

# Appendix 1:

## ITP-Sponsored Technologies Commercially Available

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# ITP-Sponsored Technologies Commercially Available

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## IMPACTS

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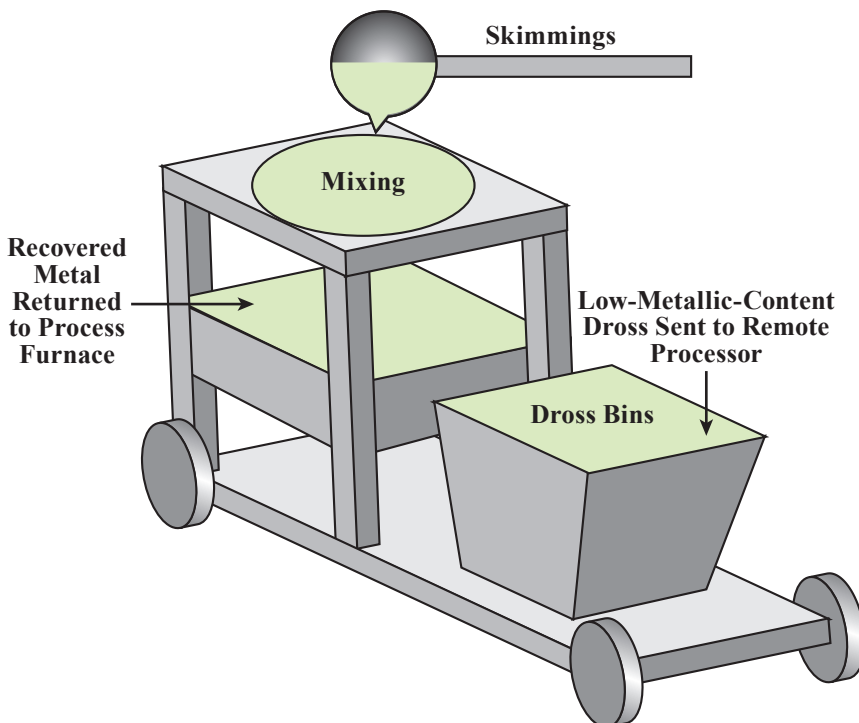
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## Affordable Metallic Recovery System Saves Energy and Reduces Landfill Waste Streams

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 reverber melters. With assistance from DOE's Industrial Technologies Program, 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.
- ◆ Commercialized in 2001
- ◆ Seven units installed in the United States

## 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

### Energy Savings

The recovered metal from the new system may be reintroduced into the process as hot ingot or in molten form, saving the energy required to remelt an ingot recovered in a traditional process. Less energy is required to transport and move the dross to an outside processor because recovery is done on-site, and the material does not have to be remelted for secondary recovery of the metallics.

### Productivity

The improved ability to decrease melting losses contributes directly to profits. 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

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

## IMPACTS

### Indirect-Fired Kiln Turns Aluminum Scrap into Valuable Feedstock

Through a grant from DOE's NICE<sup>3</sup> Program, Energy Research Company has further developed and demonstrated an innovative aluminum-scrap melting process. This 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 volatile organic compounds (VOCs) and releasing heat used to drive the process.

This innovation de-coats scrap aluminum parts in a controlled atmosphere with limited oxygen to avoid scrap-oil combustion and scrap oxidation. The resulting gases are then combusted in an incinerator, apart from the scrap, to destroy the volatile organic compounds. The heat released from this atmospheric combustion drives the de-coating process. There are currently 3 units operating in the United States and an additional 15 worldwide.

### Benefits

#### Energy Savings

Energy savings of 55% over conventional kiln decoating.

#### Environmental

Reduces solid-waste disposal needs because of reduced dross and oxidized product.

#### Productivity

Improved product quality and reduced material loss due to better process control.

### Overview

- ◆ Developed by Energy Research Company
- ◆ Commercialized in 1997
- ◆ 3 units operating in the United States in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1.55	0.378

### Emissions Reductions

(Thousand Tons, 2005)

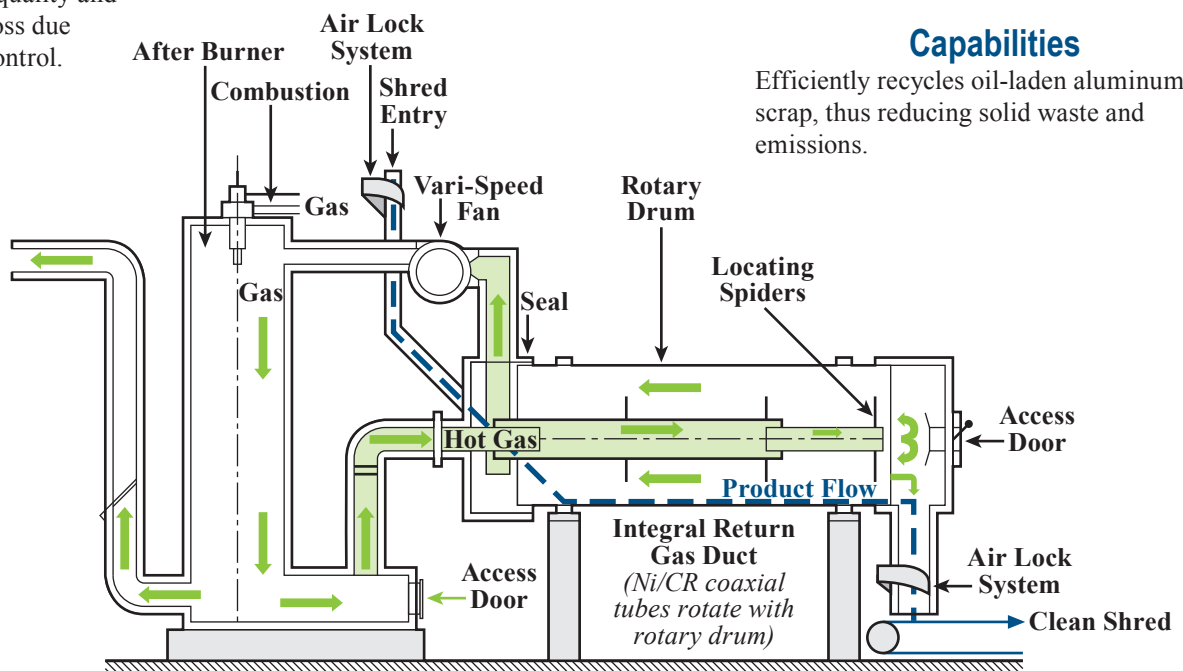
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.044	6.00

### Applications

- ◆ The secondary aluminum industry that processes scrap from the manufacturing process and used aluminum
- ◆ May also be used when processing other materials with organic binders or coatings, such as fiberglass recycling

### Capabilities

Efficiently recycles oil-laden aluminum scrap, thus reducing solid waste and emissions.



Aluminum Scrap Decoater

## Effective Scrap Sorting Provides Large Energy Benefits

Huron Valley Steel (HVS) Corporation has developed new 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.

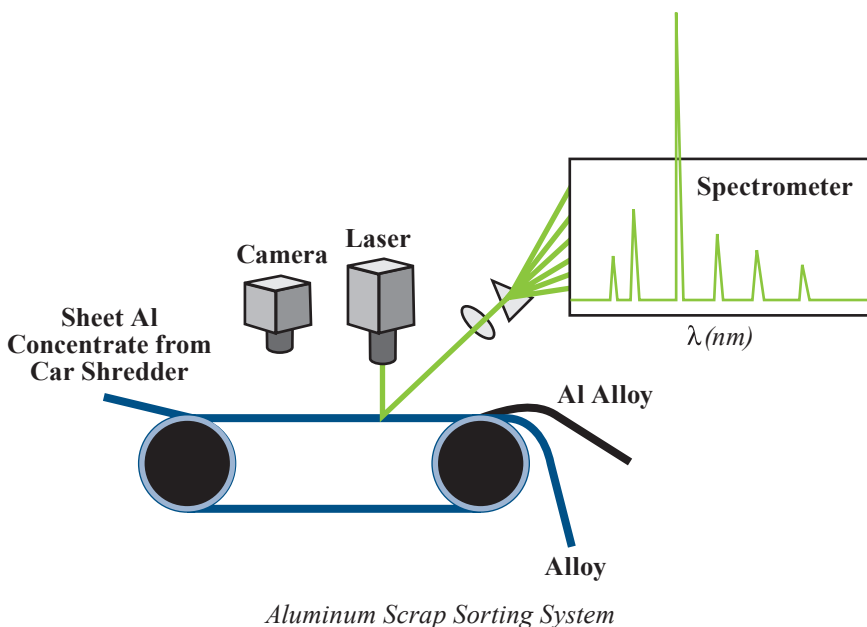
## Benefits

### Environmental

Using aluminum that otherwise would have been scrapped decreases the production of prime metal and thereby reduces greenhouse gas emissions.

### Use of Raw Materials/Feedstocks

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



## Overview

- ◆ Developed by Huron Valley Steel Corporation
- ◆ 7500 tons of sorted product processed in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1.04	0.338

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.002	0.073	0.054	6.63

## Applications

- ◆ Sorting of mixed aluminum scrap streams
- ◆ Sorting of 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.

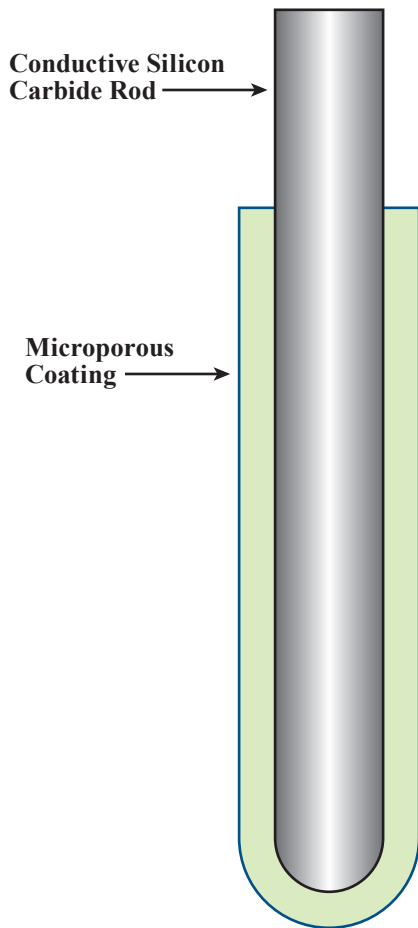
# Detection and Removal of Molten Salts from Molten Aluminum Alloys

## IMPACTS

### New Probe and Filter Will Improve Metal Quality Through Detection and Removal of Impurities

With assistance from DOE's Inventions and Innovation Program, Selee Corporation and the Alcoa Technical Center have developed and commercialized this technology to detect and reduce chloride salts in molten aluminum. These salts have been shown to initiate defects when they agglomerate and migrate to the surface of an ingot or casting. Because they are liquid at aluminum casting temperatures, they can pass through conventional filter systems, which are designed to capture solid inclusions. Moreover, they tend to reduce the efficiency of filters by causing the release of solid inclusions.

The operation principle of the salt probe and filter is based on interfacial surface phenomena between the various liquid phases (salt and aluminum) and the solid salt system material. The probe is made up of a thin, microporous, ceramic layer that is coated onto an electrically conductive silicon carbide rod. The rod is immersed into the molten aluminum and a potential difference is applied to the probe. Salt can penetrate the coating on the probe and, due to the ionic nature of the salt, an electrical current that can be measured is formed. The filter also uses microporous ceramic to separate the salts from the liquid aluminum.



*Salt Probe*

### Overview

- ◆ Developed by Selee Corporation and the Alcoa Technical Center
- ◆ 2 units are in operation in the United States and Canada
- ◆ Commercialized in 1999

### Applications

The technology will improve metal quality by detecting and removing impurities and inclusions from molten aluminum

### Capabilities

The sensor can be used as a qualitative tool to detect the presence of liquid salts above the level of 5 to 12 ppm.

### Benefits

#### Energy Savings

Elimination of melt rejection and recast due to salt contamination, with potential annual energy savings of 0.04 trillion Btus.

#### Productivity and Cost

Estimated reduction in chlorine use and release of about 71,000 cubic feet per year.

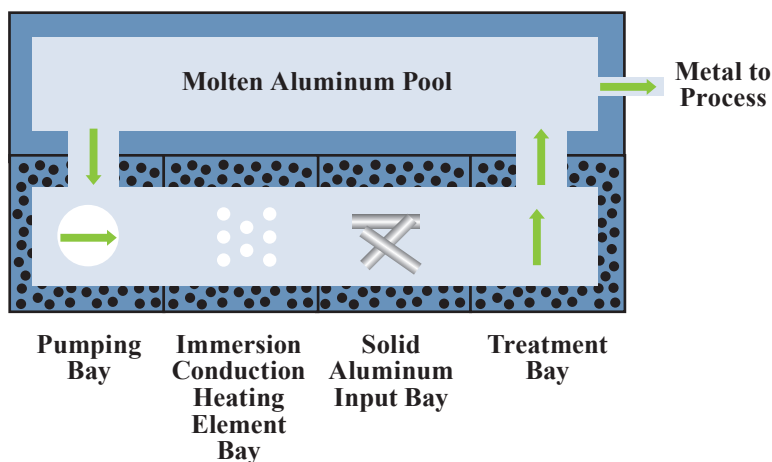
#### Product Quality

Improved metal quality, recovery, and reliability.

## 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 emission 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 to opening a heat 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 Technologies' 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<sup>2</sup>), 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.
- ◆ Currently operating in one plant in Ohio

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.006	0.006

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.001	0.001	0.120

## Applications

Current application is to aluminum melting processes but can be applied to other metal melting processes

## Capabilities

- ◆ Can be retrofit to existing furnaces.
- ◆ Applies to multiple molten metal heating operations.

## Benefits

### Cost Savings:

Reduces metal lost to oxidation to less than 1%.

### Environmental Emissions Reductions:

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



# Oxygen-Enhanced Combustion for Recycled Aluminum

## IMPACTS

### New Metal Melting System Results in Low NO<sub>x</sub> 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<sub>x</sub> 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 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<sub>x</sub> emissions while reducing energy usage and increasing melting productivity.

## Benefits

### Cost Savings

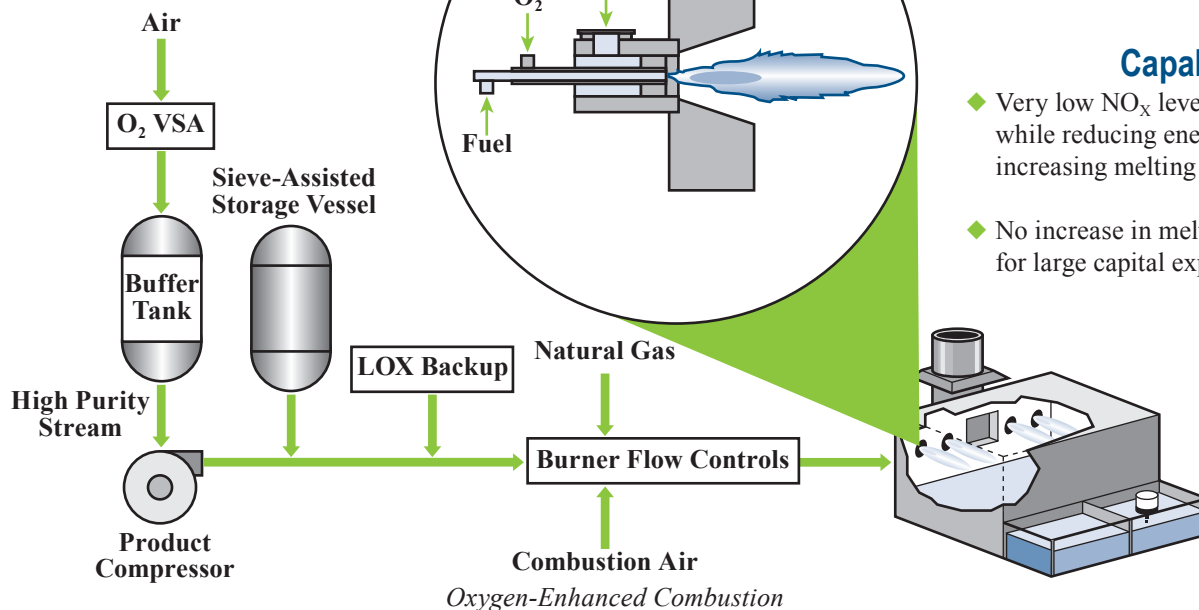
Using oxygen from storage reduces the overall oxygen consumption and costs by 33% compared to the previously installed burner.

### Environmental Quality

Reduces NO<sub>x</sub> emissions by 80%. Carbon monoxide is also significantly reduced. Both contaminants are well within stringent compliance levels.

### Productivity

Increases production rate by 26%.



## Overview

- ◆ Developed by Air Products & Chemicals, Inc.
- ◆ Demonstrated at Wabash Alloys in East Syracuse, NY
- ◆ Commercialized in 1999

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.025	0.0

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.0

## Applications

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

## Capabilities

- ◆ Very low NO<sub>x</sub> levels maintained while reducing energy use and increasing melting productivity.
- ◆ No increase in melting cost or need for large capital expenditures.

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

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

With assistance from the NICE<sup>3</sup> Program, Alumitech, Inc., now Aleris International, Inc., undertook a successful 15-month plant construction and start-up project to commercialize a process to facilitate closed-loop recycling of dross through the manufacture of industrial ceramic products from recovered nonmetallic waste.

Starting with the dross material, Aleris International separates the dross into its basic components—aluminum metal, fluxing salts, and NMP. The aluminum metal and salt fluxes can be sold back to the secondary aluminum or other industries. In 2005, aluminum metal was recovered with an embodied energy savings of about 11 million Btu per ton of dross processed with this new system. A project goal was to commercialize a new process and to make NMP usable for a variety of product applications.

### Benefits

#### Productivity

Alumitech process not only separates the aluminum and commercial oxides for reuse but also can recycle the remaining NMP into commercially salable products completely avoiding landfilling.

#### Use of Raw Materials/Feedstocks

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

#### Waste Reduction

Products from NMP being developed will reduce landfill to zero for secondary aluminum operations.

### Overview

- ◆ Developed by Alumitech, Inc. (Now Aleris International, Inc.)
- ◆ Commercialized in 1997
- ◆ 3 units operating in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
11.5	2.04

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.005	0.242	0.287	36.5

### Applications

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

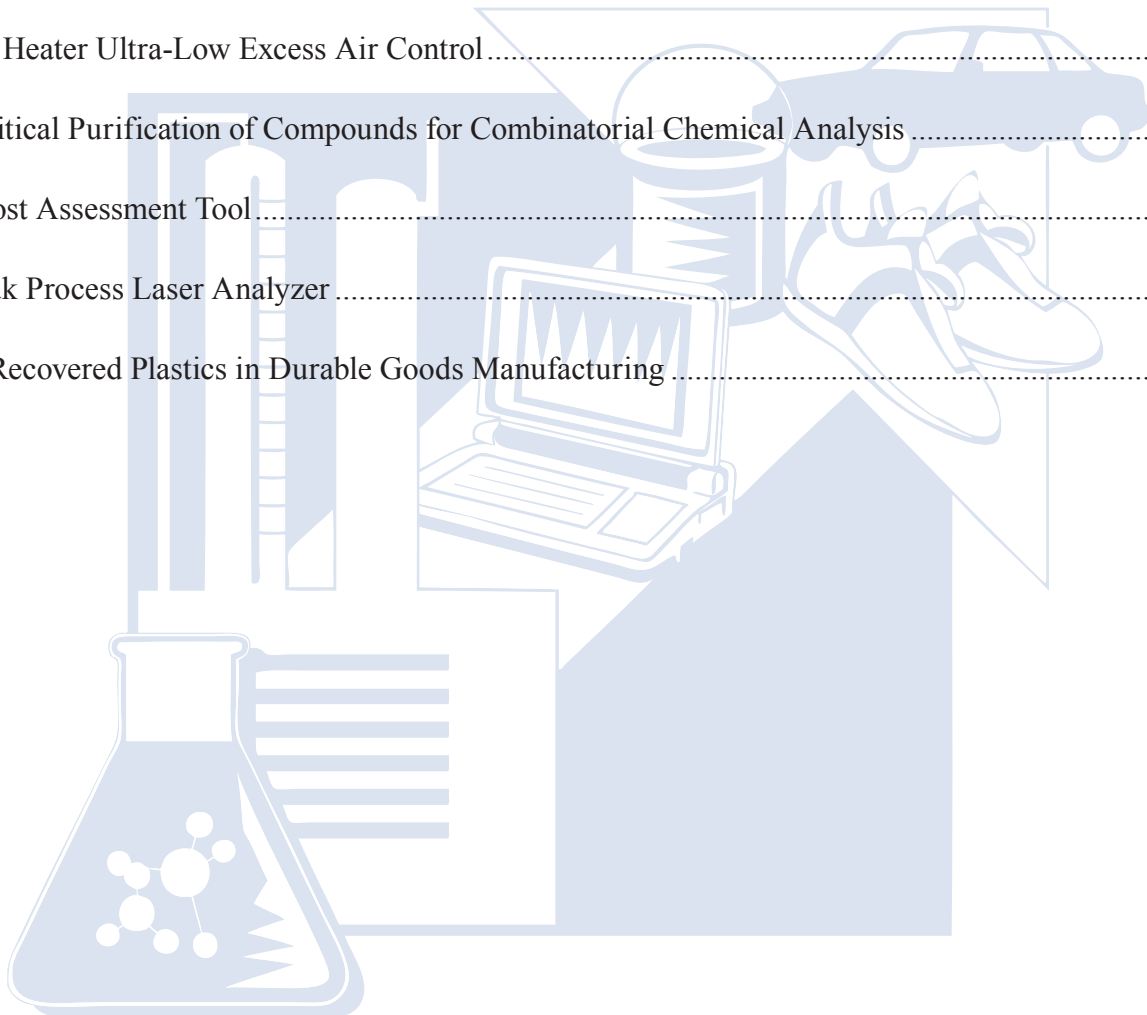
### Capabilities

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

## IMPACTS

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# Aqueous Cleaner and CleanRinse™ Recycling System

## New Recycling System Improves Aqueous Cleaning System

Most traditional systems for pollution control focus on the end-of-pipe treatment and disposal of waste. The U.S. Environmental Protection Agency (EPA) has mandated a new emphasis on improved resource usage that focuses on source reduction. Many methods, including filtration, reverse osmosis, de-ionization, and distillation, could help meet this goal but often have high energy needs or produce additional waste streams.

With assistance from DOE's Inventions and Innovation Program, EcoShield Environmental Systems developed a simple mini-reactor system that 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, creating 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. The current applications of the technology have resulted in tremendous waste prevention and large cost savings.

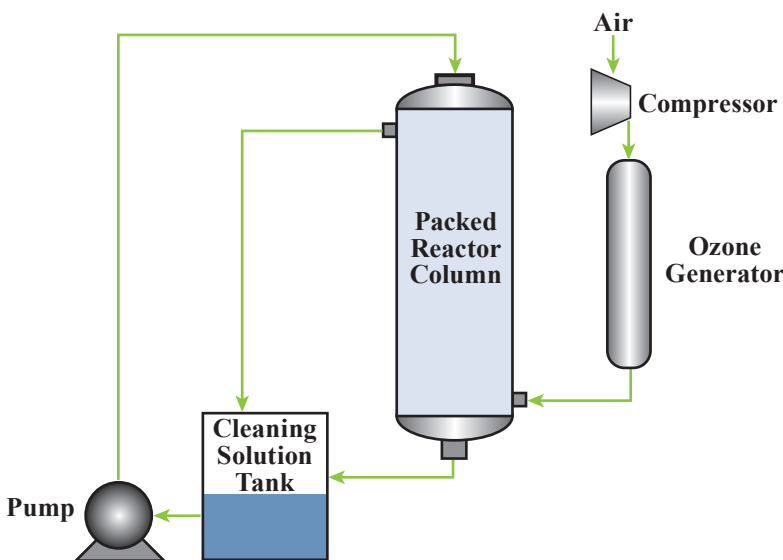
### Benefits

#### Productivity

The system extends the life of the cleaning solution and rinse water, which reduces the costs associated with waste water disposal and chemical consumption. The system also has low operational costs (less than 5 cents per hour).

#### Waste Reduction

The technology reduces the chemicals typically consumed in the traditional cleaning process and extends the life of the cleaning solution. The system can be integrated with EPA's permanent pollution prevention plans.



*EcoShield Aqueous Cleaner*

### Overview

- ◆ Developed by EcoShield Environmental Systems under an exclusive license from EcoShield Environmental Technologies Corporation
- ◆ Commercialized in 1997

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.134	0.015

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.002	0.238

### Applications

Neutral to basic pH applications where aqueous waste streams containing organic contaminants are to be cleaned

### Capabilities

- ◆ Converts excess soap to biomass using an optional companion bioreactor.
- ◆ Offers custom sizes and configurations for wash racks, cabinet washers, and automated lines.
- ◆ Is applicable for high-temperature installations.

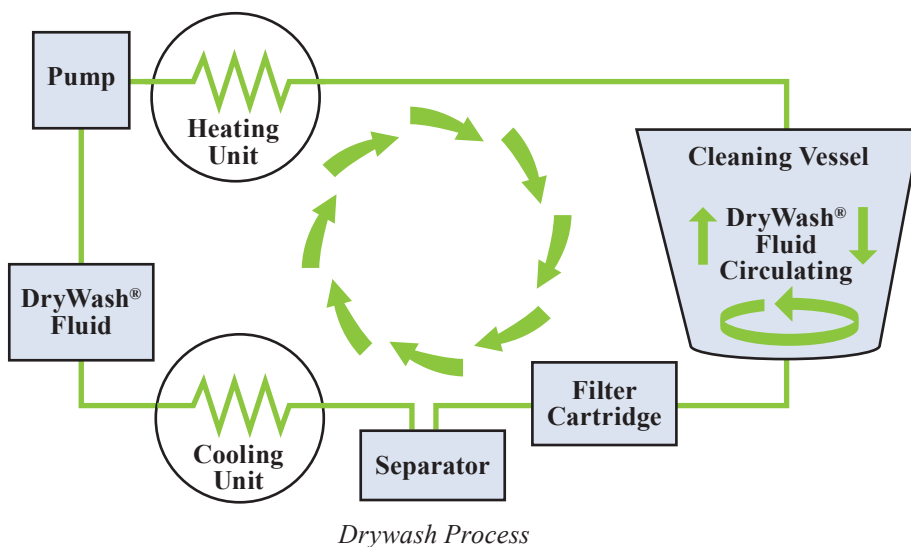
## IMPACTS

### 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<sub>2</sub>-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<sub>2</sub> – it is inert, stable, non-corrosive, and non-flammable – the DryWash system introduces a new generation of technology to the dry cleaning industry.

DryWash uses liquid CO<sub>2</sub>-based fluid (not generic CO<sub>2</sub>) 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<sub>2</sub> filled tub at a pressure of 700 to 750 pounds per square inch and 54°F to 58°F. The load is agitated and at the end of the cycle, the dirt and oily residue drop out and CO<sub>2</sub> pressure is lowered, allowing for the efficient recycling of CO<sub>2</sub>.

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



### Overview

- ◆ Developed by Raytheon Technologies, Inc. and commercialized by Global Technologies, LLC
- ◆ Commercialized in Europe in 1998 and the United States in 2000 with over 69 machines in operation in the United States

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.041	0.010

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.002	0.002	0.190

### Applications

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

### Capabilities

- ◆ Uses an environmentally benign solvent (CO<sub>2</sub> 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<sup>3</sup> 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

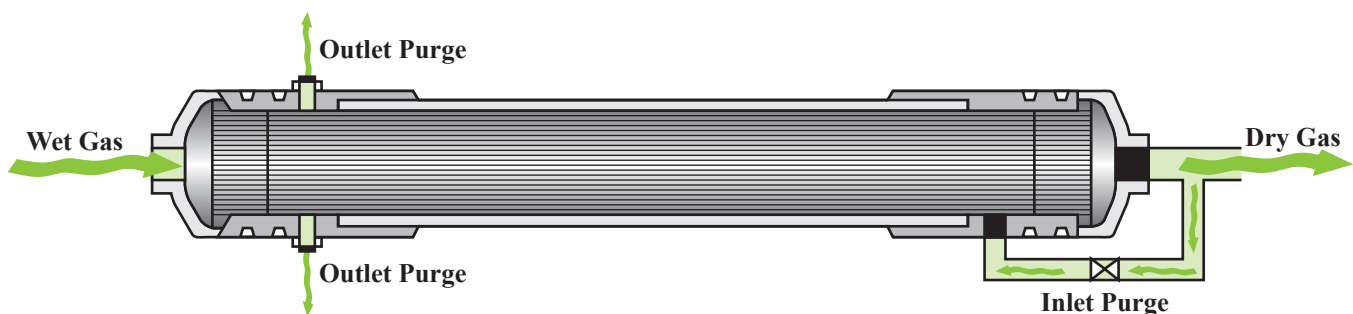
- ◆ Developed by Air Products and Chemicals, Inc.
- ◆ Commercialized in 2004
- ◆ 400 units operating in the United States in 2005

## Applications

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.
- ◆ 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*

# Low-Cost, Robust Ceramic Membranes for Gas Separation

## IMPACTS

### 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<sub>2</sub> 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 has been 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.

### 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
- ◆ Commercialized in 2005
- ◆ Installed in two U.S. location for recovery of water vapor and energy, with a third installation scheduled for early 2007

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.004	0.004

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.063

### Applications

Separation of CO<sub>2</sub> 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.

### Capabilities

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

## 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<sub>2</sub> surfactant technology performed by the Pacific Northwest National Laboratories. The Micell CO<sub>2</sub> dry cleaning technology is called the Micare™ system. Micell Technologies is 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<sub>2</sub> machine with a 60-pound capacity and able to hold liquid CO<sub>2</sub>. Garments to be cleaned are placed inside a large rotating basket in the MICO<sub>2</sub> 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<sub>2</sub> allowing it to remove dirt from the garments. After the cleaning cycle, the machine pulls the solution of liquid CO<sub>2</sub> and cleaning detergents away from the clothes, and then cleans and recycles the CO<sub>2</sub>. Most (98%) of the CO<sub>2</sub> is recycled, while a small amount of CO<sub>2</sub> 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

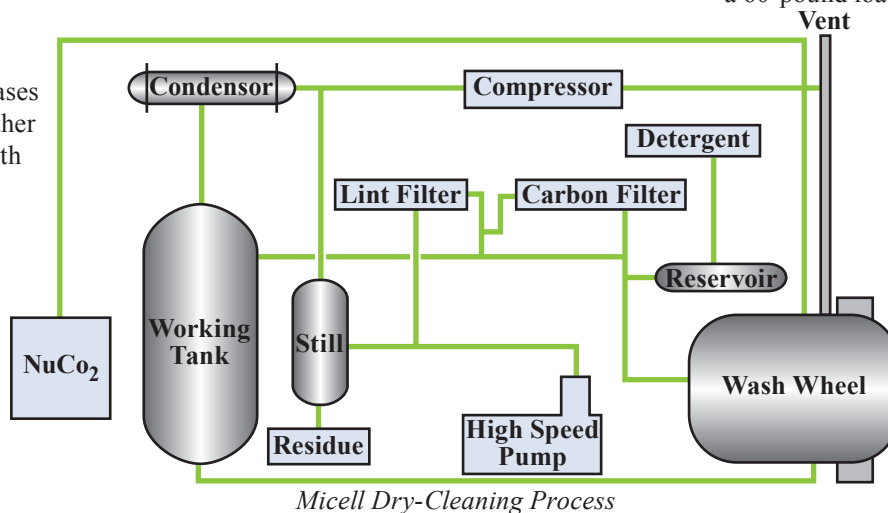
Reduces operating time and costs less to operate than the conventional perc systems.

