Appendix 2:
ITP Emerging Technologies

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ITP Emerging Technologies

Aluminum

Aluminum Salt Cake: Electrodialysis Processing of Brine

The project goal was to eliminate landfilling of aluminum salt cake by developing technologies that would separate salt cake into constituents (aluminum, salt, and nonmetallic products). Salt recovery consumes more energy and incurs more costs than any other unit operation in the recovery of salt cake constituents. A salt-recovery process based on electrodialysis is more cost-effective than currently proposed technology (evaporation with vapor recompression) for recovering salt.

Converting Spent Potliner to Products

A new technology, the cyclone melting system, is being developed that will convert spent potliner from aluminum smelting plants into commercial-quality glass fiber and aluminum fluoride products. Spent potliner contains many of the chemical oxides typically used to manufacture glass products. The benefits of this new technology are the ability to produce a value-added product from the waste, to recover fluoride from the waste in a form that can be recycled back into the aluminum production process, and to reduce waste disposal costs.

Direct Chill Casting Model

The direct chill (DC) casting process is used for 68% of the aluminum ingots produced in the United States. Ingot scraps from stress cracks and butt deformation account for a 5% loss in production. The interaction of the DC process is too complex to analyze by intuition or practical experience. A new DC casting model is being developed to increase the general knowledge of the interaction effects and should lower production losses to 2%. The model will provide insights into the mechanisms of crack formation and butt deformation, and will help optimize DC process parameters and ingot geometry.

Aluminum

(continued)

Semi-Solid Rheocasting (SSR) of Aluminum Alloys

SSR is a simple and efficient technique for converting molten aluminum into semi-solid aluminum; it is less expensive than conventional techniques and can work with existing manufacturing equipment. With this technology, die-casting machines will produce large volumes of aluminum castings with high mechanical performance. Rheocasting will save energy by reducing furnace holding temperatures, reducing die casting energy usage, increasing tool life, and providing wider aluminum usage, primarily in the transportation industry.

Vertical Flotation Melter

The Vertical Flotation Melter (VFM) is an advanced remelting process that is energy efficient and environmentally friendly. It will help the aluminum industry meet energy and environmental performance targets. The technology also applies to other industries, such as the glass container, fiberglass and steel industries.

IMPACTS

Chemicals

Affinity Ceramic Membranes with CO_2 Transport Channels

Compared with more conventional separation processes, membrane separation processes offer several advantages, including increased energy efficiency, compact design, and operational flexibility. Numerous unexploited applications exist for advanced separations in aggressive environments that rely on a membrane's affinity to a specific chemical as opposed to traditional molecular sieving. Highly selective thermally/hydrothermally stable inorganic membranes offer a solution to these difficult industrial separation applications.

Alloys for Ethylene Production

New intermetallic or metallic alloys are being developed for manufacturing ethylene production tubes that are resistant to coking and carburization. Traditionally, ethylene furnace tubes have been fabricated from cast or wrought high stainless steel alloys. Coke and metal carbide layers form on the inside surfaces of the tubes, reducing the mass flow and heat transfer of the tubes and resulting in significant downtimes. The new material will reduce these problems as well as increase the structural life of the tubes.

Catalytic Hydrogenation Retrofit Reactor

The Monolith Loop Reactor (MLR) is a novel, integrated monolith catalyst reactor system that can be retrofitted onto existing commercial slurry-catalyst stirred tank reactors. A reusable high-activity monolithic catalyst replaces the slurry catalyst, and a two-phase gas and liquid feed mixture is fed to the reactor using a specialized gas-liquid ejector. The monolith catalyst effectively concentrates or intensifies the catalytic reaction in the small parallel channels of the monolith, while the ejector correspondingly increases the gas-liquid mass transfer to match these high reaction rates. Target markets include the commodity chemical, specialty chemical, fine chemical and pharmaceutical intermediates. This new technology offers reduced energy consumption because of higher productivity, improved yields, reduced waste, and elimination of the catalyst slurry filtration step and its associated operational costs.

Chemicals
(continued)

Cavity-Enhanced Gas Analyzer for Process Control

A new industrial process control analyzer, which was successfully field-tested, measures trace acetylene concentrations in ethylene gas flows. Acetylene contamination can lead to costly upsets in producing ethylene, the world's largest volume and revenue-generating organic chemical. The new analyzer uses patented technology that is fifty times faster and one-third less expensive than conventional gas chromatography.

Concurrent Distillation

The Trutna Tray (Co-Flo Tray) improves the performance of distillation and absorption trays by using a co-current flow design. Compared with the conventional sieve tray, the co-current tray increased production capacity by more than 100% without sacrificing separation efficiency. Three tray variations have been pilot-tested using an industrial-scale distillation column. The de-entraining section of the Co-Flo Tray is routinely used by the UT Austin's Separation Research Program in all of its air/water and caustic scrubbing studies. The special collector design and the enhanced liquid/vapor separation capability offer great potential for future de-entraining applications.

