used for manufacturing and assembling electronic products.



Uniform Droplet Spray Process

Overview

- Developed by Oak Ridge National Laboratory, the Massachusetts Institute of Technology, and Northeastern University
- Currently licensed to two U.S. and four Japanese firms who are exploring the Ball Grid Array application (www.cooksonsemi.com and www.indium.com)

Applications

Can be used in the integrated circuit packaging industry with potential applications for use as a filtering media in the chemicals and petroleum industries

Capabilities

- Offers high quality production of uniform alloy droplets.
- Saves significant time and energy over traditional methods relying on cutting and milling operations.

Benefits

Product Quality

Produces uniform alloy droplets.

Profitability

Reduces labor costs compared with traditional cutting and milling operations.

Quality Control

Increases quality control because of the consistency of solder ball production.

Uniformly Drying Materials Using Microwave Energy

System Uses Microwave Energy to Dry Materials Uniformly at Half the Cost and Half the Emissions

Industrial Microwave Systems LLC, with assistance from a NICE[3] grant, successfully demonstrated and is commercializing an innovative system that uses microwave energy to dry materials. Traditionally, microwave-drying systems have scorched the portions of materials that were close to the radiation source, while materials further from the source remained moist. This result is due to a primary characteristic of microwave energy—it attenuates as it leaves its point of origin, creating hot spots across the materials being dried. This characteristic has kept microwave drying from becoming the drying technology of choice.

This new technology addresses these traditional problems by using a rectangular wave-guide. This guide is slotted and serpentined to maximize the exposure area of materials as they pass through the system. A number of wave-guides can be cascaded to form a system that dries an entire piece of fabric or other material.

Benefits

Energy Savings

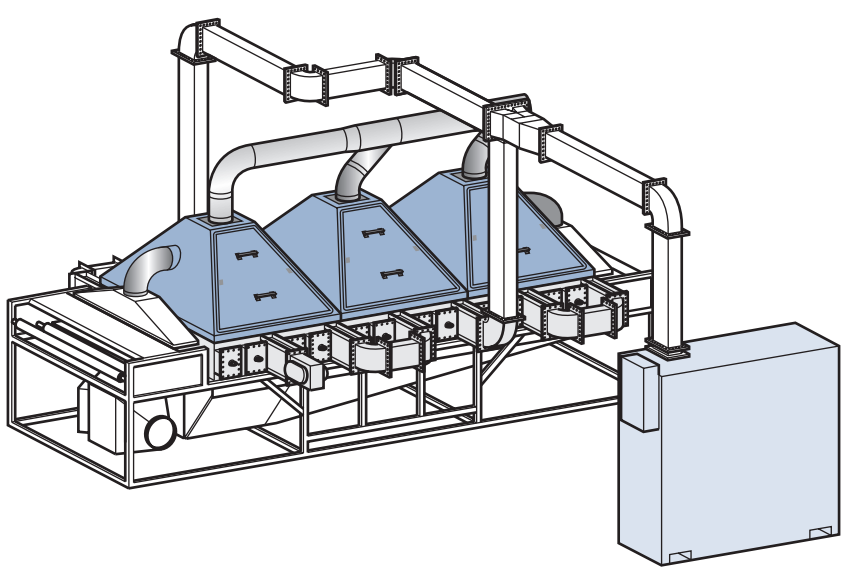
Reduces natural gas heating requirements by 20% to 50%, saving up to 12 billion Btu/year for a typical plant.

Pollution Control

Reduces greenhouse gas emissions by approximately 50%, with 68% of the particulates eliminated.

Productivity and Profitability

Reduces drying stress because of no contact drying and lowers maintenance costs because of fewer movable parts.



Microwave-Drying System

Overview

- Developed by Industrial Microwave Systems LLC (www.industrialmicrowave.com)
- Commercialized in 2000
- Currently operating at 7 facilities in the United States and 3 in foreign countries
- Being tested in five U.S. demonstration units

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.162	0.024

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.003	0.400

Applications

Can be used in the production of fabrics; agricultural and pumpable food products; industrial filters and insulation; medical dressings; paper products; geotextiles, carpeting, and roofing materials; and personal hygiene products such as diapers

Capabilities

- Provides efficient and uniform drying of materials continuously fed through the drying system.
- Works with existing systems to reduce conventional natural gas or electric drying needs.
- Reduces microwave leakage with the use of choke flanges.

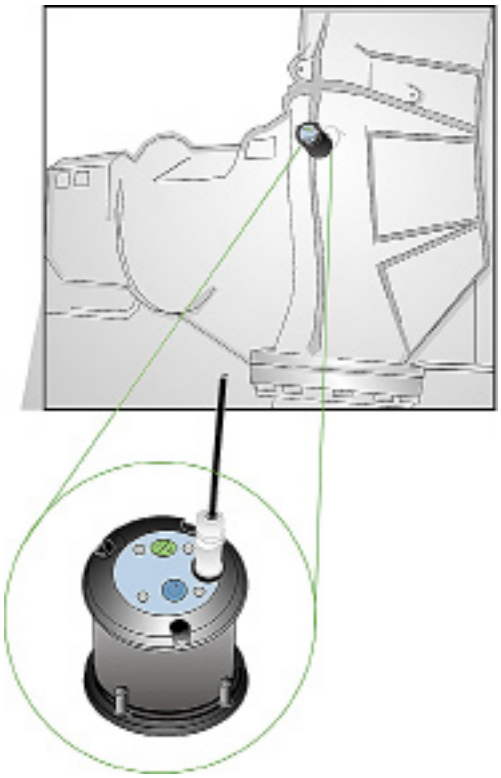
IMPACTS

New Technology Captures Freely Available Vibration Energy to Power Wireless Sensors

The industrial market for wireless sensors is growing rapidly but is constrained by implementation costs and compatibility with existing wireless networks. Typical wireless sensors and transmitters depend on batteries, which require periodic maintenance to change the battery. Maintenance costs for battery use in wireless sensor applications are estimated at $80 to $500 per replacement, including labor, which exceeds the sensor's cost.

With assistance from an SBIR grant, KCF Technologies, Inc., has developed vibration power harvesting devices that eliminate the need for battery change. Available as part of KCF's Power Harvesting Demonstration Pack, the device converts vibration energy to regulated DC power, supplying sufficient power to the wireless sensor for up to 15 years without needing any maintenance time or expenses. The technology is not overly sensitive to vibration frequency, amplitude, or other environmental characteristics.

KCF Technologies' innovation was recognized with a "Best of Sensors Expo" Award in 2008. The harvester-powered sensor was honored as one of the most promising and exciting technologies on display out of nearly 200 products at the annual Sensors Expo & Conference in Rosemont, Illinois. These devices are expected to greatly expand the use of wireless sensors throughout U.S. industry.



KCF Technologies' Vibration Power Harvesting Unit Installed on a Large Motor

Overview

- Developed by KCF Technologies, Inc., in 2006 (www.kcftech.com)
- Commercialized in 2007
- Formed strategic partnerships with Johnson Controls, Omega Piezo Technologies, Pennsylvania State University, and RLW, Inc.

Applications

Can be used wherever wireless sensor networks are deployed, including refrigeration and HVAC systems, pulp processing and paper printing, condition-based maintenance, and power generation facilities

Capabilities

- Increases data transmission capabilities for wireless sensors in high-vibration settings.
- Is compatible with existing wireless sensors.
- Enables sensor placement in infrequently accessed locations.

Benefits

Cost Savings

Eliminates downtime and costs associated with battery maintenance.

Safety

Expands sensing capabilities for machinery and equipment to increase safety and security.

Wear Resistant Composite Structure of Vitreous Carbon Containing Convoluted Fibers

New Composite Material Improves Motorcycle and Automotive Performance and Saves Energy

MRCC, Inc., and Starfire Systems, Inc., created a novel method for manufacturing a carbon composite material consisting of a vitreous silicon/carbide matrix containing carbon fibers. The new manufacturing method provides additional strength and applies metal fibers of high-thermal conductivity to aid in processing. The graphite fiber-reinforced ceramic matrix complex (CMC) operates at high temperatures and is resistant to acids, bases, and organic solvents in seal configurations. The final product can be cut into electrical contacts, mechanical seals, brakes, pumps, vanes, engine parts, and implanted prosthetics with better wear resistance, lower fade, and higher electrical conductivity than competing materials.

The funding to develop this technology was jointly provided by the United States Air Force and DOE's Inventions and Innovation Program and was used to test lighter-weight composite material and aircraft brakes. Although Starfire continues to work with the aircraft brake companies, the motorcycle and automotive brake industry has shown stronger interest in the technology. In automotive and motorcycle brakes, the lightweight material reduces the amount of energy required to accelerate the vehicle, reducing fuel consumption, and increasing the acceleration rate. The improved fuel consumption is most noticeable in "stop and go" driving where brakes are continually being applied.

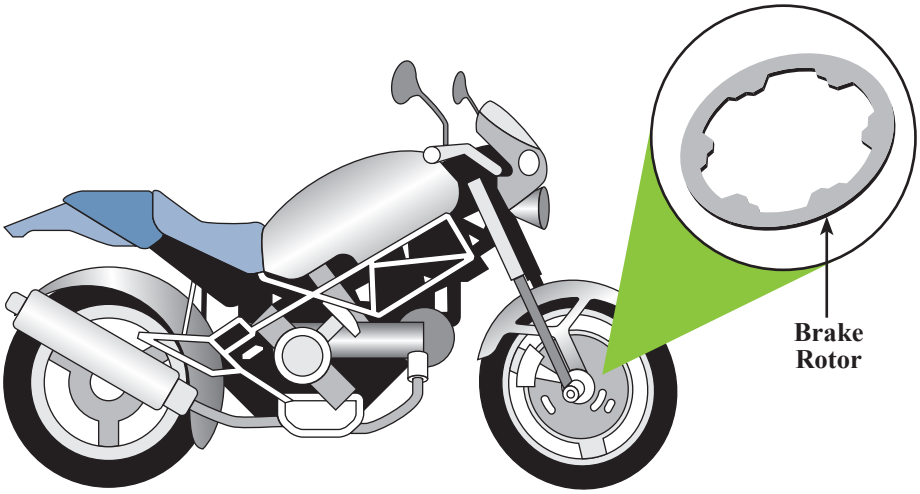
Benefits

Product Quality

Offers unusual wear resistance without lubrication.

Profitability and Productivity

Results in fewer replacements and lower costs due to longer life of the composite material; can use generally available methods to machine the products.



Starfire Systems' Motorcycle Application

Overview

- Developed by MRCC, Inc., and Starfire Systems, Inc.
- Commercialized in 2006 and being marketed by Starfire Systems (www.starfiresystems.com)
- Currently being used in motorcycle brake rotors

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.003	0.002

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.001	0.0	0.044

Applications

Can be used in the motorcycle and automotive industries and potentially the aircraft and electric rail industries.

Capabilities

- Provides metal-reinforced carbon composite that operates at high temperatures.
- Offers resistance to acids, bases, and organic solvents in seal configurations.
- Increases wear resistance, lowers fade, and produces higher electrical conductivity than competing materials.

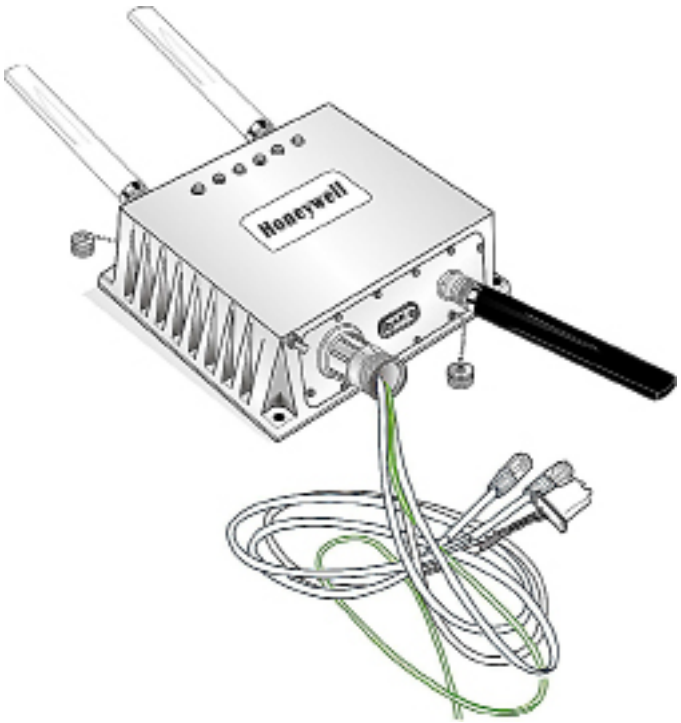
Wireless Sensors for Process Stream Sampling and Analysis

IMPACTS

Advanced New Wireless Sensor Meets Demanding Requirements of Industrial Production Lines

Sensing and controlling manufacturing present unique problems with effective sampling in harsh environments and with real-time control. The demanding requirements of industrial control of manufacturing processes need to be met while maintaining maximum security, battery life, and reliability. Wireless sensors for sampling and analyzing process streams allow monitoring in remote locations, but research is needed to determine how they satisfy the key considerations of operational reliability, sustained performance in harsh environments, invulnerability to interference, security, bandwidth efficiency, and other factors that are critical for the ultimate wide-spread deployment of robust wireless sensor networks in manufacturing.

With ITP support, Honeywell International, through its Wireless Sensors for Process Stream Sampling and Analysis project, developed and successfully commercialized a wireless system that meets all the operational considerations. The critical component of this production line measurement and control system is the Frequency Hopping Spread Spectrum board. In addition to production line measurement and control, the technology's anticipated low cost will enable wireless sensors to be used to determine energy and environmental-related process parameters that are not traditionally monitored. Industrial power and cogeneration plants can use the sensors to balance generation demands, operational efficiencies, and regulatory constraints. By implementing these sensors with advanced energy solutions, plants can reduce heat and power production costs, increase effective boiler operation range, reduce flue gas emissions, optimize production capacity utilization, extend production asset's life, and reduce maintenance.



Honeywell International's Wireless Sensor

Overview

- Developed by Honeywell International
- Commercialized and marketed by Honeywell International in 2007 (www.honeywell.com)
- Sold about 500 units in the United States in 2007

Applications

- Can be used for process control and monitoring in remote locations and for monitoring equipment health

Capabilities

- Provides cost-effective sample validation.
- Is certified for use in hazardous environments.
- Collects additional process and equipment health data.
- Is easily installed.

Benefits

Profitability
Offers low cost and easy deployment, increasing the number of measurements that can be used to improve process efficiency.

Reliability
Has been tested extensively in severe production environments such as steel mills.

Versatility
Allows remote installation without running additional wires.

Other Industries

IMPACTS

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- Textile Finishing Process 139

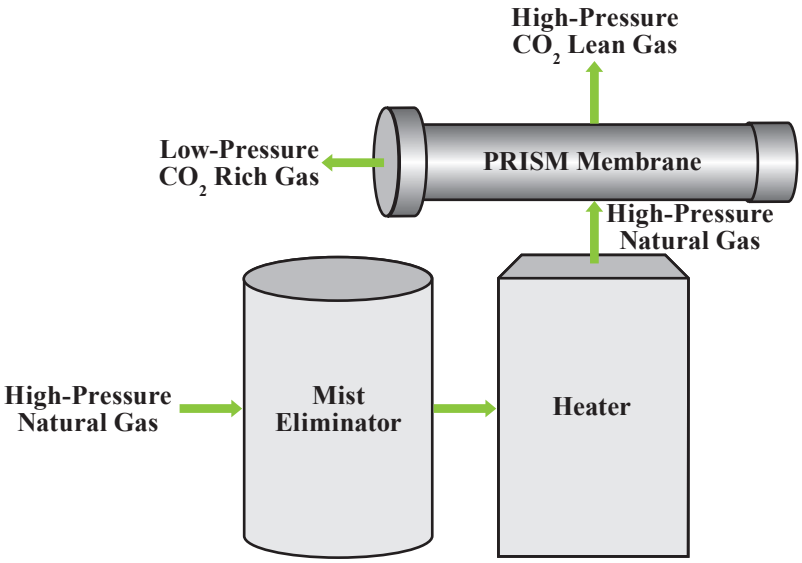
Advanced Membrane Devices for Natural Gas Cleaning

New Membrane Cost Effectively Upgrades Sub-Quality Natural Gas

Carbon dioxide (CO_2) is a common impurity that must be removed in natural gas to improve the gas's heating value or to meet pipeline specifications. Hydrogen sulfide (H_2S) often prohibits natural gas from being used to generate power and drive compressors at remote locations such as oil and gas production sites. Production companies are faced with choosing among shutting in a well, overhauling engines frequently, or dealing with logistical challenges associated with routing other fuels to the site.

With ITP support, Air Products & Chemicals, Inc., through its Advanced Membrane Devices project, developed and successfully commercialized PRISM® membranes for upgrading sub-quality natural gas. These semi-permeable polymeric membranes can be used as gas scrubbers for natural gas, removing CO_2 and H_2S from natural gas.

PRISM membranes, based on simple process designs, provide a low-cost alternative to traditional amine systems that are used to upgrade natural gas. The membranes can also be used as a bulk-removal device to minimize the size of an amine system. The benefits become even more pronounced as the industry produces natural gas from very remote locations. Fuel-gas conditioning systems that incorporate PRISM membranes provide oil and gas production companies with an economical solution to an otherwise often enormous problem. The membrane device can be used to make low-grade natural gas with high CO_2 and H_2S content into a pipeline-grade gas for domestic and industrial consumption.



Example CO_2 Removal Process Using the PRISM Membrane System

Overview

- Developed by Air Products & Chemicals (www.airproducts.com)
- Commercialized in 2001
- 110 CO_2-removal units operating in the United States in 2007

Applications

- Recovers CO_2 from associated gas in enhanced oil recovery programs
- Removes acid gas from natural gas
- Separates nitrogen from air while also yielding an oxygen-rich byproduct
- Separates hydrogen from process gas

Capabilities

Reduces impurities to allow natural gas to meet pipeline specifications.

Benefits

Environmental Quality

Avoids use of any hazardous chemicals such as amines, which can cause environmental complications.

Ease of Installation

Offers lightweight and compact units, thus facilitating their transportation and installation.

Profitability

Is ideal for remote locations with limited utilities and sour natural gas.

Reliability

Requires no moving parts, reducing maintenance costs.

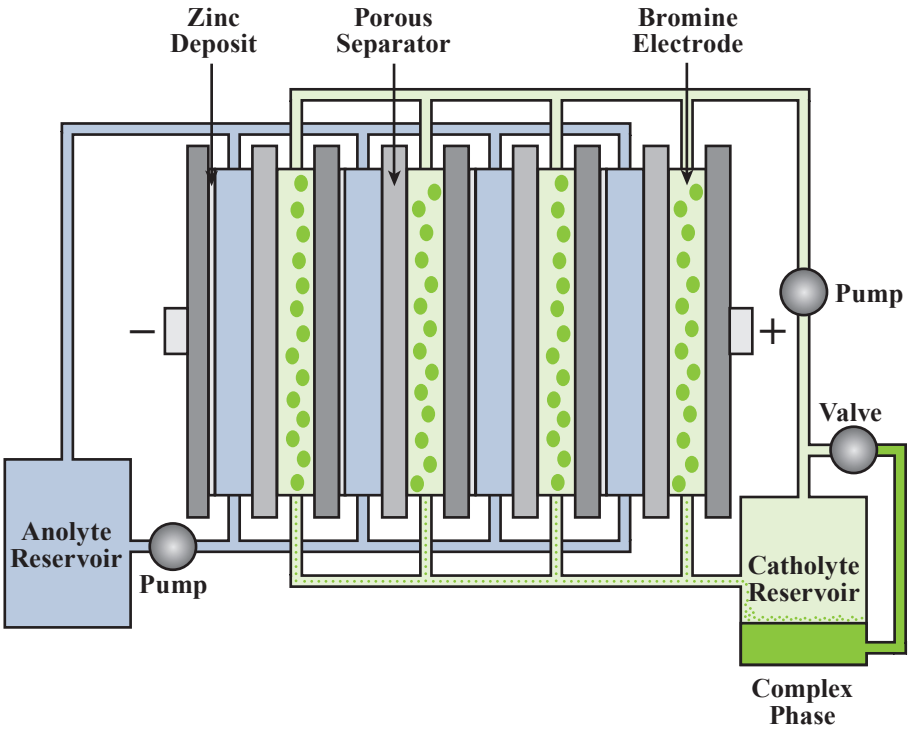
Deep Discharge Zinc-Bromine Battery Module

IMPACTS

Long-Lasting Electrical Energy Storage Module Allows Off-Peak Power Generation

Electricity consumption during peak (daytime) hours can overload utilities, forcing them to acquire more generation, transmission, and distribution capacity both at existing power generation sites and at new sites to meet growing customer demand. Also, the available generation, transmission, and distribution capacity is not fully used most of the time because peak loads need to be met even though the amount of time they are used is limited. Equipment running at low loads (less than full capacity) is less efficient. ZBB Energy Corporation, with financial assistance from DOE's Inventions and Innovation Program and another EERE Program, has developed a long-lasting, high-energy density zinc energy storage system (ZESS) module that can store energy generated during off-peak hours in order to discharge it during peak hours. Zess provides the additional capacity needed during peak times without adding new generation, transmission, and distribution infrastructure and increases the overall operational efficiency of the complete electrical system or industrial plant.

The ZESS regenerative fuel cell, also referred to as a flow-type battery, consists of an electrochemical reactor through which electrolyte is circulated from external storage tanks and where the electrodes do not take part in the chemical reaction and thus are not degraded or consumed over time. Power characteristics of the ZESS can be modified by changing the electrolyte composition. The ZESS is made from cost-competitive, plastic materials, which reduce manufacturing and disposal costs compared with traditional battery types. In addition, the ZESS offers 2 to 3 times the energy density of current lead-acid batteries. Because the cycle life is not degraded by deep discharging, cycle life is increased. The ZESS can be 100% discharged thousands of times without damage.



Schematic of Zinc-Bromine Battery Module

Overview

- Developed by ZBB Energy Corporation (www.zbbenergy.com)
- Commercialized in 2006

Applications

Can be used primarily as a peak shaving technology for electric utility and industrial companies Can also be used for energy-storage in renewable-energy and remote-area power systems and for demand charge and "time of use" management applications planned for industrial, commercial, and residential users in the immediate future

Capabilities

- Allows off-peak electricity generation to be used during peak hours.
- Discharges up to 100% with zero battery damage.
- Recharges faster; 4 to 5 hours vs. 8 to 12 hours for lead-acid battery.