#### Quality

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

#### 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 2005, there were 20 Micare machines serving Hangers Cleaners stores throughout the United States.

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.024	0.003

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.055

### Applications

Replaces 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.



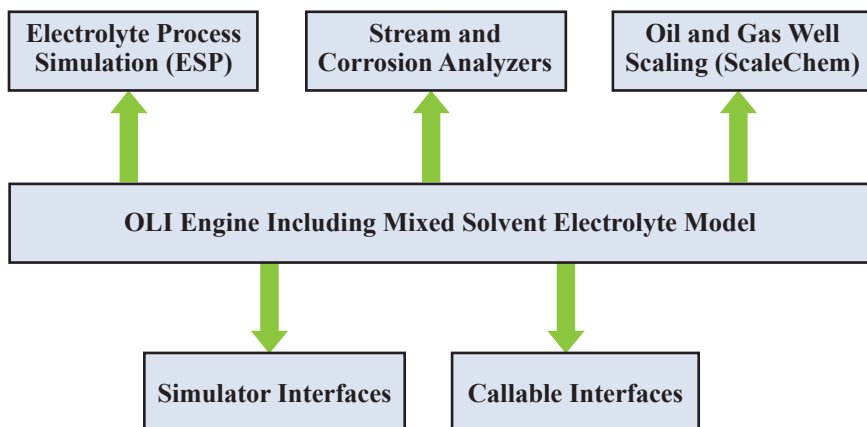
## IMPACTS

### 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.
- ◆ Commercialized in 2005
- ◆ 55 U.S. licenses sold

### Applications

Optimizes crystallization processes throughout the chemical and pharmaceutical industry

### Capabilities

- ◆ Predicts crystallization 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).

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

At present, 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 during clean-up operations. With help from a DOE NICE<sup>3</sup> 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 further 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 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.
- ◆ Commercialized in 1998
- ◆ 558,892 gallons produced and applied through 2005

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.005	0.001

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.012

### Applications

No-VOC solvents can be found as components of exterior opaque stains, exterior and interior semitransparent stains, waterproofing sealers, clear wood finishes, varnishes, and sanding sealers

### Capabilities

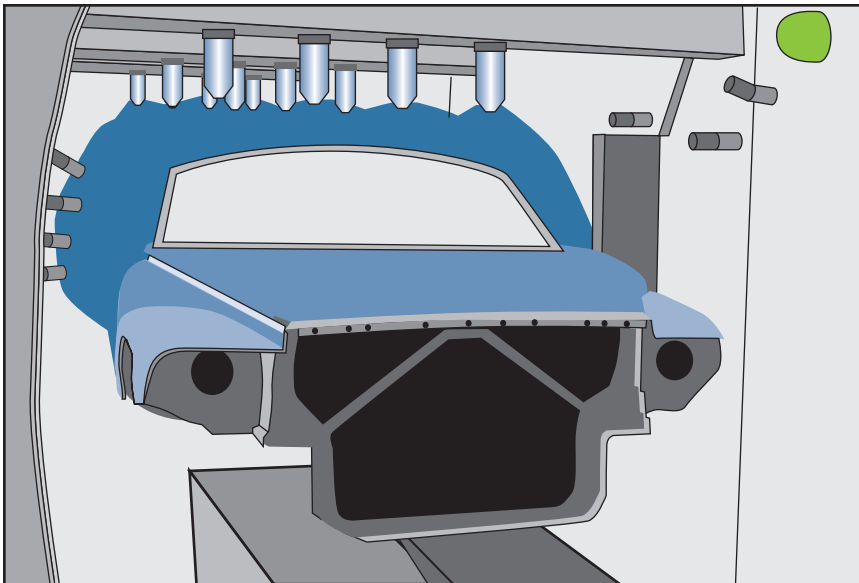
- ◆ Provides equal protection and material covering characteristics such as longevity and toughness with improved drying times and easier installation.
- ◆ Allows for quicker installation with none of the noxious fume problems associated with standard products.
- ◆ Reduces drying time and environmental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

## IMPACTS

### Full-Body Powder Antichip Process Reduces Waste Emissions

Chipping paint is a major cause of customer dissatisfaction with United States-produced automobiles. The current standard for applying antichip primer to vehicles is a solvent-borne paint spray system that has a transfer efficiency (ratio of paint solids deposited on the vehicle to total volume used) of about 50%. In addition to generating a paint sludge by-product that must be landfilled, the process emits volatile organic compounds (VOCs). Chrysler Corporation developed and demonstrated, using a NICE<sup>3</sup> grant, an innovative, new powder antichip process that contains no solvents and, considering recycling, has an effective transfer efficiency exceeding 99%. The new system virtually eliminates VOC emissions and paint sludge generation, eliminating the costs to transport and dispose of sludge.

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



*New Powder Antichip Primer Process*

### Overview

- ◆ Developed by the Chrysler Corporation
- ◆ Commercialized in 1996

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
5.69	0.595

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.004	0.070	9.52

### Applications

Antichip primer application for automobiles

### Capabilities

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

### Benefits

#### Energy Savings

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

#### Quality

Process gives better finish with reduced risk of delamination and chipping.

#### Use of Raw Materials

Conserves raw materials used to manufacture virgin coatings.

#### Waste Reduction

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

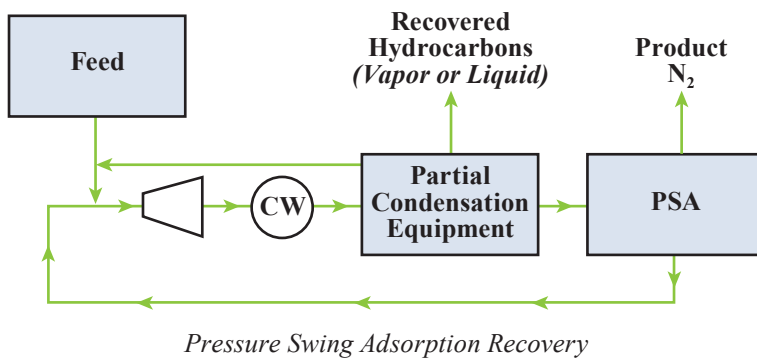
# Pressure Swing Adsorption for Product Recovery

## 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<sub>x</sub>, and CO<sub>2</sub> emissions. Flaring can also be costly, roughly equal to the value of the purchased nitrogen.

With assistance from DOE's Industrial Technologies Program, 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<sub>2</sub> 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.



## Overview

- ◆ Developed by Air Products and Chemicals
- ◆ Commercialized in 2003
- ◆ Installed in two locations in Texas

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.193	0.089

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.01	1.41

## Applications

Both chemical and refining industries, including polyethylene and polypropylene production processes that use N<sub>2</sub> for degassing the polymer fluff and for treating refinery off-gas streams. This process 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

Exit streams from certain processes can be collected and separated for reuse, eliminating the emissions and need for disposal. Disposal typically involves flaring of the waste streams; therefore, this new process can save energy and costs by eliminating flaring.

### Profitability and Productivity

Operating and emission costs are reduced by eliminating flaring, and productivity is increased by reusing products in the feed streams.

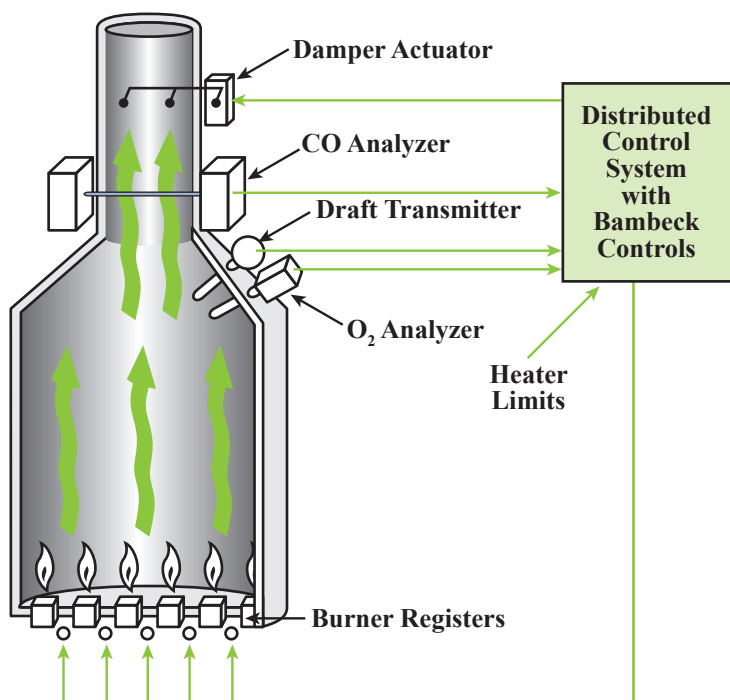
# Process Heater Ultra-Low Excess Air Control

## IMPACTS

### 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 fully automating the available air to the three types of heaters typical to a refinery will save fuel. 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<sub>2</sub> and, through the control system, sends commands to the dampers, fans, and registers to open or close. Because operators historically used an O<sub>2</sub> monitor to ensure that the combustion process has excess air, the operators need to be educated to feel comfortable seeing very low O<sub>2</sub> readings. The heater is safer because CO is a precursor to a combustible condition and O<sub>2</sub> is not. In addition, reducing the excess O<sub>2</sub> also reduces both NO<sub>x</sub> and CO<sub>2</sub> (greenhouse gas).



Bambeck Ultra-Low Excess Air Control System

## Overview

- ◆ Developed and being marketed by Bambeck Systems, Inc.
- ◆ Commercialized in 2002 with over 550 of the original technology installed
- ◆ Seven enhanced ultra-low versions installed

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.782	0.338

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.020	0.042	5.60

## Applications

A process heater or boiler control system for 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<sub>x</sub> emissions from 30% to 45% and CO<sub>2</sub> in proportion to the size of the heater.

### Safety

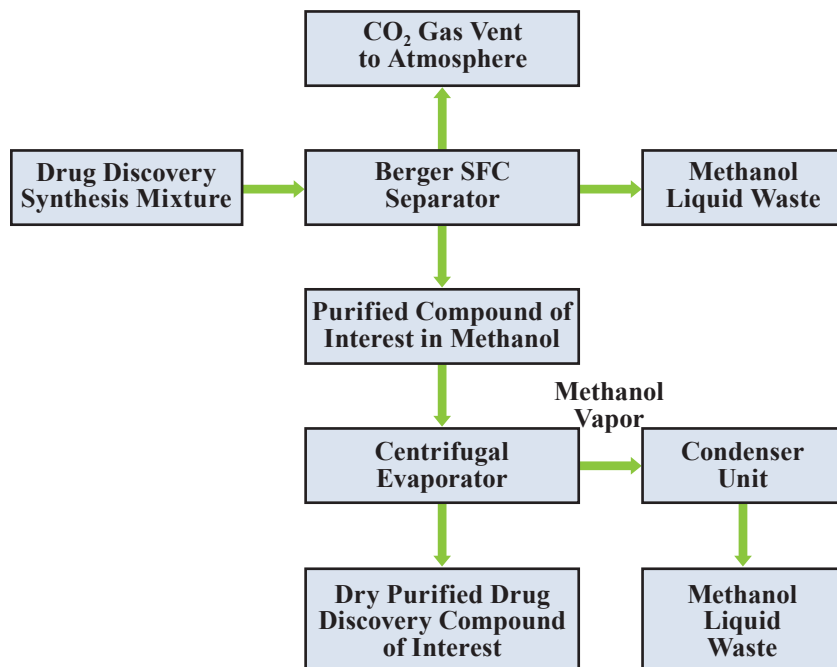
Eliminates the possibility of any dangerous combustible conditions developing in the heater.

# Supercritical Purification of Compounds for Combinatorial Chemical Analysis

## Innovative Purification Method Reduces Energy Use and Chemical Waste

With the support of a NICE<sup>3</sup> 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<sub>2</sub> rather than liquid solvents as the primary component of the mobile phase. The high diffusivity and low viscosity of CO<sub>2</sub> 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.
- ◆ Commercialized in 2000
- ◆ 87 units operating in the United States in 2005

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
1.79	0.578

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.003	0.125	0.093	11.4

## Applications

Process science and engineering technology for 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.

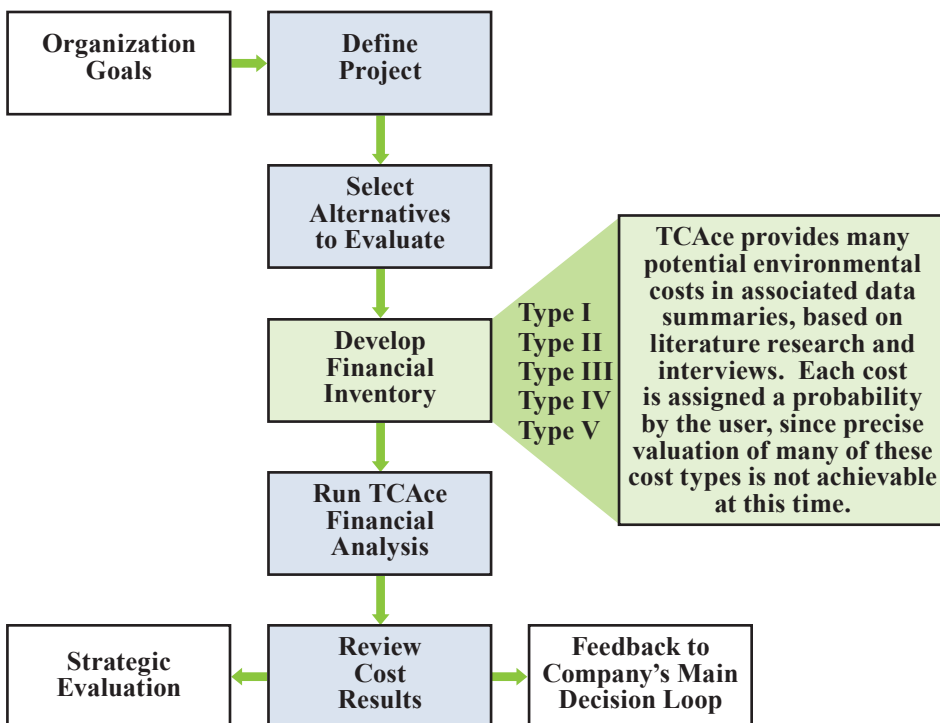
## IMPACTS

### 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 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 the U.S. Department of Energy Industrial Technologies Program 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
- ◆ Has sold 6 units to date: 2 in the United States and 4 internationally
- ◆ Commercialized in 2005

### Applications

The Total Cost Assessment Tool 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

- ◆ Identification of best environmental and economic options in business decision-making.
- ◆ Alignment of environmental goals with good business strategies.
- ◆ Integration of internal costs and externalities into a single assessment process.

### Benefits

#### Environmental Benefits

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

#### Profitability

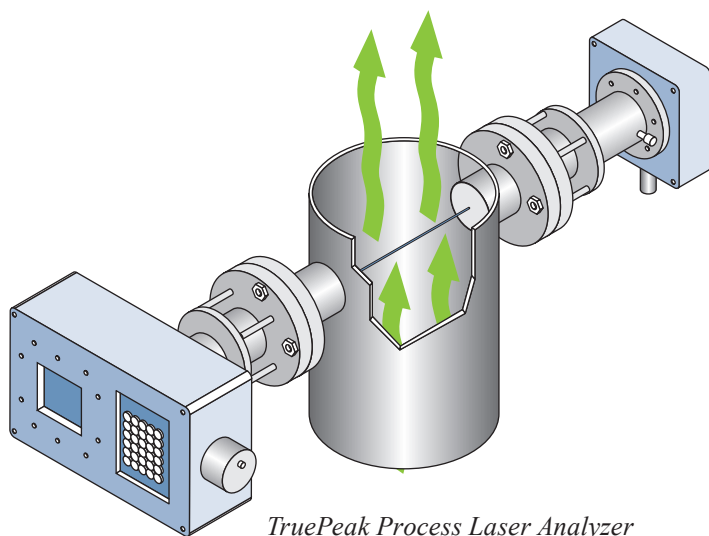
Reduces manufacturing costs by integrating life cycle assessment with life cycle cost analysis and facilitating collaborative scenario planning.

## 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<sub>2</sub>, H<sub>2</sub>O, 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.



*TruePeak Process Laser Analyzer*

## Overview

- ◆ Developed by Analytical Specialties, Inc.
- ◆ Commercialized in 2004

## Applications

O<sub>2</sub>, CO, H<sub>2</sub>O, and other 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.



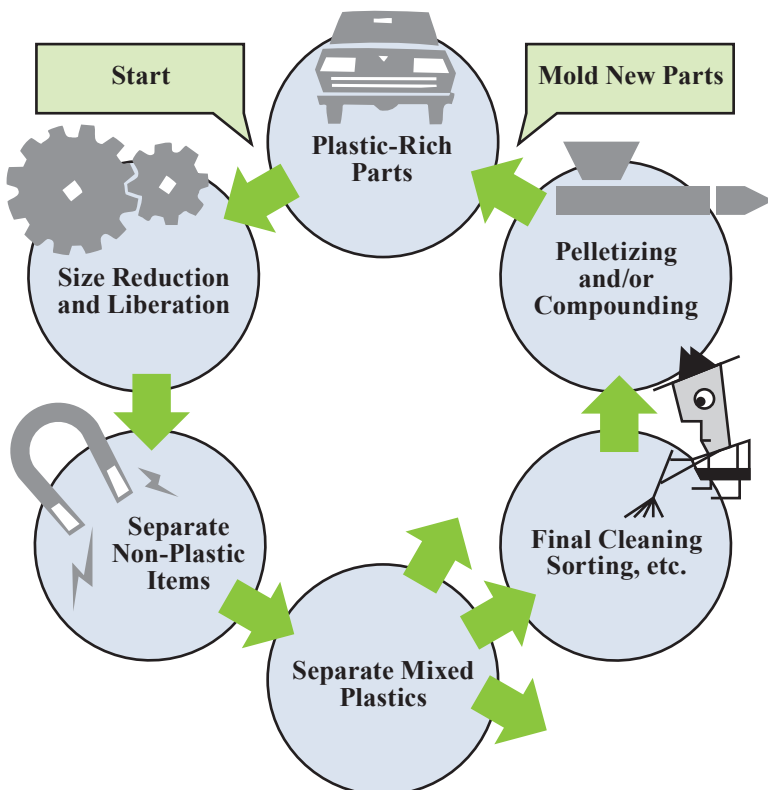
# Use of Recovered Plastics in Durable Goods Manufacturing

## IMPACTS

### New Technology Helps Close the Recycling Loop for Plastics

An advanced mechanical recovery technology that can effectively recover plastic waste material has been developed by MBA Polymers, the American Plastics Council (APC) and plastic end-users, and demonstrated using a NICE<sup>3</sup> grant. MBA's process is capable of running at rates over 5000 lb/hr and purifying as many as three different plastics from a single mixed stream. Conventional plastics cleaning and sorting processes (e.g., as used for bottle recycling) are inadequate to handle multi-component waste streams. The new demonstrated process incorporates several refined technologies that can separate metal and metallic coatings, rubber, glass, foam, and fabric as well as mixed plastics. These technologies include (1) enhanced size reduction throughout and particle size and shape control, (2) reduced product and side-stream contamination, (3) enhanced process control of separation systems for multi-material separations, and (4) advanced material separation capabilities.

The combination of these refined technologies produces an advanced plastic recycling system that is capable of effectively recovering previously unrecoverable streams of multi-component materials. The energy and related pollution savings from the MBA plastic recovery process come primarily from reducing the need to produce virgin plastics. Half of this energy is contained in the plastic itself as processed material and is lost if the scrap is not recovered or is incinerated. Using this recovered plastic instead of additional virgin plastic results in energy savings of 17,000 Btu per pound of raw material or more than 85% of the energy required for producing virgin plastics.



*MBA Polymers' Recycle Loop*

### Overview

- ◆ Developed by MBA Polymers in 1995
- ◆ Commercialized in 1996
- ◆ Currently operating one plant in California
- ◆ Operating plants in Austria and China

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.402	0.022

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.004	0.003	0.386

### Applications

Recovery of plastic from complex manufacturing scrap and end-of-life durable goods including automobiles, appliances, electrical, and electronic equipment

### Capabilities

- ◆ Separates as many as three different plastics at one time in a mixed waste stream.
- ◆ Segregates metal, metal coatings, rubber, glass, foam, and fabric from plastic waste.
- ◆ Recovers previously unrecoverable and discarded multi-component materials.

### Benefits

#### Waste Reduction

Significantly reduces landfill requirements.

#### Waste Utilization

Recovers previously discarded re-usable plastic materials and allows more cost-effective raw plastic materials for industry.

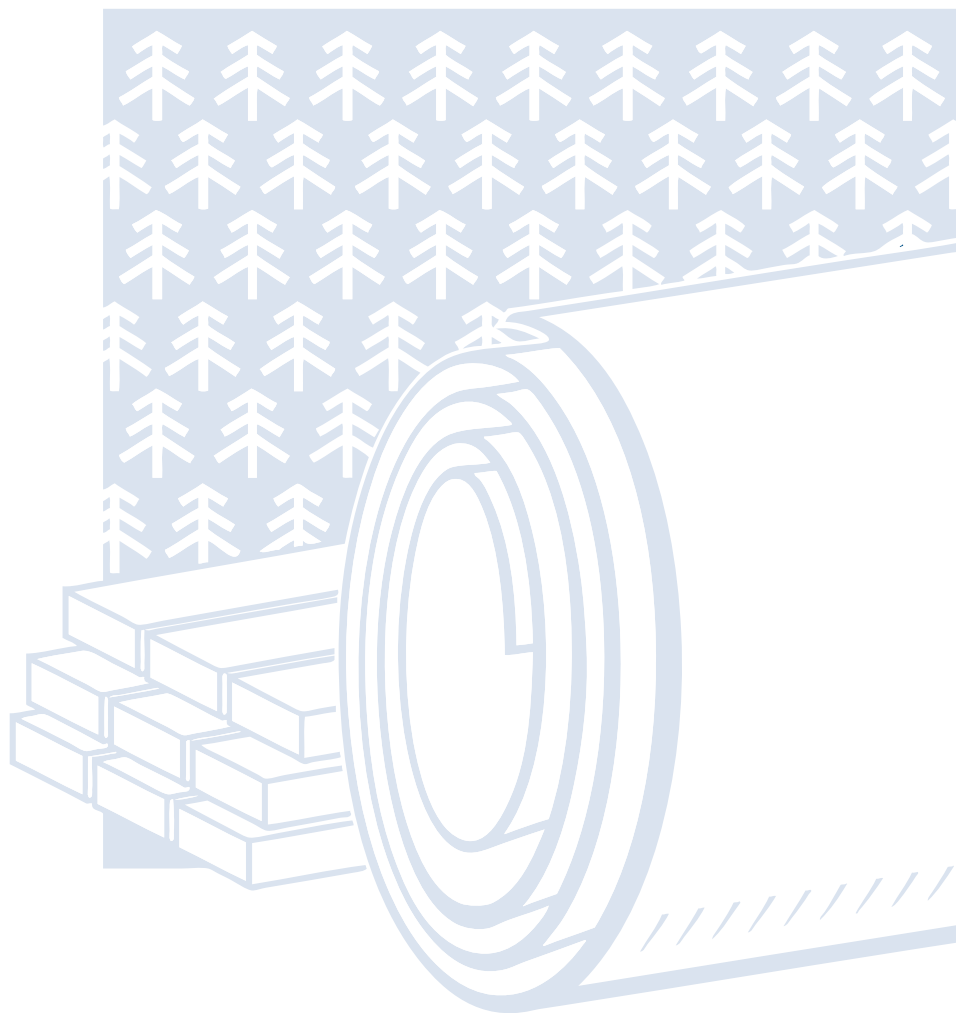


# Forest Products

## IMPACTS

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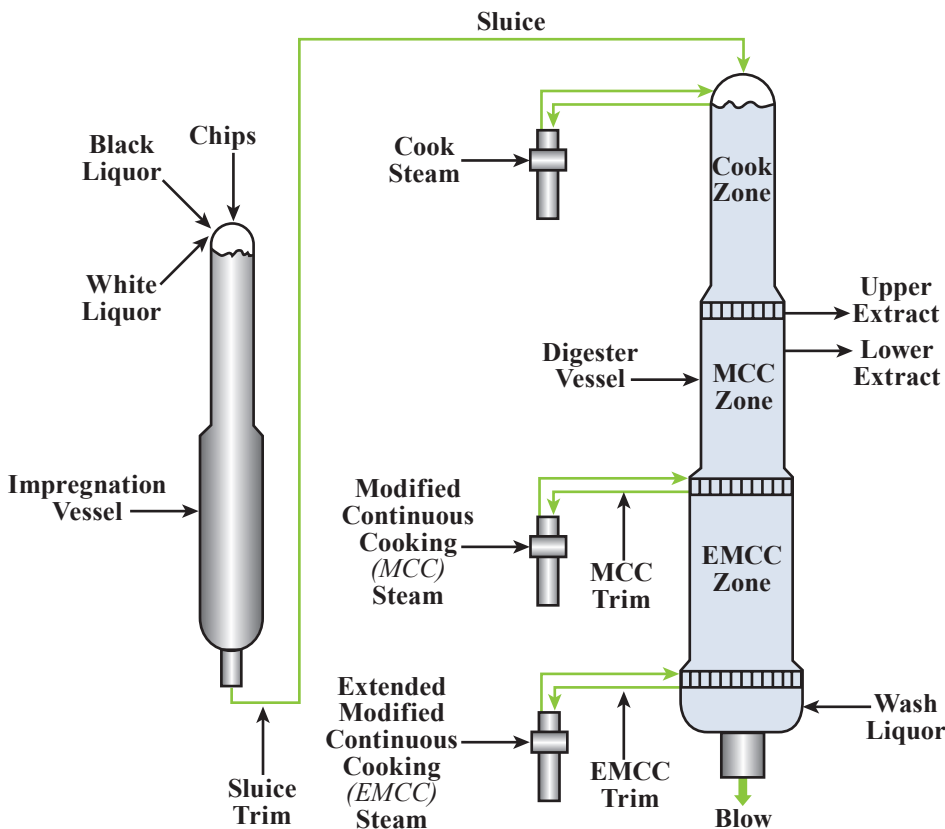


## Pulp Process Model Identifies Improvements that Save Energy and Improve Productivity

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

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
9.00	1.00

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.117	15.9

## Applications

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

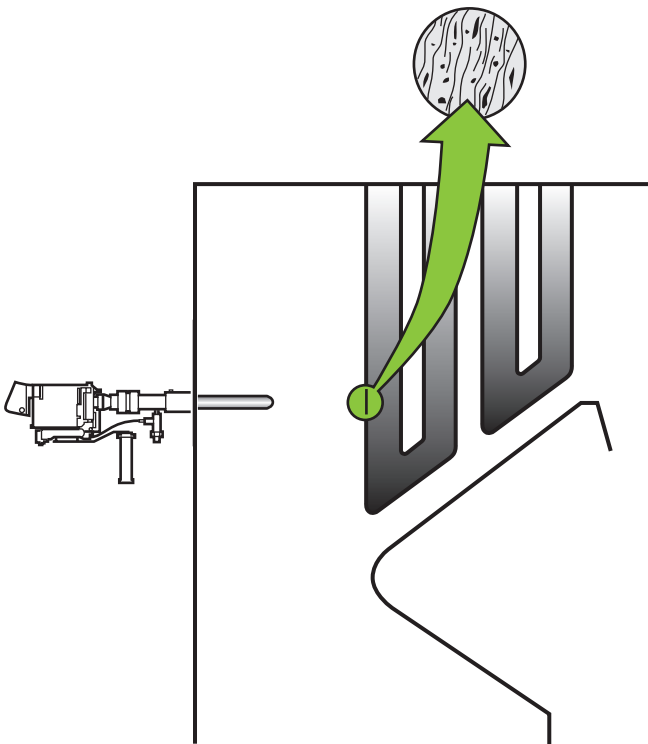
## IMPACTS

### 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.

The hand-held inspection system has demonstrated reductions in sootblower steam use of up to 20%. This steam improvement is achieved 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 soot-blower control system (under development) are expected to reduce soot blower 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.
- ◆ Commercialized a hand-held device in 2002
- ◆ 69 units in use in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1.42	0.759

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.006	0.441	0.117	16.5

### Applications

Kraft recovery boilers in the pulp and paper industry and in the coal, cement, steel, and glass manufacturing industries

### Capabilities

- ◆ Produces clear images and videos 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

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

#### Safety

The impact of sizable slag deposits on boiler internals can lead to severe damage and potential injury. The hand-held inspection system has enabled early detection and elimination of such deposits.

## New Alloys Improve Performance and Safety

Black liquor recovery boilers are critical components of kraft pulp and paper mills. These boilers burn organic waste to generate steam and electric power for the mill and allow the sodium hydroxide and sodium sulfide used in the pulping process to be recovered. The boilers are constructed with floors and walls of tube panels, and these tubes circulate pressurized water to permit generation of steam. Originally, carbon steel tubes were used for these tube panels, but severe corrosion thinning and occasional tube failure led boiler manufacturers to search for materials that could better survive in the recovery boiler environment.

As a result of this search, new weld overlay and co-extruded tubing alloys were developed and are now being used in United States kraft recovery boilers and foreign installations. These materials are currently produced by Welding Services Inc., Sandvik Materials Technology, and Sumitomo Metals for application in recovery boilers. Boiler manufacturers are using the technology in designing and fabricating new and rebuilt kraft recovery boilers

A series of alloy studies, conducted by Oak Ridge National Laboratory, Pulp and Paper Research Institute of Canada, and the Institute of Pulp and Paper Science and Technology showed that Alloys 825 and 625 are more resistant than 304L stainless steel to cracking. Sandvik Materials Technology produces Sanicro 38 (modified 825) composite tubes for the world's largest manufacturers of black liquor recovery boilers. The boilers have been delivered to plants in the US, Australia, Belgium, Brazil, Canada, China, France, Finland, Sweden, Germany, Spain and Norway.

## Benefits

### Environmental

The change in operating conditions resulting from the improved materials will reduce gaseous emissions.

### Productivity

Improved materials enable the use of black liquor with higher dry solids content, thus increasing the thermal efficiency. The improved materials decrease the number of shutdowns and improve the overall boiler efficiency and productivity.