Dimpled-Tube Heat Exchangers

A project to improve the thermal efficiency of convective sections of industrial fired-process heaters demonstrates that a dimpled-tube technology will significantly improve the energy efficiency of fired-process heaters and will reduce fouling rates. The heat-transfer enhancement approach uses a tube surface with a system of three-dimensional cavities (dimples). Cost-effective enhancement occurs because intensive vortex flow patterns are generated by cavities and provide intensive heat and mass transfer between the surface and the flowing media. A pilot-scale dimpled-tube test unit at a participating refinery increased heat flow by 50% to 60% compared with traditional tubes and reduced pressure drop by 30% to 40%.

Chemicals
(continued)

Distillation Column Modeling Tools
A computational model is being developed to optimize distillation column operation and design of column internals. A commercial-scale model will be validated to facilitate industry-wide acceptance and use. The commercialized software containing the model will calculate column design and operating parameters based on inputs of column size, packing configuration, feed conditions, and system physical properties. The model has the potential to optimize distillation column operations to save an estimated 53 trillion Btu per year by 2020.

Electrodeionization for Product Purification
This technology combines the advantages of ion exchange (an adsorption technology) and electrodialysis (a membrane separation) for a wide range of potential applications in the chemical industry, including direct production and separation of products, product purification and desalination, salt waste recovery, and water recycling. Targeted applications include organic acid production, dextrose desalination, ultrapure water production, product polishing, and waste salt recovery.

High Octane Fuel-Stocks via Reactive Distillation
High octane alkylate, an ideal clean fuel component for reformulated gasoline, is currently made using toxic liquid acid catalysts such as hydrofluoric or sulfuric acid. A commercially viable and environmentally superior alternative to conventional liquid-acid alkylation processes is being developed called the ExSact process. This pilot-tested process uses benign, engineered, solid-acid catalysts coupled with an innovative but practical, fixed-bed reactor to produce high-octane alkylate. The new process lowers utility consumption and produces fewer by-products compared to existing technologies, which result in significant savings in operating expenses.

Chemicals
(continued)

Improved Methods for Producing Polyurethane Foam
This project seeks to commercialize new silicone surfactant products that will enable flexible foam manufacturers to use environmentally benign liquid CO_2 as a blowing agent. Using CO_2 to manufacture polyurethane foams would replace methylene chloride, a toxic chemical that contributes to air pollution; would provide cleaner production that uses less energy; and would reduce the net release of CO_2, which is implicated in global warming. To validate the technology's performance, several companies will conduct full-scale production runs in their facilities.

Low Emission Diesel Engines
Diesel engine exhaust is a major source of NO_X pollution. The formation of NO_X in diesel engines is dependent on the combustion temperature, which can be affected by the engine cylinder charge. An innovative membrane is being developed to adjust the cylinder charge and reduce the NO_X emissions by delivering nitrogen-enriched air to the system. The system may reduce NO_X formation in diesel engines by 50%.

Low-Frequency Sonic Mixing Technology

This technology is an energy-efficient, electromechanical system that effectively substitutes low-frequency sonic energy for chemical and mechanical mixing, significantly improving the manufacture of a broad range of industrial products. This simple yet effective technology transfers acoustic energy into liquid, liquid-gas, and liquid-solid systems, inducing acoustic streaming. The result is improved mass transport and micromixing.

Membrane for Olefin Recovery
Selective polymer membranes are being developed to allow recovery of olefins (compounds with carbon-carbon double bonds such as ethylene and propylene) from petrochemical by-product and vent streams. These streams are often flared or used as a fuel even though the olefin is more valuable as a chemical feedstock. This new separation technology will allow olefin separation and recycling within the process.

IMPACTS

Chemicals
(continued)

Membranes for Reverse-Organic Air Separations
Underground storage tanks for gasoline traditionally vent vapors that contribute to ground-level ozone and smog. An innovative membrane system is being developed to discharge air from tanks while retaining VOCs. The membrane system has the potential to dramatically reduce gasoline loss and VOC emissions from underground storage tanks.

Nylon Carpet Recycling
This new chemical process provides recycled materials for manufacturing carpet products. The process can be used to recycle the used nylon carpet currently sent to landfills each year. The technology allows nylon manufacturers to recover and reuse caprolactam, the raw material used to make nylon 6 for carpets. A fully operating recycling plant is expected to keep more than 200 million pounds of post-consumer carpet waste out of U.S. landfills and produce approximately 100 million pounds of new caprolactam each year.

Recovery of Thermoplastics via Froth Flotation
A process for the economical separation of high-value plastics from plastics waste streams derived from home appliances and electronics scrap has been developed and is ready for licensing. Current methods for separating plastics cannot economically separate plastics of similar density from each other. The process was demonstrated at a private company site involved in the recycling business. The design capacity of the demonstration plant was 1000 pounds per hour. About 20,000 pounds of ABS and HIPS plastics were recovered with a purity of more than 98% and a yield of higher than 80%. Recovered plastics via this process were successfully used by car-part manufacturers in making automotive parts. There are significant benefits due to lower energy use and resource conservation in the reuse of plastics for industrial manufacturing.