Benefits

Adaptability

Allows for sizing and portability of systems to suit multiple applications and needs.

Cost Savings

Requires less expensive plastics to make compared with traditional batteries and standard plastic processing techniques, which also lowers fabrication costs.

Pollution and Waste Reduction

Requires only the cell stack to be replaced, which reduces disposal concerns and the costs of lead-acid batteries.

Operation and Maintenance

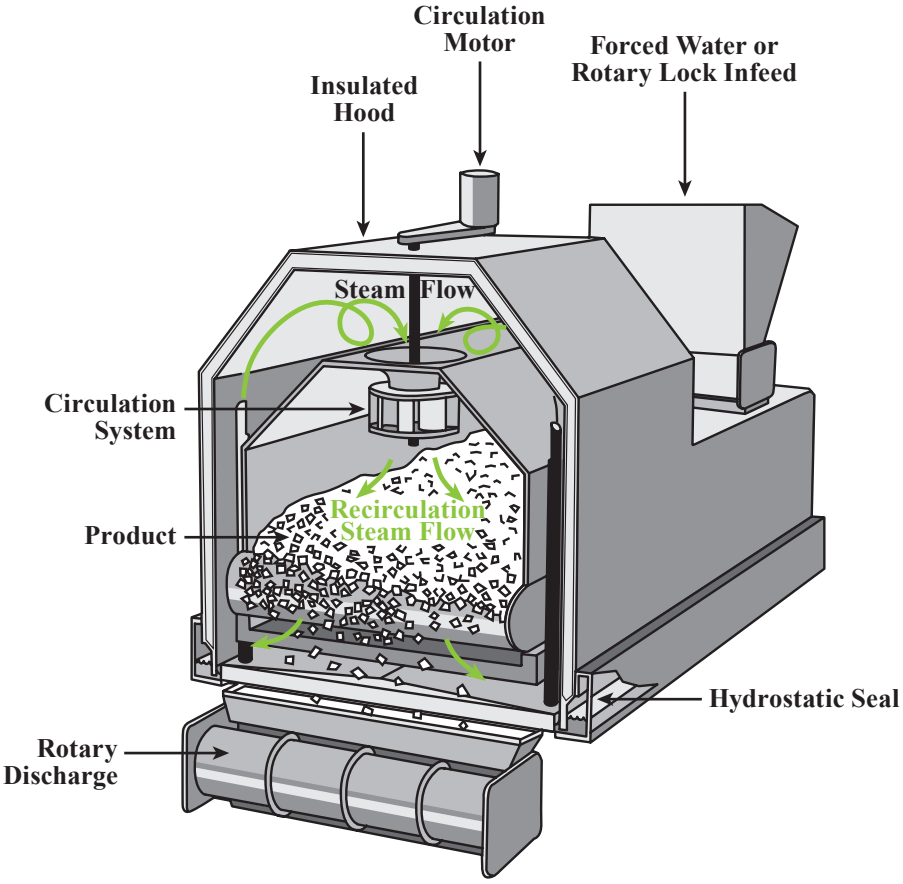
Can be left in the fully discharged state indefinitely with no maintenance compared with conventional battery systems that need to be charged regularly.

Energy-Efficient Food Blanching

New Blanching System Increases Productivity While Saving Energy

An innovative blanching technology recirculates and reuses steam, dramatically reducing water and energy use, and wastewater production. Key Technology, Inc., using a NICE[3] grant, developed and demonstrated the energy-saving and waste-reducing Turbo-Flo® Blancher/Cooker System. The Turbo-Flo system is a revolutionary advance in blanching and cooking technology. Traditional blanchers use a tremendous amount of steam or hot water (200-212°F) that is energy intensive, often overcooking the product being blanched. Currently, 60 Turbo-Flo units are operating, with energy savings of more than 70% and improved product quality.

In addition to the blancher innovations, Key Technology also collaborated with Washington State University to develop a lipoxygenase enzyme sensor that is capable of reducing blanch times in several types of vegetables. While the sensor was demonstrated in bench-scale tests, it is still in a developmental stage and not yet available commercially. When the development is complete, the new sensor will provide even more energy savings by further optimizing the blanching process.



Cut-Away of the Turbo-Flo Blancher

Overview

- Developed by Key Technology, Inc. (www.key.net)
- 60 units operating in the U.S. food processing industry

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.011	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.026

Applications

Can be used in processing of fruits, vegetables, and potatoes for shelf-life protection

Capabilities

- Reduces product-to-steam ratio.
- Saves approximately 70% of energy use.
- Eliminates process wastewater.

Benefits

Environmental

Virtually eliminates wastewater, saving more then 3.8 million gallons of water per year per unit.

Productivity

Increases yields by 2% to 5% over conventional water blanchers due to efficiency gains from shorter cook and blanch times.

Quality/Process Improvement

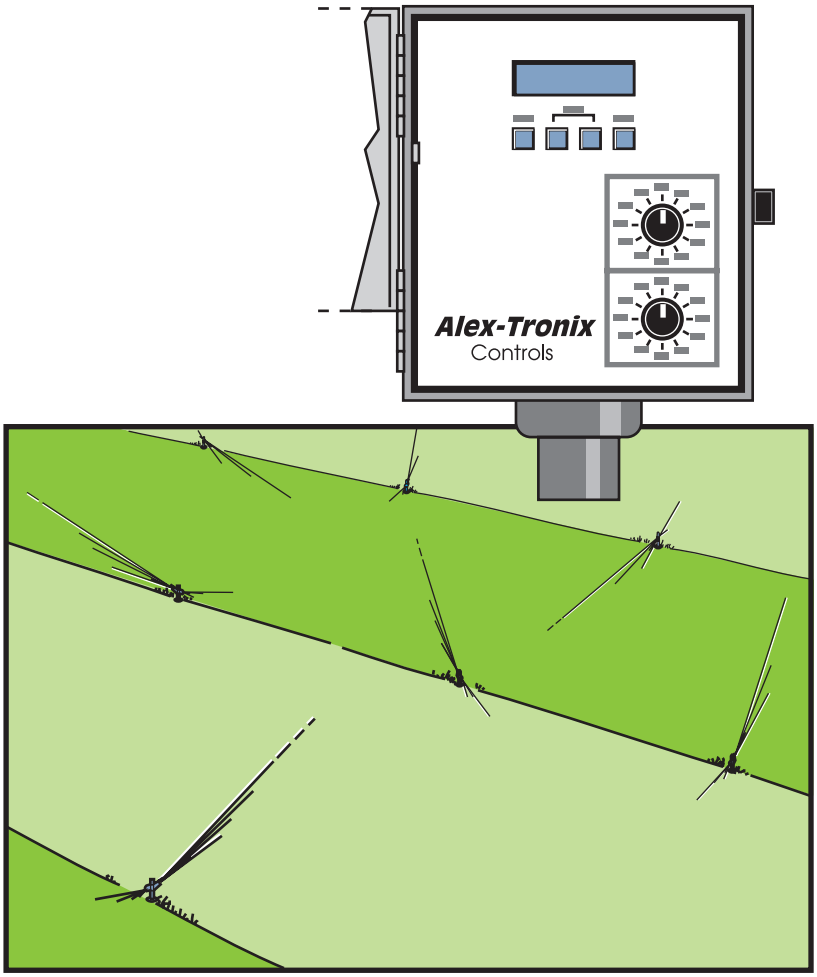
Improves nutrient retention, taste, and appearance through shorter cook cycles and takes up only about 60% as much floor space as conventional blanching/cooking equipment. Ensures more even cooking temperatures and provides consistent product definition and quality.

IMPACTS

New Solenoid Controller for Irrigation Valves Saves Energy

A battery operated, multi-station, irrigation valve control unit was developed with funding from DOE's Inventions and Innovation Program. The Battery Control System (BCS) uses low-powered, latching solenoid controllers with internal batteries that last for a minimum of 5 years.

Automated irrigation systems with latching solenoid controllers require a constant flow of electricity to keep the valves operating. A battery sends power surges to the solenoid as needed to open and close the valves. The BCS, available from Alex-Tronix Controls, uses the SWELL solenoid power saver. With the SWELL unit, the inrush and holding current requirements are only about 10% that of most other solenoids. The SWELL's greatly reduced inrush and holding current requirements allows valves to be operated at much longer distances. The BCS can operate valves reliably out to a distance of almost 20 miles. Other battery-powered controllers are limited in distance to about 1000 feet. Up to five valves can be operated simultaneously with a single irrigation controller. The solenoid coil never burns out because there is no power in the coil.



Battery Control System for Irrigation Valves

Overview

- Developed and being marketed by Alex-Tronix Controls (www.alex-tronix.com)
- Commercialized in 1999 with over 3600 units in the field
- Proven operation in laboratory and field tests

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.017	0.001

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.020

Applications

Can be used in sprinkler systems in medians, schools, shopping malls, golf courses, parks, agricultural and industrial applications

Capabilities

- Operates valves out to about 20 miles.
- Eliminates the energy and primary wiring needed to operate an irrigation system.
- Provides 10 times the battery life and 100 times the operating distance of any other controller.

Benefits

Ease of Installation

Allows controllers to be installed anywhere, without the need to install electrical meters or to use licensed electricians for installation.

Safety

Eliminates power surge and lightning-related problems associated with primary power leads because no primary wiring is needed.

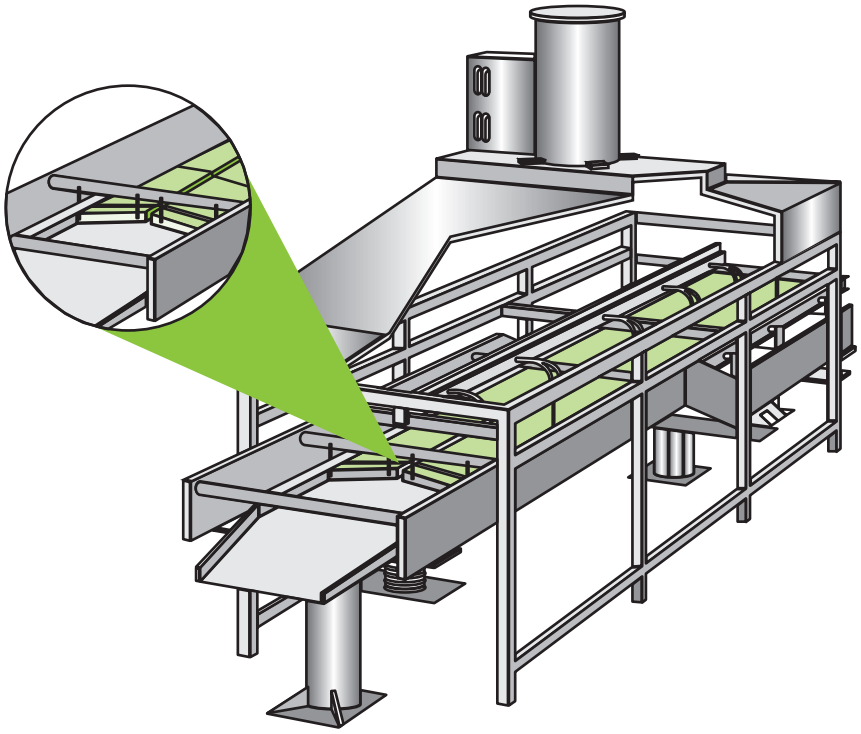
Long Wavelength Catalytic Infrared Drying System

New Infrared Drying System Removes Moisture More Efficiently Without Heating Surrounding Air

Conventional drying systems for wood particulates, typically in the form of sawdust or chips, currently employ a rotary drum dryer that shoots a raw flame through a 20' to 30' rotating drum while tumbling the wood product. Product scorching and air emission problems, particularly with carbon, NO_X, and volatile organic compounds (VOCs), are prevalent because the rotary drum operates at up to 1,000°F.

An infrared drying system was developed by Catalytic Drying Technologies, Inc. (CDT), with the support of a DOE NICE[3] grant. The long wavelength catalytic infrared drying system uses infrared energy from 3 to 7 microns to transfer energy directly to the water, activating it to a gaseous form at temperatures from 135°F to 220°F. Highly efficient and tightly controlled infrared radiant energy is delivered to the product as it travels along a conveyor engineered to uniformly expose the product to the radiant energy.

A large prototype unit was constructed and tested with sawdust, wood chips, and a variety of agricultural products. The CDT system was proven to dehydrate forest and agriculture products efficiently. A conveyance system distributes the product evenly throughout the dryer to achieve consistent drying. While equipment costs are comparable to conventional heating systems, life-cycle costs are reduced. However, the CDT system can greatly reduce drying/heating times using flameless catalytic infrared energy, resulting in smaller equipment or more throughput (or both). Reducing the moisture content with infrared drying by transferring energy directly to the moisture instead of heating the air and surrounding metal structure requires less energy, reduces air emissions and dries the product more thoroughly than conventional drying.



Catalytic Infrared Drying System

Overview

- Developed and marketed by Catalytic Drying Technologies, Inc. (www.catalyticdrying.com)
- Commercialized in 2005
- Two units operating in the U.S. in 2007 in a rice drying facility and a powdered egg production plant

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.006	0.003

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.0	0.0	0.046

Applications

Can be used by various industries such as forest products, agriculture, chemical processing, brewing and distilling, animal products, and horticulture

Capabilities

- Uses infrared energy from 4 to 7 microns to transfer energy directly to water.
- Drives off water at temperatures from 135°F to 220°F.
- Avoids the need for direct flame, which could damage the product.

Benefits

Cost Savings

Reduces operating and life-cycle costs compared with conventional dryers.

Productivity

Reduces residence time in the dryer and the amount of scorched (wasted) product.

IMPACTS

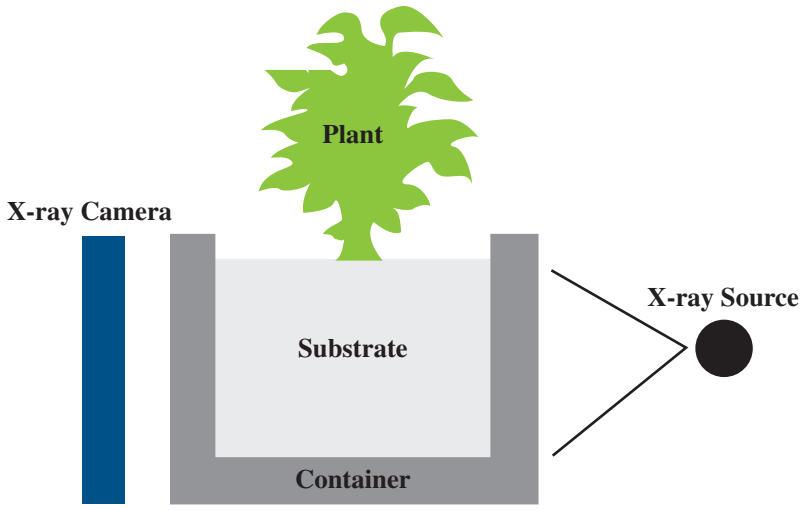
New X-Ray Technology Accelerates Plant Research

The ability to analyze plant root structure and function in a timely, cost-efficient manner is critical to meeting DOE Biomass Program goals. Plant root characterization technologies traditionally cannot handle high throughput. Additionally, it has been difficult to analyze the same plant more than once due to destructive analysis methods.

With funding from DOE's Inventions and Innovation Program, the Phenotype Screening Corporation has developed a high-throughput, high resolution, and non-destructive system to image and characterize plant roots. The effect of the application of this technology will be to accelerate progress in a wide range of genetic improvement programs, including biomass feedstock (poplar, switchgrass, corn, and soybeans). Research acceleration may produce overall improvements in the range of 30%.

The system is based on low-voltage digital x-ray radiography, used with special growth substrate material, plant containers, and image processing algorithms. Low-density polymer substrates and containers are used because they are suitable for low energy x-ray radiographic imaging. The project will primarily enable "output trait" and "value-added trait" improved products.

Both Container and Substrate are Virtually Transparent to X-rays.



Non-Invasive Root Characterization System

Overview

- Developed by Phenotype Screening Corporation (www.phenotypescreening.com)
- Commercialized in 2006
- Used by universities and other research organizations

Applications

Can be used in noninvasive root characterization studies to compare different plants' growth or a single plant's growth over time. Stressors may be introduced to see how the plants react; detailed analysis and characterization can show traits that can't be seen by the unaided eye.

Capabilities

- Allows detailed plant root measurements without destroying the plant.
- Can be customized to allow varied studies.

Benefits

Productivity

Accelerates research by about 30%, contributing to reduced research time and costs, and therefore higher productivity.

Waste Reduction

Allows measurements to be made on the same plant so fewer plants have to be grown to conduct an analysis, using less growing medium, water, and plant containers.

Plastics or Fibers from Bio-Based Polymers

Plastics from Renewable Resources Offer Significant Commercial and Environmental Benefits

Each year, 60 billion pounds of thermoplastics are produced from imported and domestic oil to make industrial and consumer products. Because oil is an increasingly limited resource with negative impacts on the environment, reducing dependence on oil in all areas is important, including product manufacturing.

Polylactide (PLA), derived from annually renewable bio-based resources, can be used in place of petroleum-based thermoplastics in many applications such as compostable packaging, film, and fibers for apparel, carpeting, and other fabrics while greatly reducing CO_2 emissions. With financial assistance from ITP, the National Renewable Energy Laboratory (NREL) along with Cargill Dow LLC and the Colorado School of Mines, developed and refined a process to use PLA in manufacturing. Substituting PLA for petroleum-derived polymers reduces fossil energy use by 62% to 68%. Projections are that 10% of the U.S. nonrenewable plastics packaging can be replaced with polylactide polymer.

This project assisted in expanding the PLA market by developing two new processing technologies. Both technologies yield semi-crystalline PLA articles that have improved physical properties. Other project tasks helped to better understand the relationship between polymer molecular structure and physical properties, which is useful information for improving process control.

Benefits

Energy Savings and Pollution Reduction

Consumes up to 68% less energy in the form of fossil resources compared with producing products from petroleum. Emits less CO_2 than petroleum-based products because the carbon comes from plants that extracted CO_2 from the atmosphere.

National Security

Reduces the nation's dependence on foreign resources and oil to produce necessary products such as clothing, food packaging, and carpets.

Overview

- Developed by NREL with Cargill Dow LLC and Colorado School of Mines
- Commercialized in 2003
- Produced at Nature Works LLC's Blair, NE facility with a capacity of 300 million pounds per year (www.natureworksllc.com)

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.088	0.018

U.S. Emissions Reductions

(Thousand Tons, 2007)

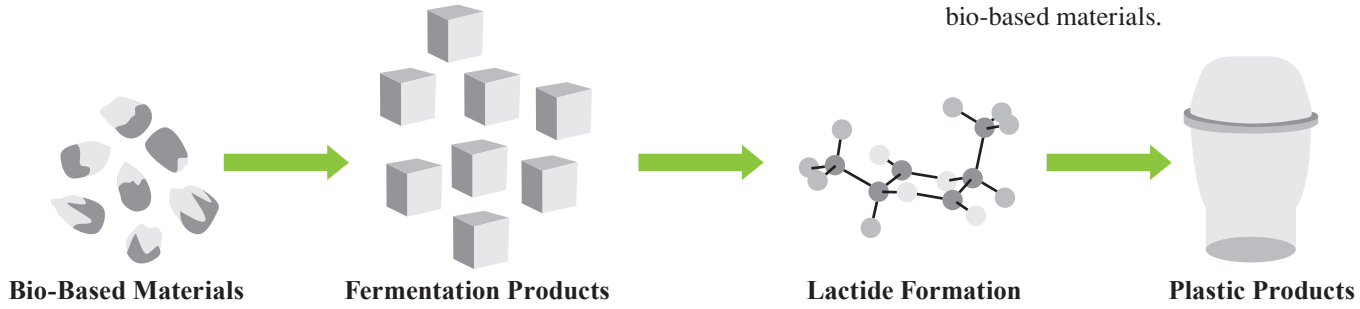
Particulates	SO_x	NO_x	Carbon
0.0	0.011	0.003	0.394

Applications

Can be used by plastics and textile industries, replacing certain packaging, films, and fibers used for apparel, carpeting, and other fabrics

Capabilities

- Competes in a market based on price and performance, with a better environmental profile than today's plastics.
- Currently could replace 10% of packaging with PLA, with more research being conducted to infiltrate the market further.
- Offers potential to use a wide variety of bio-based materials.



Process for Producing Plastic Using Renewable Resources

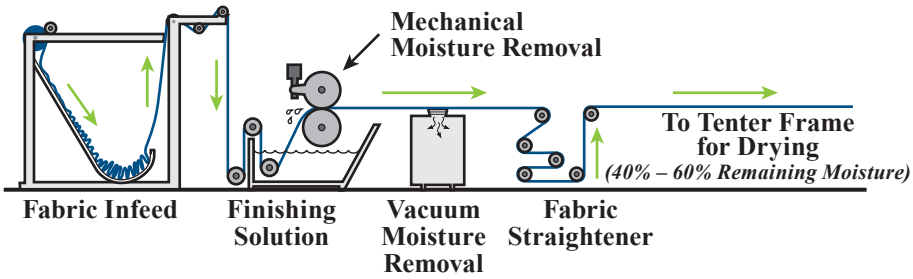
IMPACTS

New Process Increases Productivity and Energy Efficiency in Fabric Finishing

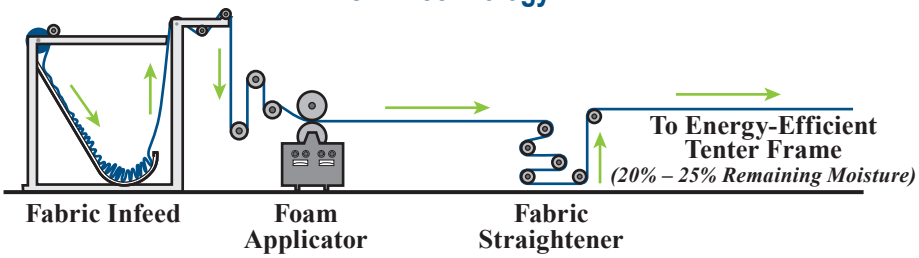
The U.S. textile industry consumes large amounts of energy and water in finishing fabrics. The finishing operation is the final step in producing fabrics and typically imparts the aesthetic and physical properties required for various fabric uses. Using conventional technology, fabric finishers immerse fabric in a solution of finishing chemicals diluted in water. Once saturated, the fabric is removed, and excess moisture is squeezed out mechanically. The moisture is further reduced by a vacuum system before the fabric is directed to fabric drying equipment called the "tenter frame." The tenter frame removes the remaining moisture by processing the fabric through a series of nozzles that expose it to hot air. Because of the relatively high moisture content, the fabric finishing process has been very energy intensive.