### Safety

In recovery boilers, tube leaks can result in serious explosions if the pressurized liquid contacts the molten salt on the floor and walls of the boiler. The use of improved materials significantly reduces the cracking of the floor and wall tubes, thus reducing the likelihood of a boiler tube leak.

## Overview

- ◆ Currently produced by Welding Services Inc., Sandvik Materials Technology, and Sumitomo Metals for application in recovery boilers
- ◆ Commercialized in 1996 and installed in over 18 kraft recovery boilers in the United States

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
4.57	0.727

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.001	0.211	0.034	4.06

## Applications

Being used in constructing new and rebuilt kraft recovery boiler floors

## Capabilities

The new materials can operate in the aggressive environments that can cause stress corrosion cracking of 304L stainless steel.

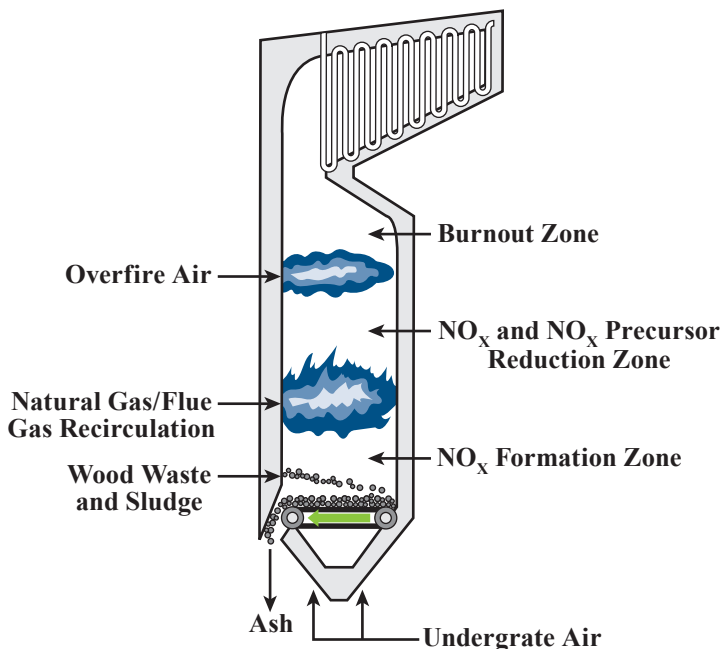
## IMPACTS

### 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub>, 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, MN. 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<sub>x</sub> emissions, and improve boiler thermal efficiency.



METHANE de-NOX Process

### Overview

- ◆ Developed by the Gas Technology Institute
- ◆ Commercialized in 1998
- ◆ Two units operating at paper mills and 26 units on coal-fired cogeneration boilers

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1.38	0.218

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.001	0.031	0.034	4.06

### Applications

A wide range of wastewood and sludge-fired stoker boilers in the forest products industry and coal-fired boilers

### Capabilities

- ◆ Improves grate combustion of difficult-to-burn fuel such as high-moisture-content waste wood.
- ◆ Substantially reduces NO<sub>x</sub> 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 land-filling them.

### Benefits

#### Ease of Operation

Cleaner gas passes through the furnace with less fouling and unburned carbon and fly ash at the bottom.

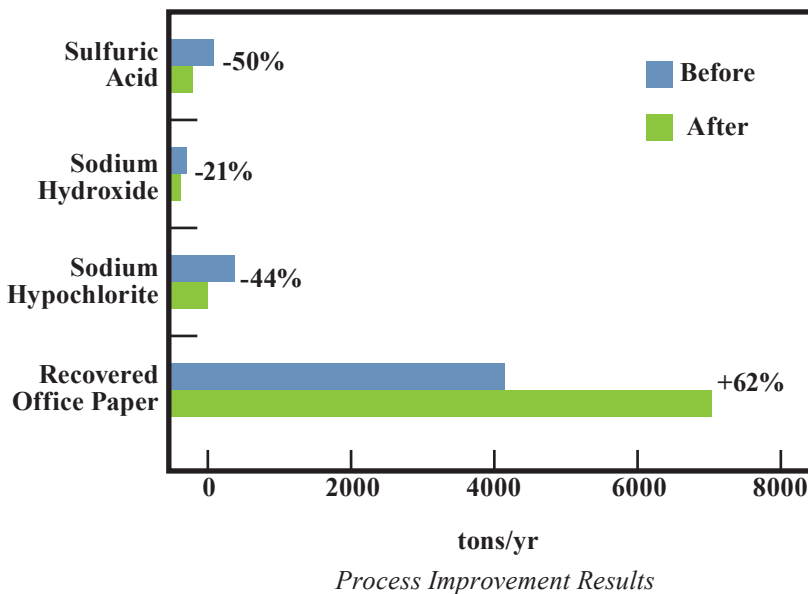
#### Productivity

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

## Optimizing Tissue Paper Manufacturing Increases Paper Recycling

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

Using a NICE<sup>3</sup> grant, Erving Paper Mills demonstrated changes to its process, which included de-ink equipment upgrades, on-line image analysis, alternative chemistry trials, and other energy-conservation projects. These improvements reduced energy and toxic chemical usage and increased the amount of recovered office paper in the feedstock. The improvements in de-inking equipment included system reconfiguration, new high-efficiency cleaners, a new high-efficiency flotation cell, and a new high-efficiency washer. These improvements resulted in higher efficiencies for removing dirt, better washing, improved clarification for process water, and lower bleaching requirements.



### Overview

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

### Applications

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

### Capabilities

Increased use of recovered office papers- from 10.5% to 17% of total feedstock.

### Benefits

#### Energy Savings

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

#### Emissions Reductions

Lower pulping temperature and new continuous-belt washer decreases solvent usage, resulting in reduced emissions of volatile organic compounds.

#### Use of Raw Materials/Feedstocks

Increasing amount of recovered office paper decreases amount of direct-entry recycled fiber used. Changes to de-inking process decreases use of several controlled chemicals



# Pressurized Ozone/Ultrafiltration Membrane System

## IMPACTS

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

With the support of a NICE<sup>3</sup> 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.

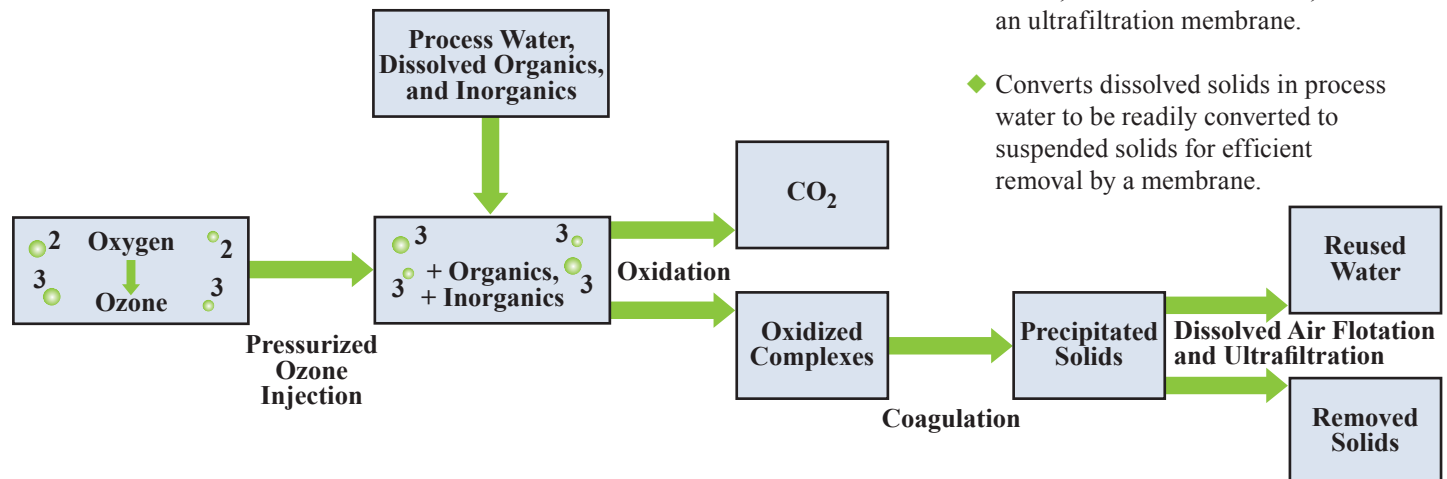
### Benefits

#### Environmental

Removes TDS in mill process water, thereby allowing mills to eliminate or reduce effluent discharge. Eliminates CO<sub>2</sub> 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

Clean process water allows production gains of 5% to 15%. Saves energy costs due to heating and drying. Reduces chemical additive use. Potentially reduces downtime in mill process water treatment systems.



Pressurized Ozone/Ultrafiltration Membrane System

### 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

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.315	0.630

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	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.

# 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. 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

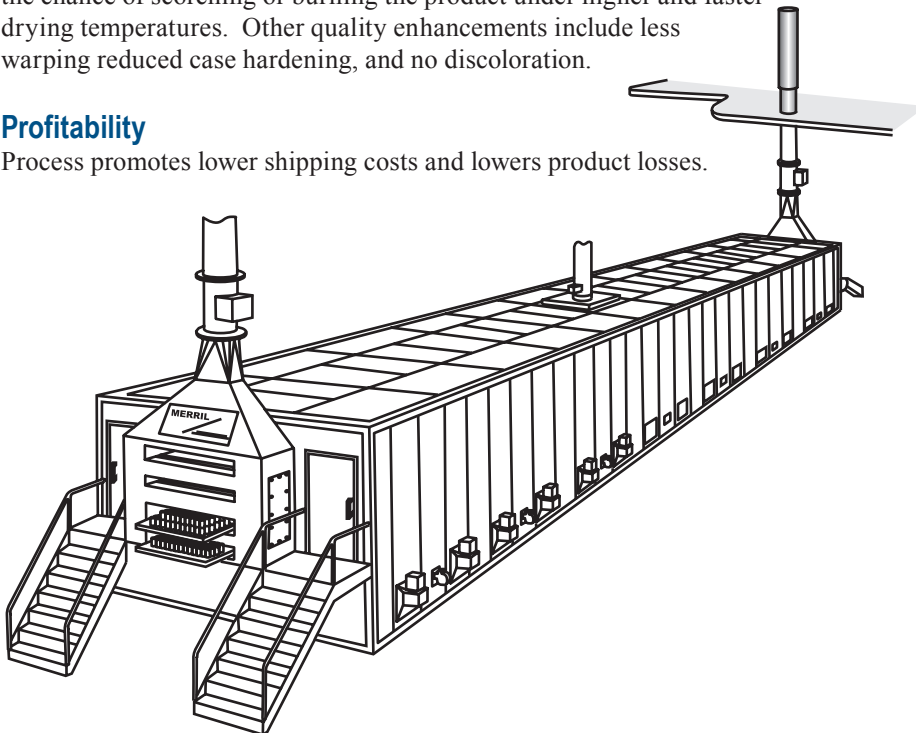
Process promotes easier stacking and wrapping.

#### Product Quality

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

#### Profitability

Process promotes lower shipping costs and lowers product losses.



*Thermodyne Evaporator—A Molded Pulp Products Dryer*

### Overview

- ◆ Developed by Merrill Air Engineers
- ◆ Commercialized in 1997
- ◆ One unit operating in Yakima, WA, one in Ireland, and one in Columbia

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.228	0.046

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.005	0.724

### Applications

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

### Capabilities

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

# XTREME Cleaner™ – Removal of Light and Sticky Contaminants

## IMPACTS

### Centrifugal Cleaner Removes Light and Sticky Contaminants from Waste Paper

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

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

### Benefits

#### Environmental

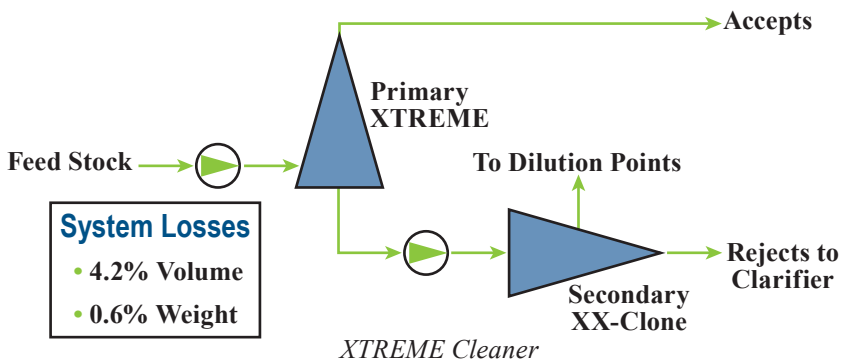
Greatly reduces the amount of waste paper being landfilled. Uses fewer chemicals and less energy to process recycled paper than does producing paper from raw wood material.

#### Productivity

Produces a 40% to 60% reduction in machine breaks or paper breaks, which are costly to paper mills due to downtime. Eliminates downtime to clean sticky contaminant buildup from processing machinery.

#### Product Quality

Allows paper mills to use a lower-grade, lower-cost furnish while still producing the same or higher-quality end product. Removes contaminants so they do not contaminate the final product and cause product rejects.



### Overview

- ◆ Developed by Thermo Black Clawson
- ◆ Commercialized in 1997
- ◆ 11 systems operating in the United States

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1.38	0.183

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.001	0.039	0.029	3.59

### Applications

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

### Capabilities

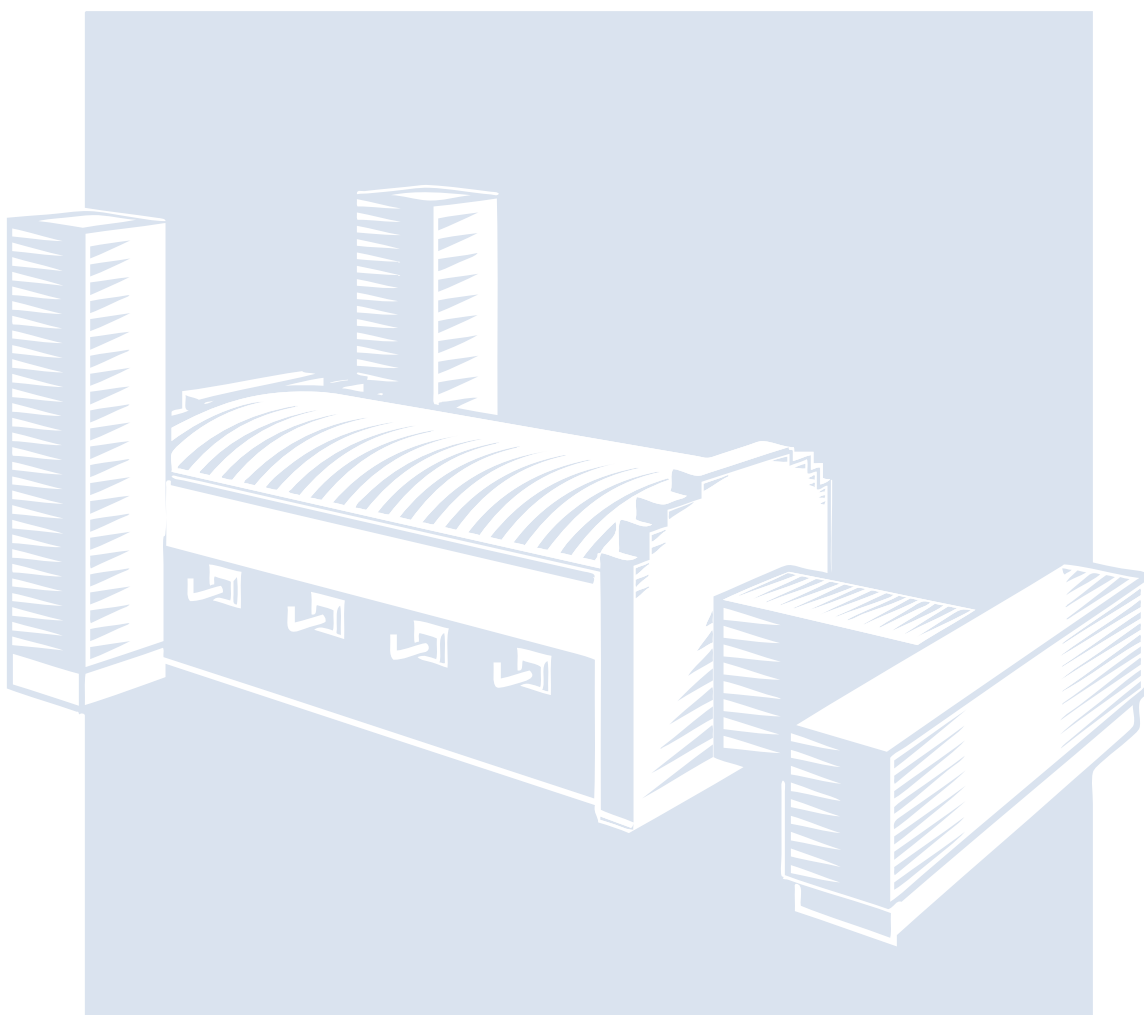
- ◆ Effectively removes lightweight sticky contaminants from all types of pulp slurries.
- ◆ Improved kneading, or “liberation”, unit better detaches and separates impurities from waste paper fibers.
- ◆ Improved vortex separation device allows greater unit capacity, longer treatment times, and more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



## IMPACTS

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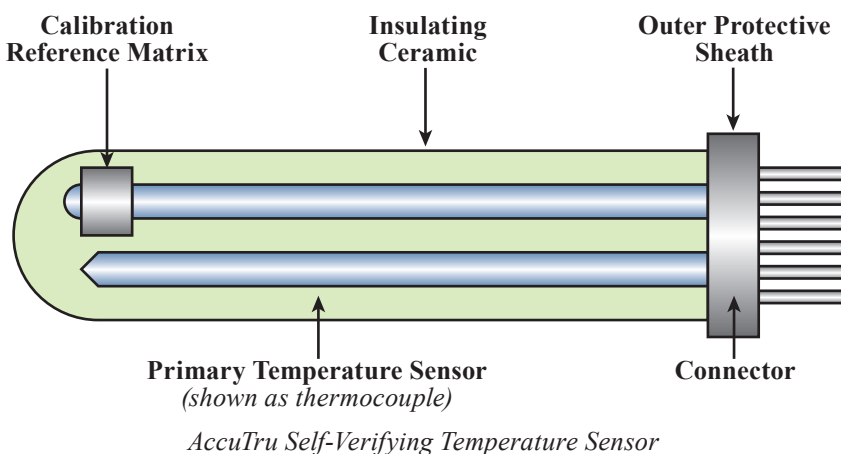
## New Material Leads to Development of Improved Monitoring Equipment

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 or RTD 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 NIST 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.

Summarizing the features of this technology:

- 1) It uses a new concept of monitoring multiple independent measurements of the system temperature and individual element health,
- 2) it continuously validates and reports the system temperature,
- 3) it reports a temperature traceable to a NIST standard for the life of the sensor,
- 4) it reports the health of the sensor, and
- 5) it warns in advance of deterioration of any of the sensor elements.



## Overview

- ◆ Developed by AccuTru International, Kingwood, Texas
- ◆ Commercialized and marketed by AccuTru
- ◆ 46 units currently operating in the United States

## Applications

Any thermochemical process where accurate and repeatable temperature read out is important:

- ◆ glass melters and delivery systems
- ◆ chemical reactors
- ◆ heat treating
- ◆ gas turbines

## Capabilities

- ◆ Reliable temperature range: -200°C to 1750°C
- ◆ Self-validating, while in service for the life of the sensor
- ◆ Warning on the onset of decalibration, predictive maintenance.

## Benefits

### Optimizing Process Yield

- ◆ Improved fuel efficiency
- ◆ Enhanced safety
- ◆ Extended equipment life

### Productivity

- ◆ 90% reduction in QC failures
- ◆ 10% increase in annual yields

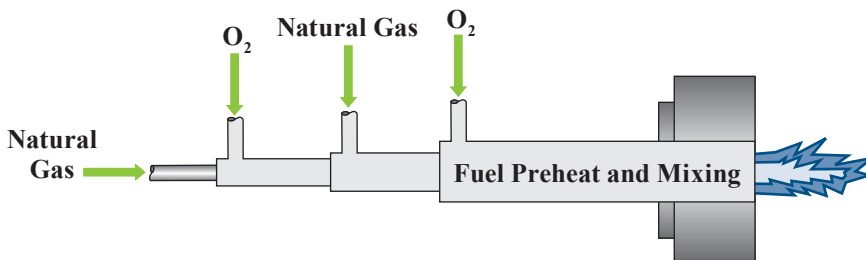
## IMPACTS

### 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<sub>x</sub> emissions in the presence of even small amounts 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<sub>x</sub> 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<sub>x</sub> Burner Design*

### Overview

- ◆ Developed and marketed by Combustion Tec, Inc., now Eclipse, Inc.
- ◆ Commercialized in 2002
- ◆ Operating in two U.S. plant in 2005

### Applications

Existing and new oxy-fuel glass melters. The largest demand currently exists 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

The high luminosity burner technology reduces NO<sub>x</sub> emissions from glass melters up to 50% and improves thermal efficiency up to 20% over traditional oxygen fuel burners.

#### Productivity

The improved burner allows cost-effective compliance with emissions regulations. The technology also provides flexibility for compliance in existing furnaces without major modifications.

#### Reliability

The technology produces a lower flame temperature and lower exit temperatures, which could extend the furnace life.





# 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/nitridecarbide family have the potential to last up to 10 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

The composite dies weigh approximately one-third less than traditional tool steel dies. The weight reduction saves time in production by eliminating some of the mechanical moving equipment.

### Waste Reduction

The longer life of ceramic dies reduces the amount of waste produced by failed tool steel casting dies. The ceramic dies also produce fewer casting rejections, reducing the energy needed to recycle the rejected castings.

## Overview

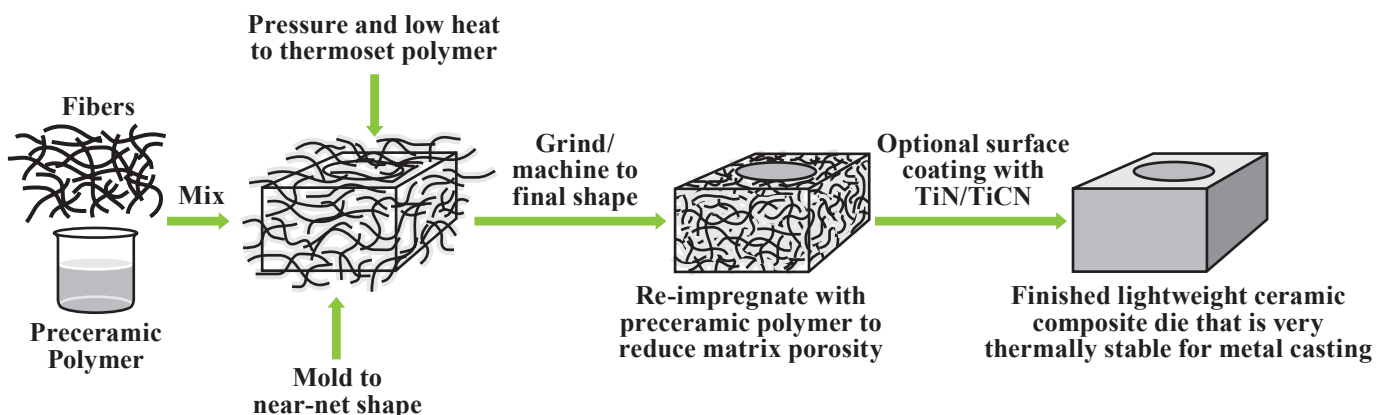
- ◆ Invented by the Materials and Electrochemical Research Corporation
- ◆ Commercialized in 2002
- ◆ Installed in several U.S. locations

## Applications

Dies for metal casting, including replacement dies that are currently tool steel

## Capabilities

- ◆ Offers resistance to corrosion, erosion, oxidation, thermal fatigue, and cracking.
- ◆ Provides stability when exposed to molten metals.
- ◆ 2 to 5 times harder than tool steels, resulting in 5 to 10 times longer useful die life.



Ceramic Composite Die Forming Process

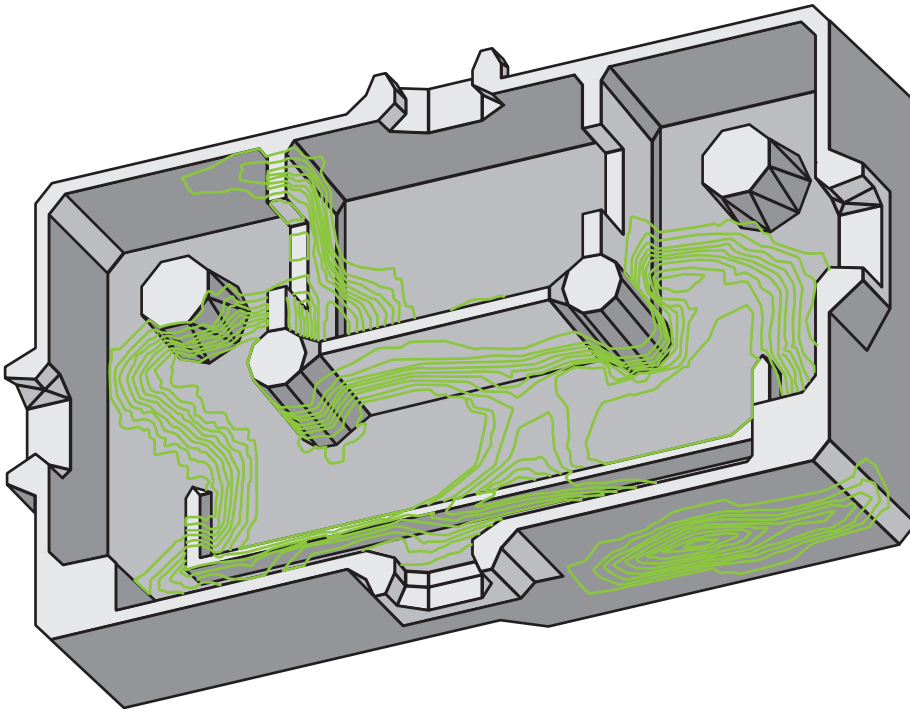
## IMPACTS

### 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 expandable polystyrene patterns for lost foam castings.



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

### Overview

- ◆ Invented and being marketed by Arena-flow, LLC
- ◆ Being used in 2 U.S. locations

### Applications

- ◆ Modeling fluid/particle applications for mold creation in the lost foam casting industry
- ◆ 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 vent and fill gun locations.

### Benefits

#### Productivity

Reduces casting defects, requires no cores, and produces higher-quality castings.

#### Waste Reduction

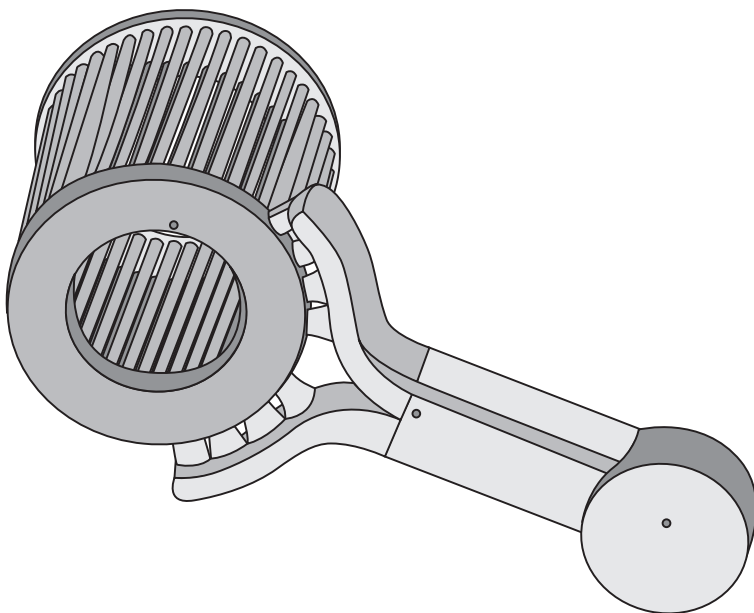
Reduces casting defects on the white side caused by pattern difficulties.

## Die Casting Copper 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 model life and increasing operating costs when used for die casting copper rotors. ThermoTrex Corporation, with the assistance of a NICE<sup>3</sup> 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. Because 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.



*Squirrel-Cage Motor with Die Cast Copper Rotors*

## Overview

- ◆ Invented by the ThermoTrex Corporation and commercialized by the Copper Development Association
- ◆ Marketed by SEW Eurodrive and FAVI S.A.

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.022	0.012

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.003	0.002	0.242

## Applications

Electric motors are used throughout U.S. industry and account for more than 60% of all electricity use in the nation. The annual market for electric motors totals about \$35 billion internationally and about \$10 billion in the United States.

## Capabilities

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

## Benefits

### Productivity

The new technique reduces production time and hand labor compared with former methods of producing copper motor rotors.

### Profitability

Motors using copper rotors decrease 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<sup>3</sup> 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 to be recycled by 50%.

## Overview

- ◆ Developed by Thixomat, Inc.
- ◆ More than 50 Thixomolding licensees in 2005.

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.001	0.001

## Emissions Reductions

(Thousand Tons, 2005)

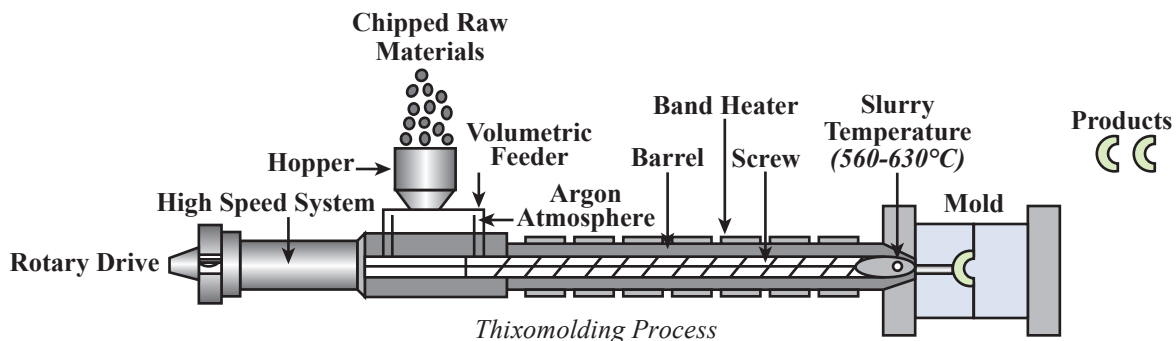
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.010

## Applications

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.



# 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. Replacing or re-melting 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, unbanded sand that is compacted by vibration. Molten metal, poured into the sand casting through a spure, 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 curtailing downstream machining and assembly.

With the assistance of a NICE<sup>3</sup> 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 a year.