With assistance from a NICE^3 grant, Brittany Dyeing and Printing Corporation demonstrated a new process for finishing textiles. In the new process the finishing chemicals are diluted with air instead of water and applied to the fabric as foam. No additional mechanical or vacuum moisture removal is necessary, thus, saving energy and water. The moisture content of the fabric is cut in half, allowing a new energy-efficient, high-speed tenter frame to be used. This new process increases the productivity of the finishing line by more than 100%.

Conventional Technology



NICE^3 Technology



Textile Finishing Operations

Overview

- Commercialized in 1999
- Demonstrated savings continue at Brittany Dyeing and Printing Corporation

U.S. Energy Savings

(Trillion Btu)

Cumulative through 2007	2007
0.204	0.023

U.S. Emissions Reductions

(Thousand Tons, 2007)

Particulates	SO_x	NO_x	Carbon
0.0	0.002	0.003	0.397

Applications

Can be used by the textile finishing industry

Capabilities

- Replaces traditional water-based textile finishing applications.
- Reduces the moisture content of fabric from finishing by more than 50%.
- Increases production capability by over 100% through higher production speeds.

Benefits

Energy Savings

Saves energy by applying chemicals in a foam media rather than liquid, reducing the moisture content and the energy needed to dry fabric.

Environmental

Dilutes finishing chemicals with air instead of water, reducing water use and the wastewater discharged.

Productivity

Allows for higher production rates (over 100% increase in production capability) because of reduced moisture content.

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ITP Emerging Technologies

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ITP Emerging Technologies

Aluminum

Direct Chill Casting Model

(www.secat.net)

The direct chill (DC) casting process is used for 68% of the aluminum ingots produced in the United States. Ingot scraps from stress cracks and butt deformation account for a 5% loss in production. The interaction of the DC process is too complex to analyze by intuition or practical experience. A new DC casting model is being developed to increase the general knowledge of the interaction effects and should lower production losses to 2%. The model will provide insights into the mechanisms of crack formation and butt deformation, and will help optimize DC process parameters and ingot geometry.

Vertical Flotation Melter

(www.er-co.com)

The Vertical Flotation Melter (VFM) is an advanced remelting process that is energy efficient and environmentally friendly. It will help the aluminum industry meet energy and environmental performance targets. The technology also applies to other industries, such as the glass container, fiberglass and steel industries.

Chemicals

Affinity Ceramic Membranes with CO_2 Transport Channels

(www.mediaandprocess.com)

Compared with more conventional separation processes, membrane separation processes offer several advantages, including increased energy efficiency, compact design, and operational flexibility. Numerous unexploited applications exist for advanced separations in aggressive environments that rely on a membrane's affinity to a specific chemical as opposed to traditional molecular sieving. Highly selective thermally/hydrothermally stable inorganic membranes offer a solution to these difficult industrial separation applications.

Catalytic Hydrogenation Retrofit Reactor

(www.airproducts.com)

The Monolith Loop Reactor (MLR) is a novel, integrated monolith catalyst reactor system that can be retrofitted onto existing commercial slurry-catalyst stirred tank reactors. A reusable high-activity monolithic catalyst replaces the slurry catalyst, and a two-phase gas and liquid feed mixture is fed to the reactor using a specialized gas-liquid ejector. The monolith catalyst effectively concentrates or intensifies the catalytic reaction in the small parallel channels of the monolith, while the ejector correspondingly increases the gas-liquid mass transfer to match these high reaction rates. Target markets include the commodity chemical, specialty chemical, fine chemical and pharmaceutical intermediates. This new technology offers reduced energy consumption because of higher productivity, improved yields, reduced waste, and elimination of the catalyst slurry filtration step and its associated operational costs.

Concurrent Distillation

(www.utexas.edu)

The Trutna Tray (Co-Flo Tray) improves the performance of distillation and absorption trays by using a co-current flow design. Compared with the conventional sieve tray, the co-current tray increased production capacity by more than 100% without sacrificing separation efficiency. Three tray variations have been pilot-tested using an industrial-scale distillation column. The de-entraining section of the Co-Flo Tray is routinely used by the UT Austin's Separation Research Program in all of its air/water and caustic scrubbing studies. The special collector design and the enhanced liquid/vapor separation capability offer great potential for future de-entraining applications.

IMPACTS

Chemicals
(continued)

Dimpled-Tube Heat Exchangers
(www.gastechnology.org)
A project to improve the thermal efficiency of convective sections of industrial fired-process heaters demonstrates that a dimpled-tube technology will significantly improve the energy efficiency of fired-process heaters and will reduce fouling rates. The heat-transfer enhancement approach uses a tube surface with a system of three-dimensional cavities (dimples). Cost-effective enhancement occurs because intensive vortex flow patterns are generated by cavities and provide intensive heat and mass transfer between the surface and the flowing media. A pilot-scale dimpled-tube test unit at a participating refinery increased heat flow by 50% to 60% compared with traditional tubes and reduced pressure drop by 30% to 40%.

Distillation Column Flooding Predictor
(www.2ndpoint.com)
A new control technology more accurately identifies incipient floods in petrochemical distillation and separation columns. The Flooding Predictor, a patented pattern recognition technology, allows a column to be operated at or near the incipient flood point. The technology identifies patterns of transient instabilities that occur just before flooding events. Identifying the incipient flood point allows the control objective to be shifted from delta-pressure to the actual flood point. Shifting the control objective virtually eliminates column flooding events, while increasing throughput.

Distillation Column Modeling Tools
(www.ornl.gov)
A computational model is being developed to optimize distillation column operation and design of column internals. A commercial-scale model will be validated to facilitate industry-wide acceptance and use. The commercialized software containing the model will calculate column design and operating parameters based on inputs of column size, packing configuration, feed conditions, and system physical properties. The model has the potential to optimize distillation column operations to save an estimated 53 trillion Btu per year by 2020.

Chemicals
(continued)

Electrodeionization for Product Purification
(www.anl.gov)
This technology combines the advantages of ion exchange (an adsorption technology) and electrodialysis (a membrane separation) for a wide range of potential applications in the chemical industry, including direct production and separation of products, product purification and desalination, salt waste recovery, and water recycling. Targeted applications include organic acid production, dextrose desalination, ultrapure water production, product polishing, and waste salt recovery.

High Octane Fuel-Stocks via Engineered Solid Acid Catalysts
(www.exelusinc.com)
High octane alkylate, an ideal clean fuel component for reformulated gasoline, is currently made using toxic liquid acid catalysts such as hydrofluoric acid. A commercially viable and environmentally superior alternative to conventional liquid-acid alkylation processes is being developed called the ExSact process. This pilot-tested process uses benign, engineered, solid-acid catalysts coupled with an innovative reactor design to produce high-octane gasoline. Low energy consumption and production of fewer by-products compared to existing technologies result in significant savings in operating costs.

Low Emission Diesel Engines
(www.compactmembrane.com)
Diesel engine exhaust is a major source of NO_X pollution. The formation of NO_X in diesel engines is dependent on the combustion temperature, which can be affected by the engine cylinder charge. An innovative membrane is being developed to adjust the cylinder charge and reduce the NO_X emissions by delivering nitrogen-enriched air to the system. The system may reduce NO_X formation in diesel engines by 50%.

Membrane for Olefin Recovery
(www.mtrinc.com)
Selective polymer membranes are being developed to allow recovery of olefins (compounds with carbon-carbon double bonds such as ethylene and propylene) from petrochemical by-product and vent streams. These streams are often flared or used as a fuel even though the olefin is more valuable as a chemical feedstock. This new separation technology will allow olefin separation and recycling within the process.

Chemicals
(continued)

Microchannel Reactor System for Hydrogen Peroxide Production
(www.fmc.com)
Newly developed reactors allow for on-site, on-demand generation of hydrogen peroxide (H_2O_2) and reduce the costs of transportation, storage, and dilution associated with conventional H_2O_2 production methods. Microchannel reactors possess extremely high surface-to-volume ratios and exhibit enhanced heat and mass transfer rates. The unique design allows for the peroxide-generating reaction to occur at H_2 concentrations above 5% without the risk of combustion. In addition, the reactor's low-pressure operating conditions maximize energy efficiency and safety.

Purification Process for Purified Terephthalic Acid (PTA) Production
(www.gtchouston.com)
A novel purified terephthalic acid (PTA) production process using a two-step crystallization technique promises to make a significant economic impact on the PTA industry. The process operates at lower pressure and temperature, significantly reducing energy consumption, and enables the use of lower purity, lower-cost para-xylene feedstock. The process uses a highly selective, proprietary organic solvent blend that allows for bromine-free oxidation, which eliminates the environmental problems caused by methyl bromide and the high cost of corrosion-resistant specialty alloys used in construction materials.

Recovery of Thermoplastics via Froth Flotation
(www.anl.gov)
A process for the economical separation of high-value plastics from plastics waste streams derived from home appliances and electronics scrap has been developed. Current methods for separating plastics cannot economically separate plastics of similar density from each other. The process was demonstrated at a private company site involved in the recycling business. The design capacity of the demonstration plant was 1000 pounds per hour. About 20,000 pounds of ABS and HIPS plastics were recovered with a purity of more than 98% and a yield of higher than 80%. Recovered plastics via this process were successfully used by car-part manufacturers in making automotive parts. There are significant benefits due to lower energy use and resource conservation in the reuse of plastics for industrial manufacturing.

Chemicals
(continued)

Scalable Production of Fermentation-Derived Acetic Acid
(www.anl.gov)
Half of the 2.3 billion pounds of U.S. acetic acid production is used in manufacturing vinyl acetate monomer (VAM) and is economical only in very large production plants. Nearly 80% of the VAM is produced by methanol carbonylation, which requires high temperatures and exotic construction materials and is energy intensive. Fermentation-derived acetic acid production allows for small-scale production at low temperatures, significantly reducing the energy requirement of the process.

Solution Crystallization Modeling Tools
(www.olisystems.com)
Reliable simulation of crystallization requires accurate modeling of many factors. A new modeling tool synthesizes several essential elements, at least one of which has been only crudely approximated in previously available tools. This new modeling tool helps chemical engineers to better predict and control the crystal size distribution. It also improves the understanding of the effects of mixing and spatial variation of temperature and composition on the product quality, and ultimately will optimize crystallization efficiency. The resulting enhanced computational fluid dynamics capabilities are also applicable to a range of industrial applications beyond crystallization.

Sorbents for Gas Separation
(www.praxair.com)
A new technology based on oxygen-selective sorbent materials and pressure swing adsorption (PSA) could cost-effectively produce industrial gases, such as nitrogen. Purification applications where oxygen is removed from argon, helium, and nitrogen streams offer early potential commercial opportunities. This technology potentially requires less energy for gas separation compared to conventional techniques and can provide high-purity gases at lower cost.

Forest Products

Biological Air Emissions Control

(www.bioreaction.com)

An innovative biological sequential treatment system that integrates two types of biological oxidation offers an attractive alternative to conventional, thermal oxidizer emissions control techniques. The two-stage system uses microorganisms to degrade (bio-oxidize) air toxins and other VOCs without using natural gas as fuel or creating secondary pollutants. The system combines a biofilter for removing low concentrations of pollutants and polishes the air stream with a biotrickling filter system for removing high concentrations of hydrophilic compounds, and will conserve water through in-vessel treatment and recycling of the scrubbing liquid.

Black Liquor Steam Reforming/Pulsed Combustion

(www.thermochem.com)

Black liquor is a liquid containing both pulping chemicals and tree organics. Historically, it was combusted to recover chemicals but this combustion is thermally inefficient and supplies about 50% of the energy needed in an integrated pulp and paper mill. A new process that gasifies the black liquor to recover chemicals and significantly more of the energy is being commercialized in two U.S. plants and a third plant in Canada. This gasification process could be further developed to produce power or transportation fuel and high performance chemicals. It also operates at significantly lower emission levels and eliminates the possibility of explosions.

Decontamination of Process Streams through Electrohydraulic Discharge

(www.ipst.gatech.edu)

In recycling paper, "stickies" cause considerable downtime and require costly minerals and polymers to be added for handling and detackifying them during the recycling process. A new mechanical method - pulsed power technology - is being demonstrated at several recycling mills to replace these costly chemicals. This technology uses a shock wave, developed from a spark discharging under water, to diffuse the stickies and create hydroxyl radicals from water, which oxidizes the stickies. This oxidation causes the stickies to lose their tack and become benign, thus allowing recycling to continue unimpeded.

Forest Products

(continued)

Directed Green Liquor Utilization (D-Glu) Pulping

(www.ncsu.edu)

Advances in the rate and selectivity of Kraft pulping without incurring major capital costs will increase the economic return of the pulp and paper industry. A high sulfidity pretreatment of wood chips is one of the most promising ways to achieve these advances. Green liquor is easily accessible in a mill and naturally rich in hydrosulfide ions, which are critical for accelerating pulping and providing a high value product. Researchers have discovered ways to reduce pulping time and energy requirements through the intelligent application of green liquor in the digester.

Fibrous Fillers to Manufacture Ultra-High Ash/Performance Paper

Mineral fillers that increase paper brightness and opacity and improve paper print quality have reduced costs by replacing wood fiber. However, filler loading has been limited to 15% to 20% because higher loading levels cause a loss of sheet strength and bulk as well as "dusting" during printing. A new fibrous filler technology has been developed that may overcome these problems and replace high-cost wood fiber. The new fillers will ultimately produce a composite paper containing up to 50% ash, with equal or better performance characteristics than conventionally attainable paper. The new technology will also lead to better retention of fillers, additives, and pulp fines, significantly reducing biological and chemical oxygen demands in the mill process water.

Gas-Fired Paper Dryer

(www.gastechnology.org)

A new paper dryer is being developed and pilot-scale tested to significantly increase the efficiency of papermaking. The Gas-Fired Paper Dryer (GFPD) is a natural-gas-fired system that uses a combination of a flame sheet and dimpled pattern on the drum's inner surface to improve combustion stability, reduce pollutant emissions, and cost-effectively enhance heat transfer from combustion products to the paper web. This patented approach could be implemented into new or existing equipment. The GFPD will ultimately help the paper industry (especially drying limited mills) reduce energy use and increase the production rate of paper machines by 10% to 20%.

Forest Products
(continued)

Innovative Back Surface Reflector for High-Efficiency Infrared Paper Drying
(www.creare.com)
An innovative back surface reflector (BSR) that will dramatically improve the efficiency, quality, and throughput of the papermaking process is being developed. Electric infrared (IR) dryers with current BSR technology suffer from extremely low energy efficiency, using only 10% of the input power supplied to an IR dryer to dry the paper; the rest is lost as waste heat. The new BSR design dramatically increases the percentage of input power that is absorbed by the paper sheet, decreasing energy costs and increasing product quality and throughput.

Laser-Ultrasonic Web Stiffness Sensor
(www.lbl.gov)
This technology uses noncontact laser ultrasonics to monitor paper mechanical properties (e.g., bending, stiffness, and rigidity) in real-time during the papermaking process. In the past, paper mechanical properties were probed with transducers in direct contact with the web. This approach is no longer used because contact transducers can damage the web, leading to costly production losses. Noncontact monitoring of paper stiffness during manufacture will reduce waste and energy use by using less refining and remanufacturing, make optimal use of pulp feedstock, and reduce production of offgrade paper.

Lateral Corrugator
(www.ipst.gatech.edu)
A new corrugator method increases box strength and reduces drying costs by aligning corrugations with the direction of the paper machine, rather than perpendicularly. With this technology, manufacturers can use thinner paper to produce boxes of equal strength and can reduce drying energy requirements. This technology will also significantly reduce cost and energy use by reducing waste and box plant inventory and by optimizing trim and transportation. An important secondary benefit of lateral corrugating is the ability to utilize paper mill trim rolls reducing mill waste and associated energy consumption.

Forest Products
(continued)

Low Temperature Plasma Technology for Treating VOC Emissions
(www.drexel.edu)
Pulp mills and wood product plants are under increasing pressure to control the emissions of volatile organic compounds (VOCs) generated during their operations. The present-day control technology – regenerative thermal oxidizers – is energy-intensive and depends on combustion technologies that heat the entire waste stream. An emerging technology using nonthermal plasmas can selectively and cost effectively destroy VOCs by producing excited species (free radicals and ions) that oxidize, reduce, or decompose pollutant molecules.

Materials for High-Temperature Black Liquor Gasification
(www.ornl.gov)
New black liquor gasification technology with combined-cycle cogeneration of steam and electricity can increase energy output for the forest products industry. However, high inorganic salt concentrations and high temperatures significantly degrade refractory materials and metallic components. Improved refractories and wear-resistant nozzle materials are being developed to enable high-temperature black liquor gasification units to attain a longer service life. These improvements will reduce operating downtime and increase energy production and support the use of black liquor gasification.

Novel Isocyanate-Reactive Adhesives for Structural Wood-Based Composites
(www.vt.edu)
Laminated veneer lumber (LVL) is a wood composite that is produced by bonding thin wood veneers together and is used for various wood construction applications. The current LVL manufacturing process is energy intensive, using adhesives that require extensive wood drying (to moisture contents of 6% to 8%) and high-temperature hot-pressing (~200°C). An alternative isocyanate-reactive that cures at room temperature (cold-setting) and is optimized for higher veneer moisture content promises significant energy savings. This new technology will also sharply reduce volatile organic compound emissions and improve product appearance and durability.

IMPACTS

Forest Products
(continued)

Oxalic Acid Technology
(www.biopulping.com)
As shown in pilot-scale tests, a short pretreatment of different types of wood chips with a dilute solution of oxalic acid saves electrical energy (20% to 30%), improves paper strength properties substantially, and reduces resin content by 30% prior to mechanical pulping. The pretreatment also removes hemicellulose from wood chips, which could then be converted into value-added chemicals, including cellulosic ethanol. Based on pilot scale results and the preliminary economics, companies are planning on conducting mill trials in the U.S. with the intent to implement this breakthrough technology at their mills as soon as possible because of the rising costs of electricity and the purchased price of softwood bleached kraft used in making paper.

Pulse Drying of Paper Pulp
(www.wavedry.com)
Paper manufacturing begins with wet pulp fibers that are progressively shaped, dewatered, and dried through evaporation into finished products. Virtually all paper manufacturing production is limited by the evaporative drying stage. The most common air drying process is impingement evaporation, where hot gas jets blow on the wet paper web. However, pulse impingement drying improves efficiency of this process by 59% and speeds overall paper production by 21%. Pulse drying of paper webs applies directly to "Yankee" and "MG" style paper drying equipment and indirectly to newsprint, box board, and finer grades of paper.

Residual Solids From Pulp and Paper Mills for Ready-Mixed Concrete
(www.uwm.edu)
The fibrous residuals from mill processing are typically sent to landfills. These residuals can be incorporated into ready-mixed concrete to improve the strength, durability, and lifespan of concrete structures, especially those exposed to weather. Adding residuals to concrete could increase the lifespan of high-performance concrete from the normal 30 years to up to 100 years. The new technology offers the pulp and paper industry a practical and economical solution for residuals solids disposal and provides the concrete industry with a low-cost source of fibers to produce a better product for its customers.

Forest Products
(continued)

Steam Cycle Washer for Unbleached Pulp
(www.ptpc.com)
A new commercial-scale Steam Cycle Washer is being developed to increase profitability by substantially reducing energy consumption, improving fiber and product quality, and ensuring that environmental compliance exceeds current regulations. This steam-pressurized, high-consistency pulp washer will enhance pulp industry profitability by allowing most pulp mills to reduce electrical power consumption for unbleached pulp production by up to 21%, evaporator load by 50%, and plant effluent and fresh-water usage by 45%.

Surfactant Spray To Improve Flotation Deinking Performance
(www.ipst.gatech.edu)
This new technology uses an atomizer to spray frother at the top of the flotation column in the wastepaper flotation deinking process to significantly reduce the loss of fiber and water and the use of chemicals in the process. Frother spray technology will provide on-line control for the frother agent distribution in the flotation slurry. This technology will be easily retrofitted to industrial flotation equipment without significant modifications to existing systems.

Glass

Advanced Combustion Space Model for Glass Melting

(www.anl.gov)

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.

Advanced Oxy-Fuel-Fired Front-End System

(www.owenscorning.com)

A consortium of companies involved in the glass industry has developed the Advanced Oxy-Fuel-Fired Front-End System. A combination of burner modeling and bench trials was used to develop a burner and block that generate the appropriate size and shape of flame for optimal heat transfer distribution. This will result in reduced energy use and decreased CO_2 emissions. The new burner system can be integrated into a front-end system with capital costs that are competitive with a conventional air/gas system. Full-scale installation and testing are under way in a Tennessee glass plant.

Enabling Tool for Innovative Glass Applications

(www.imp.mtu.edu)

Flat architectural and automotive glasses have traditionally been fabricated using technologies that have inherent cutting limitations because they are generally incapable of fabricating glass products with small radii, concave edges, or pierced holes. A new technology uses waste glass as a low-cost media for abrasive water-jet cutting of glass and other materials. This technology can refine and automate the glass manufacturing process while reducing the number of stages and equipment required to produce intricate glass products. Other waste materials can also be used.

Energy Saving Glass Lamination via Selective Radio Frequency Heating

(www.ceralink.com)

A new technique for glass lamination is being developed that will save significant amounts of energy and increase throughput. Traditional glass lamination involves bonding two or more sheets of glass with vinyl interlayers, which wastes large amounts of energy to get heat through the glass to the vinyl, where the heat is desired. The new technology heats the vinyl directly using a single-step radio frequency process. The new process will dramatically decrease the lamination time and will result in significant energy savings across the U.S. laminated glass industry.

Glass
(continued)

High-Intensity Plasma Glass Melter

A high-intensity plasma glass melter was developed with a square-foot-per-ton-per-day throughput index that is significantly smaller than commercial glass melters. This plasma technology package increases the systems' energy efficiency and reduces emissions. To achieve this high throughput and high quality, the system uses a dual-torch transferred arc-plasma technology, a rotating melt chamber to increase melt rate, skull melting to eliminate the need for a refractory lining and to reduce contamination of the glass from refractory and electrode components, and state-of-the-art control technology to provide stable conditions.

High Throughput Vacuum Processing Produces Innovative Glass/Photovoltaic Solar Cells

(www.abound.com)

A manufacturing process was demonstrated to rapidly produce cadmium telluride photovoltaic solar cells fabricated on glass superstrates. This process has extremely low direct manufacturing costs, low equipment costs, the ability for rapid capacity expansion, and the ability to improve occupational safety. The innovative process uses a proprietary system that allows continuous production of cadmium telluride cells rather than use of slower batch processes.