### Product Quality

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

## Overview

- ◆ Developed by General Motors Corporation
- ◆ Commercialized in 2004
- ◆ Employed at 3 General Motors casting facilities

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.978	0.489

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.001	0.045	0.066	8.56

## Applications

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

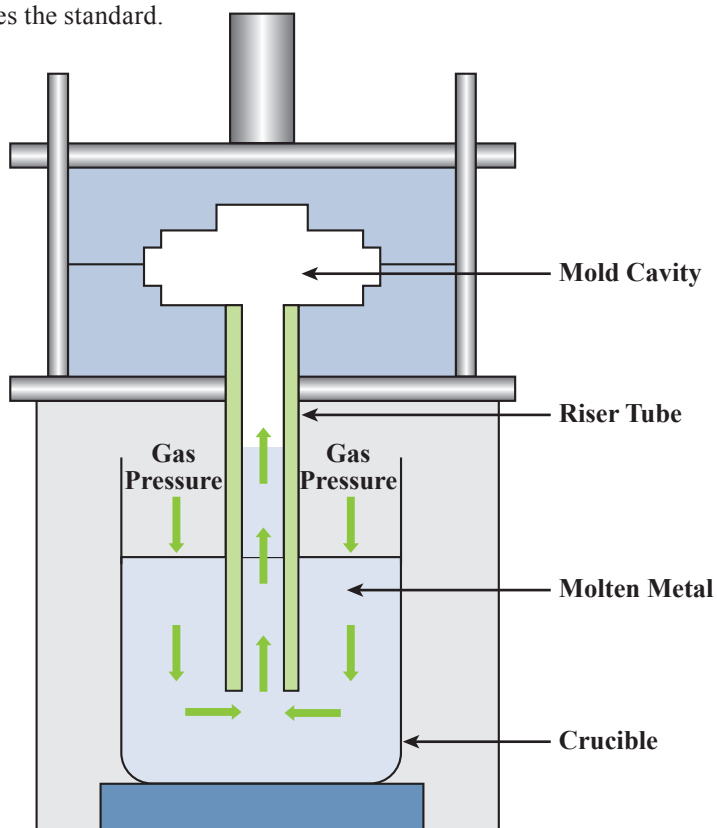
## IMPACTS

### 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 a DOE ITP grant. 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. When 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.
- ◆ Commercialized in 2005

## Applications

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.

## New Software Program Helps Detect Potential Design Problems in Die Casting

With funding from DOE 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

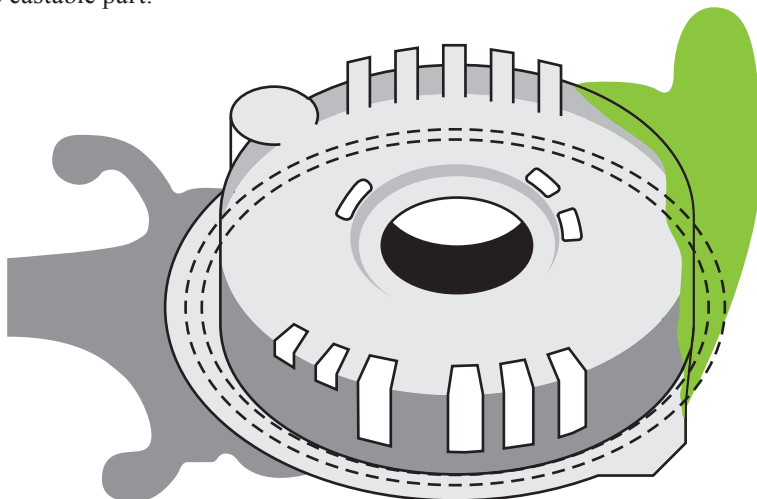
Process scrap can be reduced by 20% or more, resulting in increased yield and saving the energy formerly wasted producing defective parts.

#### Productivity

By promoting compatibility between die casting part and die design, part development lead-time and tryout/setup time can be reduced significantly.

#### Profitability

Detecting problems early in the process 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
- ◆ Commercialized in 1999
- ◆ 139 units sold to date

### Applications

CastView 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

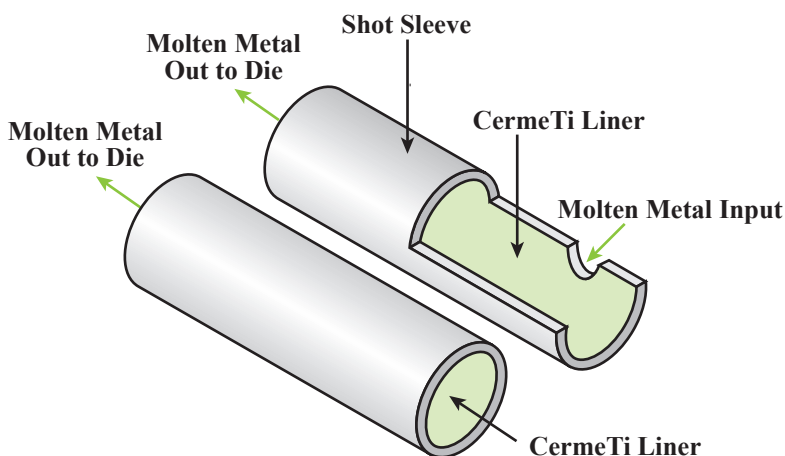
## IMPACTS

### 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<sup>3</sup> grant, Dynamet Technology, Inc., developed CermeTi<sup>®</sup>, 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<sup>®</sup> Liners*

### Overview

- ◆ Developed by Dynamet Technology, Inc.
- ◆ Commercialized in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.008	0.008

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.001	0.134

### Applications

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.



## IMPACTS

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## 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 ultrahigh pressure and temperature to obtain the final FM product. The new FM manufacturing process produces ultra-hard inserts for roller cone bits.

## Overview

- ◆ Collaboratively developed by a collaboration of 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

## Applications

Wear-resistant components for drilling

## Capabilities

FM composites have very high fracture energies, damage tolerance, and graceful failure.

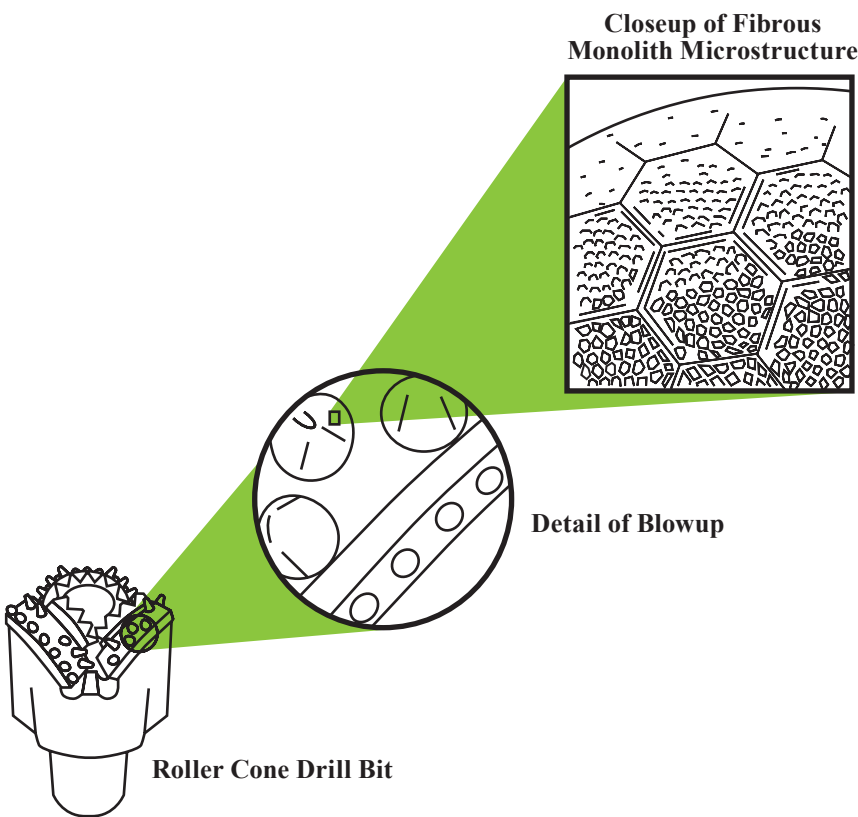
## Benefits

### 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.



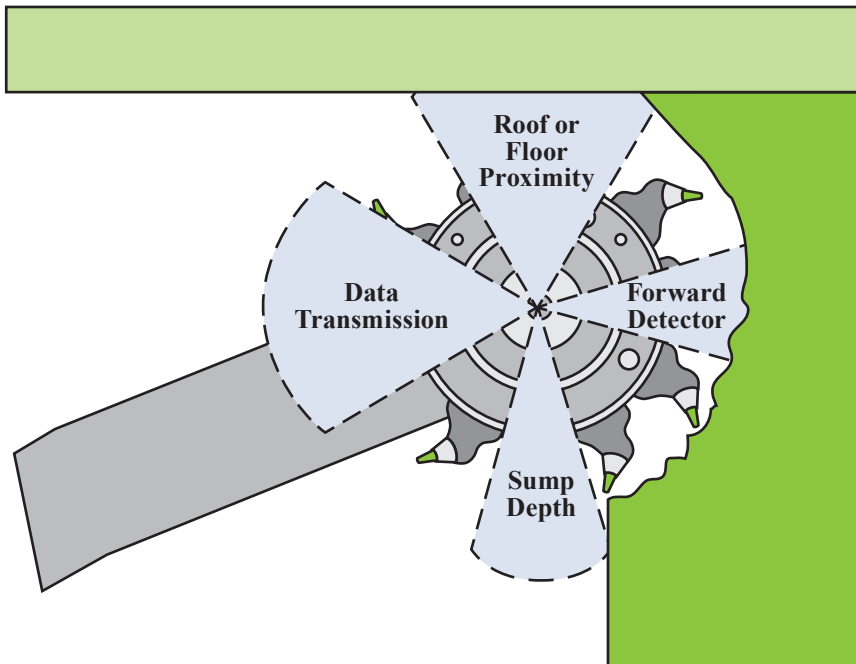
*Roller Cone Drill Bit with Fibrous Monolith Inserts*

## IMPACTS

### 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 a DOE grant, 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 radiowaves 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 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.
- ◆ Commercialized in 2002
- ◆ Used in 10 different mines within the United States

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.189	0.020

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.004	0.003	0.403

### Applications

Both underground and surface mining operations. This technology is 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

Extracting only desired material increases productivity by reducing or eliminating the cleaning step after extraction. This technology also allows for deeper mining, resulting in more material obtained from one location. Also, keeping the cutting bits out of rock results in longer bit life.

#### Safety

The remote sensing tool 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.

## 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 of a DOE grant, 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.

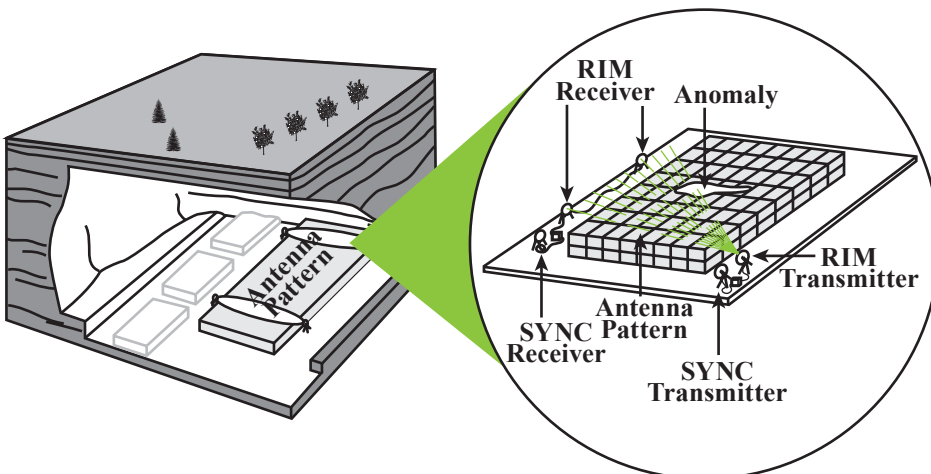
In layered sedimentary geology, a natural coal seam waveguide occurs because of the 10:1 contrast in conductivities between coal and surrounding materials. The electromagnetic wave sent by RIM through the rock reacts to these properties with a detectable change in magnitude because it is very sensitive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

In mining, forward imaging with confirmation will reduce 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.
- ◆ Commercialized in 2002
- ◆ Used in 17 different mines in the United States through 2005

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
3.98	2.34

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.011	0.505	0.377	46.0

### Applications

Both underground and surface mining operations. This technology is primarily used in the coal industry but has also been used for metalliferous mining, environmental research, and civil engineering applications. Additionally, it has been used to confirm the location of old and abandoned mine works and the integrity of barrier pillars.

### Capabilities

- ◆ In-mine RIM detects ore seams and geologic anomalies.
- ◆ Crosswell RIM delineates ore bodies, monitors heap leaches, and detects voids in coal seams.
- ◆ Drillstring radar for navigation detects voids and confirms geologic anomalies.

# Lower-pH Copper Flotation Reagent System

## IMPACTS

### 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 and energy savings along with improved recovery of copper and other minerals.

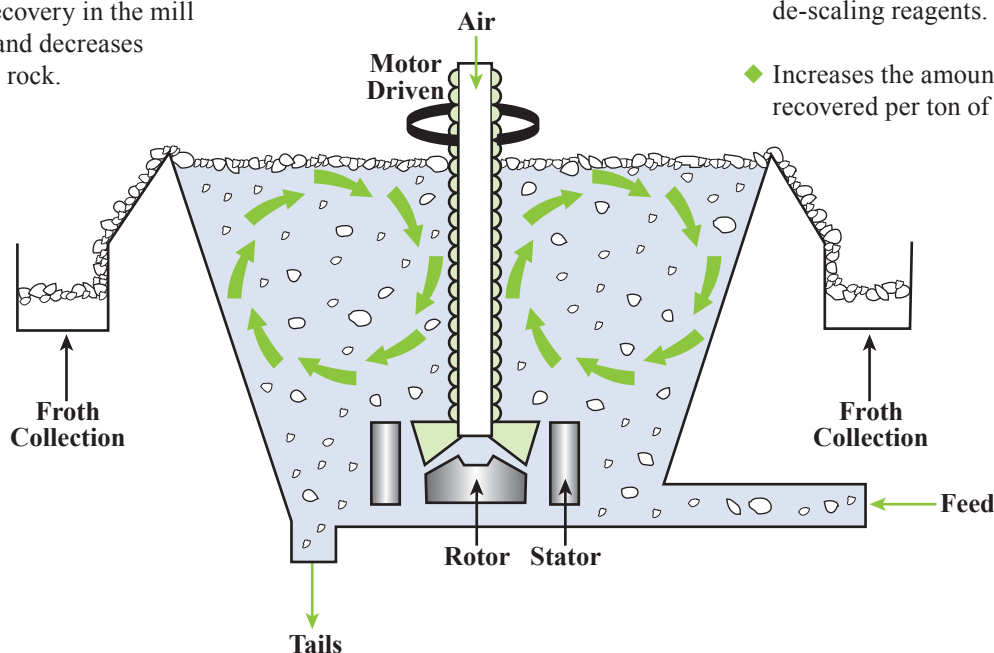
## Benefits

### 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.



Copper Flotation Reagent System

## Overview

- ◆ Developed by Versitech, Inc.
- ◆ Commercialized in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.973	0.973

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.004	0.210	0.157	19.1

## Applications

Mining processes currently using a lime additive in the separation process

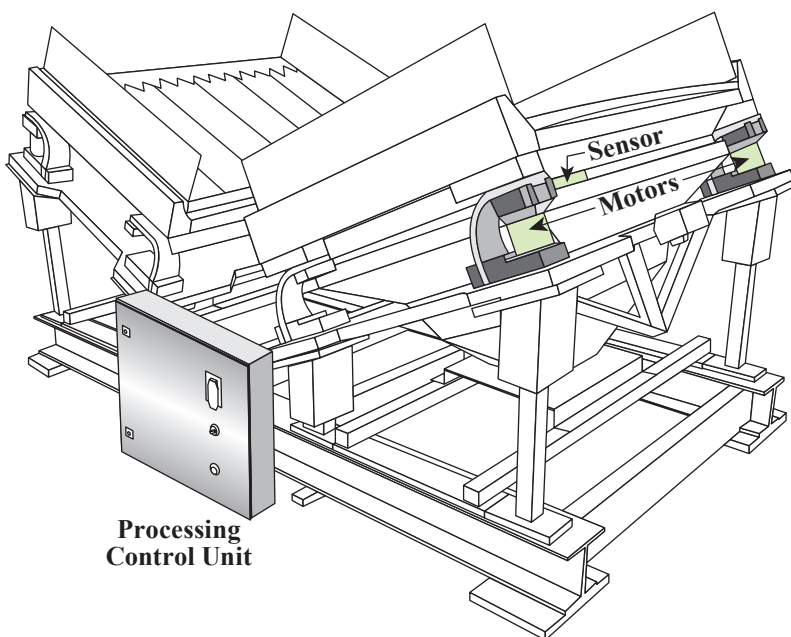
## Capabilities

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

## Smart Screening Systems Will Increase Energy Efficiency And Throughput

In mining, contemporary vibrating screening machines use an electrical motor with an eccentric rotor that generates the shaking motion. These unbalanced electrical rotors are bulky and have high maintenance costs. They also waste significant energy through useless elastic deformation of heavy supporting structure and generate very loud noises and excess heat. Excess heat and mechanical vibration reduces the life of the moving components, such as bearings.

With assistance from ITP, Quality Research, Development, and Consulting (QRDC), Inc., developed a Smart Screening System that controls the flow of energy by directing and confining the energy to the screen rather than shaking the entire support structure. The system saves energy by replacing the massive electrical motor and eccentric shaft, which typically weighs around 1,100 lbs, with miniaturized “smart” motors that weigh only 5 lbs in combination with multi-staged resonators. The processing control unit continuously receives screen panel deflection data taken from the sensor to control the electromagnetic motors. 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. Future designs may incorporate ceramic fibers in sieves so the shaking takes place at the mesh level, further focusing energy in such a way that particles will have a greater opportunity to pass through the openings.



Smart Screening System Components

## Overview

- ◆ Developed by QRDC and manufactured and sold by Smart Screening Systems, Inc.
- ◆ Commercialized in 2003
- ◆ 44 systems operating in the United States in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.003	0.001

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.029

## Applications

All mined materials that must pass through a positive size separation process using vibrating screens

## Capabilities

- ◆ Vibrates only the “live” system components rather than the entire machine and supporting structure in the material separation process.
- ◆ Allows for a smaller physical structure to achieve a given process objective.

## Benefits

### Operation and Maintenance

Reduces maintenance costs in screening operations and eliminates the need for lubrication.

### Productivity

Improves screening efficiency and capacity as well as overall process throughput.

### Safety

Reduces noise and vibration levels increasing worker safety and health.



# Wireless Telemetry for Mine Monitoring and Emergency Communications

## IMPACTS

### 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 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.
- ◆ Commercialized in 1998
- ◆ As of December 2005 four customers are using 30 units in non-coal U.S. mines

### Applications

- ◆ Both systems are useful for all mining situations and other underground work
- ◆ ComCell is applicable to steel-reinforced buildings, tunnels and transit systems

### Capabilities

- ◆ Both systems increase communications capabilities among personnel underground providing greater flexibility and mobility in communications.
- ◆ ComCell is not limited by line-of-sight transmission patterns.
- ◆ ComCell relays signals throughout the covered area, penetrating around corners and 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

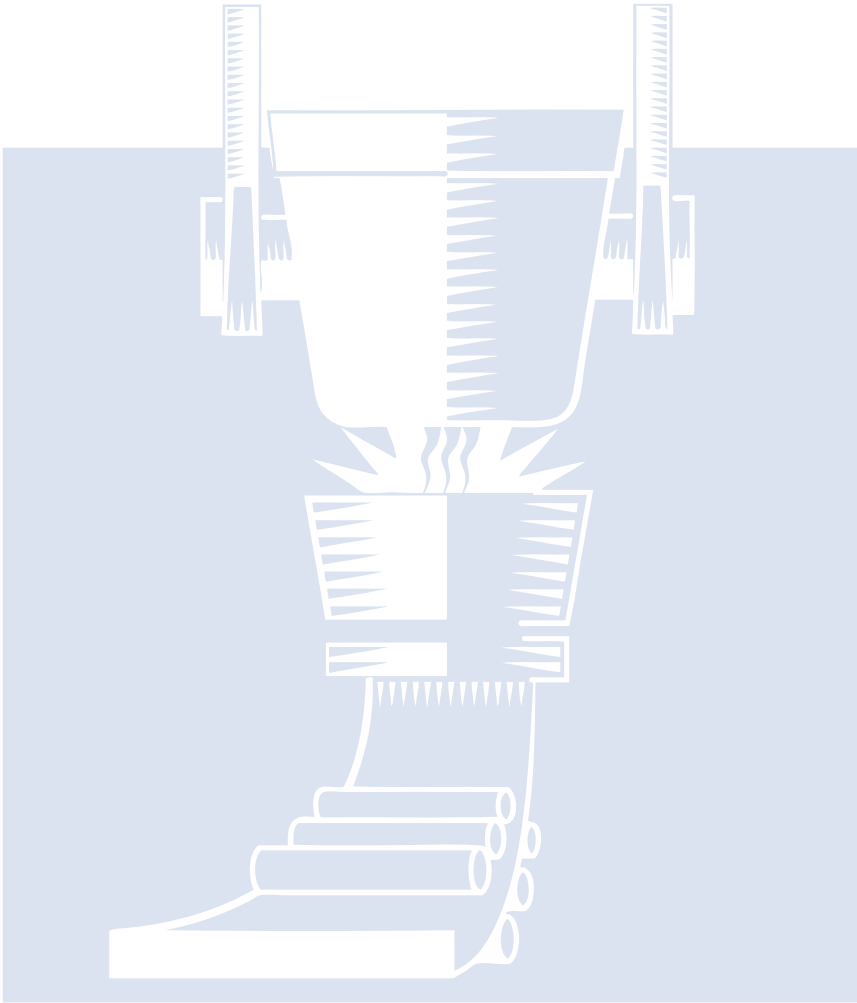
Increases the safety and acceptability of coal mining as an energy source, thereby augmenting the energy supply. Improves safety by the system's ability to provide uninterrupted communications.



**IMPACTS**

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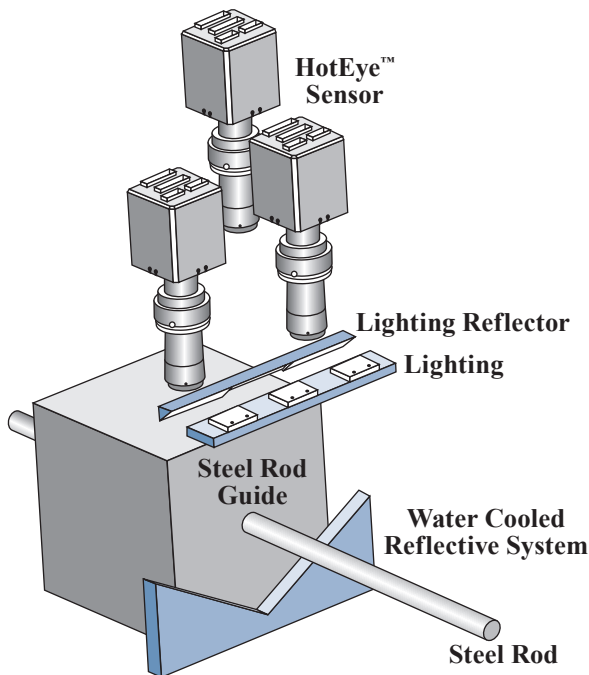


# Automatic High-Temperature Steel Inspection and Advice System

## Unique Measurement System Enhances Process Control, Reduces Scrap, 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 a NICE<sup>3</sup> grant. 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 PC's, 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.
- ◆ Commercialized in 2004
- ◆ Operating in three U.S. and two foreign steel mills in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
2.04	1.53

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.179	24.3

## Applications

The HotEye RSB System 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%.

DOE Industrial Technologies Program

# Dilute Oxygen Combustion System

## IMPACTS

### Dilute Oxygen Combustion Improves Reheat Furnace Performance and Provides Very Low NO<sub>x</sub> 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<sub>x</sub> emissions. By replacing combustion air with oxygen, DOC 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, high-velocity jets through separate lances 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<sub>x</sub> generation, providing low NO<sub>x</sub> 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 compared with 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.
- ◆ 14 burners operating at two locations in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
7.22	7.17

### Emissions Reductions

(Thousand Tons, 2005)

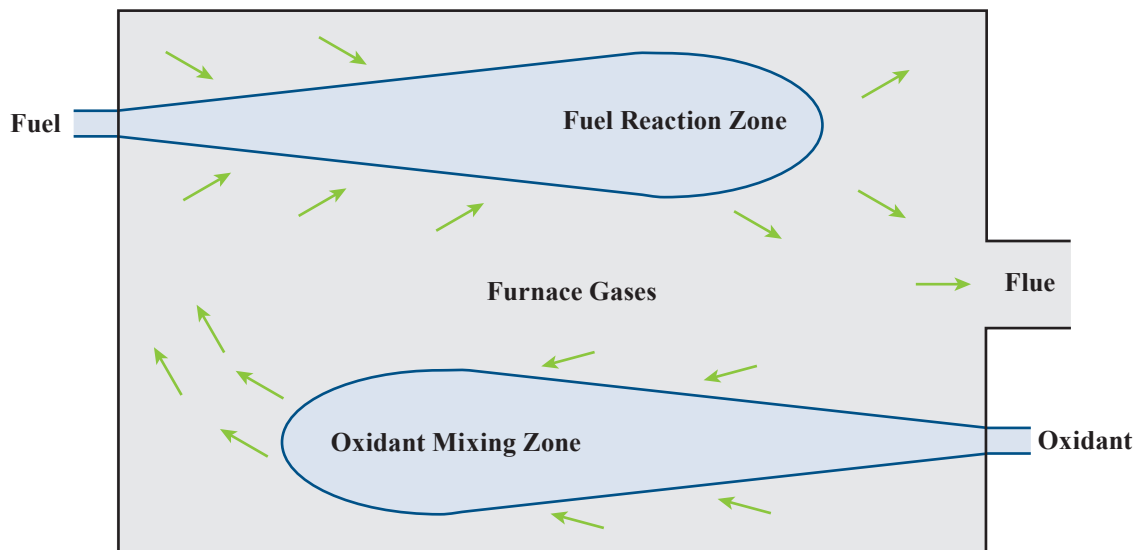
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.839	114

### Applications

- ◆ Steel and glass industry
- ◆ Any combustion system

### Capabilities

- ◆ Up to 30% increase in furnace capacity.
- ◆ Can be used on continuous or batch reheat furnaces.



*Dilute Oxygen Combustion*

## 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 dezincing 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

Removal of zinc 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
- ◆ Steel scrap sold to several dealers, steel-makers, and foundries after dezincing

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.051	0.021

### Emissions Reductions

(Thousand Tons, 2005)

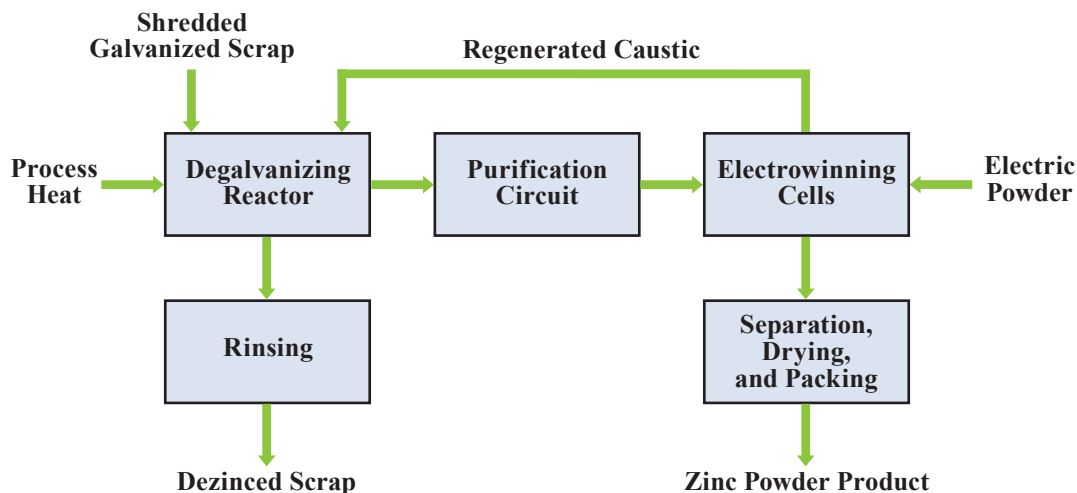
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.013	0.006	0.585

### Applications

Primarily 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*

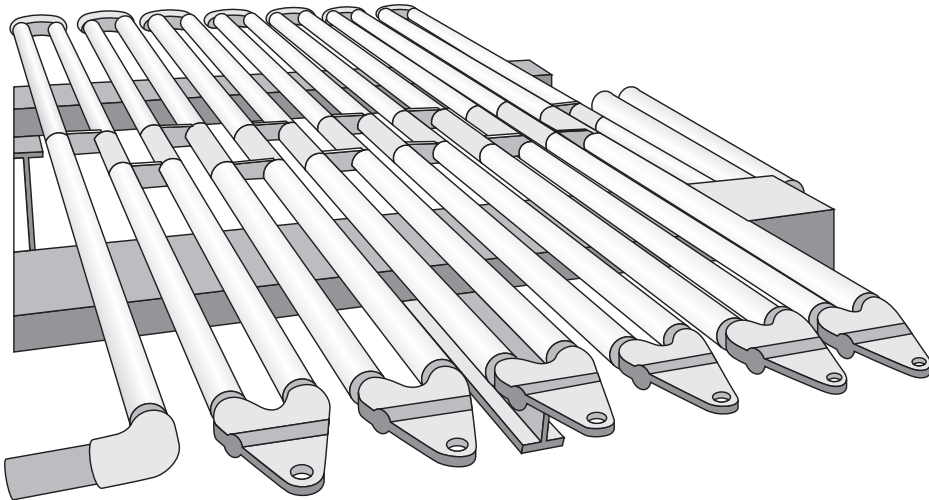
# H-Series Cast Austenitic Stainless Steels

## IMPACTS

### 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 the ITP, a combination of thermodynamic modeling developed at the Oak Ridge National Laboratory, micro-structural characterization, and mechanical property measurements were 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.
- ◆ Commercialized in 2003
- ◆ As of 2005 29 U.S. applications were operating in 4 processing plants

### Applications

Many applications 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 reduce downtime of the production equipment, reduce replacement of components, and increase productivity with reduced rejection.

## 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 other steelmaking operations 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 rapidly measures refractory lining thickness and incorporates high-speed, laser-based distance measuring equipment with a robust mechanical platform and easy-to-use software. With a laser scan rate of over 8,000 points per second, a single vessel scan can include over 500,000 individual contour measurements, providing incredibly detailed contour resolution and accurate bath height determination.

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
- ◆ 5 units in operation at four U.S. installations in 2005 and additional units in use overseas

## Applications

Rapid measurements of vessel wall and bottom lining thickness in the steel furnace or ladle environments

## Capabilities

- ◆ 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

### Energy Savings

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

### Productivity

Reduces maintenance on BOF refractory via automated furnace inspection.



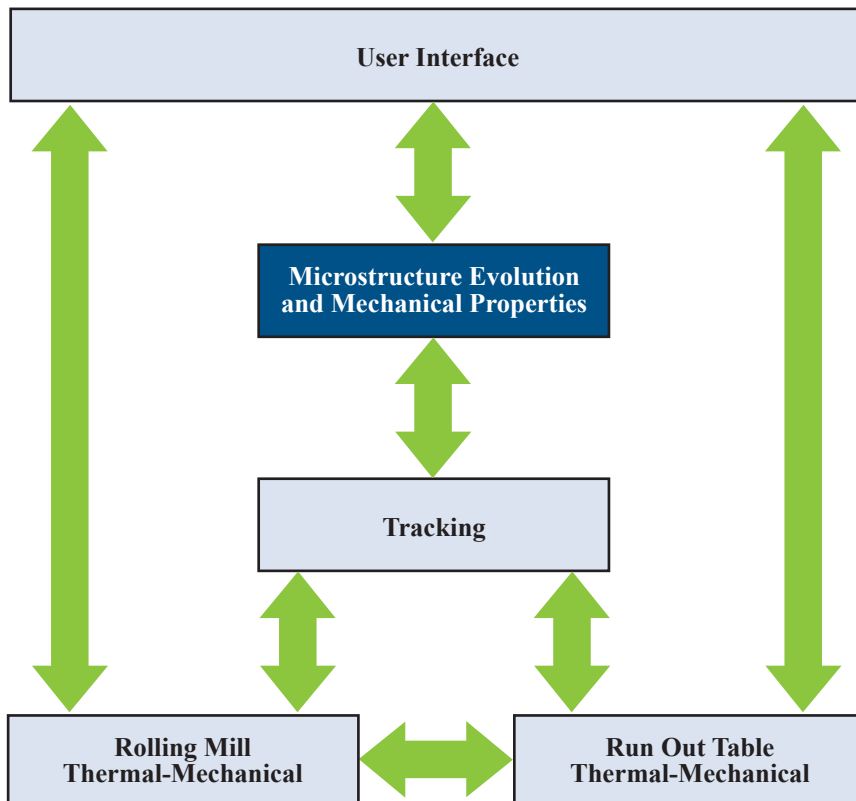
# Microstructure Engineering for Hot Strip Mills

## 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 of 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 setup 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 and being marketed by INTEG Process Group, Inc.
- ◆ Being used by five U.S. steel companies and nine foreign companies or universities

### Applications

The HSMM is applicable to 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 also 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.

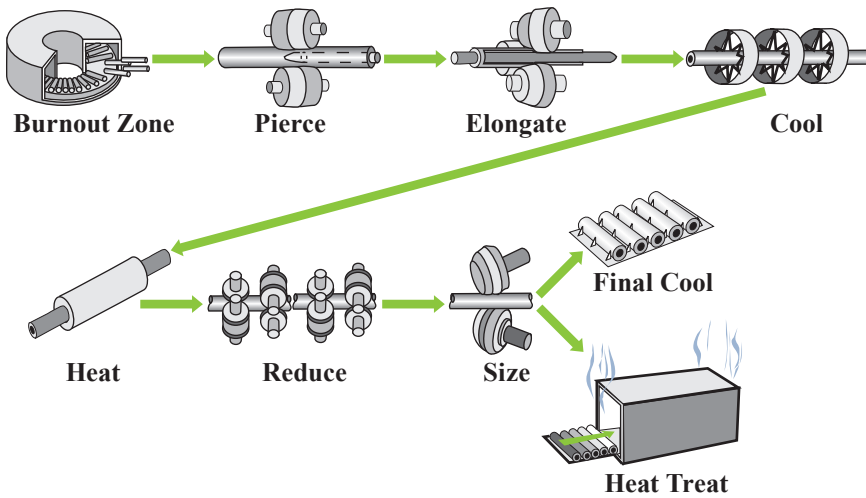
# Shorter Spheroidizing Annealing Time for Tube/Pipe Manufacturing

## 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 spheroidized 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 spheroidized annealing process changes the hard, elongated carbide particles in the steel to be spherical in shape with a preferred diameter. The size and shape of the original elongated carbides produced by the previous hotworking process influence the ability to spheroidize the carbides. The spheroidized 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
- ◆ Process being used at two facilities in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.100	0.017

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.002	0.266

## Applications

- ◆ Steel tube and pipe manufacturers
- ◆ 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 transformed 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 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 (Mittal) partnered under the U.S. Department of Energy's ITP Emerging Technology Deployment Program 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

Increased roll life reduces furnace shutdowns to replace worn components, resulting in increased production. Maintenance and furnace shutdowns decreased from weekly to quarterly. Reduced damage to steel during heat-treating, resulting in less steel scrap.

#### Product Quality

The new rolls are two to three times stronger than conventional steel roll assemblies. The strength increases 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.
- ◆ Nickel aluminide transfer rolls technology commercialized in 1993

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.068	0.035

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.004	0.551

### Applications

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

### Capabilities

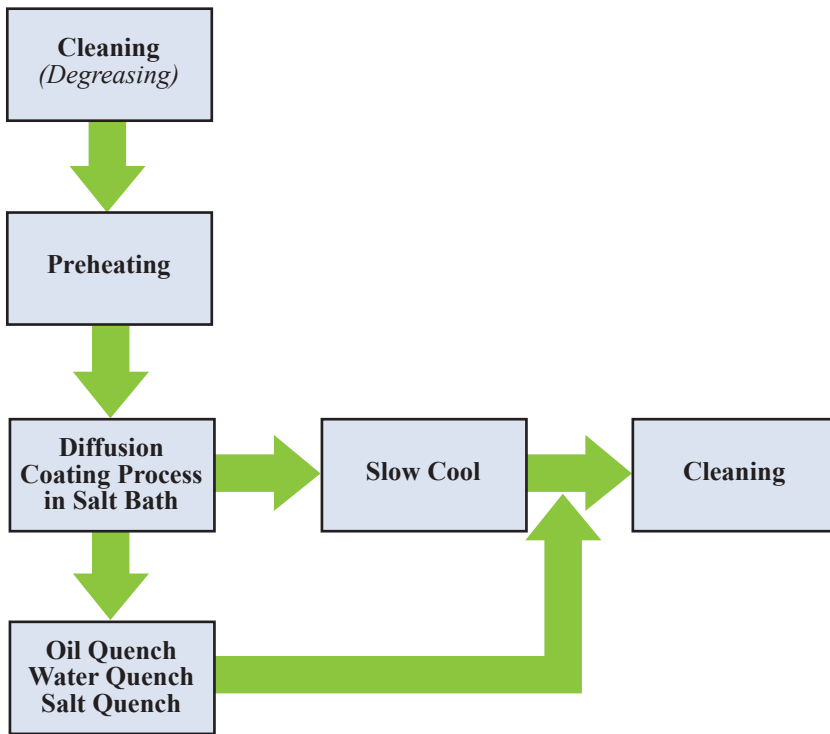
Can operate in temperatures as high as 2100°F.

# 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 DOE's NICE<sup>3</sup> 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
- ◆ Commercialized in 2005

## Applications

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.

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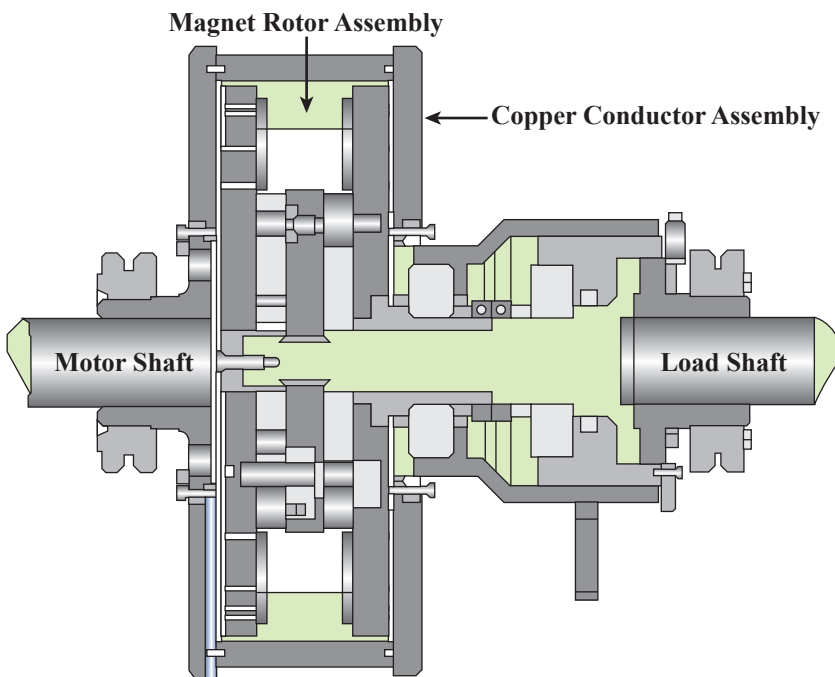
# Adjustable-Speed Drives for 500 to 4000 Horsepower Industrial Applications

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

MagnaDrive Corporation, with assistance from DOE's NICE<sup>3</sup> 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 4000 horsepower (hp). Over 5000 units are currently in use in applications up to 2500 hp, of which 11 are over 500 hp; and sales of 4000 hp units are planned in 2006.

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
- ◆ Commercialized in 2003
- ◆ 11 large and 5000 smaller units operating in the United States in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.113	0.065

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.014	0.010	1.28

## Applications

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.

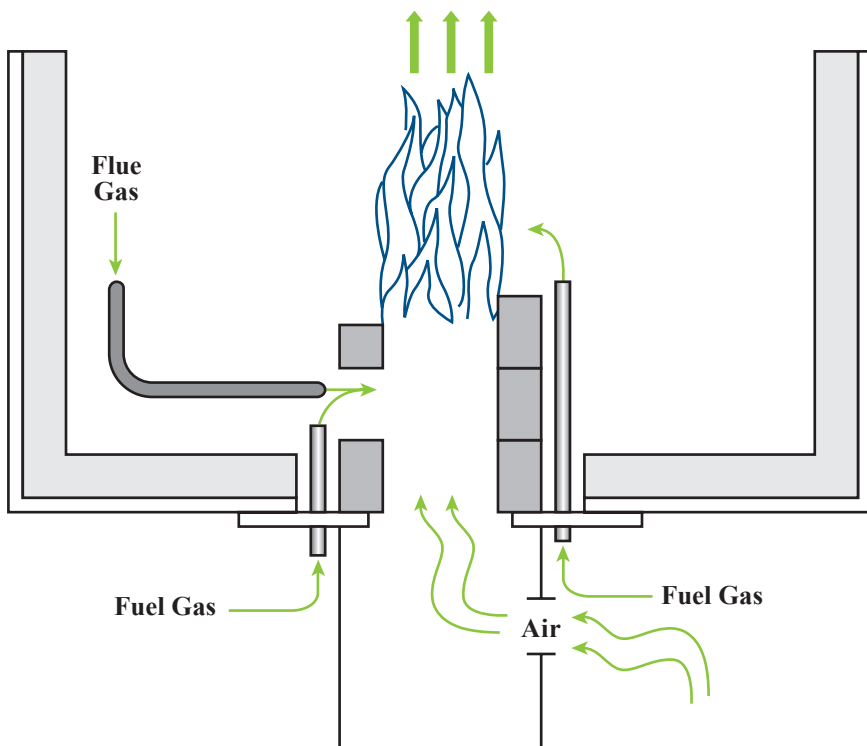
# Callidus Ultra-Blue (CUB) Burner

## 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<sub>x</sub> emissions annually. The chemicals and refining industries are facing more stringent environmental regulations to reduce NO<sub>x</sub> emissions; for example, the state of Texas has ordered refiners in the Houston area to reduce NO<sub>x</sub> 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<sub>x</sub> emissions burner. The burner uses internal flue gas recirculation to reduce 80% of the NO<sub>x</sub> 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<sub>x</sub> reductions of 200,000 tons/year are possible.



Callidus Ultra-Blue Burner

### Overview

- ◆ Developed by Callidus Technologies, Inc.
- ◆ Commercialized in 2000
- ◆ Over 3100 burner units installed by 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
18.1	6.70

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.783	106.

### Applications

High-temperature ultra-low NO<sub>x</sub> burner for the chemicals, petrochemicals, and refining industries

### Capabilities

The Callidus burner works with

- ◆ Natural or forced-draft operation
- ◆ Refinery fuel gas, natural gas, and high and low hydrogen content
- ◆ Ambient and preheated air.

### Benefits

#### Emissions Reductions

Reduces thermal NO<sub>x</sub> 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.

## Advanced Catalytic Combustion System Reduces NO<sub>x</sub> 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 DOE, 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<sub>x</sub>.

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.

### Benefits

#### Emission Reductions

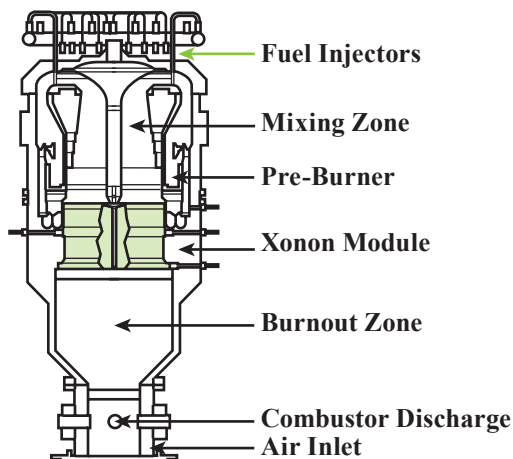
The system reduces air pollutant emissions from gas turbine energy generation systems. In its first commercial installation, the NO<sub>x</sub> output was reduced from approximately 20 ppm to well below 3 ppm.

#### Pollution Reduction

The catalytic system avoids the need for costly or burdensome exhaust cleanup systems that use toxic reagents such as ammonia.

#### Productivity

The NO<sub>x</sub> reduction process using catalytic combustion does not reduce the turbine efficiency. The system has demonstrated operating reliability greater than 98%.



*Catalytic Combustion*

### Overview

- ◆ Developed by Catalytica Energy Systems, Inc.
- ◆ Has accumulated over 18,000 hours of operation on the grid in field demonstrations
- ◆ First commercialized in 2002

### Applications

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

### 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<sub>x</sub> and less than 10 ppm for CO.
- ◆ Uses a catalyst rather than a flame to combust fuel.



# Chemical Vapor Deposition Optimization of Ceramic Matrix Composites

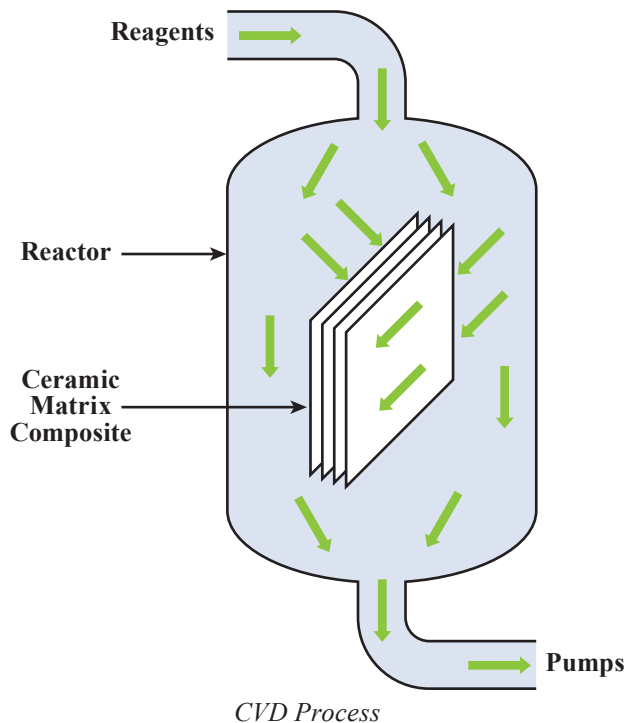
## IMPACTS

### Chemical Vapor Deposition Optimizes Industrial and Aerospace Ceramic Matrix Composites

Ceramic matrix composites comprise a new 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. Honeywell Advanced Composites, Inc. uses CVD to apply a thin, even interface coating to the surface of ceramic fibers. A coating of silicon carbide is then added to further strengthen the composite, making it stronger than conventional composites and shatterproof upon failure.

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



### Overview

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

### Applications

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

### Capabilities

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

### Benefits

#### Energy Savings

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

#### Productivity

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

#### Product Quality

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

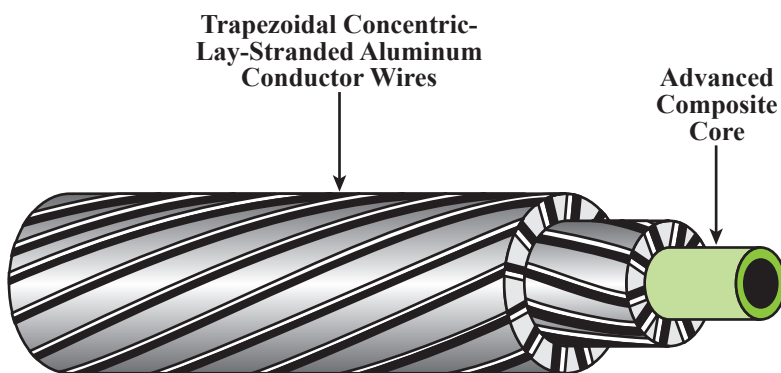
## New Aluminum Conductor Composite Core Cable Increases Transmission Efficiency and Installs Easily

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, 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 reduces the number of structures by as much as 16% or more because of its thermal stability and 25% to 40% greater strength.



*Aluminum Conductor Cable with Composite Core*

## Overview

- ◆ Developed by Composite Technology Corporation
- ◆ Commercialized in 2005
- ◆ Over 59,000 feet of line installed in the United States and 2,667 feet in foreign countries

## Applications

Provides the power industry with increased transmission efficiency and the capacity for new and existing pathways. The conductor 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.
- ◆ 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.

DOE Industrial Technologies Program

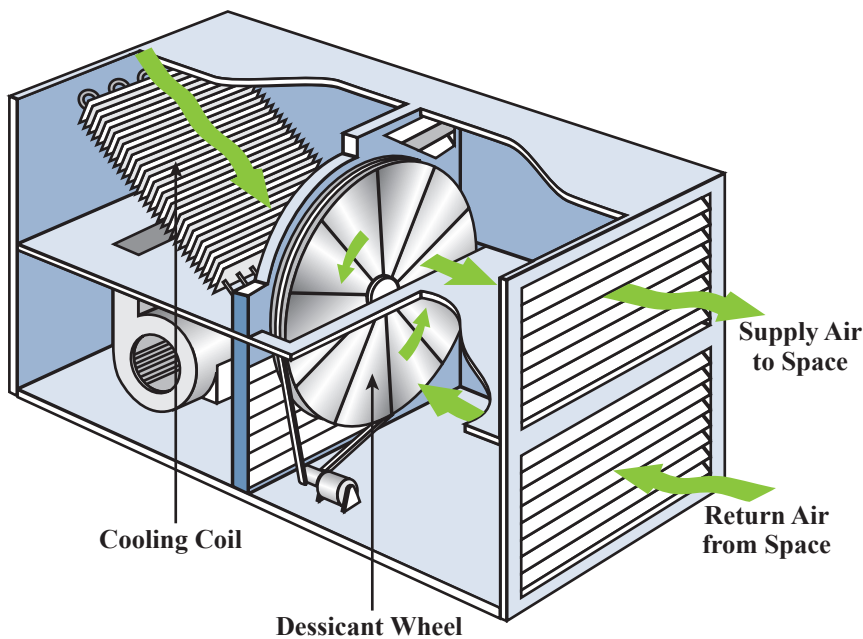
## IMPACTS

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

When cooling a residential 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. If the sensible-heat ratio falls below 75%, then overcooling occurs in meeting the moisture-removal demand. Adding heat to the space, which consumes even more energy, usually rectifies this unnecessary 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, desiccant is used to transfer moisture continuously from the supply air stream to the return air stream. 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 will 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

## Applications

Residential, commercial, and industrial HVAC systems needing dehumidification down to 25°F dew points

## Capabilities

- ◆ Reduces the amount of cooling and reheat needed 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

### Energy Savings

Uses desiccant to improve the dehumidification performance of the cooling coil, saving 15% to 80% over traditional cooling-dehumidifying systems.

### Productivity/Comfort

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

### Waste Reduction

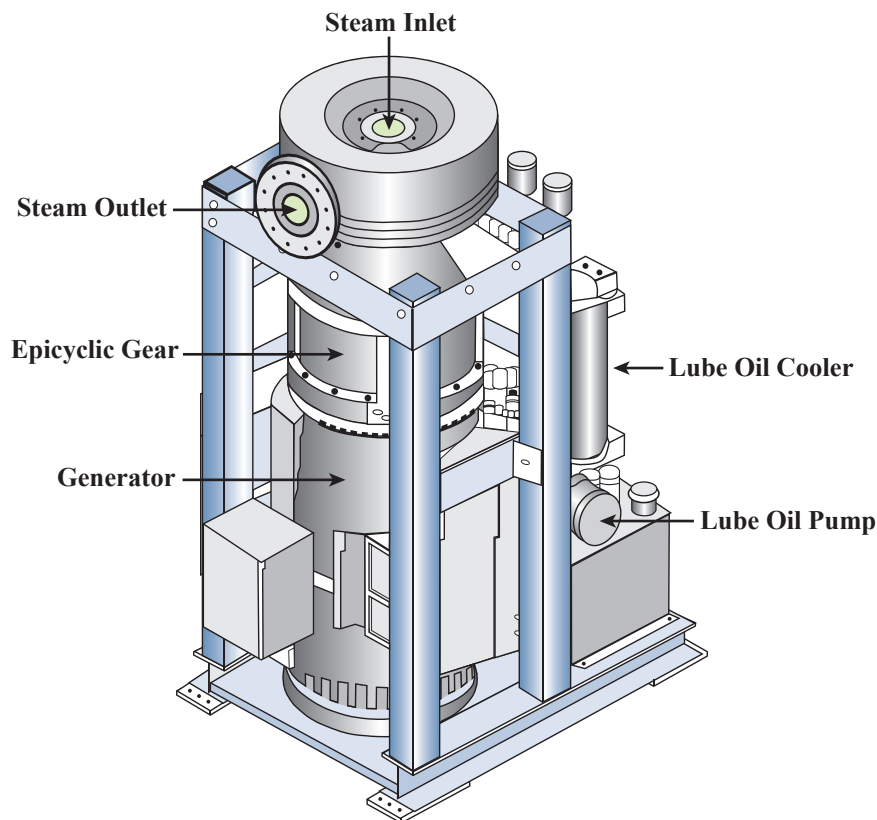
Avoids the need for stand-alone dehumidification equipment or dedicated outdoor air units; uses return air to regenerate the desiccant versus high-temperature heat of traditional desiccant systems.

# Dual-Pressure Euler Turbine for Industrial and Building Applications

## 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 U.S Department of Energy’s NICE<sup>3</sup> 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% to 70% 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 Corporation
- ◆ Commercialized in 2004
- ◆ 2 units operating in the United States in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.018	0.013

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.002	0.211

## Applications

Steam systems using pressure reduction valves (PRV) in pressurized steam lines

## 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<sub>2</sub> and NO<sub>x</sub> emissions by 50%.

### Productivity

Designed to operate with poor quality steam.

# Energy-Conserving Tool for Combustion-Dependent Industries

## IMPACTS

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

Using a NICE<sup>3</sup> 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
- ◆ 24 units operating in the United States in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.006	0.002

## Emissions Reductions

(Thousand Tons, 2005)

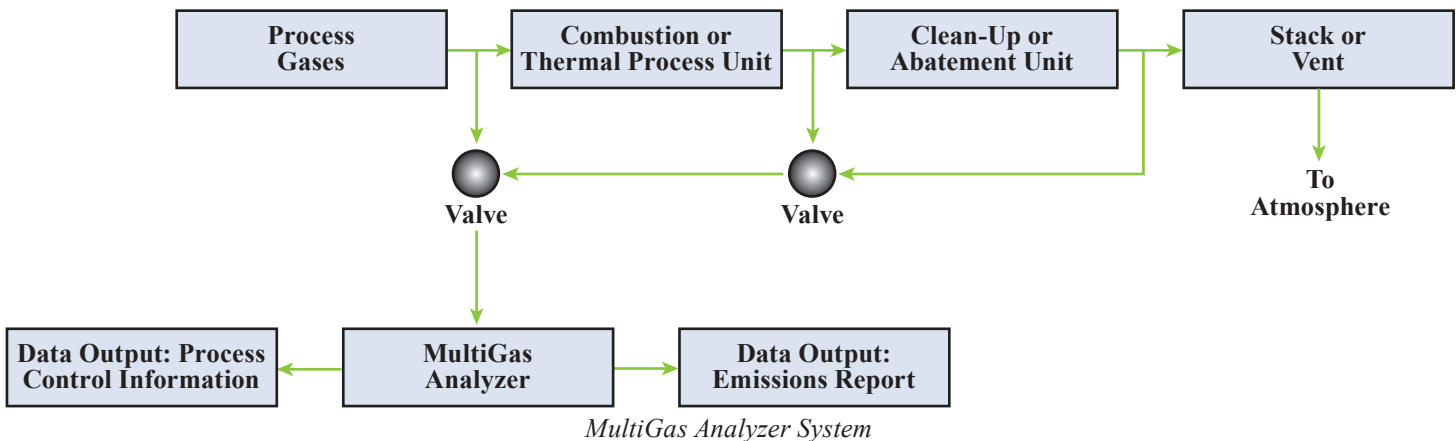
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.034

## Applications

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.



# Evaporator Fan Controller for Medium-Temperature Walk-In Refrigerators

## Fan Controller Saves Energy in Two Ways

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

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

## Benefits

### Energy Savings

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

### Productivity

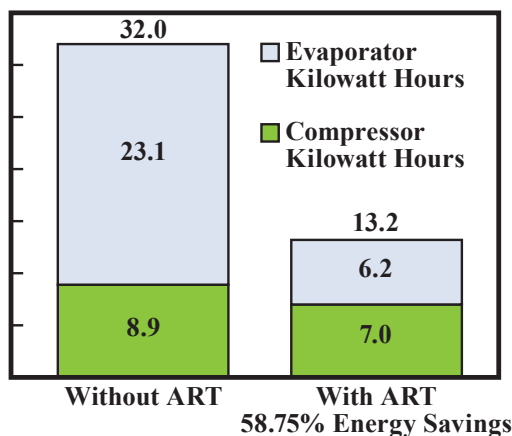
Even temperature distribution and lower air velocity improve working conditions and result in workers keeping refrigerated spaces closed.

### Product Quality

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

### Profitability

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



Average Daily Energy Consumption for a 29,200 Btu Evaporator

## Overview

- ◆ Developed by Advanced Refrigeration Technologies, Inc.
- ◆ Commercialized in 1997
- ◆ Being sold by RS Services
- ◆ Over 1431 units operating in 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.070	0.016

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.003	0.003	0.309

## Applications

Decrease in energy consumption in low- and medium-temperature walk-in refrigeration and freezer systems in restaurants, cafeterias, mess halls; grocery and convenience stores; hospitals; colleges and other educational facilities; naval vessels; and custom industrial and commercial applications

## Capabilities

- ◆ Control logic cuts evaporator and compressor energy consumption and lengthens component life.
- ◆ Controller can be retrofitted into existing refrigeration systems or incorporated into the design of new equipment.
- ◆ New models have the capability to monitor energy use and savings associated with the ART controller. Monitored information may be downloaded to a PC.

# Fiber-Optic Sensor for Industrial Process Measurement and Control

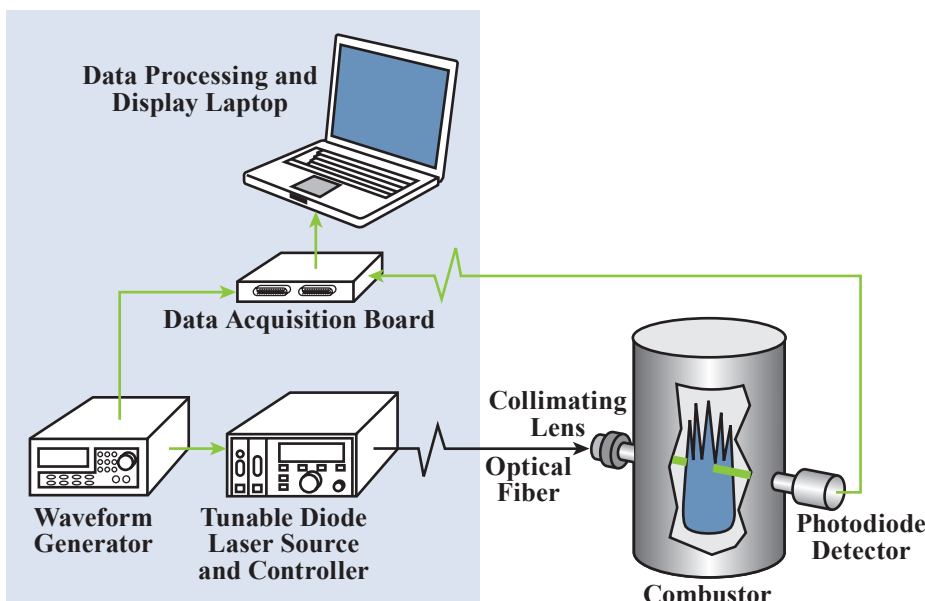
## IMPACTS

### 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
- ◆ A derivative of this technology is being applied as a leak detection system for pharmaceutical production lines

## Applications

- ◆ Coal-fired power plants to achieve accurate real-time temperature measurements
- ◆ Solid propellant combustion to enhance the capabilities of the next generation of solid-fuel vehicles
- ◆ 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

### Reliability

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

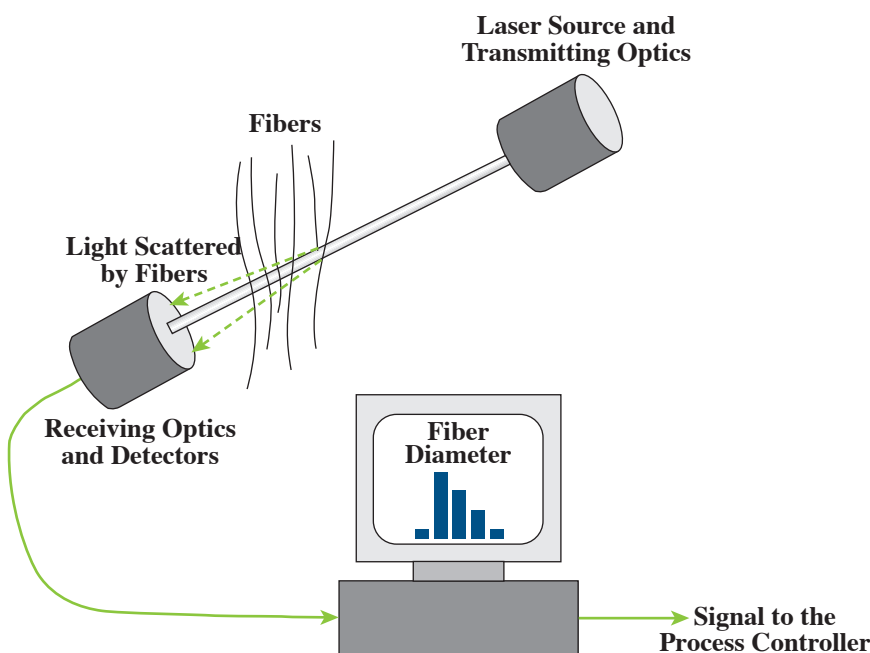
### Profitability

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

## Revolutionary Optical Technology Provides On-Line and Off-Line Measurement of Fiber Sizes

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, and 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 new 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
- ◆ Sale, lease arrangements, and contract measurements completed for several major fiber manufacturers in the United States

## 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<sub>2</sub> 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.