Manufacturing Ceramic Products from Waste Glass

(www.haunlabs.com)

Ceramic products have traditionally been processed from raw materials that require high firing temperatures and energy-intensive processing steps. A new technology lowers energy costs by substituting raw materials with recycled waste glass. Products manufactured by this new method are less sensitive to contaminants in the glass and can be made from difficult-to-recycle green or mixed-color container glass waste. Firing temperatures can be reduced by as much as 37%, lowering energy costs and CO_2 emissions. The technology has been used to design a low-cost highly-automated manufacturing process for producing ceramic tile from large volumes of waste glass. High-quality ceramic tile with competitive specifications has been processed from 92% to 100% recycled glass with a wide range of colors and surface textures. The technology has been applied to several types of glass, including post-consumer container, flat and lamp glass, and industrial fiber-glass waste streams.

IMPACTS

Glass
(continued)

Submerged Combustion Melting
(www.gastechnology.org)
A consortium of companies developed a high-intensity glass melter based on the submerged combustion melting technology. This melter serves as the melting and homogenization section of a segmented, lower-capital-cost, energy-efficient Next Generation Glass Melting System. This technology will potentially increase efficiency, lower capital costs, provide more flexible operation, and lower emissions.

Metal Casting

Cupola Furnace Process Model
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, is being enhanced and updated. The model was incorporated into a user-friendly artificial-intelligence program that can help optimize the temperature, processing time, and other key variables of furnace operation. This improved operation results in energy savings, product quality enhancement, and waste reduction.

Integrating Rapid Solidification Process Tooling and Rapid Prototyping in Die Casting
(www.rsptooling.com)
In this project, a new and unique Rapid Solidification Process (RSP) technology will be introduced to the tooling industry to reduce lead time for prototyping and producing dies. In addition to increased productivity, the RSP tooling technology will substantially increase tool life while reducing energy use and scrap compared with conventional machining practices. Tools have been produced for the die casting, plastic injection, investment casting, glass forming, and forging industries.

Lost Foam Casting Technology
(www.eng.uab.edu)
Lost foam casting is a highly flexible process suitable for casting metal components with complex geometries. Research supported by ITP has led to a greater understanding of the process and to new control measures. These will increase foundry energy efficiency and reduce scrap. Emerging technologies from the ITP-supported research include: in-plant quality assurance procedures to measure casting parameters; real-time x-ray apparatus which allows visualization of the metal/pattern replacement process; and an apparatus for measuring pattern permeability (fusion) which is a major factor in the replacement process.

Metal Casting

(continued)

New Treatment for Improved Aluminum High-Pressure Die Casting

(www.cccintl.com)

Traditional components for stamping and cutting functions in the aluminum and other metal industries have limited lifetimes and require periodic replacement to maintain product quality. A new zirconium-based treatment can increase component life by up to 50 times, which reduces process downtime and production costs and increases product quality. Potential applications include metal working, forging, internal combustion and turbine engines, and other high-wear industry processes.

Process to Recover and Reuse Sulfur Dioxide in Metal Casting Operations

(www.adsorption.com)

Sulfur dioxide (SO_2) is used as a catalyst in forming cold-box molds and cores in the metalcasting industry. The SO_2 is typically used once, scrubbed with a caustic solution, and then discarded (flushed to sewer or sent to a waste treatment facility). This new process recovers the SO_2 for reuse by processing it through a pressure-swing adsorption system that is expected to recover at least 95% of the SO_2. Using this process will reduce energy consumption, eliminate the need for caustic effluent, and pay back costs in less than 1 year

Mining

Dense-Medium Cyclone Optimization

(www.vt.edu)

Dense-medium cyclones are used to separate coal or other minerals from waste rock in most modern coal plants and in a variety of mineral plants, including iron ore, diamonds, and potash. A set of engineering tools to improve the efficiency of dense-medium cyclones is being developed and demonstrated. These tools include low-cost density tracers to rapidly assess cyclone performance, mathematical process models to predict the effects of operating and design variables, and a model-based expert system for trouble-shooting cyclone circuits. These tools will successfully improve plant productivity, reduce energy costs, and minimize waste rock generation.

Drill-String Radar Navigation for Horizontal Directional Drilling

(www.stolarhorizon.com)

Horizontal drilling in a coal seam can relieve methane gas trapped in a coal bed, increasing the safety of coal miners and supplying methane, a desirable resource. Gamma sensors, currently used for horizontal drilling, cannot withstand the vibration of the drill and require additional costly drilling steps. Instead of gamma sensors, drill-string radar transmits radio waves and measures their reflection to identify boundary rocks, reducing vibration sensitivity and allowing real-time measurement while drilling. This technology will reduce the risk, cost, and time required for extraction.

GranuFlow™ Process in Coal Preparation Plants

(www.cq-inc.com)

The GranuFlow technology involves adding a binding agent such as an asphalt emulsion to a slurry of coal and water prior to mechanical dewatering. The binding agent agglomerates the fine-sized coal, increasing its capture during mechanical dewatering, thereby reducing coal loss to impoundments. The GranuFlow treatment also reduces moisture content, alleviating downstream handling, dusting, and freezing problems.

IMPACTS

Mining
(continued)

Grinding-Mill Optimization Software
(www.mines.utah.edu)
Millsoft 3D is simulation software for visualizing the charge motion in semi-autogenous mills and ball mills used in the mining industry. The software also provides various quantitative information, such as power, forces on the mill lifters, and wear. The three-dimensional code uses the discrete element method to model the individual collisions of ball and rock particles. The software handles mills of all sizes and can be used for shell lifter design and energy optimization of SAG mills.

High-Temperature Superconductors in Underground Communications
(www.lanl.gov)
Underground communications are important for the mining industry, urban first-responders, and others who frequently work underground. The through-the-earth radio system can increase underground mining production by improving communication and eventually allowing orientation and position information, which can benefit both an individual miner and a mining machine. Most importantly, fast wireless communication improves underground mining safety through early response to problems. A new system has been built using conventional copper and semiconductor designs and higher-performance superconducting designs. Using superconducting materials in underground communications equipment increases the range and clarity of through-the-earth wireless networks.

Magnetic Elutriation Technology for Processing Iron Ore
Magnetic elutriation improves the quality of low-grade domestic iron ore by using an alternating-current pulsed-magnetic field to clean iron ore into a highly refined product. This new continuous countercurrent system is being demonstrated in the field. The technology efficiently separates the tailings and middling particles out of the iron ore without using harmful chemicals.

Mining
(continued)

Novel Dry Coal Deshaling Mobile Unit
(www.eriez.com)
A new dry deshaling technology removes materials with high-ash content prior to loading and further coal cleaning. The new coal-cleaning unit provides high-density separation near the extraction point or working face of a mining operation. The system requires no water, facilitating easier product transportation and waste material hauling. These features enable mine personnel to remove waste rock and minimize coal losses to the rejection stream. This new method reduces land impacts and waste emissions while lowering capital and operating costs.

Real-Time Coal/Ore-Grade Sensor
(www.resonon.com)
Various project partners helped in the development of a real-time coal content/ore-grade sensor for exploration, mining, and processing operations. The project used the unique spectral characteristics of coal and ore to quantify coal content and ore grade in real time. The sensor would be suitable for both surface and underground mining operations either at the working face or where mined material is being processed. This feature would allow for greater selectivity and would decrease environmental impacts and energy requirements in exploration, mining and processing activities.

Soft (Unfired) Ceramic Particles via Dynamic Cyclone Classification
(www.novafilter.com)
Many industrial processes involve the separation of particles from an airstream. The mining industry, in particular, has indicated a need for improved separation methods and reduced waste. In this technology, the particles are separated and transported by boundary layers and induced airflow vorticity near a stack of rotating (slightly separated) disks, which minimizes particle impact and attrition, as well as component wear. The dynamic cyclone classifier offers substantial potential for indirect energy savings by reducing the amount of off-spec product processed to achieve the same amount of product output. Smaller scale devices, operating under the same separation principles, can generate sharp particle classification cuts below 10 microns and are targeted for the pharmaceutical/neutriceutical, food/additives, cosmetic and specialty chemical markets.

Steel

High Quality Iron Nuggets Using a Rotary Hearth Furnace

A new process, that was demonstrated in a pilot plant, is an iron making technology that uses a rotary hearth furnace to turn iron ore fines and pulverized coal into iron nuggets of similar quality as blast furnace pig iron. The new technology will be able to effect reduction, melting, and slag removal in only about 10 minutes. The process is a simple one-step furnace operation that requires less energy, capital, and operating costs than existing pig iron technology. Consequently, high-quality iron product can be produced at a substantially lower cost.

Hot Oxygen Injection into the Blast Furnace

(www.praxair.com)

A new injection system has been developed to directly inject hot oxygen in blast furnace tuyeres. Material and energy balances on the blowpipe/raceway zone of the blast furnace have shown that injecting ambient temperature oxygen offers little overall benefit, whereas injecting hot oxygen offers several mechanisms for improving burnout. This process increases coal injection rates and reduces coke consumption. Consequently, direct injection of hot oxygen into blast furnace tuyeres improves operating cost, energy consumption, and emissions.

Laser-Assisted Arc Welding

(www.inl.gov)

Applying this new process to steel welding will meet the needs for a new joining technology. The benefits of combining laser- and arc-welding processes will ease the current requirement for precise fit when laser welding alone. Using filler metals in the arc-welding component of the process will result in greater flexibility in the choice of materials that are joined. The process could easily be applied to nonlinear joint geometries. This process will increase the welding throughput and productivity over either laser or arc welding alone.

Steel
(continued)

Metallic Iron Nodule Technology in Electric Arc Furnace Steelmaking

(www.umn.edu)

Scrap steel substitutes are becoming increasingly valuable for material currently used in electric arc furnace smelting because of lower production costs. A novel approach is investigating ways to process available raw materials into a value-added, high quality iron feedstock product at a lower total cost. By overcoming furnace and feedstock limitations, high-quality steel scrap substitutes are being produced, increasing final steel quality produced in electric arc furnaces, and reducing overall production costs.

Method of Making Steel Strapping and Strip

A new continuous process has been developed that produces high quality steel strapping and strip from rod stock produced from scrap steel. The process yields a higher quality, less expensive, product while increasing the amount of recycled steel in the finished product. The continuous process has lower processing and capital costs than the conventional production method while increasing the strength of the final product.

Modeling of Post Combustion in Steelmaking

(www.praxair.com)

Currently, many furnaces used for molten steel production employ post-combustion technology to transfer heat to the molten steel bath. For typical electric arc furnaces and basic oxygen steelmaking furnaces, a significant amount of CO is available during the steelmaking process. Combustion of a portion of the available CO to CO_2 (post-combustion) can release heat energy above the molten steel bath. Efficient transfer of the heat energy from the post combustion gases to the molten steel bath can reduce steel production costs, save energy, and improve productivity. To optimally design the injection parameters for post combustion, modeling the injector location, geometry, and oxygen flow rates before plant trials is more cost effective, thereby minimizing operational problems associated with high temperatures (e.g., failed lances and burned hoods). The technology developed from this project enables a modeling program to be conducted in a fraction of the time it would take to start the program from scratch.

IMPACTS

Steel
(continued)

Non-Chromium Passivation Techniques for Electrolytic Tin Plate
(www.steel.org)
Two previously identified non-chromium passivation treatments for electrolytic tin plate are being compared in a plant trial to determine their commercial viability. These new techniques will replace the existing cathodic dichromate treatment method that is facing environmental use restrictions. In addition, continued use of chromate treating solutions will result in ever-increasing operating costs.

Optical Sensor for Post-Combustion Control in Electric Arc Furnace Steelmaking
(www.steel.org)
This project is developing an optical sensor for electric arc furnace steelmaking based on measuring off-gas temperature and carbon monoxide, carbon dioxide, and water vapor concentrations. The remote-sensing optical instrument is based on tunable infrared-laser technology and will provide input signals for control and optimization of oxygen use and post-combustion emissions. This new technology will also address needs for improving energy use and developing automated process controls.

Oscillating Combustion
(www.gastechnology.org)
Oscillating combustion creates 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. Oscillating combustion is easily retrofitted to existing burners since no modifications to the burner or the furnace are necessary. Only the addition of oscillating valves, a valve controller, and associated piping changes are required.

Processing Electric Arc Furnace (EAF) Dust into Salable Chemical Products
(www.drinkardresearch.com)
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.

Steel
(continued)

Regeneration of Hydrochloric Acid Pickling Liquor
The PHAR® hydrochloric acid regeneration system is an innovative method of regenerating spent hydrochloric acid from steel pickling. Conventional pickling technology generates 1.5 billion gallons of spent pickle liquor nationwide each year, resulting in costly and energy-intensive handling, treatment, and disposal. This new technology eliminates the disposal problem, significantly reducing operating, environmental, and capital costs. The process uses sulfuric acid to restore hydrochloric acid for reuse. Salable ferrous sulfate heptahydrate is a by-product.

SQA™ : Surface Quality Assured Steel Bar Program
(www.ogtechnologies.com)
The Surface Quality Assured (SQA) system is intended to alleviate surface quality problems faced by the special quality steel bar and rod industry and their customers, the forging industry. Surface defects in hot rolled bars is one of the most common quality issues faced by the American steel industry, accounting for roughly 50% of all steel bar rejects. The SQA system will minimize surface defects in hot rolled steel products by using process sensors to identify online automatic root causes to detect surface defects and by applying advanced diagnostic methodologies to analyze the data. The SQA system will detect these defects in real-time to mark them for downstream removal.

Steel Foam Materials and Structures
Metal foams with high levels of controlled porosity are an emerging class of ultra-lightweight materials receiving increased attention for a broad range of applications. Steel foams produced via a powder metallurgy process are about 50% lighter than conventional steel materials and can be produced as monolithic foams, as foam-filled tubular structures, and in sandwich panel geometries. The efficient energy-absorption characteristics of steel foams can increase safety in commercial and military vehicles. The light weight can improve operational efficiency and competitiveness in shipbuilding and rail systems. These foams can also be recycled and reproduced, as well as produced from recycled metal scrap. Additional process scale-up development is required to position steel foams for production readiness and commercialization.

Crosscutting Technologies

Carbon Films for Next Generation Rotating Equipment Applications

(www.uic.edu)

Two super-low-friction carbon surfaces, Near Frictionless Carbon (NFC) film, and a carbon surface converted from carbide, Carbide Derived Carbon (CDC), have been combined to achieve extended wear life and higher energy savings in rotating-equipment applications. Results indicate that CDC has impressive commercial potential for improving the wear life, increasing reliability and reducing dry-running breakdowns in mechanical seals, sliding bearings, and shafts. The technology is a net shape and size process that forms an adherent, low-friction, wear-resistant layer, as opposed to a coating, for all silicon carbide and other metal carbide components. Friction coefficients in the same range as the best diamond or diamond-like coatings were demonstrated, as well as dry-running capability.

Chromium Tungsten Alloys for Use as Reaction Vessels

(www.ornl.gov)

Chromium-tungsten alloys are a new class of steels having the unique properties of strength, toughness, and stability when subjected to thermal cycling. These properties are a function of the alloy's microstructure, which results in highly favorable material properties. Chromium-tungsten applications include reaction vessels where significant reductions in plate thickness (by up to one-half) are expected and heat-transfer tubing applications where thinner-walled tubes will significantly improve heat transfer.

Crosscutting Technologies

(continued)

Continuous Fiber Ceramic Composite (CFCC): Combustion Liner

(www.mysolar.cat.com)

Two classes of continuous fiber ceramic composite (CFCC) materials were developed for gas turbine combustors and other stationary hot section components (e.g., transition pieces, shrouds, and nozzles). One class of CFCCs consists of continuous silicon carbide fibers in a matrix of silicon carbide, and a second class consists of oxide fibers in an oxide-based matrix. The CFCCs provide oxidation resistance and thermal and mechanical properties in air. However, silicon carbide-based CFCCs suffer degradation from water vapor attack in the hot section of gas turbines operating at high firing temperatures and pressure ratios. To improve their environmental resistance, Environmental Barrier Coatings (EBCs) were applied to the silicon carbide-based CFCCs. While the oxide-based CFCCs do not require EBCs, their mechanical properties are improved by applying thermal protection coatings to the surface. Field testing of CFCC liners in gas turbines has been ongoing in California and Massachusetts for years.

Diagnostics and Control of Natural Gas Fired Furnaces via Flame Image Analysis

An on-line multi-sensor system using vision technology and artificial intelligence techniques is developed and tested. This system uses images from the inside of the furnace to provide input to the following sensors: 1) a flame sensor capable of combustion optimization and burner balancing; and 2) a temperature profiler. These capabilities were tested on a heat treating furnace in Missouri, resulting in 7.4% energy savings. This technology can improve furnace thermal efficiency and product quality and lower NO_X and CO emissions.

IMPACTS

Crosscutting Technologies
(continued)

Distributed Wireless Multisensors for Reducing Motor Energy Use

(www.ge.com/research/grc_2_2_1.html or www.sensicast.com)

Motors consume an estimated 63% of all electricity used in industry. To reduce plant power consumption, sensors are often used to monitor the efficiency of motors used in industrial applications but deploying sensors for continuous monitoring of noncritical motors is costly. Distributed wireless technology offers continuous monitoring to both smaller and less critical motors through low-cost, distributed, multi-measure, wireless sensors. Reducing the cost and complexity of sensor deployment is anticipated to allow continuous monitoring to become pervasive, which will allow industries to better maintain and improve the efficiency of their electric motor assets.

Energy Saving Controls for HID Lamps

(www.eesolutions.org)

This new technology is a simple, cost effective approach designed to work with conventional (magnetically ballasted) HID lamps of 70 to 1000 Watts, conserving up to 40% of typical energy consumption by managing illumination to customer needs or applicable standards. These intelligent controls save up to 50% of the maintenance costs associated with HID lighting. Many solutions offer improved HID lighting efficiency, but require replacement of existing lamps. This technology can be retrofit onto existing lamps thus saving capital costs. The fact remains that HID lighting is the most cost- and energy-efficient technology available today for high power (>100Watts) lighting applications and this technology significantly improves energy efficiency and reduces maintenance costs in this lighting category.

Crosscutting Technologies
(continued)

Energy-Savings' Model for the Heat Treatment of Aluminum Castings

(www.wpi.edu)

A research program is extending the understanding of the evolution of microstructures during the heat treatment of complex, multi-component alloys. Quantitative relations among process, microstructure, and properties have been developed and applied to aluminum castings. The methodology developed can serve as a framework to develop quantitative process models for other alloy systems, including ferrous alloys. Compared with the current technology that specifies heat treatment cycle and furnace loadings based on prior specifications and historical "rules of thumb," the models are expected to reduce solutioninzing heat treatment times by 50% to 80%, leading to 25% to 50% reductions in cycle time and energy consumption and 50% indirect reduction in non-energy environmental impacts and variable costs. The models are available for further commercialization and applications.

Enhancement of Aluminum Alloy Forgings

(www.qcforge.com)

The forging process creates parts which are typically stronger and more durable than those manufactured by other metalworking processes. The thermal cycles of heating and reheating, can cause significant grain growth in the raw material. Large grains can result in degraded fatigue properties in the final product. Rapid infrared (IR) heating has been developed in order to shorten these thermal cycles, allowing significantly less opportunity for grain growth. Ongoing production testing has confirmed the rapid IR system results in higher-quality forgings in the form of improved fatigue life and smaller grain size. The direct application of IR improves the thermal transfer of energy, resulting in less overall energy consumption.

High Efficiency Liquid-Desiccant Regenerator

(www.ailr.com)

The use of desiccants, which have a high affinity for moisture, can greatly reduce the energy required for typical drying and dehumidification. A new generation of liquid desiccant technology was developed that lowers overall cost and size, while improving the performance characteristics of existing dehumidification technologies. This new regenerator has the potential to almost double the efficiency of liquid-desiccant systems.

Crosscutting Technologies
(continued)

High Temperature Refractory Ceramic

A new castable refractory liner material to be used in high temperatures has been developed. The capabilities of this new ceramic liner will be a 200°C improvement in maximum allowable operating temperatures, an operating life extension of five times, and additional cost savings in installation. The possibilities of source materials to be burned in cogeneration could be greatly increased.

Industrial Fuel Cell Micro-Generator

(www.gencellcorp.com)

The industrial fuel cell micro-generator is a new, low-cost, small-scale molten carbonate fuel cell power plant for improving the efficiency of fuel cell micro-generators and their usefulness for small manufacturers. The micro-generator consumes only half the natural gas required by competing technologies to produce an equivalent amount of electricity and creates virtually no waste. This smaller fuel cell is ideally suited as an uninterruptible power supply or as standby power if an electrical grid fails. Prototype units of the micro-generator are being tested in Europe and Asia.

Intelligent Controls for Refrigeration Systems

(www.adatech.com)

As much as 15% of electricity consumed by commercial and industrial refrigeration units can be saved by using intelligent defrost cycle controls. In typical installations, the defrost cycle is initiated at regular intervals during the day by a timer clock that is set to accommodate the peak humidity conditions of summer. In many cases, this causes the defrost cycle to begin too soon, and to run for an extended period of time. A new, low-cost frost sensor for defrost control systems has been developed and patented to start the defrost cycle only when necessary and to stop the cycle as soon as the ice has been removed from the heat exchanger.

Crosscutting Technologies
(continued)

Intensive Quenching Technology for Heat Treating and Forging Industries

(www.intensivequench.com)

Intensive quenching technology (IQT) for steel products was developed as an alternative way of quenching steel parts. While conventional quenching is usually performed in environmentally unfriendly oil, the IQT process uses environmentally friendly water or low-concentration water/mineral salt solutions. Complete development and commercialization of IQT in heat-treating, powder metal, and forging industries will significantly reduce energy consumption and environmental impacts, thus enhancing the economic competitiveness of the domestic steel, metal casting, and mining industries.

Low-Cost, High-Efficiency, Periodic-Flow Gas Turbine for Distributed Energy Generation

(www.ventions.com)

An innovative gas microturbine is being developed that can realize higher thermal-to-electrical efficiencies and lower manufacturing costs compared with existing microturbine designs. The expensive recuperator used in current microturbines is replaced with a lower-cost regenerator that increases cycle thermal efficiency by 10% or greater and simultaneously reduces capital cost by 40%. The new system also is estimated to reduce CO_2 and other pollutant emissions by 15% to 40%.