## IMPACTS

### 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

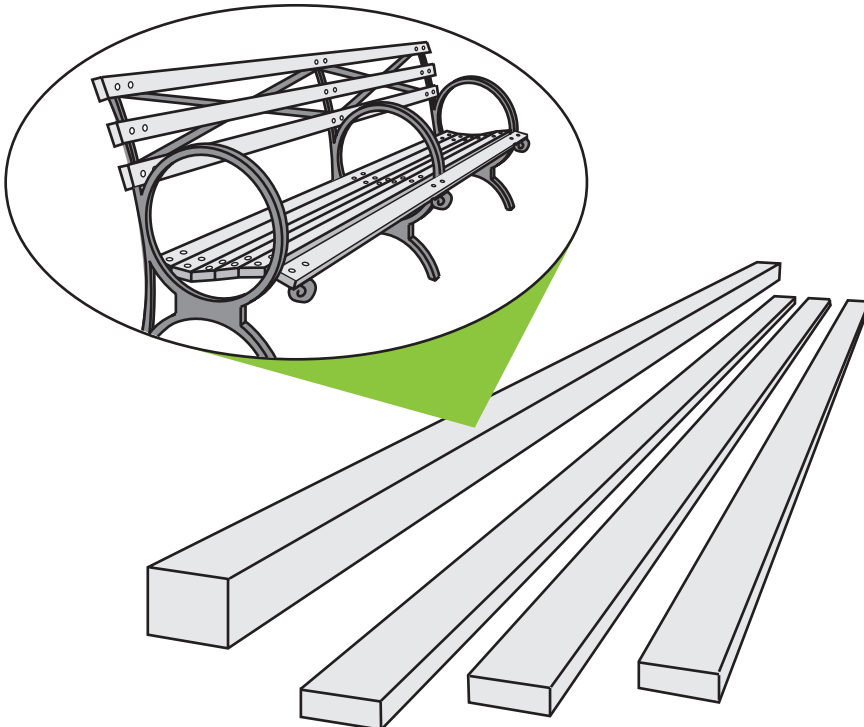
Below the cost of many competitive materials and can be reground and reused in the same process. It is lightweight and can be 1/10th the density of concrete.

#### Product Quality

Their 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
- ◆ One plant operating in the United States with the capacity to process 1 ton/hr of coal fly ash to make plastic lumber, siding, and fencing
- ◆ 1 pilot plant is making synthetic structural lumber using coal fly ash as the main ingredient

### Applications

Among the products made with the Century-Board process are roof tiles, artificial slate, siding, molding, doors, utility poles, marine and dimensional lumber, picture frames, office partitions, and wallboard

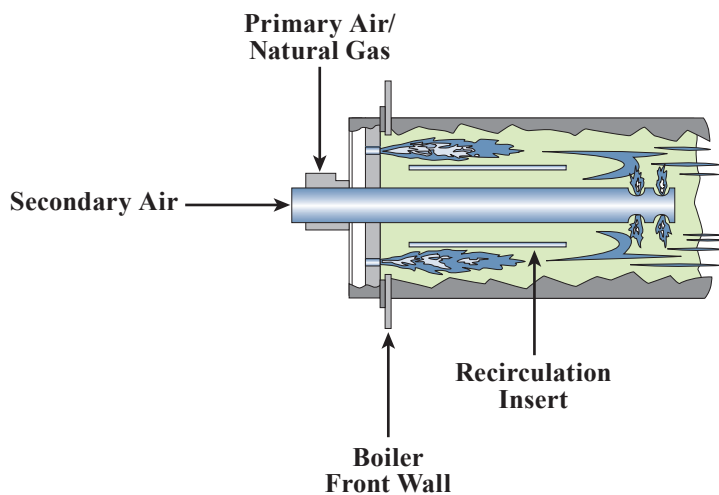
### Capabilities

Even though Century-Board will focus on the fly ash-based lumber, the following have been successfully tested in their process as the major ingredients: waste glass, sand, ashes from wood and municipal waste burning, wood flour, waste from metal smelting, red mud from aluminum refining, mixed recycled plastics, coral dust, rice hulls and rice hull ash, agricultural plant ashes, waste cotton and polyester fibers, paper processing wastes, heavy metal contaminated waste, contaminated soil, foundry sand, sewage sludge, slate dust, and rubber tires.

## New Burner Significantly Reduces Emissions Compared with Conventional Technology

The forced internal recirculation (FIR) burner combines several techniques to dramatically reduce NO<sub>x</sub> 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<sub>x</sub> formed in the combustor.

The FIR burner was developed by GTI and several sponsors, including DOE. The FIR burner technology is licensed to Johnston Boiler Company (fired tube 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 fired tube 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 Johnson Boiler Company for fired tube boilers
- ◆ Operating on 22 boilers in 2005

## Applications

Currently used in fired tube 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<sub>x</sub> through staged combustion with internal recirculation of products of partial combustion. Burner design is suitable for new or retrofit applications on a wide range of combustion chamber configurations.

## Benefits

### Emissions Reductions

Results in very low NO<sub>x</sub> 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

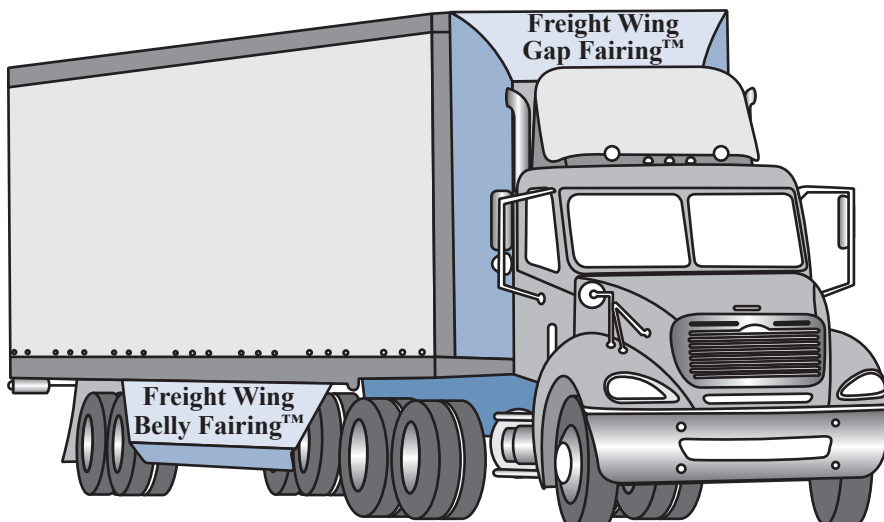
Reduces developmental, operating, maintenance, and capital costs compared with “current generation” low-NO<sub>x</sub> burner systems.

## IMPACTS

### 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. Freight Wing arranged a testing partnership with Transport America to retrofit five of their trailers for an operational test. These tests enabled Freight Wing to identify some problems and finalize the designs. The product was marketed starting in the fall of 2004, and soon thereafter the company made its first sale of two belly fairings and two gap fairings to a fleet called LVL, Inc., in Little Rock, Arkansas. In 2005, Freight Wing sold 48 fairings to ten major trucking fleets. Additional research is also underway to develop second-generation designs using different materials and aerodynamic concepts.



*Freight Wing Fairings Installed on a Semi-Trailer*

### Overview

- ◆ Developed and marketed by Freight Wing, Inc.
- ◆ Commercialized in 2004.
- ◆ Freight Wing fairings currently used by 11 trucking fleets in the United States

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.002	0.002

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.001	0.0	0.038

### Applications

The Freight Wing fairings are used on semi-trailers to reduce the effects of aerodynamic drag

### Capabilities

- ◆ Reduces aerodynamic drag on semi-trailers.
- ◆ Retrofits on existing semi-trailers.

### Benefits

#### Energy Savings

Reduces fuel usage by 7%.

#### Emission Reduction

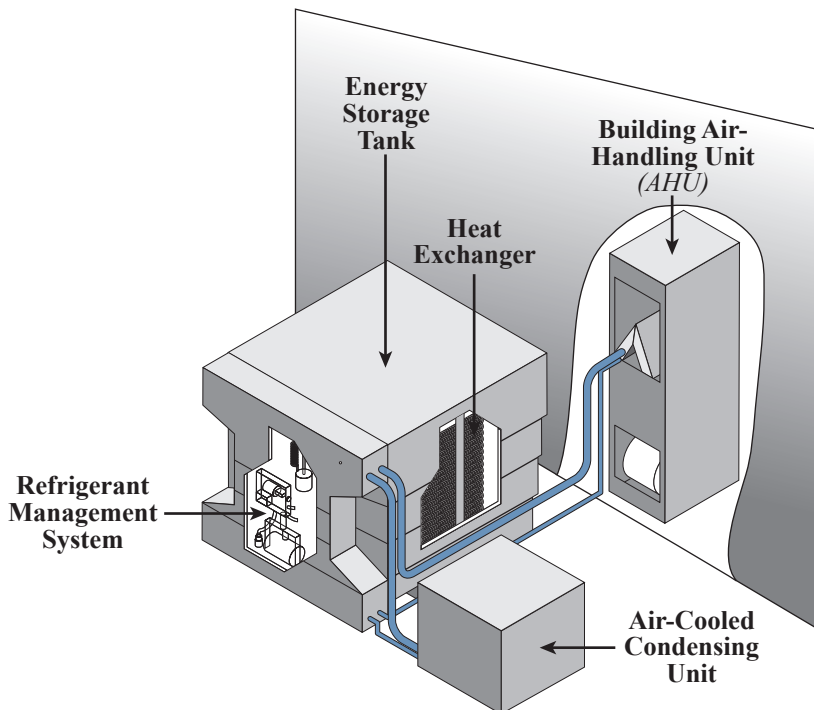
Reduces emissions of combustion products, including particulates, SO<sub>x</sub>, NO<sub>x</sub>, and CO<sub>2</sub>.

## 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®. The Ice Bear storage module was engineered to complement 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 and an air-cooled condensing unit operate 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 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 light commercial AC applications.



Ice Bear Storage Module

## Overview

- ◆ Base technology developed by Powell Energy Products, Inc.
- ◆ Patents acquired by Ice Energy, Inc. in 2003
- ◆ Commercialized by Ice Energy, Inc. in 2005

## Applications

Used in conjunction with 3.5-to-20 ton AC units in markets such as

- ◆ Small to big-box retail
- ◆ Small businesses and office buildings
- ◆ Restaurants
- ◆ Fire stations, libraries, and community centers
- ◆ Branch banks and schools

## 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

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

### Emissions Reductions

From studies sponsored by the California Energy Commission and the Sacramento Air Quality Management District, reduces emissions from 23% to 40%. Reduces NO<sub>x</sub> emissions equivalent to taking a car off the road for each unit.

### Energy Savings

Depending on climate zone and application, reduces energy requirements by 5% to 25%.

## 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 United States 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

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

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
1002	69.4

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.521	40.3	10.7	1510

### Applications

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

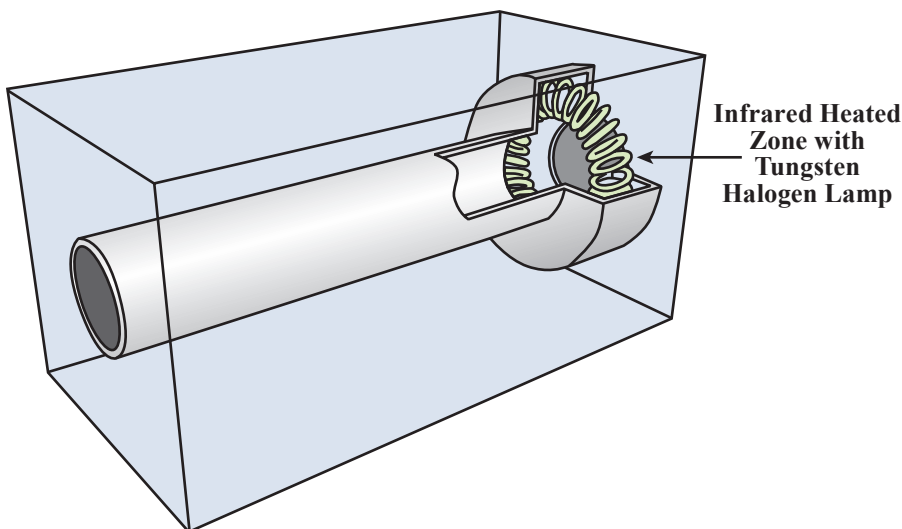
### Capabilities

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

## New Heating System Results in Fewer Repetitive Stress Injuries While Saving Energy

Employees of General Motors, Delphi Automotive Steering Systems in Athens, Alabama, suffered repetitive stress injuries from placing protective polymer boots over car steering wheel assemblies. Delphi came to Oak Ridge National Laboratory (ORNL) requesting the development of a heating technology to heat and expand the lower 2 inches of a polymer boot without using hot fluids or heating the worker or surroundings. The infrared boot heater was developed from these requirements. A tungsten halogen lamp based infrared heater goes from cold to full power in 0.2 second and shuts down in less than a second.

The technology converts electrical energy to radiant energy at 90% efficiency. The heat can be delivered to only the areas needing to be heated, and the design can be cold walled. Because the polymer expands, the force required for installation is virtually eliminated, thus reducing repetitive stress injuries. The subsequent cooling also results in an improved seal. A single infrared boot heater saves 6.25 million Btu over conventional electrical rod type heating in one year.



*Infrared Polymer Boot Heater*

## Overview

- ◆ Developed by Oak Ridge National Laboratory
- ◆ Commercialized in 2000
- ◆ 5 units installed in the United States

## Applications

Designed to heat thermoplastic and polymer boots for applications that require placing boots on steel parts (steering assemblies, CV joints, etc.)

## Capabilities

- ◆ Capable of rapid heating (at 50-400°C/second) and cooling.
- ◆ Does not require any medium such as gas for transmission and is noncontact.
- ◆ The radiant energy couples only to the part of the polymer that requires it.

## Benefits

### Increased Productivity/Safety and Improved Product

The expansion of the polymer resulting from heating virtually eliminates the force required for installation. The subsequent cooling also results in an improved seal.

### Reduced Waste and Materials

Grease formerly used for installing polymer boots is eliminated.

# In-Situ, Real Time Measurement of Melt Constituents

## IMPACTS

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

A new probe uses laser-induced breakdown spectroscopy (LIBS) to determine the elemental constituents in an aluminum, glass, and steel melt. 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, into a molten aluminum sample, 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.

In the glass industry, both the melt and raw ingredients can be monitored. The probe has several applications in the aluminum and steel 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.

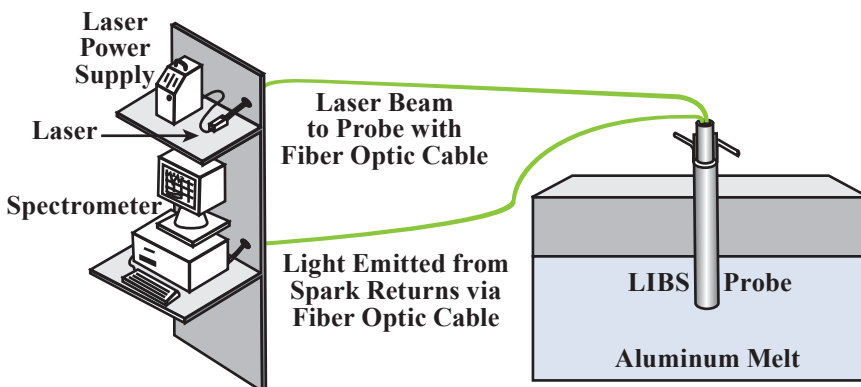
## Benefits

### Productivity and Profitability

Determining melt constituents and temperature in-situ, real-time, and simultaneously 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.



*Laser-Induced Breakdown Spectroscopy System*

## Overview

- ◆ Developed and marketed by Energy Research Company
- ◆ Installed on an aluminum melt furnace in 2003
- ◆ Installed in a glass plant in 2004

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.481	0.222

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.026	3.53

## Applications

Identifies elemental constituents in metal and glass melts during the alloying and fabrication process

## Capabilities

- ◆ Measures aluminum melt constituents with 5% accuracy and a 0.002% minimum detection limit.
- ◆ Monitors trace alkali metal content in electronic glass compositions.

## 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

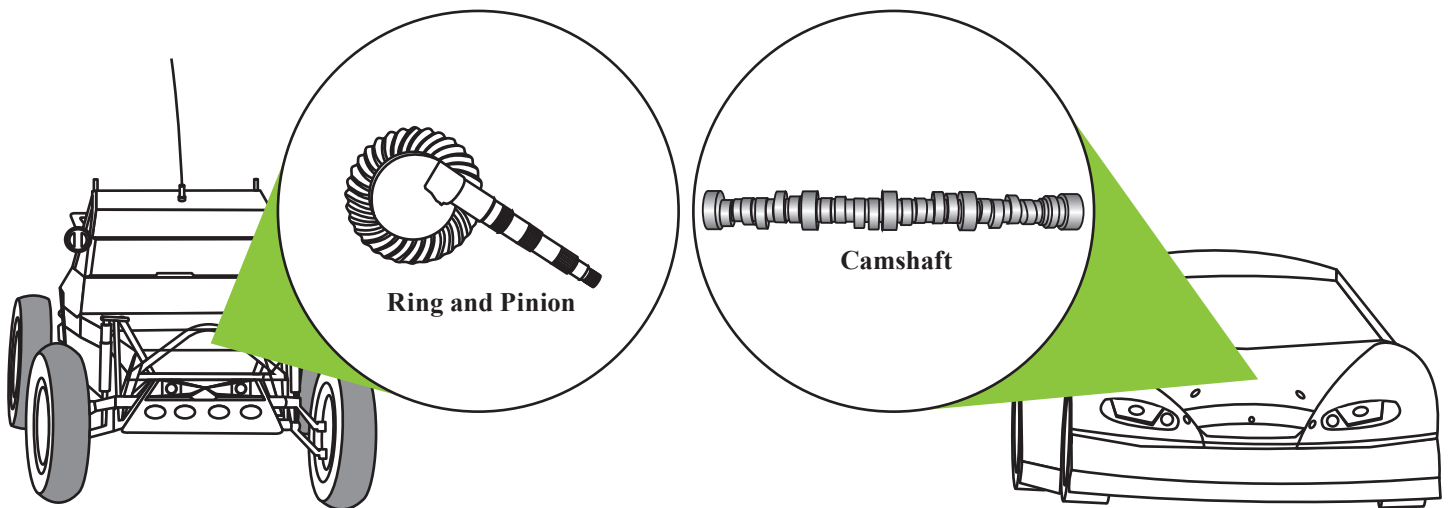
- ◆ Developed by a consortium of project partners including the Center for Heat Treating Excellence, Metal Processing Institute – Worcester Polytechnic Institute, Northwestern University, and QuesTek
- ◆ Commercialized by QuesTek in 2003

### Applications

High-performance gear and bearing applications for the transportation sector. 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*



# Method of Constructing Insulated Foam Homes

## IMPACTS

### An Innovative Building System That Is Energy Efficient, Structurally Sound, and Easily Constructed

The concerns of the home building industry center around increasing productivity in the construction process, improving the quality of American homes, expanding opportunities for affordable home ownership, enhancing the U.S.'s competitive position relative to global markets, and ensuring the cost-effective and energy-efficient operation and maintenance of homes.

With the help of a grant from DOE's Inventions & Innovation Program, Amhome USA, Inc., developed a method of constructing buildings that are both energy efficient and structurally sound. The new 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 primary innovation of this system is the way the walls are constructed, which requires less labor compared with traditional wood-frame houses.

## Benefits

### Environmental

The Amhome method saves timber by using 35% less wood than frame homes and saves insulation by using recycled insulation in the roof.

### Productivity/Quality

Homes using the innovative EPS foam can be built faster than traditional wood-frame homes. The homes' superstructure is reinforced with concrete and steel for more stability, and the entire house is united into one solid piece.



*Concrete Being Pumped into the Wall Cavity of an Insulated Foam Home*

## Overview

- ◆ Commercialized by Amhome USA, Inc., in 1996
- ◆ 326 homes constructed through 2005
- ◆ Marketed by Home Corporation International, Inc.

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.038	0.006

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.001	0.095

## Applications

- ◆ New single-family residences
- ◆ New multifamily dwellings
- ◆ Small commercial buildings

## Capabilities

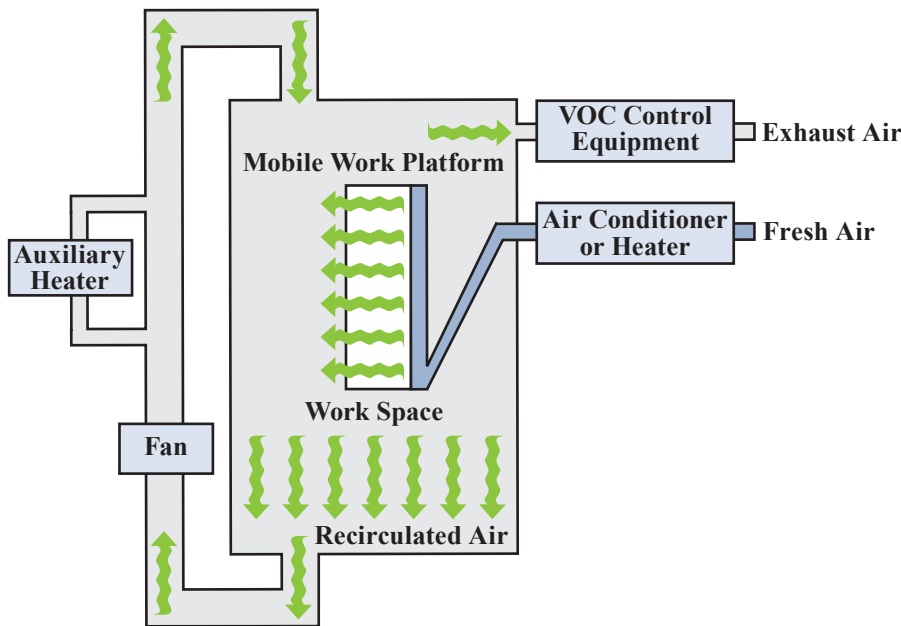
- ◆ Provides an R-40 wall using EPS foam insulation panels to form the exterior walls.
- ◆ Provides an R-50 roof/ceiling using EPS foam between the rafters.

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

## New Surface-Coating Technique Reduces Air Pollution and Energy Use

Volatile organic compounds (VOCs) are released during the application of spray coatings in paint enclosures, which expose workers to toxins, create air pollution emissions, and create 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 comfortable temperatures and control pollution emissions.

A new spray booth technology developed by Mobile Zone Associates with the help of a grant from the Inventions and Innovation Program greatly reduces the amount of energy needed to heat and cool ventilation air during surface coating operations. 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 guidelines. The technology is currently being used by the US 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
- ◆ 1 installation operating in the United States in 2005

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.031	0.007

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.001	0.001	0.120

## Applications

Applying 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 OSHA, EPA and NFPA standards for worker conditions.

## Benefits

### Profitability

The technology 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

Testing has shown the technology is able to maintain or improve production speed and quality.

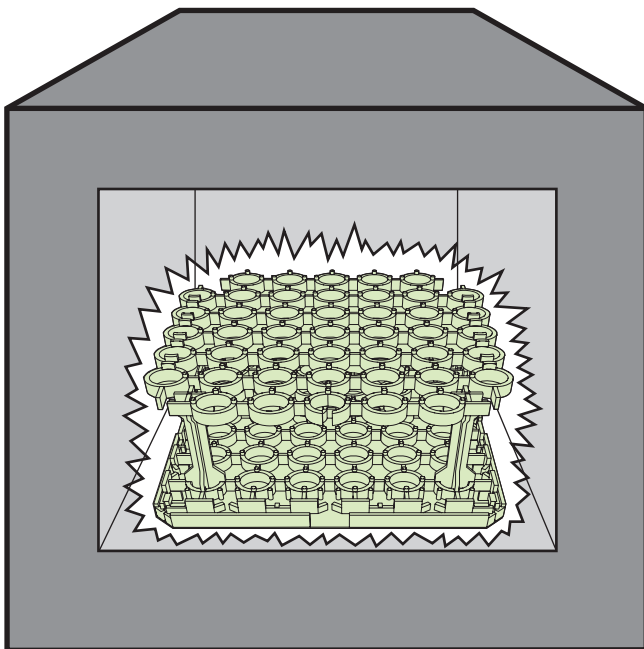
# Nickel Aluminide Trays and Fixtures Used in Carburizing Heat Treating Furnaces

## IMPACTS

### Advanced Material Use Results in Decreases in Energy and Operating Costs

Typically, 90% of all heat treating furnace problems are caused by alloy issues such as failure of assemblies at high heat and short life of the assembly racks. Since 1992 Delphi Corporation, Oak Ridge National Laboratory, and DOE have been working together on nickel aluminide ( $\text{Ni}_3\text{Al}$ ) fixtures for furnaces. The research and development has focused on nickel aluminide alloys (including alloy development) and the welding, melting and casting technologies associated with  $\text{Ni}_3\text{Al}$ .

Delphi installed 500  $\text{Ni}_3\text{Al}$  base trays as part of their carburizing furnaces, which are very large gas-fired systems (up to 150 ft long) and heat treat hundreds of tons of steel per day. The  $\text{Ni}_3\text{Al}$  fixtures last 3 to 5 times longer than current high-performance steel alloys and are at least 3 times stronger at operating temperature than conventional alloys. These properties result in improved energy and production efficiencies. Using the stronger  $\text{Ni}_3\text{Al}$  fixtures enabled Delphi to meet production goals with only two new furnaces instead of the three that would have been required with the current technology fixtures.



Heat Treating Furnace Containing Nickel Aluminide Trays

### Overview

- ◆ Developed by Delphi Corporation and Oak Ridge National Laboratory
- ◆ Commercialized in 2001 by Alcon Industries, Inc.

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.034	0.0

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.0

### Applications

Nickel aluminide can be used in the heat treat industry for trays, fixtures, radiant tubes, cast link belts, rollers, fans, and miscellaneous furnace parts.

### Capabilities

Nickel aluminide alloy is a high-strength heat-resistant alloy that is very resistant to carburization. The  $\text{Ni}_3\text{Al}$  fixtures last 3 to 5 times longer than current high-performance steel alloys and are at least 3 times stronger at operating temperature than conventional alloys.

### Benefits

#### Profitability

The ability to meet production requirements in two furnaces instead of three has increased profitability by avoiding capital expenditure and reducing maintenance, energy, and alloy costs.

#### Reliability

The high strength and lower carburization of the trays and fixtures increase the life of the trays and has significantly decreased furnace problems.

## Photovoltaic (PV) Roof Tile Assembly Delivers Clean Solar Electricity to Buildings

With the help of a grant from the Inventions and Innovation Program, PowerLight Corporation has developed the PowerGuard roofing system that offers building insulation, shading, roof protection, and solar power generation encompassed in a single roofing panel. The roofing panel includes a photovoltaic module mounted on a 3-inch-thick styrofoam board coated with a proprietary, cementitious coating. Designed specifically for flat or slightly sloped commercial and industrial building roofs, the panel works as a retrofit over existing roofs, as a new roof with new construction, and for re-roofing. The system can be tailored to capacities of 1 kW or greater and allows easy expansion.

PowerGuard installations are saving energy and money from New York to Hawaii as well as overseas. A 540-kW system installed at the Santa Rita Jail in Dublin, California reduces the jail's annual energy load by over 800,000 kWh. On the opposite coast, a 186-kW system installed atop Tompkins County Public Library in Ithaca, New York generates 200,000 kWh per year despite the fact that Ithaca receives only 60% of the solar radiation compared with Southern California. Electricity demand is reduced when it is most expensive, such as during peak demand periods on hot summer days. Reducing the load during peak demand periods also decreases the threat of blackouts and other problems associated with overloading the utility grid.

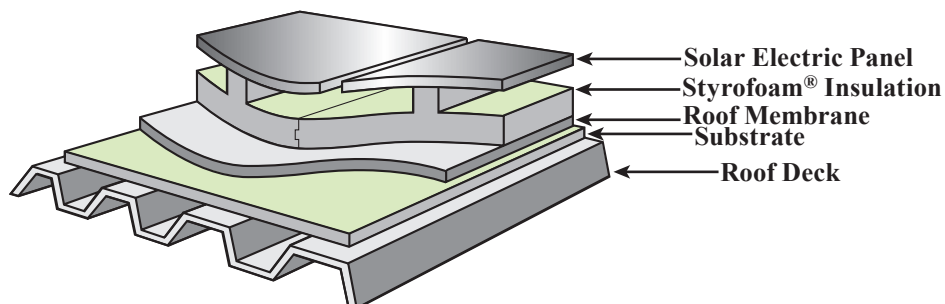
## Benefits

### Ease of Installation

PowerGuard can tailor systems from 1 kW up to the building's peak load and offers easy expansion. The panels use a tongue-and-groove design to interlock adjacent panels for fast installation without penetrating existing roofing material.

### Product Life

The lightweight PowerGuard system is designed to survive severe weather conditions and protects the roof membrane from harsh UV rays and thermal degradation for up to 30 years, approximately doubling the life of the roof.



PowerGuard System Cutaway View

## Overview

- ◆ Developed by PowerLight Corporation
- ◆ Commercialized in 1994
- ◆ Installations from New York to Hawaii and overseas.

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.385	0.141

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.001	0.030	0.023	2.77

## Applications

- ◆ Installed on commercial or residential buildings that have flat or low-slope roofs
- ◆ Economical for building owners and utilities located in summer-peaking service areas where utilities offer time-of-use rates

## Capabilities

- ◆ PowerGuard is a photovoltaic power system in which the photovoltaic modules are integrated with the materials used for a building's roof.
- ◆ Feeds clean AC power into the building, displacing high daytime utility rates.