Maximus™ Sonic Stop-Fill Device for LP Gas and Anhydrous Ammonia Tanks

(www.adeptscience.net)

A new technology is being developed to prevent liquefied petroleum (LP) gas and anhydrous ammonia tanks from being overfilled. Outage gauges, the current technology used for this function, release LP gas or anhydrous ammonia for the entire duration of the tank refill. The resulting vapor release is wasteful, environmentally unfriendly, and potentially a health and fire risk. In contrast, the Maximus stop-fill technology relies on an advanced acoustic method to noninvasively detect the presence of liquid or gas at a specific point on a tank. As the liquid level rises, the acoustic signals received by the sensor change, indicating the presence of liquid on the other side of the tank wall. The Maximus thereby achieves the exact same result as an outage gauge without wasted energy, environmental pollution, or safety risks.

Crosscutting Technologies
(continued)

Micro Gas Analyzer Solutions for Advancing Industrial Efficiency
(www.honeywell.com)
An innovative technology for on-line sampling and analysis of gas process streams in an industrial environment is being developed to enhance industrial efficiency. This new device couples a sampling and measurement system with a revolutionary gas composition micro-analyzer to provide continuous, on-line monitoring of gas process streams. By identifying and communicating variations in gas stream composition, the technology will improve product quality, reduce process upsets, avoid product loss and reduce waste.

Miniature, Inexpensive, Amperometric Oxygen Sensor
(www.eere.energy.gov/inventions/pdfs/oxygen.pdf)
A new sensor to measure oxygen partial pressure from parts-per-million levels to 100% oxygen has been developed. It has particularly good sensitivity in the combustion range of 0.1% to 5% oxygen partial pressure. The new amperometric sensor, which is a multi-layer ceramic capacitor, is ideal for inexpensive mass production. The large reduction in cost of the sensor will economically allow any combustion process, including industrial, commercial, or residential furnaces and boilers, to be more closely monitored and controlled, thus saving energy.

New Regenerative Cycle for Vapor Compression Refrigeration
(www.mdienergy.com)
A new refrigeration technology is being developed that increases efficiency and saves energy relative to existing refrigeration techniques. The technology uses a novel thermodynamic cycle characterized by the regenerative use of the potential energy of the working fluid. A compressor compresses the working fluid to only 50% to 60% of the final pressure, while a jet device provides additional compression by using the internal potential energy of the working fluid flow. The compressor requires less mechanical energy, resulting in significant energy savings.

Crosscutting Technologies
(continued)

On-Line Laser-Ultrasonic Measurement System
(www.timken.com)
An on-line laser-based ultrasonic measurement of thickness and eccentricity was purported to improve the productivity of seamless mechanic steel tube making by 30% to 50% through reduced setup time, reduced out-of-specification products, and improved material use. The gauge used in the measurement also would help reduce energy consumption and pollutant emissions. The gauge has been in service since March 2002; succeeding models have added features including adjustment for variation in tube position and extension of the inspection range to smaller diameters and wall thicknesses. The original installation had an estimated annual energy savings of about 5%, or 23 billion Btu, primarily from increases in efficiency (target size is achieved faster) and quality (record low tube wall scrap rates were reached).

Particulate Ejection Coal Fired Turbine
(www.novafilter.com)
A sub-scale prototype of a medialess inertial rotary disk filter was successfully evaluated to operate at the high temperatures/pressures typically found in coal-fired gas turbine generators. This technology demonstrates 98% to 99% coal ash removal efficiency without fouling, thus reducing the need for conventional disposable porous ceramic candle filters for hot gas filtration. Constant filtration efficiency and non-varying pressure drop across the all-metal filter eliminates brittle ceramic failures and allows operation at higher gas temperatures, which eliminates gas reheating and improves energy efficiency. The continuously self-cleaning technology may also eliminate landfilling of spent/replaced ceramic candles.

Process Heater System
(www.exxonmobil.com)
A new generation of process heaters has been developed and demonstrated that is extremely low in emissions. This innovative system incorporates several advanced technologies: 1) ultra-low-emission (ULE) burners; 2) a specially designed fired heater with enhanced heat recovery, optimized for use with the ULE burner systems; and 3) on-line tube metal temperature sensors and burner control system to optimize heater operation, reduce maintenance costs, and increase run lengths. The technology will have applications for a broad range of refining and chemical processes. The advanced heater components are being developed for new or retrofit applications.

Crosscutting Technologies
(continued)

Production Scale-up of Activated Carbons for Ultracapacitors
(www.tda.com)
Electric and hybrid vehicles are promising technologies for decreasing the dependence on petroleum. Cost effective and efficient energy storage devices are needed for these vehicles to remain economically viable, and ultracapacitors are a leading energy storage technology for this purpose. The most important parameter in determining the power and energy density of a carbon-based ultracapacitor is the amount of surface area accessible to the electrolyte, which is primarily determined by pore size distribution. The major problems with current carbons are that their pore size distribution is not optimized for liquid electrolytes and the best carbons are very expensive. Methods that use low-cost feedstock (carbohydrates) were developed to prepare porous carbons with tunable pore size distribution at a greatly reduced production cost.

Radiation Barrier Heating Mantle for High-Temperature Furnaces
(www.procedyne.com)
Retort furnaces, which consist of a heating-mantle jacket surrounding a retort vessel, are widely used to generate high temperatures for the metal-processing, chemical-processing, and heat-treating industries. A new porous wall radiation barrier (PWRB) heating mantle represents a breakthrough in heating mantles that significantly increases heat-transfer rates over both the existing gas-fired heating mantle and the electrically heated mantle. This unique development results in a heat-transfer rate in the 1,800°F to 2,400°F range that is 2 to 4 times greater than electric and conventional gas-fired mantles.

Robotically Enhanced Manufacturing Line
(www.timken.com)
Conventional metal processing lines employ equipment that frequently use energy inefficiently, release greenhouse gases, and increase the exposure of laborers to process related safety risks. A new project is developing an advanced, low-volume manufacturing line that operates on-demand, thereby saving energy and manpower. The system is designed to replace over-sized, energy-intensive furnaces that require continuous and therefore unproductive heating. In development, the novel process has been demonstrated to be about 22% more energy efficient than conventional small lot processing methods. This manufacturing line is also more productive and produces fewer emissions.

Crosscutting Technologies
(continued)

Self-Dressing Resistance Welding Electrode
The project is designed to produce an electrode from a unique metal-matrix composite material that employs a ceramic substrate, which enhances the thermal resistance properties of the composite material, as the load-bearing element. The composite material also uses a metal matrix as the conduit for the electric current flow. The technology will include optimized materials and validated welding performance.

Sensing and Control of Cupola Furnaces
(www.tntech.edu)
This project is developing an intelligent, integrated industrial process sensing and control system to optimize the performance of cupola furnaces. This system regulates the melt rate, temperature, and iron composition of the furnace. Improved control of furnace variables will increase energy efficiency, furnace yield, and productivity and will reduce environmental emissions.

Sunlight Responsive Thermochromic (SRT™) Window System
(www.pleotint.com)
A new high-performance window capable of variable tint is being developed that combines dynamic sunlight control, high insulation values, and low solar gain. The Sunlight Responsive Thermochromic windows can reversibly change light transmission based on thermochromic materials activated solely by the heating effect of the sun. The window design allows for good daylighting, a low solar heat gain coefficient, a low U-value, and a high insulation value. Energy savings up to 30% are estimated compared with traditional window systems.

Super Boiler
(www.gastechnology.org)
The Super Boiler concept using ultra-high-efficiency, ultra-low-emission steam generation technologies is targeted for broad industrial applications over the next 15 to 25 years. The concept combines a suite of enabling technologies such as a staged intercooled combustion system with forced internal recirculation, high-intensity heat transfer surfaces, an advanced transport membrane condenser, and a smart control system in an integrated package. The performance goals include 94% fuel efficiency, 5 vppm NO_X and CO, and 50% size and weight reduction compared with a conventional firetube boiler.

Crosscutting Technologies
(continued)

Thermal Imaging Control of High Temperature Furnaces
(www.gastechnology.org)
The near-infrared thermal imaging system fine-tunes the main furnace controller for improved combustion performance. The system uses multiple infrared wavelengths combined with a periscope probe to map the full field of combustion space during furnace operation. Control algorithms minimize differences between measured field temperatures and temperature set points and send output signals to the main furnace combustion control. Optimizing the combustion process has been shown to decrease the total fuel use by at least 5%, with a corresponding decrease in airborne emissions.

Thermoelectric Generator for Diesel Engines
(www.hi-z.com)
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. A prototype generator is being tested by a truck manufacturer and has been driven on their test track for 500,000 miles to demonstrate the ability to endure shock and vibration.

Third-Generation Flywheels for Electricity Storage
(www.launchpnt.com)
A new type of electricity storage flywheel is being developed that can be scaled up cost effectively to much larger power and capacity than existing flywheel designs. This new third-generation flywheel – the Power Ring – uses totally new architecture and is designed to eventually reach electricity storage capacities exceeding 5 megawatt-hours per unit. The design uses a new class of magnetic bearing and a thin-walled composite hoop rotated at high speed to store kinetic energy. Power Ring flywheels will have many applications to support the U.S. power grid and to provide a reliable source of emergency power during electrical outages.

Crosscutting Technologies
(continued)

Tough-Coated Hard Powders
(www.allomet.net)
Revolutionary tough-coated hard powder (TCHP) pseudoalloys combine the highest extremes of fracture toughness, hardness, wear resistance, light weight, low coefficient of friction, and thermal properties ever known. Designed nanostructures are created by nano-encapsulating extremely hard micrometer-scale core particles (e.g., diamond) with very tough materials (e.g., tungsten carbide and cobalt), which in the consolidation process become the contiguous matrix. As many unique properties can coexist in a TCHP variety as there are different core particle materials present in the uniform tough substrate. Extreme strength, double-digit component and tool life multiples, and reduced friction and thermal losses combine to enable tens of billions of dollars in annual cost, energy, and environmental impact improvements.

Ultrananocrystalline Diamond Coatings
(www.thindiamond.com)
Ultrananocrystalline diamond (UNCD) coatings can be grown on various substrates by using emerging microwave plasma chemical vapor deposition technology. The coatings exhibit a unique microstructure that provides superior mechanical (high hardness), tribological (low coefficient of friction), chemical (inertness to chemical attack), and electronic (wide range of conductivity via doping) properties. Multipurpose mechanical pump seals will be the first to benefit from these coatings by extending the lifetime of ceramic seal faces and saving energy by reducing frictional losses at the sealing interface.

Utility Interactive Inverter System for Distributed Generation
(www.advanced-energy-conv.com)
A 2.5-kW utility interactive inverter system has been developed and is being tested and refined for use in distributed generation. The system embodies zero-voltage switching technology that will yield a system that is smaller, less expensive to manufacture, and more efficient than existing commercial technologies. By strategically focusing on a 2.5-kW utility interactive inverter employed in solar photovoltaic applications the company has found a stable regulatory environment and a market that is quickly expanding in this power level which supports numerous technologies.

Crosscutting Technologies
(continued)

Variable Speed, Low Cost Motor for Residential HVAC Systems
(www.dynamotors.com)
Existing variable-speed motors cost at least four times as much as single-speed motors and thus are currently used in only 5% of residential HVAC systems. A revolutionary low-cost, brushless, variable-speed motor technology uses solid-state switches on the rotating armature to control motor torque and speed. A variable-speed motor running continuously at half speed compared with a single-speed motor running at full speed but half the time uses 25% of the power to move the same amount of air in an HVAC blower, thus saving energy.

Wireless Sensor Network for Motor Energy Management
(www.eaton.com)
Energy use of large motors (over 200 hp) has already been reduced with advanced monitoring and diagnostic systems served by conventional field wiring. Deploying monitoring systems on smaller motors could further reduce motor energy use by 18% but is not cost-effective with conventional wiring and thereby does not promote the identification of energy savings and opportunities to improve uptime. Wireless sensors that monitor voltage and current and integrate with advanced energy and inferential condition management software are being developed to serve this need. The technology will use smart sensors with embedded intelligence as well as network system robustness to ensure system security, self-configuration capability, cost effectiveness, and the ability to accommodate plant complexity.

Other Industries

BEI Cellulose Hydrolysis Process
(www.brelsfordenginc.us)
The BEI Dilute-Acid Cellulose Hydrolysis (DACH) Process and Reactor System uses a double tubular reactor system in two stages, which is automatically controlled to continuously convert cellulose feedstock into fermentable sugars solution products. The second stage of the BEI-DACH process reactor system recovers excess and surplus process heat and acid-chemicals for reuse in the first stage, providing exceptional energy and acid efficiencies and related economic savings. The BEI-DACH reactor system process hydrolyzes cellulose into a pentose, hexose, and glucose sugars solution at the point of use. These DACH sugars may then be continuously yeast-fermented into ethanol and/or single-cell-protein and into other organic chemicals as commercial products.

Biofine Technology
(www.biometicsma.com)
The Biofine technology can convert low-grade cellulose-containing wastes from paper mills, municipal solid waste plants, logging and agricultural operations, and other sources into levulinic acid, a versatile platform chemical that is an intermediate to several high-value chemical and oxygenated fuel products. Cellulose is converted to levulinic acid using a novel, high-temperature, dilute acid hydrolysis reaction system.

Clean Energy from Biosolids
(www.enertech.com)
The innovative and unique SlurryCarb™ process receives waste as a slurry and subjects it to heat and pressure in a reactor unit to rearrange the slurry molecularly. This step produces a homogeneous, clean fuel with an energy density significantly greater than untreated material. The high-energy renewable "E-Fuel" can be used efficiently in conventional combustion equipment as a substitute for fossil fuel.

IMPACTS

Other Industries
(continued)

Distributed Optical Fiber Sensors for Continuous Liquid Level Tank Gauging

The Noverflo Multipoint Tank Gauging (NMTG) system is a family of fiber optic sensor arrays designed for the oil and gas, transportation, and food/beverage processing industries. Compared with similar products, the NMTG offers a simple design that allows both low and high accuracy measurements to be made at a very low cost. The system can make accurate measurements in liquids of shifting densities and performs continuous density measurements at any tank level. A new data acquisitions system allows the NMTG to monitor hundreds of sensors and numerous external-switching devices without any upgrades to existing systems.

Eco Oil: A Superior-Performance, Bio-Based Motor Oil

(www.peaksandprairies.net)

One way to reduce dependence on foreign oil is to reduce the consumption of refined petroleum products. Eco Oil is an enhanced, bio-based synthetic motor oil that will help reduce refined petroleum consumption, adding stability to our national supply. Increased availability of bio-based motor oil also provides product diversity, creating additional options for government and consumer purchases, and results in fuel savings because of reduced engine friction. Reduced fuel usage also could lead to lowered emissions from internal combustion engines, reducing pollution.

Helical Reaction Hydraulic Turbine

(www.gcktechnology.com)

The Gorlov Helical Turbine (GHT) is a newly developed technology that is relatively inexpensive and ecologically benign and provides a reliable source of electricity by extracting the kinetic energy from flowing water. It is designed for hydroelectric applications in free flowing watercourses, which eliminates the need for a dam or other obstruction to the natural current flow. The GHT uses airfoil-shaped blades, which provide a reaction thrust that can rotate the GHT at twice the speed of the water flow. The GHT is self-starting and can produce power from a water flow as low as five feet per second, with power increasing in proportion to the water velocity cubed. Testing has demonstrated the GHT's superior power efficiency (35%) in free flowing water currents compared with conventional turbines.

Other Industries
(continued)

High-Intensity Silicon Vertical Multi-Junction Solar Cells

(www.photovolt.us)

A solar cell combines high voltage with low series resistance operation to create efficient concentrated solar power conversion at low cost. Output power densities exceeding 1000 times that of conventional solar cells have been demonstrated. The simple design of the cell results in lower manufacturing costs and robust reliability compared with existing concentrator cells. Basically, the solar cell technology enables high intensity photovoltaic concentrator systems that provide considerably lower $/watt cost than conventional photovoltaic modules. Immediate applications include large-scale electric power generation (>100 kW) in sunny regions of the world.

High Speed/Low Effluent Process for Ethanol

(www.bio-process.com)

The High Speed/Low Effluent (HS/LE) process increases ethanol fermentation 5 to 8 times faster compared with current industry rates by using a newly developed, self-aggregating yeast strain. Either a "consecutive batch" or "continuous cascade" technology can be used for this fermentation process, for either wet mill or dry mill corn ethanol production. Cane juice, molasses, sweet sorghum, and other sugar/starch feedstocks may also be used with this process. In addition, a low-energy distillation process can improve ethanol production economics.

Hi-Q Rotor

(www.hiqproducts.com)

A new type of rotor for wind turbines is being developed based on single strip geometry that is stronger and more stable than conventional 3-blade devices. The Hi-Q Rotor is comprised of an elongated strip that has one end bent six times (360°) into a three-dimensional shape with radial symmetry. This unique design gives the rotor the ability to spin in the slightest flow of air, thereby effectively generating electricity at low wind speeds, where traditional turbines are ineffective.

Other Industries
(continued)

Horizontal Ribbon Growth
(www.oakland.edu)
This innovative technology consists of a process to develop crystalline silicon sheet from a polycrystalline silicon source. Its primary goal is the efficient, low-cost production of high-quality crystal silicon sheet for the solar and electronics industry. Development of this process will provide several important benefits, such as high production rates, low cost in terms of material and energy input, good dimensional control, improved crystal quality, and remarkable purity the same as the source material.

Hydrodyne Process for Tenderizing Meat
The hydrodyne process offers a unique way of tenderizing meat, particularly tougher meat with less fat. The innovative technology reduces beef tenderization time from weeks to a fraction of a second by using hydrodynamic shock waves. The process can increase beef tenderness in tougher meat cuts by as much as 72% without changing natural appearance, texture, or flavor. The USDA evaluated this technology and found it to be effective and also beneficial in food safety.

Hydrogen Generation from Biomass
(www.virent.com)
A newly patented process is enabling the economic production of hydrogen from a range of biomass-derived feedstocks, including glycerol and sugars. The key breakthrough in the reforming process is a proprietary catalyst that operates in the aqueous phase and has high hydrogen selectivity at low temperature. The process reforms water soluble oxygenated hydrocarbons in a single step and produces a hydrogen rich gas that is easily purified and that can be used as fuel stock for energy systems requiring a clean source of hydrogen, including fuel cells and transportation.

Other Industries
(continued)

Low Head, Vortex Induced Vibrations River Energy Converter
(www.vortexhydroenergy.com)
A revolutionary technology is being developed to extract useful energy from low-head or low-power falling water resources. The technology is based on the vortex-induced vibrations (VIV) of cylinders. For decades, engineers have been trying to prevent VIV from damaging offshore equipment and structures. By exploiting and maximizing VIV rather than preventing it, the vibrations can be transformed into a valuable electrical resource. In harnessing this potentially destructive force, the calculated energy density is five times greater than the best available competing technology, which is a free-flowing water turbine.

Novel Membrane-Based Process for Producing Lactate Esters
(www.vertecbiosolvents.com)
This research aims to develop nontoxic replacements for halogenated and toxic solvents. The new method, called "Direct Process", uses proprietary advanced fermentation, membrane separation, and chemical conversion technologies to convert renewable carbohydrate feedstocks into lactate esters in an energy-efficient, waste-reducing, and cost-effective way.

Plastics, Fibers, and Solvents from Biosynthetically Derived Organic Acids
(www.dnpgreen.com)
Biologically-derived succinic acid is produced by fermenting sugar derived from grains and other biomass. After separation and purification, the succinic acid is used as a chemical intermediate that is converted into a wide assortment of products such as plastics for automobiles and household items, fibers for clothing, food additives, solvents, deicers, agricultural products, ink, and water treatment chemicals.

IMPACTS

Other Industries
(continued)

Powering Cell Phones with Fuel Cells Running on Renewable Fuels
(www.tekion.com)
Small passive fuel cells that operate on air and formic acid are being developed to reduce electricity consumption from charging batteries. This renewable-fuel micro fuel cell will be used to charge cell phones, which use about 1.5 billion kWh per year, two-way radios, laptops, PDAs, and other portable devices including military and emergency applications.

Thermophotovoltaic Electric Power Generation Using Exhaust Heat
(www.jxcrystals.com)
This new technology produces electricity directly from furnace exhaust waste heat by using infrared-sensitive photovoltaic cells. The cells are mounted inside ceramic tubes that are heated in the high-temperature exhaust stream from furnaces. This technology allows on-site generation of electricity from waste heat in industrial or residential applications.

Tidal Energy Systems
(www.verdantpower.com)
The kinetic energy of flowing water is a source of renewable energy. Systems similar to underwater wind turbines have been developed and are being demonstrated in tidal currents. The systems convert the kinetic energy of the tidal current to mechanical power, which is applied through a gearbox to an internal generator or to a direct-drive generator for electrical power. These water-to-wire, dam-less hydro systems have demonstrated little to no environmental impacts. On-going studies are showing that fish are safely swimming either around or through the slow revolving rotors of these kinetic hydropower systems

Other Industries
(continued)

Variable Length Wind Turbine Blade
(www.frontierwind.com)
The use of variable length blades on wind turbines, as opposed to the current use of fixed length blades, improves the wind turbine's performance, efficiency, and cost-effectiveness. Low wind speed provides better electrical output with longer blades, while high wind speeds demand shorter blades to minimize mechanical loading. The outboard (tip portion) of the blade fits inside the inboard (inner portion) and can be telescoped in and out according to wind conditions. Energy capture is expected to increase by about 10% to 15%, by increasing wind capture at existing sites and by expanding the number of locations where wind energy is feasible. Can be used in new or retrofit applications. Reduces system loading thus increasing system life while increasing energy generation.

Wind Fins: Novel Lower-Cost Wind Power System
(www.windfins.com)
An innovative vertical axis wind turbine is being developed as an alternative to conventional small horizontal-axis wind turbines (HAWTs). The Wind Fin technology exploits the kinetic energy of a vertically aligned, aerodynamic oscillating blade to generate electricity. The unique design blends more readily into the natural landscape than HAWTs and virtually eliminates lethality to birds and bats. Wind tunnel tests have shown that this technology will be comparable to or superior in performance to similar-sited wind turbines (20 kW) but at approximately half of the system cost. In addition, the Wind Fin can generate power at wind speeds as low as 5 mph, whereas many alternative systems require wind speeds of 10 mph or greater to begin operation. Testing has indicated that the technology will be technically and economically feasible over a wide range of sizes, potentially resulting in Wind Fins with a power output of 50 kW to 100 kW.

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Historical ITP Technology Successes

Absorption Heat Pump/Refrigeration Unit

(www.energy-concepts.com)

An advanced water ammonia absorption unit was developed that is powered by waste heat and provides refrigeration to refineries. The unit also recovers salable products, liquid petroleum gas or gasoline, which were formerly flared as reformer waste propane gas. Two units were installed in refineries and have cumulatively saved 2.87 trillion Btu since 1997.

Advanced Turbine System

As part of the Industrial Power Generation Program, an advanced metallic material, first-stage turbine vane was developed. This vane allows turbines to operate at higher compression ratios and/or temperatures than conventional gas turbines resulting in an efficiency improvement of 15%, less down-time, and less maintenance. The use of these vanes has resulted in an energy savings of 245 billion Btu.

Aerocylinder Replacement for Single-Action Cylinders

(www.smedbergmachine.com)

The aerocylinder, a machinery shock absorber, replaces conventional, single-action compressed-air cylinders in industrial forging, stamping, and welding applications. The aerocylinder has been installed on over 400 stamping and welding presses, primarily in the automotive industry. Using this system reduces downtime, prolongs equipment life, improves final product quality, and has resulted in an energy savings of more than 340 billion Btu since 1988.

Aluminum Roofing System

(www.transmet.com)

This technology uses aluminum chips to reflect about 70% of the solar radiation received on asphalt roofs, which reduces building cooling needs. This invention has saved over 635 billion Btu since its introduction in 1984 and is now used on more than 35 million square feet of roofing.

Aluminum Scrap Decoater

(www.er-co.com)

An innovative aluminum-scrap melting process was developed that efficiently recycles oil-laden aluminum scrap, reducing solid waste and emissions. The process uses an indirect-fired controlled-atmosphere kiln to remove machining lubricants, oils, and other materials from the scrap aluminum. Once removed, these materials are combusted in an afterburner, destroying all VOCs and releasing heat that can be used to drive the process. Since 1997, the three facilities using this process have cumulatively saved 1.93 trillion Btu.

Aqueous Cleaner and CleanRinse™ Recycling System

(www.ecoshieldenv.com)

A simple mini-reactor system for cleaning aqueous waste streams chemically converts organic oily contaminants into surfactants and emulsifiers. This conversion increases the cleaning solution's ability to remove oil, grease, and dirt. The system regenerates the cleaning solution on-site, generating less waste water and often decreasing the cleaning time required. The system has low energy needs and can be coupled with an energy-efficient bioreactor that will convert excess soap into biomass. Since 1997, the two systems in use have cumulatively saved 149 billion Btu.

Arc Furnace Post-Combustion Lance

(www.praxair.com)

A technology was developed that was 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 six installed systems have saved a total of 2.46 trillion Btu of energy.

Auxiliary Air-Conditioning, Heating and Engine Warming System for Trucks

(www.ponypack.com)

An auxiliary power unit was developed to maintain cab power in heavy-duty, long-haul trucks when the main engine is not operating. This unit takes fuel from the truck's fuel tanks to heat and air-condition the cab and sleeper, to generate electricity to keep the battery charged, and to furnish hot water to keep the truck's engine warm. Since 1988, more than 3000 units have been installed on trucks and have saved an estimated 19.9 trillion Btu in the form of diesel fuel.

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.

IMPACTS

Biphase Rotary Separator Turbine

A biphase turbine recovers waste energy from pressurized process streams that separate into liquid and gas when the streams are depressurized. Conventional turbines cannot be used efficiently with two-phase flows because they cannot withstand the forces released during the liquid's rapid evaporation to a vapor. This turbine is being used by 125 large (500-ton) chillers and is saving 15 kW per chiller, for a cumulative savings of 107 billion Btu.

Brick Kiln Design Using Low Thermal Mass Technology

(www.swindelldressler.com)

An innovative brick kiln was developed that uses low thermal mass and low-NO_X burner technologies. This brick kiln 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. These innovations result in a reduction in natural gas usage of 35% compared to a conventional kiln. The two brick kilns have cumulatively saved 280 billion Btu.

Catalytic Distillation

(www.neochem.net)

Distillation is one of the most energy-intensive industrial processes, accounting for over 40% of the energy consumed by the chemicals industry each year. This single-stage catalytic reaction/distillation process has become a major commercial success and has improved the energy efficiency and productivity of certain chemical processes, including the production of methyltertiary- butyl-ether (MTBE) and tertiary-amyl-methyl-ether (TAME). Since its introduction in 1982, the 36 units installed in the United States have saved 43 trillion Btu.

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 9.5 trillion Btu in energy savings since its commercialization in 1984.

Chemical for Increasing Wood Pulping Yield

(www.chemstone.com)

Unevenly processed wood chips in the pulp industry result in poor-quality pulp, often requiring reprocessing. A cooking aid was developed that reduced the amount of virgin wood feedstock needed to process wood chips and increased pulp yield and quality. The cooking aid helps pulp-cooking liquors penetrate the chips, resulting in more uniform cooking, and enabling the production of more uniform fibers in less time and with less energy. Since 1995, 23 mills in the United States have used this chemical system to save over 8 trillion Btu.

Chemical Separation by Fluid Extraction

This technology removes hazardous organic compounds from contaminated solid or liquid waste streams. The technology is more energy efficient than conventional technical hazardous waste treatment methods. The use of this technology has resulted in energy savings of 440 trillion Btu since 1990.

Chemical Vapor Deposition Optimization of Ceramic Matrix Composites

Ceramic matrix composites comprise a 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. A computer model was developed and used to increase the throughput of two CVD coating reactors that optimized the coating process used to make ceramic matrix composites.

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.

Historical ITP Technology Successes

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 17.7 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.

Component Cleaning

A chemical product for industrial cleaning was developed based on supercritical fluid technology. Equipment was developed that converted carbon dioxide (CO_2) into a fluid that was used to clean metal, plastics, printed wire boards, etc. This technology takes the place of chlorofluorocarbon (CFC) solvents in the cleaning process and has reduced the energy needed to evaporate the solvents during the drying process.

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.

Continuous Cascade Fermentation System for Chemical Precursors

(www.bio-process.com)

A cascade reactor for ethanol production from carbohydrate feedstocks was developed that eliminated 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. This continuous operation allows quick and complete saccharification and fermentation of feedstocks and removal of ethanol into a gas phase as it is produced. Since its introduction in 1996, this reactor has saved over 800 billion Btu.

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.

Delta T Dryer Control System

(www.moisturecontrols.com)

This dryer control system significantly improves control capability because it measures moisture content continuously in the dryer rather than only at the exit from the dryer. This more precise temperature control saves 10% to 20% more energy than conventional dryer control systems. Over 300 Delta T control systems have been installed and have saved more than 17 trillion Btu since 1985.

IMPACTS

Direct Source-to-Object Radiant Heating Panels

(www.radiantnow.com)

Radiant heating systems transfer heat directly to a person or object in a manner similar to sunlight, eliminating energy consumed by mechanical heat-delivery requirements. These systems can save up to 50% in heating costs compared with baseboard electric-resistance heating and up to 30% compared with heat pumps. Since 1981, more than 375,000 radiant heating panels have been sold, saving more than 1.45 trillion Btu.

D'MAND® Hot Water Recirculating and Waste Prevention System

(www.gothotwater.com)

A system was developed for water heaters to conserve water and energy while providing hot water on demand. The system moves the tepid water back to the water heater rather then discarding it prior to hot water delivery. The primary energy savings are from the reduced amount of energy needed to heat the water returned to the water heater tank. More than 33,000 units have been installed in residential and commercial applications and have cumulatively saved 604 billion Btu.

Dual-Cure Photocatalyst

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. A novel photocatalyst system was developed as part of a dual-cure process that allows light-activated, simultaneous polymerization of two monomers to produce a material consisting of two independent but interpenetrating polymer networks. The VOC emission levels from this process are substantially below those obtained using conventional coating technologies, and cure times are shorter. Since its introduction in 1995, this system has saved over 3.7 trillion Btu.

Dye Bath Reuse

To reduce the use of chemicals, water, and energy, two process modifications were developed for batch-dying 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.

Electronic Starter Device for Fluorescent Lamps

A quick and reliable electronic lamp starter was developed for small fluorescent applications. This technology was an important improvement for lower wattage fluorescent lamps which still use older preheat circuit designs. Use of the inexpensive and easily installed starter can double the life of a fluorescent lamp. More than 1.6 million units have cumulatively saved 3.1 trillion Btu.

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.

Energy-Efficient Process for Hot-Dip Batch Galvanizing

(www.ferrotech.com)

This process combines a thermally stable flux solution and a preheat furnace to reduce energy use and increase batch galvanizing productivity while reducing waste generation. Hot-dip galvanizing is widely used to protect steel from corrosion. The process was used at a Pennsylvania steel company and saved 4 billion Btu of energy.

Historical ITP Technology Successes

Evaporator Fan Controller for Medium-Temperature Walk-in Refrigerators

A new control system was developed for low- and medium-temperature walk-in refrigerators and freezers that senses refrigerant flow and adjusts the evaporator fan speed, saving fan motor energy when cooling is not needed. Energy consumption is reduced by about 40%, and lower running times increase equipment life span and cut maintenance and replacement costs. Since 1997, more than 1400 controllers have cumulatively saved 85 billion Btu.

Fluidized-Bed Waste Heat Recovery System

A self-cleaning waste heat recovery system was developed to replace industrial furnace conventional recuperators. The 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.

Glass Feedstock Purification

An optical sortation technology, which removes ceramic and other contaminants from glass cullet using optical sensors and computer-controlled jets of compressed air, was developed. This technology was used to recycle 50 tons/day of glass at one plant for two years thus resulting in a cumulative energy savings of 48 billion Btu.

Guide for Window Routing Device

(www.bi-glass.com)

A tool guide to control the operation of a router was developed for converting single-glazed wooden-framed windows into double-glazed windows. Single-pane glass can thus be replaced with panes that are more energy-efficient without replacing the sash members or the entire window. This technology was used by licensees in the United States and England and has saved more than 520 billion Btu of energy.

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

Materials and fabrication techniques were developed that 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 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 Dehumidifier

(www.heatpipe.com)

A system was developed to recover reheat energy and to control the humidity in all types of buildings. This system uses heat pipe technology to increase the humidifying capacity of air-conditioning equipment and operates without any mechanical or electrical inputs. More than 12,000 units have been sold and have cumulatively saved 1.38 trillion Btu.

High-Efficiency Direct-Contact Water Heater

(www.kemcosystems.com)

This industrial/commercial water heating system uses 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. More than 3,000 units are in use throughout the United States, and have saved a cumulative total of more than 300 trillion Btu in natural gas.

IMPACTS

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%.

High-Temperature Radiant Burner

(www.alzeta.com)

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) that are generated during semiconductor manufacturing. The burner operates reliably at high process temperatures and provides uniform, well controlled heat while increasing the efficiency of traditional burner systems. Since its introduction in 1995, over 5000 burners have saved more than 9.4 trillion Btu in the United States.

Hot Blast Stove Process Model and Model-Based Controller

A central control system was developed and installed on a blast furnace to optimize the thermal efficiency of the hot-blast stove system. The controller is linked to process optimization algorithms that determine heating fuel rates, thus minimizing fuel requirements and reducing the number of disruptions in iron production. This invention has saved more than 220 billion Btu since its installation in 1998.

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.

Hydrochloric Acid Recovery System

(www.betacontrol.com)

An on-site, closed-loop HCl recovery system was developed for galvanizers and small- and medium-size steel manufacturers. Benefits of the recovery system included reduced demand for virgin HCl, the elimination of the use of chemicals for neutralizing waste acid, and energy and cost savings associated with processing, transporting and disposing of the waste acid The use of this system resulted in cumulative energy savings of 410 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.

Hyperfiltration Process for Food

(www.niroinc.com)

A membrane hyperfiltration process is being used to separate juice into pulp and liquid fractions. This process replaces the energy-intensive thermal evaporation step in the concentration process. This process has been installed in 17 locations and has saved more than 13 trillion Btu since 1989.

Improved Composite Tubes for Kraft Recovery Boilers

(www.sandvik.com)

Originally, carbon steel tubes were used for tube panels in black liquor recovery boilers, but severe corrosion thinning and occasional tube failures led the forest products industry and boiler manufacturers to search for materials that could better survive in the recovery boiler environment. As a result of this search, weld overlay and co-extruded tubing alloys were developed and are being used in over 18 U.S. kraft recovery boilers and numerous foreign installations. Boiler manufacturers used these improved tubes in new and rebuilt kraft recovery boilers to cumulatively save over 4.5 trillion Btu in the United States.

Historical ITP Technology Successes

Improved Poured Concrete Wall Forming System

(www.liteform.com)

A method for pouring concrete walls for building basements and crawlspaces was developed that uses lightweight, highly insulative extruded polystyrene forms. If left in place, these forms create walls that are both load-bearing and thermally insulating, up to R-22. Over 47 million square feet of walls have been installed that have cumulatively saved 978 billion Btu.

Infrared Polymer Boot Heater

(www.inductoheat.com)

This electric high energy flux infrared heater and control system efficiently heats thermoplastic and polymer boots for applications requiring placement of the boots on steel parts (e.g., vehicle steering assemblies and CV joints). The technology converts electrical energy to radiant energy at 90% efficiency and delivers the heat only to areas needed to be heated. The 5 boot heater systems, in use since 2000, have cumulatively saved 0.22 billion Btu.

Ink Jet Printer Solvent Recovery

(www.quadtechworld.com)

A solvent recovery system for commercial printers was developed that reduces emissions of VOCs, including methyl ethyl ketone, methanol, isopropyl alcohol, and acetone. This closed-loop recycling system reduces the amount of fluid required by ink-jet printing, thereby reducing printing costs and improving productivity by reducing printer downtime for fluid replacement. Since 1997, the 658 systems that were installed have cumulatively saved 450 billion 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.

Lightweight Steel Containers

A process for manufacturing lightweight steel containers uses the container's internal pressure for rigidity rather than a thick wall. The resulting container wall is substantially thinner, which reduces the container's metal content by 40% but provides equivalent or better strength. The process saves energy by using less material in the container, less material processing, and less transportation weight. Two container production lines have cumulatively saved 3 billion Btu.

Membrane Filtration Technology to Process Black Olives

A zero discharge wastewater purification and reclamation system was installed at an olive production plant. This system used a cyclone separation system followed by ultrafiltration and reverse osmosis to recycle wastewater back into the plant. Since its installation in 1997, it has saved 100 billion Btu.

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 spinoff technology was commercialized for wastewater treatment.

Meta-Lax Stress Relief Process

(www.bonal.com)

A process applies subresonant vibrational energy to relieve stress in metal objects. The process replaces heat treating applications and reduces the energy and time needed to heat treat metal. The equipment is portable and treats a wide variety of work pieces in a pollution-free operation. More than 990 units have cumulatively saved 136 trillion Btu.

Methanol Recovery from Hydrogen Peroxide Production

(www.fmc.com)

A process was developed to recover and clean contaminated methanol for reuse in producing hydrogen peroxide. This process recovers more than 90% of the methanol needed to produce hydrogen peroxide, thereby saving the energy needed to produce virgin methanol. The process also saves energy by reducing the transportation of virgin methanol. The two units using this process have cumulatively saved 244 billion Btu.

Method of Constructing Insulated Foam Homes

(www.homecorpintl.com)

A method was developed for constructing buildings that are both energy efficient and structurally sound. The home consists of an exterior patented wall system made of expanded polystyrene (EPS) foam insulation panels with an internal steel-reinforced concrete post and beam design. This wall has an R-40 insulation panel with an internal steel-reinforced concrete post and beam design. The roof is insulated by EPS slabs sandwiched between the rafters and has an R-50 insulation value. The 326 homes constructed using this method saved a cumulative total of 38 billion Btu since 1996.

IMPACTS

Nickel Aluminide Trays and Fixtures for Carburizing Heat Treating Furnaces

Nickel aluminide alloy is a high-strength heat-resistant alloy that is very resistant to carburization. Nickel aluminide heat-treating furnace assemblies were used to replace steel rack assemblies that failed at high heat in an auto parts production plant. Compared with conventional alloys, the new assemblies last three to five times longer and are at least three times stronger at the high operating temperatures, which improves energy and production efficiencies. Since 2001, the new assemblies have cumulatively saved 34 billion Btu.

Night Sky – A New Roofing Technology

A natural evaporating roofing/cooling system was developed for flat or slope-roofed commercial buildings to increase the roof's life expectancy and reduce building cooling loads by 50%. This system spray-cools water on the roof at night and then applies the cooled water to reduce subsequent cooling loads. Systems involving more than 95,000 square feet have been installed and have cumulatively saved 2 billion Btu.

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.

No-Clean Soldering Process

After soldering, electronic equipment used to be cleaned using CFC solvents. Changing the soldering technique eliminated the need to use CFC solvents for cleaning, resulting in energy savings and reduced CFC waste. This process has cumulatively saved 3.9 trillion Btu.

Onsite Process for Recovering Waste Aluminum

In the production of aluminum automobile wheels approximately 30% of the aluminum content is machined away as chips during the cutting and grinding steps. A 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. This process has resulted in cumulative energy savings of 139 billion 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.

Oxy-Fuel Firing

(www.praxair.com)

This oxygen-enriched combustion system for glass-melting furnaces significantly reduces energy requirements. About one-fourth of all glass-melting capacity in the United States has been converted to oxy-fuel firing. In addition to energy savings, this technology reduces NO_X emissions by up to 90% and particulates by up to 30%. Since its commercialization in 1990, oxy-fuel firing technology has saved more than 25 trillion Btu.

Paint Wastewater Recovery

(www.zenon.com)

A system was developed 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. Energy savings resulted from the reduced fuel use for transporting and incinerating the waste. The process has cumulatively saved over 30 billion Btu of energy.

Pallet Production Using Postconsumer Wastepaper

A process produces paper pallets made of 40% postconsumer waste paper. Substituting virgin wood with this recycled product reduces by 60% the energy required to produce pallets, saves landfill space, and decreases air and water pollution. The process has cumulatively saved over 2 billion Btu.

Historical ITP Technology Successes

Pervaporation to Recover and Reuse Organic Compounds

(www.mtrinc.com)

A membrane technology was developed which treats small-volume, less than 20 gallons per minute, waste streams contaminated with organic compounds. Small-volume wastewater streams are difficult and expensive to treat with most conventional organic-compounds control technologies. The three installed units cumulatively saved 57 billion Btu.

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.

Pinch Analysis and Industrial Heat Pumps

(www.veritechenergy.com)

Pinch analysis was used to locate the most productive process modifications and heat pump opportunities within a complex process to improve overall process efficiency. A pinch analysis of a wet-corn-milling plant showed that adding two new thermal vapor recompression heat pumps to existing evaporators could reduce overall process fuel use by 33%. These two heat pumps have cumulatively saved 917 billion Btu.

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.

Powder Paint Coating System

The current standard for applying anti-chip 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%. A powder anti-chip process that contains no solvents and, considering recycling, has an effective transfer efficiency exceeding 99% was developed. The 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 due to greatly reduced air-heating requirements and the elimination of energy requirements for incinerating VOCs. This system has been installed in 14 locations in the United States and has saved more than 5.6 trillion Btu since 1996.

PowerGuard® Photovoltaic Roofing System

(www.sunpowercorp.com)

A roofing system was developed that offers building insulation, shading, roof protection, and solar power generation encompassed in a single roofing panel. These have been installed on commercial or residential buildings that have flat or low-slope roofs. Since its introduction in 1994, more than 21 MW have been installed across the United States for an energy savings of 385 billion Btu.

Real-Time Neural Networks for Utility Boilers

(www.neuco.net)

A computer model was developed that uses an advanced form of artificial intelligence known as neural networks to optimize combustion in coal-fired boilers. This system improved boiler efficiency by as much as 5% and reduced NO_X, CO_2 and SO_X emissions. 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. The system has been installed on 64 boilers and has saved more than 57 trillion Btu since 1995.

Recovery of Acids and Metal Salts from Pickling Liquors

Steel fabrication processes often use pickling (immersing steel in acid) to remove oxide layers from recently heated steel. The Pickliq® process was developed to make sulfuric acid recovery cost-effective for smaller installations. The 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. Since its introduction in 1995, the process has saved more then 11 billion Btu in the United States.

IMPACTS

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.

Recycling of Aluminum Dross/Saltcake Waste

(www.aleris.com)

The melting process used by the secondary aluminum industry when recycling aluminum creates a waste stream known as black dross/saltcake. A new process was developed that separates the dross into its basic components — aluminum metal, fluxing salts, and nonmetallic products. The aluminum metal and salt fluxes can be sold back to the secondary aluminum industry or other industries. The remaining nonmetallic products can be made into commercially salable products completely avoiding land filling. Since 1997, the three plants using this new process have cumulatively saved 13.5 trillion Btu.

Removal of Bark from Whole Logs

A machine, the Cradle Debarker™, was developed that removes bark from delimbed tree stems in a process that strips off less wood, allows for greater operator control, and improves the productivity of the debarking process. Unlike drum debarkers, which use a covered cylinder, the open top of this debarker lets the operator remove stems that have completed the debarking process and recycle others that require further processing. The four debarker units have cumulatively saved 132 billion Btu.

Restaurant Exhaust Ventilation Monitor/Controller

(www.melinkcorp.com)

Typical exhaust hoods in restaurants operate at full speed all day long and sometimes all night long even when cooking is not taking place. A microprocesor-based controller for commercial kitchen ventilation systems was developed that optimizes system performance for four key parameters: kitchen comfort, fire safety, occupant health, and energy efficiency. It monitors and reduces the fan speed during idle periods of kitchen activity to save energy and employs sensors that monitor heat and smoke levels for safety. More than 2,700 units have been sold and have saved more than 600 billion Btu since 1994.

Retractable® Labyrinth Packing Seals for Turbine Shafts

(www.turbocare.com)

This invention is a redesigned shaft-sealing ring for utility and industrial steam turbines that self-adjusts from the gap required for start-up to that required for normal operation. The result is less wear damage and improved turbine efficiency. The packing seals are still available for sale from TurboCare, Inc. More than 600 of these seals have been installed and have saved more than 74 trillion Btu. Additionally, spinoff technologies were developed to further improve steam power efficiency.

Reverse Brayton Cycle Solvent-Recovery Heat Pump

A reverse Brayton cycle heat pump was developed to economically and efficiently recover solvents from numerous industries. This heat pump reduces the demand for new solvents, saving petroleum feedstock and the energy used to produce virgin solvents, and captures for reuse solvents that would have been released to the atmosphere. Ten heat pumps have been installed and have cumulatively saved 4.98 trillion Btu.