# Predicting Corrosion of Advanced Materials and Fabricated Components

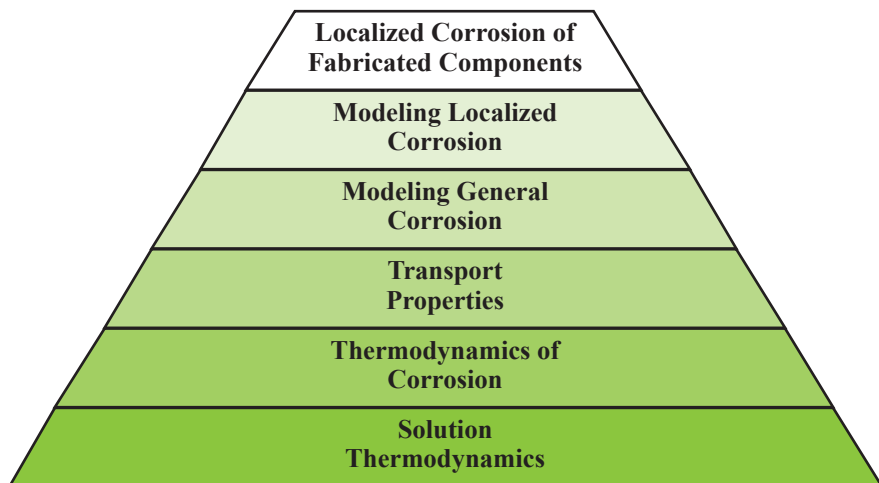
## IMPACTS

### 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 project 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.
- ◆ Commercialized in 2005
- ◆ 33 customers leasing the CorrosionAnalyzer in the United States

### Applications

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.

## 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

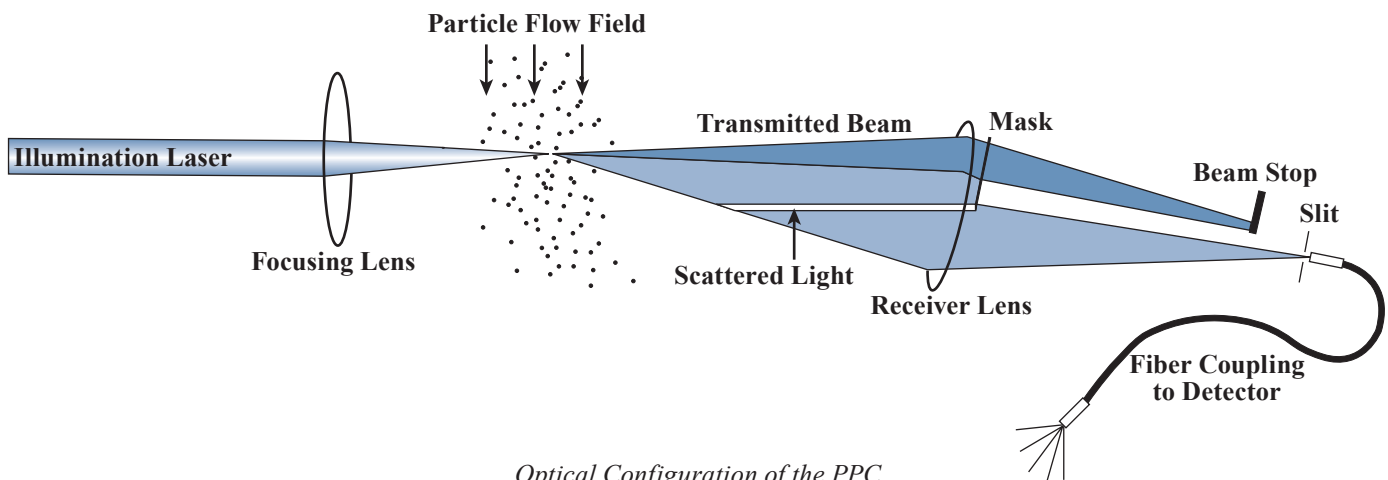
- ◆ Developed and being marketed by Process Metrix, LLC (formerly Insitec)
- ◆ Commercialized in 2004
- ◆ Six units being used in the United States in 2005

### Applications

Process particle counters are applicable 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

## IMPACTS

### 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> 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<sub>x</sub> emissions.

## Benefits

### Emissions Reductions

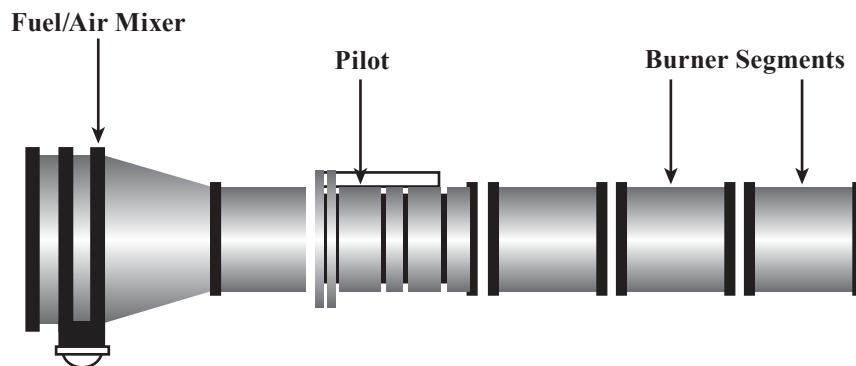
Simultaneously achieves low NO<sub>x</sub>, CO, and unburned hydrocarbon emissions due to the fully premixed burner design.

### Productivity

This simple technology approach to low NO<sub>x</sub> emissions results in little downtime; any problems are easily repaired.

### Profitability

Eliminates the need for “post-combustion” pollution-control devices to reduce the cost of NO<sub>x</sub> 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
- ◆ Commercialized in 1999
- ◆ Since 1999, over 200 burners have been installed in the United States

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.135	0.042

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.005	0.660

## Applications

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

- ◆ Ultra-low NO<sub>x</sub> and CO industrial burner capable of achieving sub-9 ppm NO<sub>x</sub> and sub-50 ppm CO emissions.
- ◆ No loss in thermal efficiency relative to current 30 ppm burner designs with high efficiency controls option.
- ◆ Stable operation over a broad range of emission levels, from sub-7.5 ppm NO<sub>x</sub> to sub-30 ppm NO<sub>x</sub>, with one burner design.

## New Fastening System Reduces Energy Use of Buildings

Roofing systems for industrial and commercial buildings continue to make significant strides in their performance and durability. Fasteners are essential to keeping many of these roofs intact by joining of pieces or multiple layers. However, the combination of newer roofing materials, known as singly-ply membranes, with conventional metal fasteners leads to increased heat loss. This loss occurs because the metal screw and plate of the fastener are only minimally insulated from the surroundings and conductive heat flow occurs through the thermal bridge created by the metal fastener.

The RR-1 Insulated Screw Cap Assembly, developed by The Romine Company of Newark, Ohio, with the aid of a grant from the DOE's Inventions and Innovation Program, is a simple but effective solution to heat loss and back-out problems found with many conventional fasteners. This improved fastener consists of an injection-molded fiberglass-reinforced nylon anchor, soft insulating plug, and optional grappel washer. The system is simple to install and extremely strong.

The energy advantage of the RR-1 results from the fastener depth and insulation value. The metal screw portion of the fastener is embedded at least one inch into the insulation board, reducing the heat transfer through the fastener. A foam plug is inserted in the cavity created and acts as an insulator. The new fastener design is more resistant to condensation and corrosion, which makes the fastener less likely to corrode and lose holding strength over time.

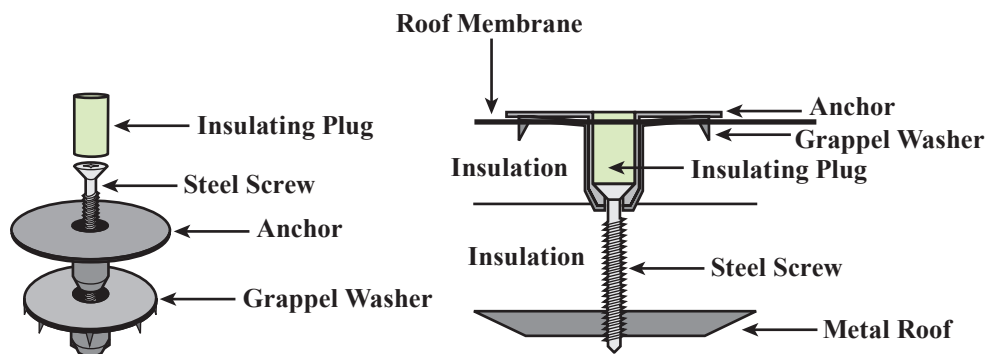
## Benefits

### Productivity

The simple flush mount requires less torque and time to screw in (no predrilling required) and provides a smoother finish than conventional fasteners. The RR-1 is also produced from less costly materials, so it is a more economical choice than other all-plastic fasteners.

### Durability

In tests conducted on wind uplift, the strength of the RR-1 insulating fastener proved to be greater than the holding power of the metal decking. The RR-1 fastener also resists back-out. These features, and fastener tear-out, are particularly critical with the newer flexible membrane roofing materials.



The RR-1 Insulated Screw Cap Assembly

## Overview

- ◆ Developed and marketed by The Romine Company
- ◆ Commercialized in 1997
- ◆ 315,200 units sold through 2005

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.011	0.002

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.039

## Applications

The technology may be used on commercial and industrial buildings with membrane roofs and metal roofs. The screw caps may also be applied as a retrofit to older roofs.

## Capabilities

- ◆ Replaces conventional metal or plastic fasteners to improve the energy performance in building roofs.
- ◆ Optimized for fastening single-ply roofing or rigid insulation to metal decking.
- ◆ Resists typical problems for fasteners including back-out and corrosion.



# Simple Control for Single-Phase AC Induction Motors in HVAC Systems

## 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 the 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 airflow 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 airflow to only what is needed.

#### Product Quality

Reduces noise for sleeping hospital patients and hotel guests and provides quieter conditions for classrooms and conference rooms.

### Overview

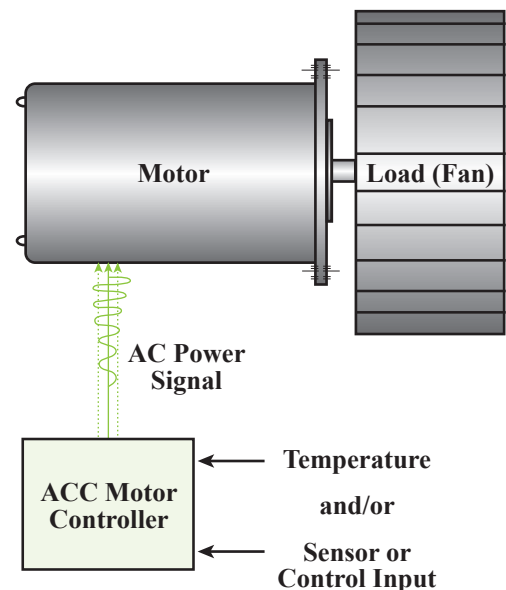
- ◆ Developed by Opto Generic Devices, Inc.
- ◆ Commercialized in 2005

### Applications

Controls small single-phase motors up to 240 V<sub>AC</sub> and 12 amps full load, including HVAC system fans found in hospitals, residences, hotels, nursing homes, schools, and other institutions. Also controls fan coils, unit ventilators, and exhaust fans.

### Capabilities

- ◆ Accepts one or two analog inputs, including temperature and low DC voltage from a sensor or building management system.
- ◆ Adaptively varies the airflow across fan coils to control indoor climate.
- ◆ Reduces system noise.



*OGD Electric Motor Control*

## New Sensors Rapidly and Accurately Detect Hydrogen, Improving Industrial Safety and Efficiency

Molecular hydrogen, H<sub>2</sub>, is a combustible gas that is produced in large quantities by many industries and has a broad range of applications. When H<sub>2</sub> 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<sub>2</sub>, these methods require bulky, expensive equipment.

Using solid-state technology developed at the U.S. Department of Energy's 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

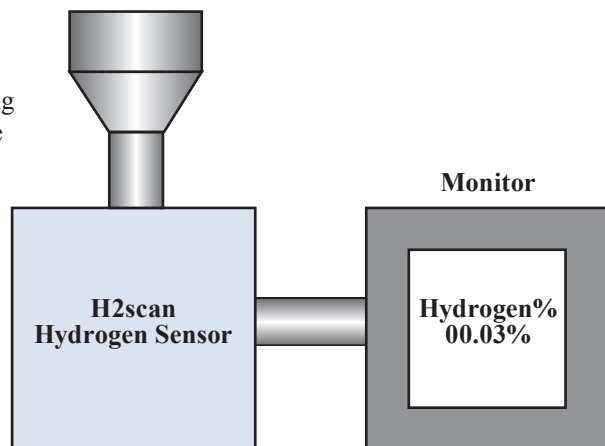
Hydrogen plays a critical role in float-glass manufacturing, an energy-intensive industry that produces 2.6 million tons of glass per year. Improper monitoring can substantially increase defects and waste energy.

### Productivity

The solid-state devices can detect 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

Solid-state sensors 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
- ◆ Commercialized in 2003
- ◆ Over 850 units sold through 2005

## Applications

- ◆ Monitoring trace levels of H<sub>2</sub> in high-purity feed gases for chemical processes
- ◆ Monitoring hydrogen production from methane and refinery offgases, where hydrogen is often mixed with carbon monoxide
- ◆ 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.

## 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 by 15% to 20%. A typical furnace contains 10 radiant tubes, which use an average of 3 SpyroCors per tube. Through 2005, 137 furnaces have been equipped with SpyroCors for a savings of 534 billion Btu.

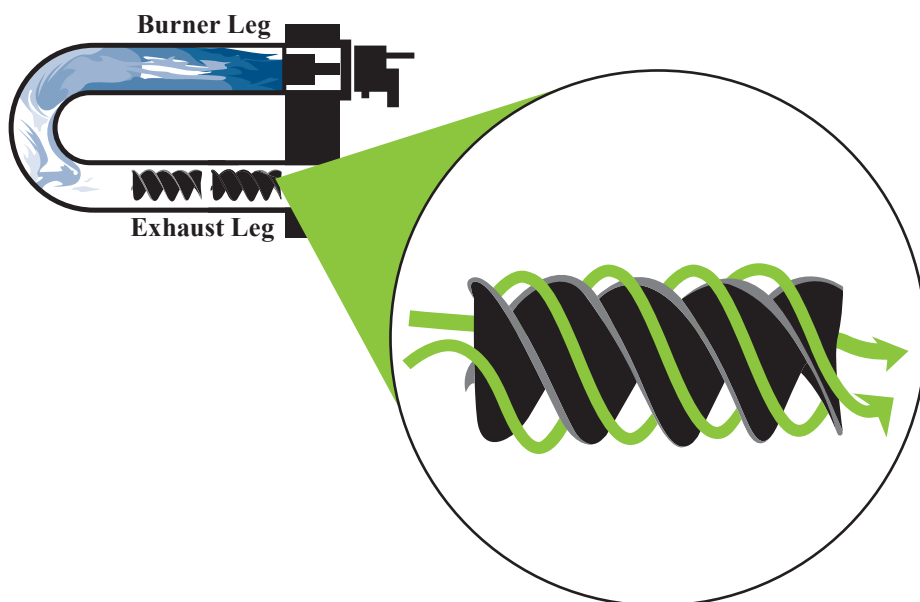
## Benefits

### 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
- ◆ More than 4100 units sold through 2005

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.834	0.534

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.062	8.48

## Applications

To be inserted into radiant tube heaters typically used in metal heat-treating furnaces that use natural gas burners

## 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-g 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 the 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.

## Overview

- ◆ Developed and marketed by SuperDrive, Inc.
- ◆ Commercialized in 2004
- ◆ Currently installed on three transit buses in Piqua, OH

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.003	0.002

## Emissions Reductions

(Thousand Tons, 2005)

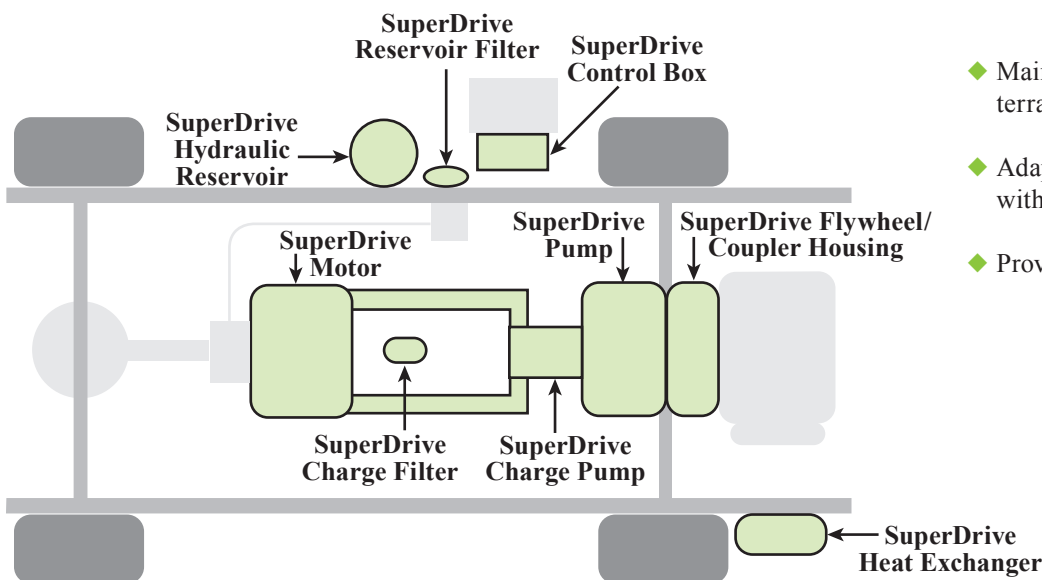
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.001	0.0	0.037

## Applications

The SuperDrive system 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.
- ◆ Adapts to unique characteristics or trucks with different engines and transmissions.
- ◆ Provides hydraulic braking.



SuperDrive Components

# Three-Phase Rotary Separator Turbine

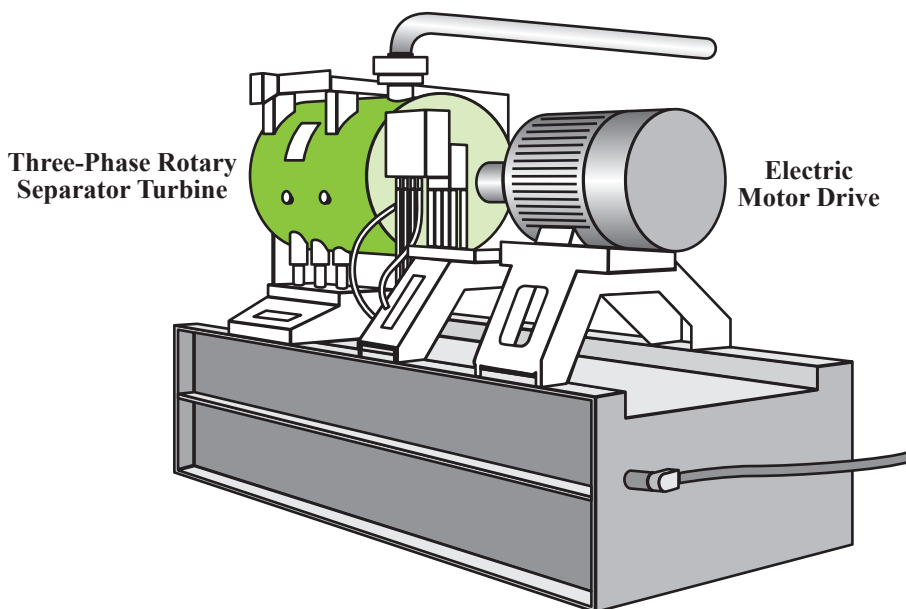
## IMPACTS

### New Turbine Efficiently Separates Gas, Oil, and Water While Generating Electricity from Waste Energy

Using a NICE<sup>3</sup> 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 2005 by Multiphase Power and Processing Technologies
- ◆ 2 units operating in the United States in 2005

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.024	0.009

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.002	0.001	0.176

### Applications

Replaces traditional separation technologies used in petroleum and chemical industries

### Capabilities

- ◆ Creates its own source of clean shaft power.
- ◆ Weights 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.

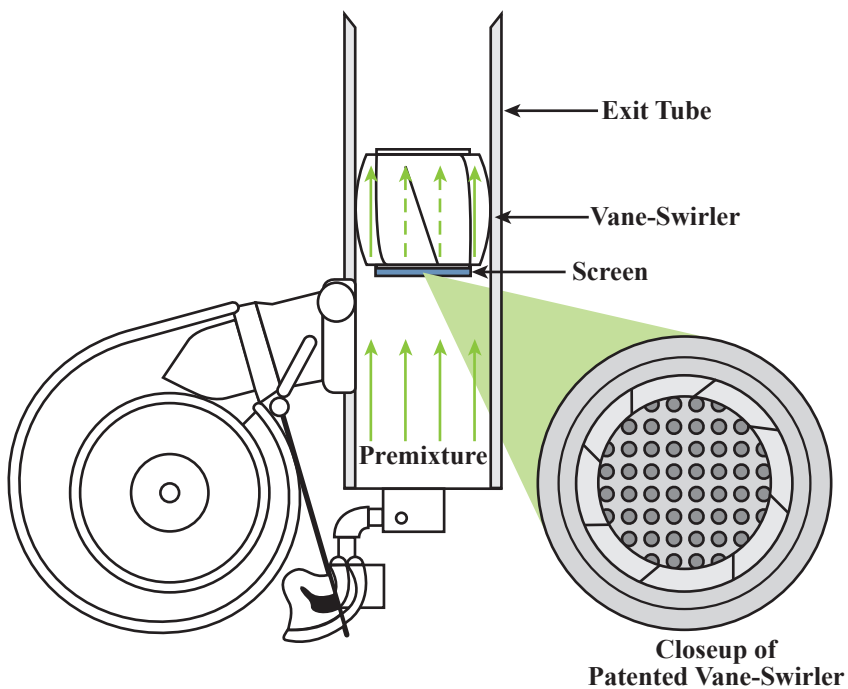
#### Environmental

Purifies the process water without adding harmful chemicals commonly used in traditional separators.

## Reduction of Burner NO<sub>x</sub> Production with Premixed Combustion

Industries that are dependant on combustion processes are faced with more stringent environmental regulations to reduce NO<sub>x</sub> emissions. Some states require NO<sub>x</sub> emissions reductions as great as 90% for chemical and refining industries. The recently developed M-PAKT™ Ultra-Low NO<sub>x</sub> Burner uses lean premixed combustion gases and low swirl flow of combustion gases to achieve NO<sub>x</sub> emissions levels <10 ppm (an NO<sub>x</sub> 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 Industrial Technologies Program. 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<sub>x</sub> 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
- ◆ Estimated to reduce NO<sub>x</sub> by over 220,000 pounds in 2005

## Applications

The novel ultra-low NO<sub>x</sub> burner concept can be used on a wide range of combustion systems:

- ◆ Furnaces and boilers
- ◆ Chemical and refining industry process heaters
- ◆ Gas turbines

## Capabilities

Reduces thermal NO<sub>x</sub> 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<sub>x</sub> solutions because the components are simple and are made from conventional materials.

### Pollution Reduction and Energy Efficiency

Typically reduces NO<sub>x</sub> to less than 10 ppm without compromising energy efficiency.

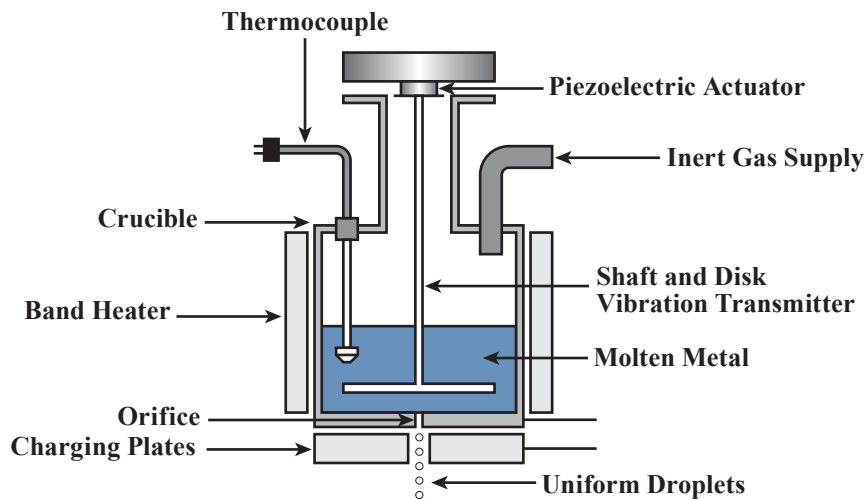
# Uniform Droplet Process for Production of Alloy Spheres

## 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, which 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 United States and four Japanese firms who are exploring the Ball Grid Array application

### Applications

Directly benefits 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.

## New System Uses Microwave Energy to Dry Materials Uniformly at Half the Cost

Industrial Microwave Systems LLC with assistance from a Department of Energy NICE<sup>3</sup> 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 serpentine 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. Leakage of microwave energy is greatly reduced by using choke flanges to limit the amount of radiation reaching outside openings.

### Benefits

#### Energy Savings

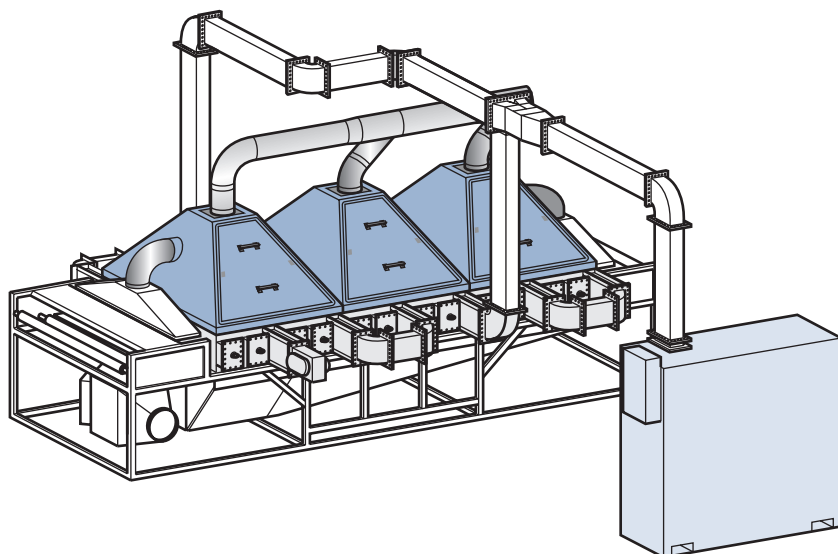
Reduces natural gas heating requirements by 20% to 50% saving up to 12 billion Btu/year for a typical plant.

#### Pollution Control

Reduces greenhouse gas emissions by approximately 50% with 68% of particulates eliminated.

#### Productivity and Profitability

Reduces drying stress because of no contact drying, lower maintenance costs because of fewer movable parts.



*Microwave-Drying System*

### Overview

- ◆ Developed by Industrial Microwave Systems LLC
- ◆ Commercialized in 2000
- ◆ Currently operating at 6 facilities in the United States and 3 in foreign countries
- ◆ Five demonstration units being tested in the United States

### Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.114	0.024

### Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.001	0.003	0.400

### Applications

- ◆ Fabrics
- ◆ Agricultural and pumpable food products
- ◆ Industrial filters and insulation
- ◆ Medical dressings
- ◆ Paper products
- ◆ Geotextiles, carpeting, and roofing materials
- ◆ 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.



# Waste Fluid Heat Recovery System

## IMPACTS

### Heat Recovery System Extracts Energy From Waste Fluids

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

### Benefits

#### Energy Savings

Reduces energy consumption by recovering heat usually lost through disposal of waste. Can recover up to 70% of the heat carried to settling ponds or sewers. Hospitality industry installations have demonstrated a simple payback of 1.7 years.

#### Other

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

#### Productivity

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

#### Profitability

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

### Overview

- ◆ Invented and developed by WaterFilm Energy, Inc.
- ◆ Commercialized in 1997
- ◆ Over 2460 units installed in the United States

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.115	0.027

### Emissions Reductions

(Thousand Tons, 2005)

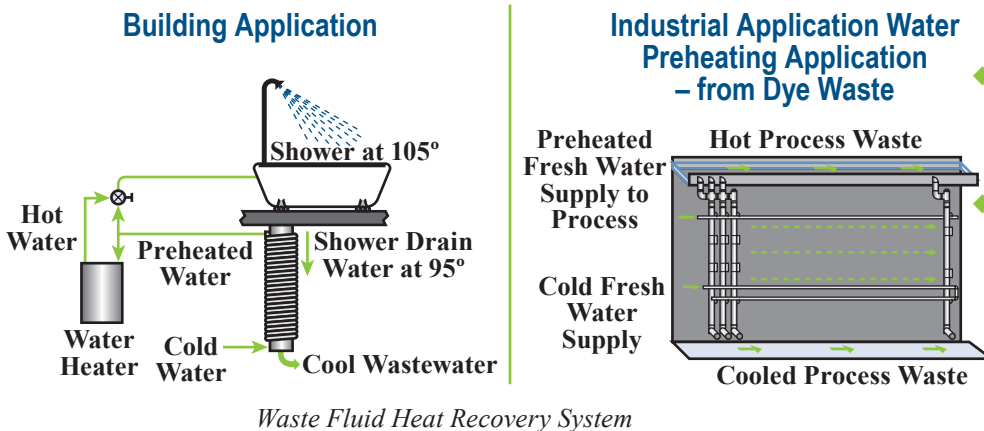
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.003	0.004	0.481

### Applications

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

### Capabilities

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



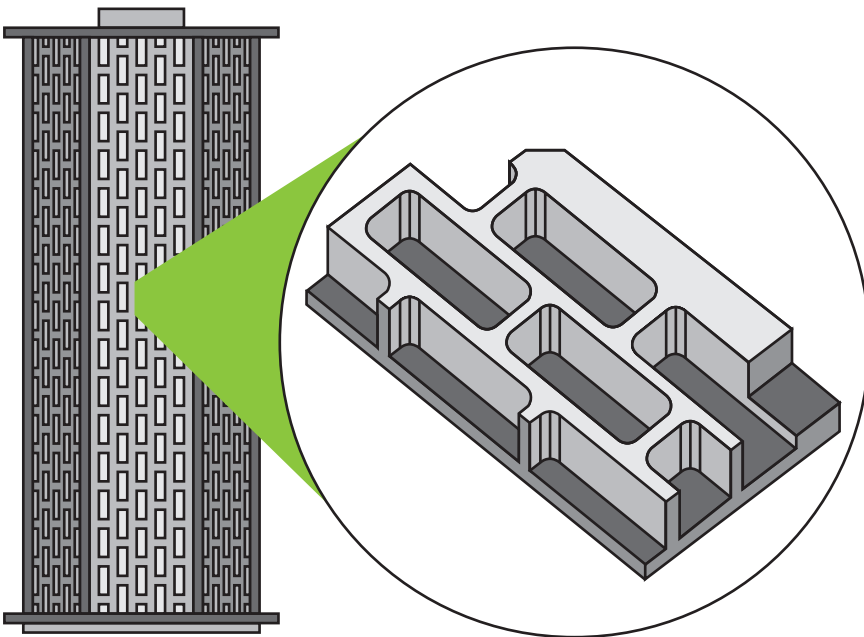
Waste Fluid Heat Recovery System

## Waste-Minimizing Plating Barrel Increases Productivity

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

The Whyco barrel, developed by Whyco Technologies, Inc. and demonstrated using a NICE<sup>3</sup> grant, is constructed by machining a staggered pattern of rectangular-shaped pockets into the traditional thick-walled polypropylene barrel. After machining, the barrel's structure resembles a honeycomb formation into which thousands of small, now shorter, holes are drilled. This patented staggered-cell design allows for the greatest number of holes per open area while maintaining structural integrity. This thin-walled honeycomb structure increases the hydrodynamic pumping action during barrel rotation, creating greater solution transfer than the traditional barrel design. The Whyco barrel also has higher current density plating leading to faster plating cycles, reduced bath concentration due to higher mass transfer rates, and better plating of difficult chemistries such as alloy plating.