Robotic Inspection System for Storage Tanks

(www.solexrobotics.com)

This technology consists of a remotely operated robotic inspection vehicle that is submerged in bulk liquid storage tanks to gather input on structural and corrosion problems. This system replaces the time-consuming conventional inspection process of draining the tank, washing it out, inspecting it, and then refilling it. This technology has cumulatively saved 280 billion Btu.

RR-1 Insulating Screw Cap

A new insulated screw cap assembly was developed for use on commercial and industrial buildings with membrane and metal roofs. The new assembly replaces conventional metal or plastic fasteners and improves the energy performance of the roofs. The assembly reduces heat transfer through the fastener and is more resistant to condensation and corrosion. More than 300,000 fastener assemblies have been sold since 1997, cumulatively saving 13 billion Btu.

Historical ITP Technology Successes

Scrap Tire Recycling

This process converts scrap tires into high-value products, conserving energy and new materials while reducing the amount of scrap tires sent to landfills. This treatment process combines surface-treated rubber particles with other polymers such as polyurethane, epoxy, and polysulfide to form unique composites with improved strength, tear resistance, and resilience. This process has saved a cumulative 0.16 trillion Btu in natural gas.

Selective Zone Isolation for HVAC Systems

(www.retrozone.com)

A method for selectively controlling air flow from a central HVAC system can now fit into ducts that cannot accept conventional dampers because of poor access. The flexible dampers can save 20% to 30% of a typical heating and cooling bill in a large house or commercial building by sealing off unoccupied rooms. More than 4000 systems have been sold and have cumulatively saved 305 billion Btu.

SIDTEC™ Condenser Maintenance Program

(www.gewater.com)

An on-line condenser tube cleaning system uses ultra-high molecular weight polyethylene tube cleaners to remove both soft and hard deposits. The system maintains system efficiency and keeps the thermal power plant operating. Twelve power plants have used the system and have cumulatively saved 136 trillion Btu.

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.

Smart Screening Systems for Mining

A smart screening system was developed that vibrates only the screen rather than the entire machine and supporting structure in the material separation process. The system saves energy by replacing the massive electrical motor and eccentric shaft with miniaturized "smart" motors combination with multi-staged resonators. The motors are programmed to vibrate the screening panel at an optimal set rate, even as the material load varies over time, thus optimizing the throughput and energy savings of the screening system. Since its introduction in 2003, the 44 units installed in the United States have saved 3 billion 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.

SolaRoll® Solar Collector System

A flexible rubber tubing solar collector system was developed to be used to heat hot water, swimming pools, and building heating systems. The collectors are an extrusion of ethylene-propylene-diamine rubber and are primarily used for heating swimming pools. The systems replace conventional natural gas or electric heat pump systems. More than 35 million square feet of SolaRoll® have been sold and have saved more than a cumulative 25 trillion Btu of energy.

SOLARWALL® Air Preheating System

(www.solarwall.com)

A solar air heating system heats incoming ventilation and makeup air using a metal cladding system installed on the south-facing wall of a building. This system also reduces a buildings heat loss in the winter and lowers the cooling loads in the summer by preventing solar radiation from striking the south wall of the building. More than 40 systems with over 200,000 square feet of wall are operating in the United States and have cumulatively saved 76 billion Btu. A spinoff technology has been developed that resulted in a combined solar heat and power system.

IMPACTS

Solvent Recovery from Effluent Streams

(www.mtrinc.com)

A membrane system was developed for recovering volatile organic compounds and chlorofluorocarbons from petrochemical waste streams. This system allows solvents to be recovered from waste streams that are too diluted or too concentrated with solvents to use other methods. In addition to eliminating the environmental release of these solvents, the 27 units in operation in the United States have saved more than 15 trillion Btu since 1990.

Stalk and Root Embedding Plow

(www.romeplow.com)

A stalk and root embedding plow was invented that reduces costs and saves time in preparing cotton fields for planting. Disposing of cotton stalks and roots in the field after harvest is an energy-intensive operation. Nationwide, many cotton farmers use conventional tillage practices that involve shredding the stalks and making several tillage passes over the field to prepare a new seedbed. The plow deeply entrenches whole stalks and roots into the soil in one pass, eliminating the need to shred the stalks. The 79 plows sold in the United States have saved a cumulative total of 123 billion Btu of energy.

Steel Reheating for Further Processing

(www.praxair.com)

A low NO_X, oxygen-burner retrofit using 100% oxygen was developed for steel reheating that requires less fuel to heat steel. These burners result in energy savings of 60% per ton of steel while increasing the quality of the metal. Emissions are reduced enough to eliminate the need for NO_X removal equipment and the steel is more uniformly heated resulting in better mill performance and an increase in productivity. Since its introduction in 1998, this system has saved 1 trillion Btu.

System 100® Compressor Controls

(www.cccglobal.com)

A compressor control system was developed that allows the operation of both pipeline and process compressors to operate efficiently without surge or recycle. The compressors are usually powered indirectly by natural gas (steam for process compressors and gas-powered turbines for pipeline compressors). Energy savings are typically in the 5% to 10% range. Total sales of the control systems were more than 3600 units and they have cumulatively saved more than 400 trillion Btu.

The Solar SKYLITE Water Heater

(www.solarroofs.com)

A solar skylight water heater system was developed that uses lightweight, low-cost polymeric materials. A typical installation uses two solar collectors and the entire system can be installed in a few hours. The system can serve as a skylight and provide energy to the home's water heater. More than 1400 systems have been installed and these have cumulatively saved more than 75 billion Btu of energy. A spinoff technology was developed that improves solar energy capture.

Thin Wall Casting of Stainless Steel

An alloy of cast stainless steel composition was developed that allows the use of the Hitchiner counter-gravity casting process for stainless steel parts rather than conventional sand casting. Using the Hitchiner process allows components to be cast with wall thickness of less than 3mm - nearly two to three times less than conventional casting. This process increases automation, increases throughput by a factor of two to three compared with the conventional process, and produces a significantly higher yield with very low defect rates. The use of this alloy has saved over 460 billion Btu since 2000.

Ultrasonic Tank Cleaning

(www.telsonic.com)

Chemical and pharmaceutical companies typically use volatile organic compound (VOC)-emitting solvents to clean their storage tanks in a process that is both labor and energy-intensive. An ultrasonic tubular resonator was developed that eliminates the use of VOC-emitting cleaning solvents and reduces cleaning time from about 1 day to 1 hour. 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. Energy savings from the use of this technology are based on decreased cleaning energy use as well as the reduced use of solvents. Since 1995, this technology has saved more than 40 billion Btu.

Historical ITP Technology Successes

Use of Recovered Plastics in Durable Goods Manufacturing

(www.mbapolymers.com)

An advanced mechanical recovery technology that can effectively recover plastic waste material from complex manufacturing scrap and end-of-life durable goods including automobiles, appliances, electrical, and electronic equipment was developed. This technology separates as many as three different plastics at one time in a mixed waste stream and segregates metal, metal coatings, rubber, glass, foam, and fabric from the plastic waste. Since its introduction in 1996, this technology has cumulatively saved over 400 billion Btu.

Variable-Frequency Microwave Furnace

(www.microcure.com)

Microwave heating can speed the curing of thermo-setting resins and polymer-matrix composites. Conventional microwave furnaces use standing waves that create a non-uniform energy distribution in the working cavity. A variable-frequency microwave furnace was developed that eliminates non-uniform energy distribution and provides reproducible heating with every batch. Various types of polymer products can be uniformly cured, often in 5% of the time of conventional processing. The 48 units in the United States have saved 47 billion Btu since 1995.

V-PLUS™ Refrigerant Oil Cooling System

(www.vilter.com)

The V-Plus system injects refrigerant liquid into the outlet stream of a screw-compressor for industrial refrigeration and cooling systems. The result is increased system capacity, extended system lifetime, and energy savings. Over 250 units have been installed and have saved more than 1 trillion Btu since 1982.

Wallace Energy Systems Solar Assisted Heat Pump Water Heater

A system was developed for extracting heat from a source (air or water) and applying this heat to water. The heat pump water heater provides both water heating and space cooling. The systems can be used in applications that need large amounts of hot water and cooling, such as laundries and schools. More than 103 units are in use and have cumulatively saved 118 billion Btu.

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.

Waste Fluid Heat Recovery System

A heat recovery system that extracts energy from waste fluids was developed that increases heat transfer coefficients two to four times higher than conventional designs. Using a new coil and tube design for the heat exchanger reduces energy consumption by recovering up to 70% of heat usually lost in the waste fluid. More than 2660 units were sold since 1997, cumulatively saving 144 billion Btu.

Waste-Minimizing Plating Barrel

(www.selectives.net)

An innovative plating barrel uses a honeycomb formation that results in a thinner walled barrel. The new barrel has greater solution transfer, higher current density plating, reduced bath concentration, and better plating of difficult chemistries such as alloy plating. Energy savings result from reduced process time and better plating efficiency. More than 1100 of these new barrels have been sold since 1997, cumulatively saving 4.1 trillion Btu.

IMPACTS

◆ XTREME Cleaner™ – Removal of Light and Sticky Contaminants

(www.kadant.com)

A new centrifugal cleaner was developed that replaces conventional dispersion systems in paper mills for recycling waste paper containing "stickies," wax, polyethylene, and binding glue. The new cleaner uses 50% less energy than the conventional systems, significantly reducing costs for paper mills and allowing them to use lower-grade, lower-cost furnish without compromising the quality of the final paper product. The cleaner eliminates downtime for removing sticky contaminant buildup from processing machinery and reduces machine or paper breaks. Since 1997, twelve cleaner systems have cumulatively saved 1.56 trillion Btu.

Appendix 4:
Method of Calculating Results for the IAC Program

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Method of Calculating Results for the IAC Program

The Industrial Assessment Centers (IAC) within the Industrial Technologies Program (ITP) have been successfully generating energy savings for over 30 years. Twenty-six IACs located within engineering departments at top universities across the U.S. conduct energy assessments for small- and medium-sized manufacturers and train the future workforce of energy engineers.

The following table presents energy savings calculated and summed from four sources associated with the IAC program from 1977-2007: (1) IAC energy assessments, (2) assessments performed by IAC student alumni, (3) replication assessments within firms served by the IAC, and (4) IAC website-related energy savings. Output and savings estimates rely on information from the IAC assessment database (administered by Rutgers University), the IAC student registry, and evaluations conducted by Oak Ridge National Laboratory (ORNL). The IAC database documents savings recommendations and implementation history for plant assessments conducted over a 26-year period, covering more than 14,000 assessments and over 105,000 savings recommendations. The IAC student registry, established in 2001, tracks the progress of students from their starting date until their departure from the IAC. Finally, ORNL evaluations have studied the longer-term effects of plant assessments, career paths of IAC alumni, and the savings potential of web-based materials offered by the IAC.

Tabulations shown in the table are based on data collected by the IACs and studies done to estimate the nonassessment benefits. The first two rows of the table show the number of assessments conducted each year and the savings associated with each new assessment. The savings from each assessment are assumed to persist for seven years. Therefore, the energy saved in each year (shown in row three) is the sum of energy savings from new assessment savings for that year plus the savings from measures implemented in the previous six years that continue to persist.

The contribution of assessments (or other, equivalent professional services) performed by IAC student alumni is estimated based on averaged student registry data and feedback from IAC alumni who are practicing energy engineers. In 2007, 123 fully trained students graduated from the IAC, and cumulatively over 2,745 IAC students graduated. According to ORNL research and alumni feedback, about 50% of the alumni have remained in the energy-efficiency business and each alumnus performs the equivalent of 4 assessments per year for 11 years after leaving the IAC program. The benefits of each energy assessment (or equivalent intervention) were assumed to persist for seven years, after which the aged energy assessment was "retired" for the purposes of this estimation. The annual energy savings from alumni assessments are shown in row four in the table.

The savings from replications from assessment activities are calculated as 25% of the energy saved in the prior year from all assessment activities. This calculation accounts for the ancillary effect of additional implementations that are initiated later but are the result of the IAC's influence. These implementations may be accomplished at the same plant as the original implementations, or at other plants within the same company, or within other plants at other companies as plant managers/engineers/workers change jobs but take the energy efficiency know-how with them. The annual energy savings from replication activities are shown in row five in the table.

The IAC website maintained at Rutgers University was estimated to begin having an impact on energy savings in 1998. The methodology for determining the savings from web users relies on server data, IAC assessment savings, and data from the literature to approximate energy savings associated with the on-line, user-friendly version of the IAC database. While most centers host IAC-related websites, several of which contain useful software tools and publications developed by students and faculty, IAC savings estimates focus solely on the on-line version of the IAC database. The output estimate for the IAC website is based on the number of unique plants that used the on-line database. Server reports from Rutgers have identified about 82,200 annual visitors to the website, 6,850 of which were likely to represent unique U.S. plants. According to software use experience for similar programs, only 11% of those accessing the IAC database likely use it and only 14% of this number implement energy saving projects with the information provided. The estimates of energy savings are based on the savings generated by the unique plants that use the on-line database each year to implement energy-saving projects. Each unique plant that implements a project is assumed to save the equivalent of a single IAC assessment, or 8,182 MMBtu in 2007. As with the other assessments, energy savings are assumed to persist for seven years.

The annual and cumulative energy savings from all IAC activities are shown in the table for each year. In 2007, the annual energy savings are 224 TBtu and the cumulative energy savings through 2007 are 1,714 TBtu. Energy cost savings, carbon reduction, and other benefits are related to energy savings by projected fuel prices and emission coefficients. The cumulative energy cost savings and the cumulative carbon reduction are shown for the IAC program through 2007 in the last two rows of the table.

IMPACTS

Item	1977	1978	1979	1980	1981	1982	1983	1984
Number of Assessments	82	70	636	224	359	253	211	248
Annual Energy Saved Per New Assessment *(MBtu/Assessment-Year)*	3,212	3,212	3,212	3,212	3,212	1,782	2,047	3,504
Energy Saved From Assessments *(TBtu)*	0.263	0.488	2.53	3.39	5.01	5.65	6.41	7.11
Energy Saved From Alumni Assessments *(TBtu)*	–	–	0.09	0.27	0.57	0.84	1.26	2.27
Replication Energy Savings *(TBtu)*	0.0	0.065	0.125	0.52	0.24	0.37	0.16	0.19
Annual Energy Savings *(TBtu)*	0.263	0.553	2.74	4.18	5.82	6.86	7.82	9.57
Cumulative Energy Savings *(TBtu)*	0.263	0.816	3.56	7.74	13.6	20.4	28.2	37.8
Energy Cost Savings *(B$)*	0.001	0.004	0.018	0.039	0.075	0.120	0.169	0.229
Carbon Reduction *(MMTCE)*	0.005	0.015	0.066	0.143	0.250	0.376	0.519	0.695

Item	1985	1986	1987	1988	1989	1990	1991	1992
Number of Assessments	368	298	324	388	340	360	455	531
Annual Energy Saved Per New Assessment *(MBtu/Assessment-Year)*	4,208	4,520	3,898	3,842	4,724	3,821	3,207	3,942
Energy Saved From Assessments *(TBtu)*	8.49	7.92	8.40	8.87	10.0	11.2	12.2	12.8
Energy Saved From Alumni Assessments *(TBtu)*	3.96	6.27	8.79	11.8	16.0	19.9	23.3	27.1
Replication Energy Savings *(TBtu)*	0.44	0.80	0.84	0.88	1.09	1.39	1.19	1.26
Annual Energy Savings *(TBtu)*	12.9	15.0	18.0	21.5	27.1	32.5	36.7	41.2
Cumulative Energy Savings *(TBtu)*	50.7	65.7	83.7	105	132	165	202	243
Energy Cost Savings *(B$)*	0.307	0.382	0.470	0.572	0.707	0.882	1.07	1.28
Carbon Reduction *(MMTCE)*	0.932	1.21	1.54	1.93	2.43	3.02	3.68	4.43

Item	1993	1994	1995	1996	1997	1998	1999	2000
Number of Assessments	585	776	879	867	720	723	755	705
Annual Energy Saved Per New Assessment *(MBtu/Assessment-Year)*	3,314	3,074	2,978	3,002	2,500	2,185	2,856	2,408
Energy Saved From Assessments *(TBtu)*	13.4	14.6	16.0	17.1	17.8	18.2	18.4	18.1
Energy Saved From Alumni Assessments *(TBtu)*	30.0	33.3	36.4	38.9	41.0	43.2	45.9	47.7
Replication Energy Savings *(TBtu)*	1.70	1.64	1.84	2.04	2.17	1.84	1.66	2.25
Web Users Energy Savings *(TBtu)*	–	–	–	–	–	0.04	0.12	0.20
Annual Energy Savings *(TBtu)*	45.1	49.6	54.2	58.1	61.0	63.3	66.1	68.3
Cumulative Energy Savings *(TBtu)*	288	337	392	450	511	574	640	709
Energy Cost Savings *(B$)*	1.51	1.76	2.02	2.34	2.66	2.96	3.29	3.74
Carbon Reduction *(MMTCE)*	5.24	6.13	7.10	8.14	9.24	10.4	11.6	12.8

Item	2001	2002	2003	2004	2005	2006	2007	2008
Number of Assessments	639	649	620	635	555	450	385	–
Annual Energy Saved Per New Assessment *(MBtu/Assessment-Year)*	3,935	6,800	6,620	7,140	7,070	9,540	8,182	–
Energy Saved From Assessments *(TBtu)*	18.2	19.9	21.3	24.5	27.4	30.3	32.3	–
Energy Saved From Alumni Assessments *(TBtu)*	54.3	69.4	85.1	106	127	155	178	–
Replication Energy Savings *(TBtu)*	1.97	3.33	6.14	6.05	6.78	6.65	8.68	–
Web Users Energy Savings *(TBtu)*	0.38	0.79	1.29	1.91	2.76	3.98	4.65	–
Annual Energy Savings *(TBtu)*	74.9	93.4	114	139	164	196	224	–
Cumulative Energy Savings *(TBtu)*	783	877	991	1,129	1,294	1,490	1,714	–
Energy Cost Savings *(B$)*	4.25	4.82	5.61	6.72	8.48	10.7	13.5	–
Carbon Reduction *(MMTCE)*	14.1	15.8	17.9	20.4	23.3	26.9	30.9	–

Appendix 5:
Method of Calculating Results for the BestPractices Program

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Method of Calculating Results for the BestPractices Program

In support of the Industrial Technologies Program's (ITP's) mission to improve the energy intensity of the U.S. industrial sector, BestPractices is designed to provide industrial plant managers with information to evaluate opportunities and implement projects that improve the efficiency of energy systems within their production facilities. These process-supporting energy systems include those with motors and drives, pumps, air compressors, steam, and process heat. BestPractices relies on four main activities to deliver technical information to a target audience of larger, more energy-intensive manufacturing establishments: (1) large plant assessments, (2) training, (3) software tool development, and (4) qualification of specialists by BestPractices to address industrial applications of energy-intensive pumping, compressed air, steam, and process heating systems.

Estimates of energy savings presented in this report are based on a methodology originally developed by Oak Ridge National Laboratory in 2002 and refined as the result of a peer review conducted in 2004. The impacts presented for 2007 BestPractices activities reflect the on-going efforts to implement recommendations from the peer review and improve the accuracy of savings estimates. Improvements include (1) integration of results from a participant survey, (2) better understanding of energy characteristics of participating plants, (3) consistent registration information for software users, and (4) follow-up implementation information from assessments. Savings estimates for years prior to 2004 have not been adjusted to reflect these most recent improvements.

The ITP Tracking Database provides data on participants in all activity areas and uses the data to estimate output and savings outcome performance of BestPractices. Participants include representatives from domestic or international manufacturing plants, corporations, research or educational institutions, state and local governments, and engineering or consulting organizations. Using information on participant affiliation, the tracking database provides estimates of the number of unique, domestic plants participating in each activity. The number of unique plants is then scaled back to estimate the number of unique U.S. plants that are believed to take action to implement energy savings projects as a result of the dissemination of this information.

Estimates of energy savings from BestPractices' activities focus on the four core activities of assessments, training, software, and qualified specialists. As a result of the peer review, estimates were constrained to these activities because of their significant savings potential and the higher quality of available data. The basic methodology for estimating the energy outcome of BestPractices is a combination of implemented energy savings reported for assessments and calculated savings for training, software use, and qualified specialists. Energy benefits generated by assessments are based on implementation results from follow-up with participating manufacturing plants. Savings associated with unique U.S-based plants that implement projects following interaction with qualified specialists or by participating in training or use of software are estimated using recent participant survey feedback and historical assessment data from BestPractices and the Industrial Assessment Centers (IACs). Savings and descriptions for each of the four main delivery activities are summarized below.

Large Plant Assessments

In 2006, under the new Save Energy Now campaign, ITP shifted resources to conduct system-focused assessments at 200 energy-intensive manufacturing plants across the country. Prior to this, ITP offered annual plant-wide assessments (PWAs) to a limited number of large plants. The two assessment approaches are vastly different. Save Energy Now assessments are provided to a larger number of plants; however, they are limited to analysis of a single energy system and demonstration of the relevant ITP software tool. Conversely, PWAs were delivered to a smaller group of plants to identify overall energy use in manufacturing processes and develop a more comprehensive set of opportunities for savings. Both approaches highlight opportunities for best energy management practices for industry, including the adoption of new, efficient technologies.

In 2007, 250 Save Energy Now assessments (SENA) were completed; replication activities were limited and are not included in the impacts estimate. Implemented savings reported from SENAs totaled 18.56 TBtu. Savings from the PWAs in previous years are assumed to persist for seven years, and this effect adds 75.24 TBtu in savings for 2007. The total energy savings generated in 2007 from BestPractices assessments in large, energy-intensive plants was 93.79 TBtu, and the cumulative savings generated from 2000 through 2007 was 269.82 TBtu.

IMPACTS

Training

Training activities continue to play a key role in the BestPractices' strategy. Participants who attend end-user training learn how to apply the software in their own plants to identify and implement savings in energy-intensive systems. The number of unique plants participating in a training activity is recorded in the ITP Tracking Database. From 1998 through 2007, representatives from over 5,600 unique plants attended BestPractices' training sessions. In 2007, of 562 plants attending training sessions, about 171 were estimated to actually take action to implement projects in their own energy-intensive systems, resulting in an estimated savings of 1.21 TBtu. Additionally, savings that persist from measures implemented as a result of training conducted in previous years contributed 51.94 TBtu in 2007. BestPractices' training saved 53.15 TBtu in 2007 and cumulatively saved 304.11 TBtu from 1998 through 2007.

Software Tools Distribution

BestPractices has a variety of resources to help address a company's energy management needs and facilitate energy-efficiency decision-making. A range of software tools is available to help a plant manager perform a self-assessment of a plant's fan, motor, pumping, compressed air, steam, or process heating systems. Software tools available in 2007 included Fan System Assessment Tool (FSAT), AirMaster+, MotorMaster, Pumping System Assessment Tool (PSAT), Steam System Scoping Tool, Steam System Assessment Tool, Process Heating Assessment Tool (PHAST), and 3E Plus. Users may download the software from the BestPractices website or use the Save Energy Now CD-ROM, which contains the entire suite of BestPractices' software tools.

Software is proving to be a powerful means of disseminating technical information for BestPractices. According to the tracking database, over 2,500 unique plants obtained BestPractices' software in 2007. Over 344 plants are estimated to have taken action to implement projects, saving an estimated 3.47 TBtu. Savings from measures implemented in previous years that persist in 2007 contributed 45.64 TBtu. BestPractices' software saved 49.11 TBtu in 2007 and cumulatively saved 248.72 TBtu from 1998 through 2007.

Qualified Specialists

Qualified specialists are industry professionals who have completed additional training and demonstrated proficiency in using BestPractices' software tools. Specialists apply these tools to help industrial customers identify ways to improve system efficiency. In 2007, BestPractices offered specialist qualifications in the following software tools: Steam Systems, PSAT, AirMaster+, FSAT, and PHAST.

By the end of 2007, 613 software specialists were qualified by BestPractices. That same year, an estimated 1150 plants interacted with qualified specialists, resulting in implemented projects at 587 plants. Estimated savings from qualified specialists' activities in 2007 are 6.52 TBtu. Savings that persist in 2007 from measures implemented in 2001 through 2006 contributed 22.28 TBtu. Qualified specialists saved 28.80 TBtu in 2007 and cumulatively saved 78.66 TBtu from 2001 through 2007.

Conclusion

The table below shows the total annual energy savings from ITP's BestPractices activities from 1998 through 2007. The subtotals from the four delivery activities are added together to calculate the total annual energy savings for 2007 of 225 TBtu and a cumulative energy savings of 901 TBtu. Fuel prices and emission coefficients for various fuels from Energy Information Administration publications were used to determine cumulative energy cost savings and carbon reduction.

Method of Calculating Results for the BestPractices Program

	1998	1999	2000	2001	2002	2003	2004
Large Plant Assessments							
Unique Plants Implementing Improvements Each Year	–	–	2	14	17	8	9
New Plant Replications	–	–	–	1	10	22	5
Annual Energy Savings from Large Plant Assessments *(TBtu)*	–	–	0.61	1.28	9.45	20.5	27.4
Cumulative Energy Savings from Large Plant Assessments *(TBtu)*	–	–	0.61	1.89	11.3	31.9	59.3
Training							
Unique Plants Reached Each Year	75	150	300	330	791	652	693
Unique Plants Implementing Improvements Each Year	38	75	150	165	396	326	347
Annual Energy Savings from Training *(TBtu)*	0.84	2.51	5.86	10.2	28.5	44.0	49.8
Cumulative Energy Savings from Training *(TBtu)*	0.84	3.35	9.21	19.4	47.9	91.9	142
Software Tools Distribution							
Unique Plants Reached Each Year	479	959	4,793	10,718	9,608	5,847	1,842
Unique Plants Implementing Improvements Each Year	96	192	959	2,143	1,922	1,169	368
Annual Energy Savings from Software *(TBtu)*	0.24	1.04	4.63	13.3	21.1	32.4	36.0
Cumulative Energy Savings from Software *(TBtu)*	0.24	1.28	5.91	19.2	40.3	72.7	109
Qualified Specialists							
Number of Qualified Specialists	–	–	–	27	89	177	300
Unique Plants Interacting Each Year with Qualified Specialists	–	–	–	13	43	85	667
Unique Plants Implementing Improvements Each Year	–	–	–	7	22	43	352
Annual Energy Savings from Qualified Specialists *(TBtu)*	–	–	–	0.17	0.77	3.30	8.42
Cumulative Energy Savings from Qualified Specialists *(TBtu)*	–	–	–	0.17	0.94	4.24	12.7
Sum of All BestPractices Areas							
Unique Plants Reached Each Year	554	1,109	5,095	11,076	10,469	6,614	3,216
Unique Plants Implementing Improvements Each Year	134	267	1,111	2,330	2,367	1,568	1,081
Annual Energy Savings *(TBtu)*	1.08	3.55	11.1	25.0	59.8	100	122
Cumulative Energy Savings *(TBtu)*	1.08	4.63	15.7	40.7	101	201	322
Energy Cost Savings *(B$)*	0.005	0.023	0.096	0.265	0.629	1.32	2.30
Carbon Reduction *(MMTCE)*	0.019	0.083	0.282	0.732	1.81	3.61	5.81

Method of Calculating Results for the BestPractices Program

IMPACTS

	2005	2006	2007	2008	2009	2010	2011
Large Plant Assessments							
Unique Plants Implementing Improvements Each Year	8	200	250	–	–	–	–
New Plant Replications	1	0	0	–	–	–	–
Annual Energy Savings from Large Plant Assessments *(TBtu)*	40.8	75.9	93.8	–	–	–	–
Cumulative Energy Savings from Large Plant Assessments *(TBtu)*	100	176	270	–	–	–	–
Training							
Unique Plants Reached Each Year	1,197	929	562	–	–	–	–
Unique Plants Implementing Improvements Each Year	599	282	171	–	–	–	–
Annual Energy Savings from Training *(TBtu)*	54.1	55.3	53.0	–	–	–	–
Cumulative Energy Savings from Training *(TBtu)*	196	251	304	–	–	–	–
Software Tools Distribution							
Unique Plants Reached Each Year	3,088	3,536	2,547	–	–	–	–
Unique Plants Implementing Improvements Each Year	618	477	344	–	–	–	–
Annual Energy Savings from Software *(TBtu)*	41.7	49.2	49.1	–	–	–	–
Cumulative Energy Savings from Software *(TBtu)*	150	200	249	–	–	–	–
Qualified Specialists							
Number of Qualified Specialists	351	443	613	–	–	–	–
Unique Plants Interacting Each Year with Qualified Specialists	844	1,084	1,150	–	–	–	–
Unique Plants Implementing Improvements Each Year	434	553	587	–	–	–	–
Annual Energy Savings from Qualified Specialists *(TBtu)*	14.9	22.3	28.8	–	–	–	–
Cumulative Energy Savings from Qualified Specialists *(TBtu)*	27.6	49.9	78.7	–	–	–	–
Sum of All BestPractices Areas							
Unique Plants Reached Each Year	5,138	5,749	4,509	–	–	–	–
Unique Plants Implementing Improvements Each Year	1,660	1,512	1,352	–	–	–	–
Annual Energy Savings *(TBtu)*	151	203	225	–	–	–	–
Cumulative Energy Savings *(TBtu)*	474	676	901	–	–	–	–
Energy Cost Savings *(B$)*	3.92	6.26	8.99	–	–	–	–
Carbon Reduction *(MMTCE)*	8.55	12.2	16.3	–	–	–	–

Appendix 6:
Method of Calculating Results from DOE's Combined Heat and Power Activities

◆ CHP Table 197

Method of Calculating Results from DOE's Combined Heat and Power Activities

Industrial Distributed Energy, a cross-cutting activity within the Industrial Technologies Program (ITP), builds on activities conducted by DOE's Office of Industrial Technologies during the 1980s and 1990s and the DOE Distributed Energy Resources program since 2000. Since 1990, the use of distributed energy within the United States, primarily combined heat and power (CHP), has increased significantly. CHP capacity additions between 1990 and 2007 totaled 56.1 GW, according to the CHP Installation Database maintained by ICF International for DOE through a contract with Oak Ridge National Laboratory.

According to a report prepared by ORNL, if CHP capacity were to reach 20% of U.S. electricity production by 2030, more than 5.3 quad of energy would be saved, and CO_2 emissions would be reduced by 848 million metric tons. This represents 60% of the projected greenhouse gas emissions production from 2006 to 2030.

DOE distributed energy activities since 1990 include R&D, market transformation, and deployment activities. R&D activities have focused on developing advanced reciprocating engine systems, advanced industrial gas turbines, microturbines, thermally activated technologies, fuel cells, and integrated energy systems. As a result, many commercial products have been successfully developed. Market transformation activities have focused on project support, education, and outreach and have recently been led by eight Regional Clean Energy Application Centers that offer individualized solutions to end users and promote the adoption of CHP to state policymakers and regulators. DOE also has continually supported public-private partnerships with various CHP stakeholders through collaborations with other federal agencies, state governments and agencies, trade associations and private industry, and non-government organizations in order to increase market deployment of CHP technology.

Before 2007, attribution of energy from DOE distributed energy activities was not well documented. ICF International recently developed a preliminary methodology for calculating and attributing energy savings from DOE distributed energy activities. This methodology will be refined and reviewed by external peers.

The energy savings' benefit of a CHP system is from the aggregate reduction in overall fuel consumption. A CHP system replaces both a separate on-site thermal system (furnace or boiler) and purchased power (typically electricity from a central station power plant) with a single, integrated system that produces thermal energy and power concurrently. To calculate the fuel use avoided by a CHP system, both outputs of the CHP system must be accounted for. The CHP system's thermal output displaces the fuel normally consumed in on-site thermal generation in a boiler or other equipment, and the power output displaces the fuel consumed from grid-connected power plants. Quantifying a CHP system's fuel savings involves subtracting the fuel use released from the CHP system from the fuel use that normally would occur without the system (i.e., using conventional separate heat and power).

The CHP energy savings' estimates are based on CHP operating characteristics contained in the CHP Installation Database, which is recognized as the leading source for current and comprehensive data on U.S. CHP installations and market trends. As of June 1, 2009, the database contained 3,518 operating CHP installations representing 84,923 MW of electric capacity. The database includes detailed data for each site including location, application, CHP technology, fuel type, electric generating capacity, ownership, servicing utility, and system start-up date. The database contains partial information on thermal application and capacity, sales to the grid, thermal sales, annual fuel use, annual generation, and annual thermal utilization. Annual CHP capacity additions were generated from the database starting in 1990 by system size (<20 MW, 20 to 50 MW, > 50MW) and fuel type.

CHP energy savings' estimates are derived from operating information (i.e., fuel consumption, electricity, and thermal energy generated) for the CHP fleet contained in or derived from the CHP database. A key operating parameter is the CHP system's power-to-heat ratio. This parameter was calculated directly for sites with data on both electric generation and thermal output. For sites missing information on the thermal output, a typical power-to-heat ratio was assumed based on the prime-mover technology and the electric capacity of the CHP system. Performance characteristics, including the power, thermal, and overall efficiencies of the operating CHP capacity, are estimated for 13 different fuel types; and summary data are derived for each fuel type, including annual electric generation, thermal output, and fuel consumption.

In the absence of data to track the DOE program impact for every CHP installation, a portion of energy savings from all CHP systems installed since 1990 were linked to DOE's efforts. Attribution of benefits for DOE activities are based on DOE program activities to advance CHP technology in each market segment and are estimated to be 50% of the capacity additions <20 MW, 25% of the capacity additions from 20 to 50 MW, and 10% of the capacity additions >50 MW. DOE's most extensive efforts have supported CHP <20 MW, which uses engine, microturbine, and fuel cell technologies. DOE also supported turbine technology focused on CHP units from 20 to 50 MW; manufacturers have also transferred these technologies to CHP units >50 MW.

Method of Calculating Results from DOE's Combined Heat and Power Activities

Total CHP capacity additions from 1990 to 2007 and the resulting energy savings attributed to DOE activities based on the methodology described above are depicted in the table. The annual and cumulative energy savings from CHP systems are shown in the table for each year. In 2007, the annual energy savings are 201 TBtu and the cumulative energy savings through 2007 are 2,332 TBtu. Energy cost savings, carbon reduction, and other benefits are related to energy savings by projected fuel prices and emission coefficients. The cumulative CHP energy cost savings and the cumulative carbon reduction are shown through 2007 in the last two rows of the table.

Through current and expanded funding from the *American Reinvestment and Recovery Act*, ITP is advancing CHP as one of the more promising efficient energy solutions that can help to revitalize the American economy, enhance the nation's energy security, and reduce carbon pollution. CHP can achieve efficiencies of as much as 80% compared with roughly 45% for conventional heat and power production.

Total CHP Capacity Additions with Energy, Cost, and Carbon Savings Attributed to DOE Activities

Item	1990	1991	1992	1993	1994	1995	1996	1997	1998
Capacity Additions (MW)									
<20 MW	385.7	243.0	234.1	179.4	200.1	201.1	206.9	164.8	154.8
20 -50 MW	903.1	687.8	342.3	435.7	398.0	372.2	229.1	93.6	221.9
>50 MW	3,462.3	2,453.8	2,693.0	2,651.9	5,131.4	2,162.5	2,123.4	2,311.3	1,123.5
Total Capacity Additions	4,751	3,385	3,269	3,267	5,730	2,736	2,559	2,570	1,500
Annual Energy Savngs (*TBtu*)	23.2	39.8	52.7	66.6	85.6	96.2	107.1	116.7	124.6
Cumulative Energy Savings (*TBtu*)	23.2	63	115.7	182.3	267.9	364.1	471.2	587.9	712.5
Cumulative Energy Cost Savings (*B$*)	0.033	0.087	0.154	0.234	0.331	0.429	0.541	0.661	0.792
Cumulative Carbon Reduction (*MMTCE*)	0.6	1.6	2.9	4.6	6.7	9.1	11.8	14.8	17.9
Item	**1999**	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**
Capacity Additions (MW)									
<20 MW	252.6	317.2	299.3	238.2	222.9	182.8	214.2	187.4	171.7
20 - 50 MW	177.7	386.8	379.8	361.0	132.0	124.5	28.0	149.2	99.0
>50 MW	1,825.9	2,425.4	5,528.9	4,436.0	3,395.0	3,192.0	1,391.0	0.0	224.0
Total Capacity Additions	2,256	3,129	6,208	5,035	3,750	3,499	1,633	337	495
Annual Energy Savngs (*TBtu*)	134.5	149.6	170.3	180.2	190.6	194.0	199.6	199.8	201.3
Cumulative Energy Savings (*TBtu*)	847.0	996.6	1,166.9	1,347.1	1,537.7	1,731.7	1,931.3	2,131.1	2,332.4
Cumulative Energy Cost Savings (*B$*)	0.926	1.082	1,272	1,457	1,668	1,917	2,239	2,514	2,794
Cumulative Carbon Reduction (*MMTCE*)	21.3	25.1	29.3	33.9	38.7	43.6	48.6	53.7	58.8

Appendix 7:
Methodology for Technology Tracking and Assessment of Benefits

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- Methods of Estimating Benefits 200
- Deriving the ITP Cost/Benefit Curve 201

Methodology for Technology Tracking and Assessment of Benefits

Technology Tracking

For over 30 years, the Industrial Technologies Program (ITP), previously 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 or historical 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 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 following:

- 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
- Other impacts of the technology, such as employment and effects on health and safety
- Marketing issues and barriers

Methods of Estimating Benefits

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 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 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.

The cumulative energy savings represents the accumulated energy saved for all units for the total time the technology has been in operation. This includes previous savings from now-mature units and decommissioned units, even though these units are not included in the current year's savings.

Once cumulative energy savings have been determined, long-term impacts on the environment are calculated by estimating 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 1.25 pounds of sulfur oxides (known acid raid precursors) are emitted to the atmosphere. Thus, every million-Btu reduction in coal use results in the elimination of 1.25 pounds of polluting sulfur oxides.

The results for annual and cumulative energy saving, as well as cumulative pollutant emission reductions for actively tracked technologies, are shown in Table 1 on pages 8 and 9 of this report.

Deriving the ITP Cost/Benefit Curve

The approach to estimating the net benefits of ITP energy savings used here relied on the following methodology. First, estimate the cumulative production cost savings which provides an estimate of the gross benefit of the ITP program since its inception. Next, estimate the cumulative appropriations that were allocated by the government to support the development of these technologies that saved energy. Finally, make adjustments to the gross energy savings to account for the cost to industry of adopting the new technologies. The method is based on the following sequence of steps:

- Cumulative energy savings – The accumulated energy savings (Btu) produced by ITP-supported technologies have been commercialized and tracked since the program began. As of 1997, this figure was 1,729 trillion Btu and in 2007 it was 3,555 trillion Btu.

- ITP appropriations – This is the cumulative funding provided for ITP programs. As of FY 2007, this number was $2.94 billion.

- Cost of industrial energy saved – This is the average fuel price (dollars/Btu) that would have been paid to purchase energy multiplied by annual savings. The nominal prices (in dollars per million Btu) for various fuels are reported in the Energy Information Administration's Annual Energy Review (AER). In the 2007 AER, these are extended back in time from 2007 to 1978. These prices are adjusted for inflation based on an index of all fuels and power as reported by the Bureau of Labor Statistics, but normalized to 2007 so that all prices are in current dollars. These annual fuel prices are multiplied by the amount of energy saved per fuel type per year for each of the ITP commercialized and tracked technologies.

- Correct for Implementation Costs – Since reliable information was not available about the incremental capital and operating and maintenance costs of these new technologies, an assumption must be made to adjust for these costs. The assumption used is that industry demands at least a two-year payback period on all such investments, so the first two years of the cumulated energy savings was ignored for each of the technologies, given that these first two years savings are needed to recoup the life-cycle capital costs of adopting the new technology. Again, these costs are normalized for inflation just as are the fuel prices for savings.

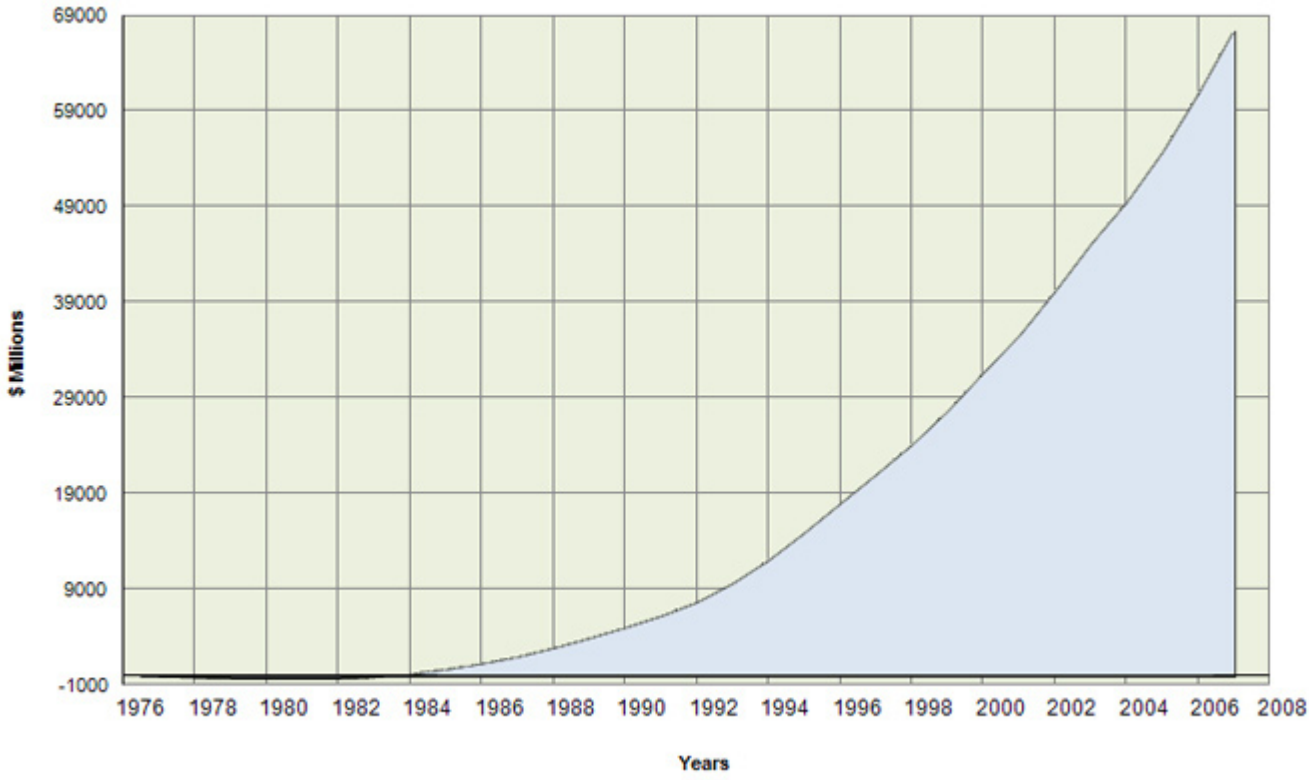
For each technology, the annual energy savings by fuel type is multiplied by the real price of that fuel. The sum of all energy saved times the average real energy price yields an estimate of the annual savings for all technologies in that particular year.

In addition to technology energy savings, savings from the IAC Program, the BestPractices Program, and CHP activities were also determined on an annual basis as described in Appendices 4, 5, and 6, respectively. The economic benefits are the accumulation of these savings over time adjusted for inflation, as described above. The economic costs are two-fold: ITP appropriations and the implementation costs reflected in the two-year payback period. The appropriations are adjusted for inflation by using the implicit deflator for non-defense federal government expenditures, as published by the Bureau of Economic Analysis of the U.S. Department of Commerce. The implementation costs are adjusted for inflation in the same manner as fuel savings. The net economic benefits are then the benefits minus the costs.

Just as this method may not account for some benefits – spinoffs, derivative technologies, etc. – this method also may not account for some incremental costs. For example, there may be incremental capital costs associated with the use of a particular technology that are not currently captured in the tracking process, and thus are not included in the cost side of the equation.

The results of the application of this method are shown in the following graph.

Cumulative Production Cost Savings Minus Cumulative Program and Implementation Costs



The cumulative federal costs for ITP through fiscal year 2007 total $2.94 billion. Cumulative energy savings from completed and tracked ITP projects and programs add to approximately 8.50 quadrillion Btu in 2007, representing a net cumulative production cost savings of $67.75 billion after adjusting for inflation (using the implicit price deflator for GDP, renormalized to 2007). These production cost savings represent the net total value of all energy saved by technologies developed in ITP programs plus the energy cost savings from the IAC Program, the BestPractices Program, and CHP activities, minus the cost to industry of using the technologies (estimated by assuming a two-year payback on investment) minus ITP appropriations. The graph shows that benefits substantially exceed costs.

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