To date, more than 1100 of these innovative barrels are in use at Whyco and other plating companies.



*Whyco's Staggered-Cell Design*

## Overview

- ◆ Developed by Whyco Technologies, Inc. and marketed by Selectives
- ◆ Commercialized in 1997
- ◆ Currently 1100 plating barrels in use

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
3.54	0.526

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.002	0.078	0.077	9.72

## Applications

Metal-plating operations; metal finishing and electroplating

## Capabilities

Increases process efficiency of metal plating operations.

## Benefits

### Energy Savings

Energy savings from reduced process time and better plating efficiency.

### Productivity

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

### Use of Raw Materials

Due to better plating efficiency, product yields have improved by up to 40% while cycle times have decreased by up to 25%.

### Waste Reduction

Because this process reduces drag-out (drag-out refers to the chemical solution held in barrel holes by capillary action) barrel users have reported up to a 60% decrease in plating solution loss.

# Other Industries

## IMPACTS

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# Absorption Heat Pump/Refrigeration Unit

## Advanced Water Ammonia Absorption Cooling Finds Profitable Application in Refinery Operations

Refineries usually prefer ambient cooling with cooling towers because refrigeration systems cost more initially, create headaches in operating and maintaining compressors, and significantly increase the demand for electricity. With assistance from ITP and a grant from the Inventions and Innovation Program, Energy Concepts Company developed an advanced ammonia refrigeration unit powered by waste heat. It overcomes the disadvantages of a refrigeration system. It recovers fuel from reformer waste gas and raises the capacity of a catalytic cracker. The unit debottlenecks the net gas compressors in a cracker. The inlet vapors are cooled, which increases the compressor capacity.

A commercial unit operating in Commerce City, Colorado, is providing up to 265 tons of refrigeration capacity to refrigerate the reformer plant net gas/treat gas stream and is recovering a net 45,000 barrels/year of gasoline and LPG. The 290°F waste heat content of the reformer reactor effluent powers the unit. The absorption cooling system is directly integrated into the refinery processes and uses enhanced, highly compact heat and mass transfer components. The refinery's investment was paid back in less than 2 years as a result of increased recovery of salable product, which was formerly flared. It is important to note that the recent increase in fuel prices has lowered this system's payback considerably.

## Overview

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

## Energy Savings

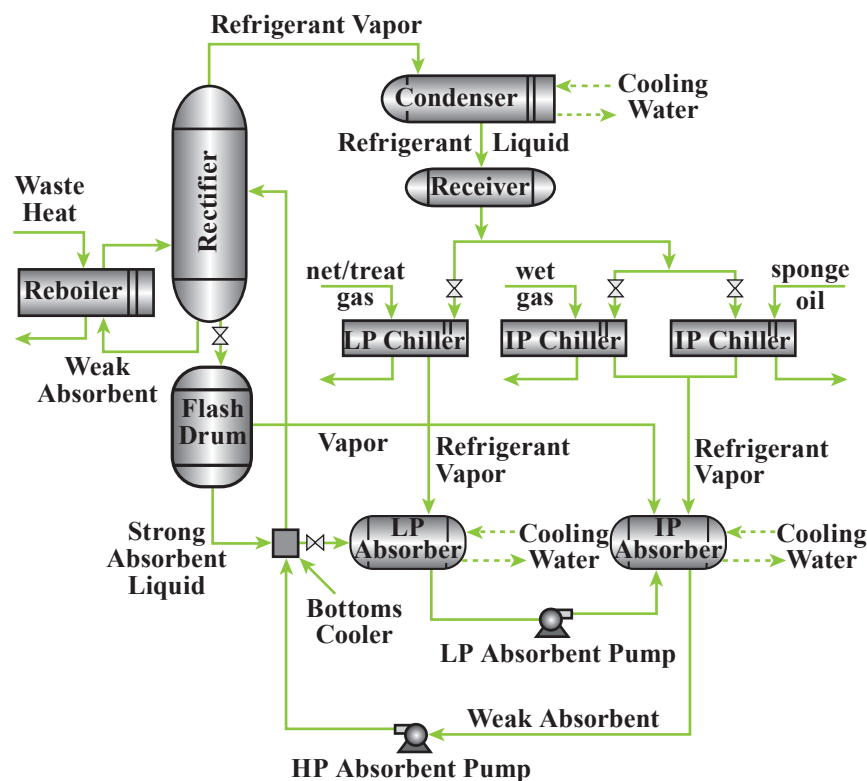
(Trillion Btu)

Cumulative through 2005	2005
2.54	0.306

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.002	0.178	0.047	6.66



Absorption Heat Pump/Refrigeration Unit

## Applications

- ◆ Resource recovery in the petroleum refining and chemical industries
- ◆ Refrigeration and space conditioning for commercial and industrial facilities

## Capabilities

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

## Benefits

### Profitability

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

# Advanced Membrane Devices for Natural Gas Cleaning

## IMPACTS

### New Membrane Cost Effectively Upgrades Sub-Quality Natural Gas

Carbon dioxide (CO<sub>2</sub>) 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<sub>2</sub>S) 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 DOE 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<sub>2</sub> and H<sub>2</sub>S 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<sub>2</sub> and H<sub>2</sub>S content into a pipeline-grade gas for domestic and industrial consumption.

### Overview

- ◆ Developed by Air Products & Chemicals
- ◆ Commercialized in 2001
- ◆ 110 CO<sub>2</sub>-removal units operating in the United States in 2005

### Applications

- ◆ Recovers CO<sub>2</sub> from associated gas in enhanced oil recovery programs
- ◆ Removes acid gas from natural gas

### Capabilities

Can reduce impurities to allow natural gas to meet pipeline specifications.

### Benefits

#### Environmental Quality

The PRISM membranes do not use any hazardous chemicals such as amines, which can cause environmental complications.

#### Ease of Installation

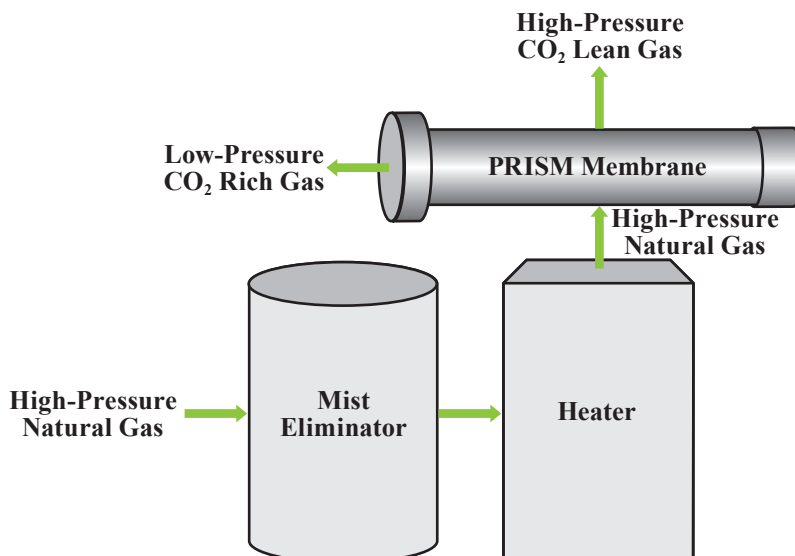
Units are lightweight and compact, thus facilitating their transportation and installation.

#### Profitability

The membranes are ideal for remote locations with limited utilities and sour natural gas.

#### Reliability

No moving parts mean minimal maintenance costs.



*CO<sub>2</sub> Removal Process Using the PRISM Membrane System*

# Brick Kiln Design Using Low Thermal Mass Technology

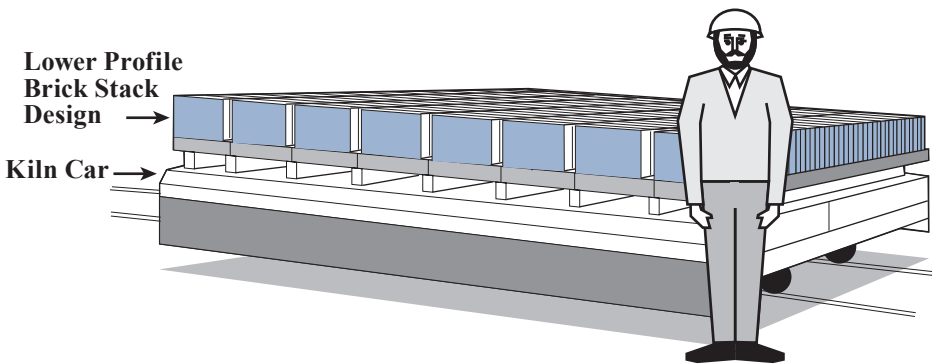
## Innovative Brick Kiln Using Low Thermal Mass and Low-NO<sub>x</sub> Technologies

Swindell Dressler and Pacific Clay Brick have successfully developed and demonstrated, using a NICE<sup>3</sup> grant, a tunnel-kiln design with a low thermal mass. This new 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<sub>x</sub> gas burners. These innovations result in a reduction in natural gas usage of 35% compared to a conventional kiln.

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

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

Several process changes reduce NO<sub>x</sub> emissions: lower kiln firing temperatures (2100°F versus 2250°F), newer high-velocity burners, and a fully automated Process Management System that will maintain set points, including furnace-zone and rapid-cool zone temperatures.



*New Low Profile Brick Kiln Car*

## Overview

- ◆ Developed by Swindell Dressler
- ◆ Commercialized in 1996
- ◆ 2 units operating in 2005

## Energy Savings

*(Trillion Btu)*

Cumulative through 2005	2005
0.280	0.032

## Emissions Reductions

*(Thousand Tons, 2005)*

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.004	0.514

## Applications

Brick and ceramic material kilns

## Capabilities

- ◆ Uses low thermal mass kiln design to reduce energy consumption and increase throughput.
- ◆ Has better process control with better placement of more but smaller burners.
- ◆ Employs low-NO<sub>x</sub> burners.

## Benefits

### Productivity

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

### Waste Reduction

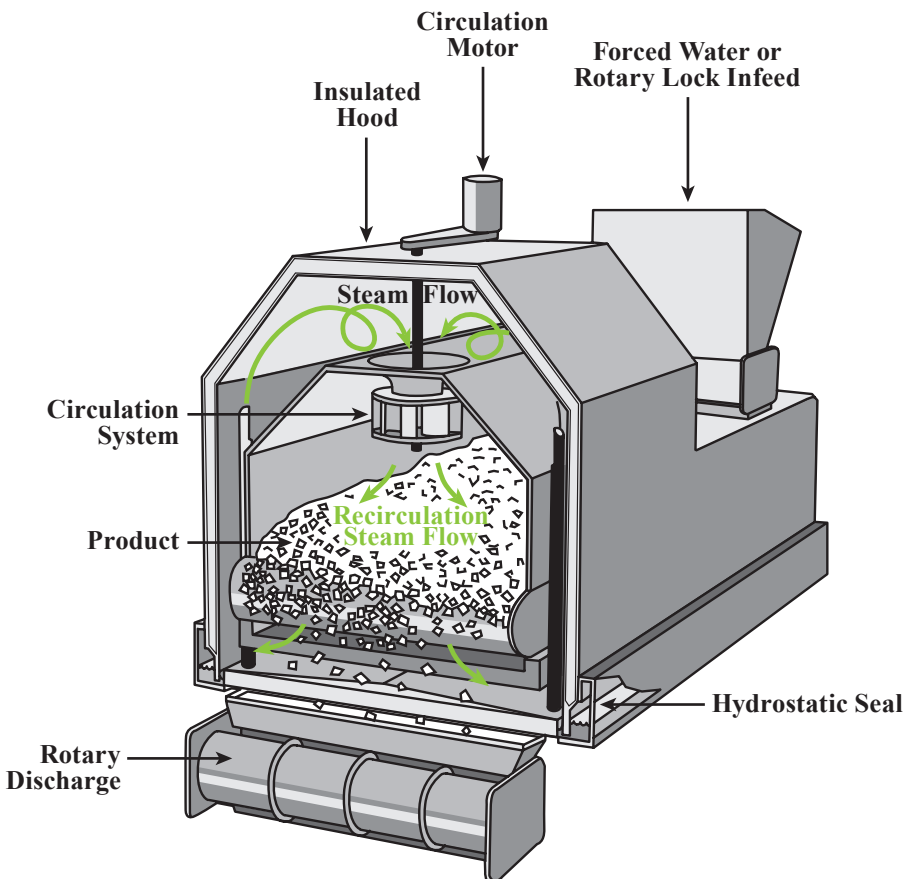
Reduces rejection rate due to better process control and even heat distribution.

## IMPACTS

### New Blanching System Increases Productivity While Saving Energy

This innovative blanching technology recirculates and reuses steam, dramatically reducing water and energy use, and wastewater production. Key Technology, Inc., using a NICE<sup>3</sup> grant, developed and demonstrated the energy-saving and waste-reducing Turbo-Flo<sup>®</sup> 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. There are currently 60 Turbo-Flo units 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.
- ◆ 60 units operating in the U.S. food processing industry

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.008	0.001

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.026

### Applications

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

Wastewater is virtually eliminated with the Turbo-Flo. Estimated water savings from the use of this system are over 3.8 million gallons of water per year per unit.

#### Productivity

With efficiency gains, shorter cook and blanch times increase yields by 2% to 5% over conventional water blanchers.

#### Quality/Process Improvement

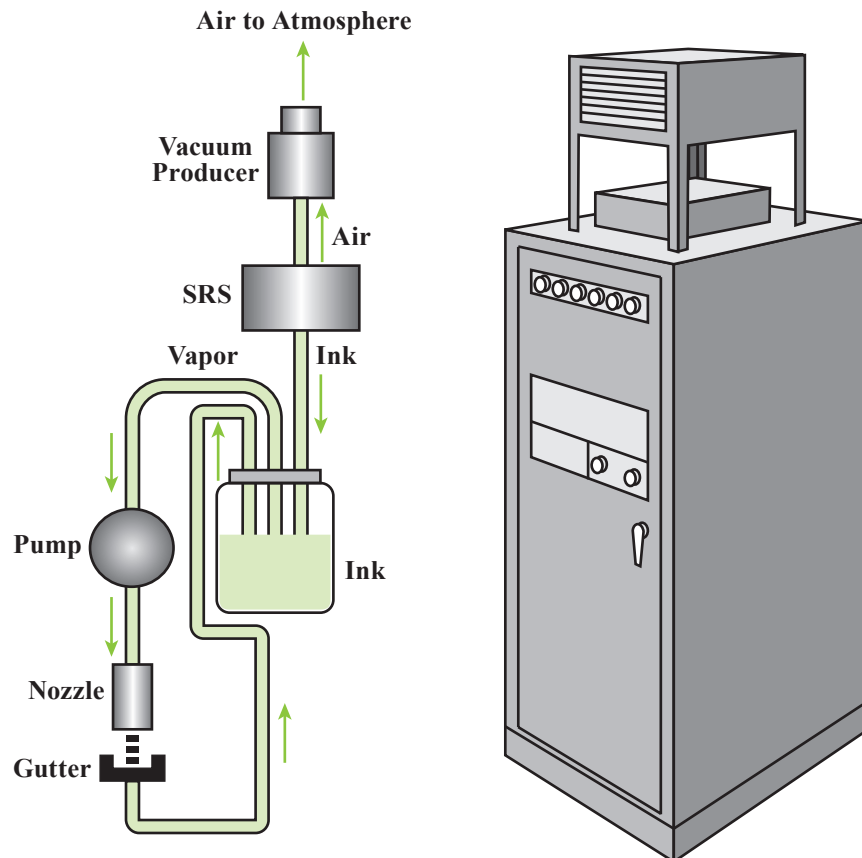
The Turbo-Flo system improves nutrient retention, taste, and appearance through shorter cook cycles and takes up only about 60% as much floor space as conventional blanching/cooking equipment. The Turbo-Flo system ensures more even cooking temperatures, and provides consistent product definition and quality.

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

Quad/Tech International (QTI) developed a new solvent recovery system (SRS) for commercial printers. This system was demonstrated using a NICE<sup>3</sup> grant. The SRS captures and reuses 60% to 70% of the volatile organic compounds (VOCs) associated with the printing process. The SRS can also reduce the amount of ink and solvent that would be lost as vapor by up to 50% on average, resulting in a significant reduction in emissions. Additionally, because less fluid is used, the fluid containers do not have to be changed as often, resulting in labor savings and less downtime on the production line. Lastly, reduced VOC and acetone emissions make the work environment healthier for employees.

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

QTI has over 640 of these units currently in operation. Energy savings result from the reduced need to manufacture the solvent, manufacture the plastic containers that the solvent is shipped in, and transport the solvent.



The Quad/Tech Solvent Recovery System (SRS)

### Overview

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

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.397	0.052

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.022	1.05	0.780	95.2

### Applications

Capturing and reusing VOCs in commercial printing processes

### Capabilities

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

### Benefits

#### Productivity

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

#### Use of Raw Materials/Feedstocks

Recovery of ink and solvent reduces make-up streams, saving ink and solvent. **DOE Industrial Technologies Program**



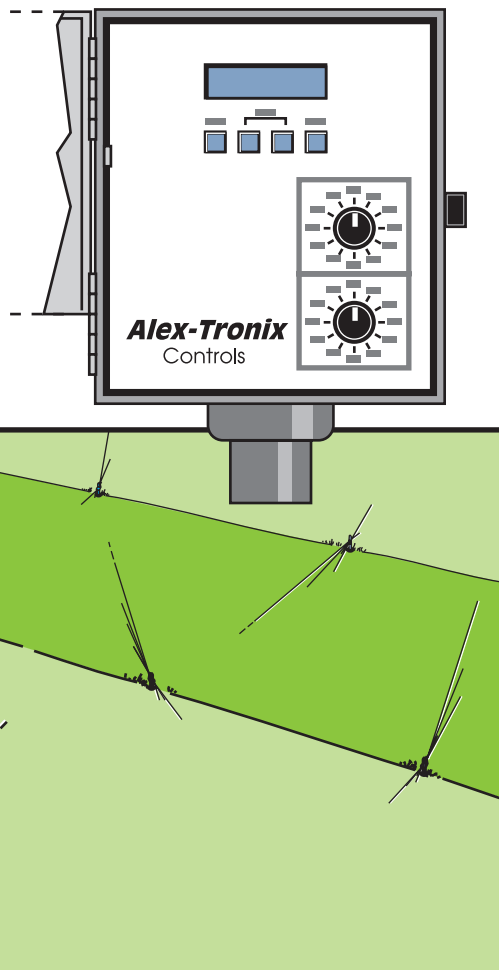
# Irrigation Valve Solenoid Energy Saver

## 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
- ◆ Commercialized in 1999 with over 3000 units in the field
- ◆ Proven operation in laboratory and field tests

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.015	0.001

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.023

### Applications

For 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.
- ◆ Technology has 10 times the battery life and 100 times the operating distance of any other controller.

### Benefits

#### Ease of Installation

Controllers can be installed anywhere. There is no need to install electrical meters or to use licensed electricians for installation.

#### Safety

There are no electrical safety concerns. Power surge and lightning-related problems associated with primary power leads are eliminated because there is no need for primary wiring.

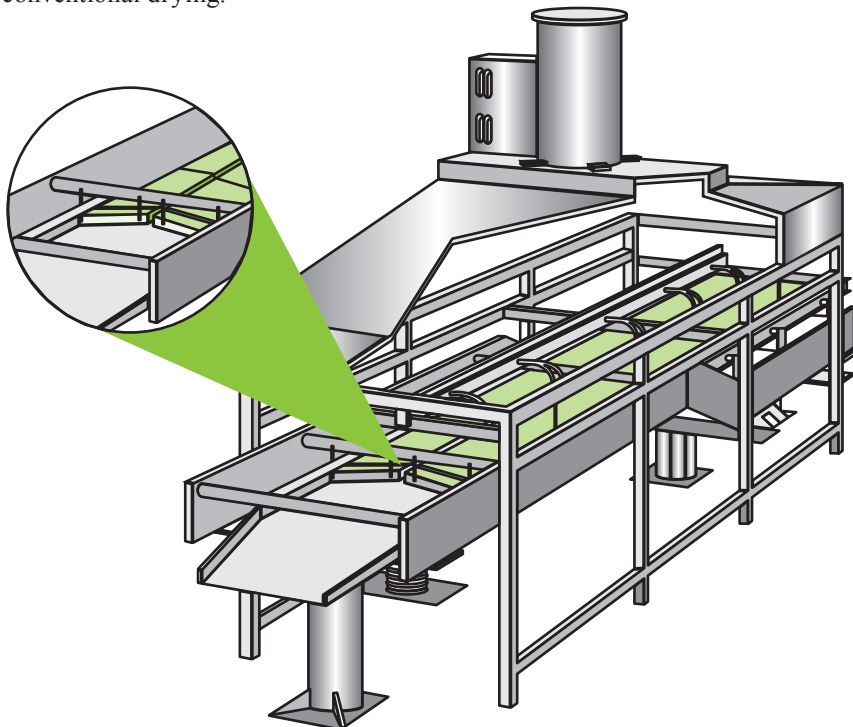
# Long Wavelength Catalytic Infrared Drying System

## 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  $\text{NO}_x$  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<sup>3</sup> 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, so the current focus has been on the conveyance system for distributing the product evenly throughout the dryer to achieve consistent drying. Equipment costs are comparable to conventional heating systems. 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.
- ◆ Commercialized in 2005
- ◆ One unit operating in a rice drying facility in 2005

## Applications

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 capital costs compared with conventional dryers.

### Emission Reductions

Reduces  $\text{NO}_x$  and VOC emissions by operating at higher temperatures.

### Energy Savings

Saves up to 80% of the energy used in conventional drying systems.

### Productivity

Decreases residence time in the dryer and reduces the amount of scorched (wasted) product.

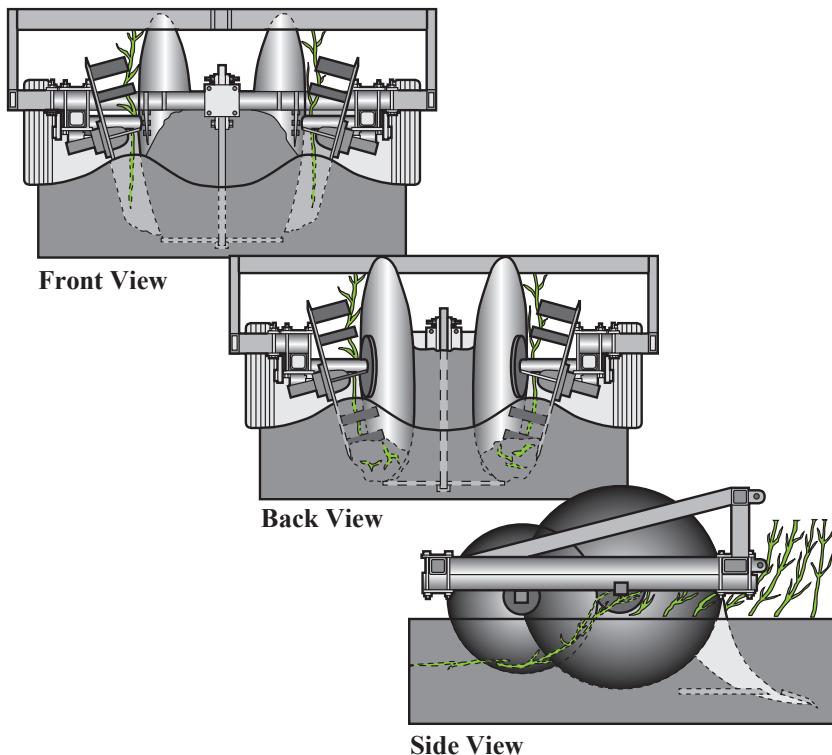
## IMPACTS

### New Stalk and Root Embedding Plow Reduces Costs and Saves Time in Preparing Fields

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. These tillage operations consume over one-half of farmers' annual fuel budget, and most farmers are frustrated with the high costs and time requirements. Over the last 50 years, farmers have tried several alternative tillage systems, all of which involve uprooting the cotton plants and mixing the crop residue into the soil. All uprooters have shortcomings, and none have gained wide acceptance across the Cotton Belt.

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

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



Stalk and Root Embedding Plow

### Overview

- ◆ Invented by the University of Arizona and being sold by the Rome Plow Company
- ◆ Commercialized in 1996
- ◆ 79 units operating in 2005

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.123	0.021

### Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.0	0.0	0.438

### Applications

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

### Capabilities

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

### Benefits

#### Environmental

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

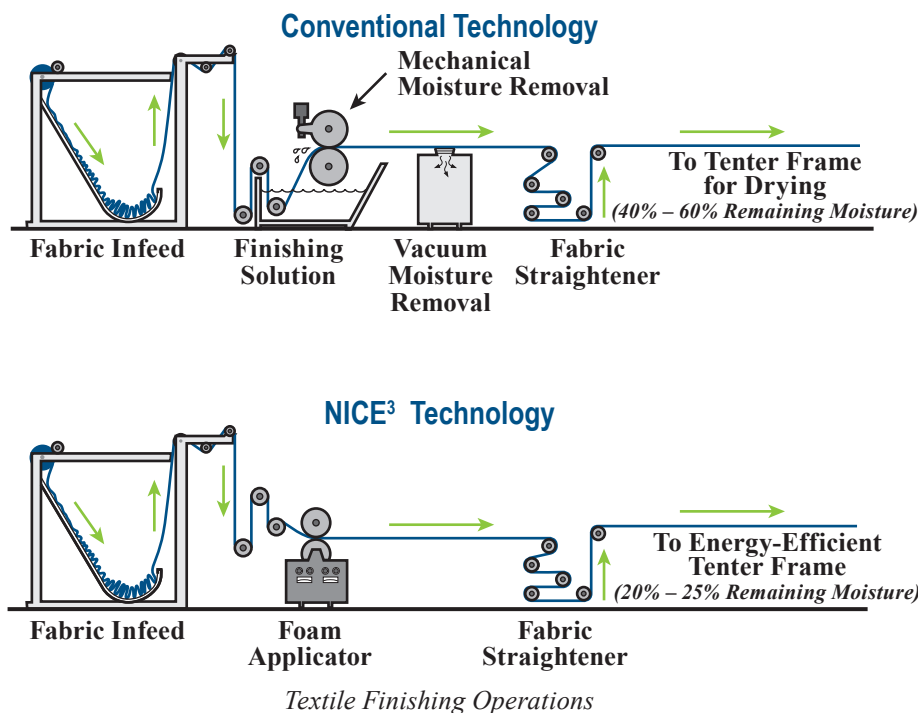
#### Productivity

Requires 75% to 80% less time to dispose of crop residue and prepare a new seedbed compared with conventional tillage practices. Saves 4 to 7 repeat passes of tillage machinery to work and prepare fields. Results in cost savings of \$50/acre compared with conventional tillage practices.

## New Process Increases Productivity and Energy Efficiency in Fabric Finishing

The United States 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<sup>3</sup> grant, Brittany Dyeing and Printing 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%.



## Overview

- ◆ Commercialized in 1999
- ◆ Demonstrated savings continue at Brittany Dyeing and Printing Corporation

## Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.159	0.023

## Emissions Reductions

(Thousand Tons, 2005)

Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.002	0.003	0.397

## Applications

Process applies to 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

Energy savings result from application of chemicals in a foam media rather than liquid – this reduces the moisture content; thus, less energy is needed to dry fabric.

### Environmental

In the new system, finishing chemicals are diluted with air instead of water; thus, less water is used and less wastewater discharged.

### Productivity

Reduced moisture content allows for higher production rates (over 100% increase in production capability).

# Utilization of Corn-Based Polymers

## IMPACTS

### 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.

Poly lactide (PLA), derived from annually renewable corn, 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. With financial assistance from DOE, the National Renewable Energy Laboratory 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 20% to 50%. The PLA plastics also result in reduced emissions of CO<sub>2</sub> compared with the petroleum-based thermoplastics. 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

Compared with producing products from petroleum, corn-based PLA consumes 20% to 50% less energy in the form of fossil resources. Additionally, the carbon comes from plants that extracted CO<sub>2</sub> from the atmosphere, thereby emitting less CO<sub>2</sub> than petroleum-based products.

#### National Security

Using U.S.-grown corn instead of oil reduces the nation's dependence on foreign resources and oil to produce necessary products such as clothing and food packaging.

### Overview

- ◆ Research being led 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

### Energy Savings

(Trillion Btu)

Cumulative through 2005	2005
0.051	0.018

### Emissions Reductions

(Thousand Tons, 2005)

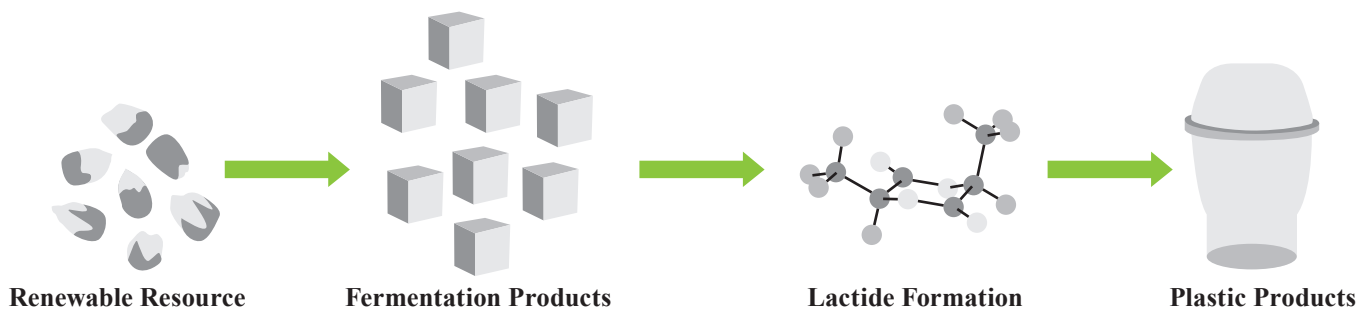
Particulates	SO <sub>x</sub>	NO <sub>x</sub>	Carbon
0.0	0.011	0.003	0.394

### Applications

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 can replace 10% of packaging with PLA, with more research being conducted to infiltrate the market further.



Process for Producing Plastic Using Renewable Resources