Chemicals
(continued)

Solution Crystallization Modeling Tools
Reliable simulation of crystallization requires accurate modeling of many factors. A new modeling tool synthesizes several essential elements, at least one of which has been only crudely approximated in previously available tools. This new modeling tool helps chemical engineers to better predict and control the crystal size distribution. It also improves the understanding of the effects of mixing and spatial variation of temperature and composition on the product quality, and ultimately will optimize crystallization efficiency. The resulting enhanced computational fluid dynamics capabilities are also applicable to a range of industrial applications beyond crystallization.

Sonic Assisted Membrane
Membrane filtration systems are used to separate and recover products in a wide variety of applications. One of the main impediments to the broader use of micro and ultrafiltration membrane filters in biological applications is the occurrence of a layer of gel on the membrane surface, resulting in significant reduction in flux. A sonic device produces low frequency, high intensity, acoustic vibrations, which induce micro turbulence in the fluid near the membrane surface minimizing gel layer formation. This technology reduces maintenance costs and increases the number of biological applications for membranes.

Sorbents for Gas Separation
A new technology based on oxygen-selective sorbent materials and pressure swing adsorption (PSA) could cost-effectively produce industrial gases, such as nitrogen. Purification applications where oxygen is removed from argon, helium, and nitrogen streams offer early potential commercial opportunities. This technology potentially requires less energy for gas separation compared to conventional techniques and can provide high-purity gases at lower cost.

ITP Emerging Technologies

Forest Products

Biological Air Emissions Control

An innovative biological sequential treatment system that integrates two types of biological oxidation offers an attractive alternative to conventional, thermal oxidizer emissions control techniques. The two-stage system uses microorganisms to degrade (bio-oxidize) air toxins and other VOCs without using natural gas as fuel or creating secondary pollutants. The system combines a biofilter for removing low concentrations of pollutants and polishes the air stream with a biotrickling filter system for removing high concentrations of hydrophilic compounds, and will conserve water through in-vessel treatment and recycling of the scrubbing liquid.

Black Liquor Steam Reforming/Pulsed Combustion

Black liquor is a liquid containing both pulping chemicals and tree organics. Historically, it was combusted to recover chemicals but this combustion is thermally inefficient and supplies about 50% of the energy needed in an integrated pulp and paper mill. A new process that gasifies the black liquor to recover chemicals and significantly more of the energy is being commercialized in two U.S. plants and a third plant in Canada. This gasification process could be further developed to produce power or transportation fuel and high performance chemicals. It also operates at significantly lower emission levels and eliminates the possibility of explosions.

Borate Autocausticizing

Boron-based autocausticizing is a new, cost-effective technology to recover Kraft pulping chemicals. This technology can be used to recover either part or all of the sodium hydroxide requirements of the Kraft process through de-carbonation of sodium carbonate, supplementing or replacing the lime cycle. Because the de-carbonation reactions take place directly in the recovery boiler, instead of the lime kiln, this process reduces energy consumption and provides either increased causticizing capacity or reduced calcining requirement.

Forest Products

(continued)

Decontamination of Process Streams through Electrohydraulic Discharge

In recycling paper, "stickies" cause considerable downtime and require costly minerals and polymers to be added for handling and detackifying them during the recycling process. A new mechanical method - pulsed power technology - is being demonstrated at several recycling mills to replace these costly chemicals. This technology uses a shock wave, developed from a spark discharging under water, to diffuse the stickies and create hydroxyl radicals from water, which oxidizes the stickies. This oxidation causes the stickies to lose their tack and become benign, thus allowing recycling to continue unimpeded.

Directed Green Liquor Utilization (D-Glu) Pulping

Advances in the rate and selectivity of Kraft pulping without incurring major capital costs will increase the economic return of the pulp and paper industry. A high sulfidity pretreatment of wood chips is one of the most promising ways to achieve these advances. Green liquor is easily accessible in a mill and naturally rich in hydrosulfide ions, which are critical for accelerating pulping and providing a high value product. Researchers have discovered ways to reduce pulping time and energy requirements through the intelligent application of green liquor in the digester.

Fibrous Fillers to Manufacture Ultra-High Ash/Performance Paper

Mineral fillers that increase paper brightness and opacity and improve paper print quality have reduced costs by replacing wood fiber. However, filler loading has been limited to 15% to 20% because higher loading levels cause a loss of sheet strength and bulk as well as "dusting" during printing. A new fibrous filler technology has been developed that may overcome these problems and replace high-cost wood fiber. The new fillers will ultimately produce a composite paper containing up to 50% ash, with equal or better performance characteristics than conventionally attainable paper. The new technology will also lead to better retention of fillers, additives, and pulp fines, significantly reducing biological and chemical oxygen demands in the mill process water.

IMPACTS

Forest Products
(continued)

Gas-Fired Paper Dryer
A new paper dryer is being developed and pilot-scale tested to significantly increase the efficiency of papermaking. The Gas-Fired Paper Dryer (GFPD) is a natural-gas-fired system that uses a combination of a flame sheet and dimpled pattern on the drum's inner surface to improve combustion stability, reduce pollutant emissions, and cost-effectively enhance heat transfer from combustion products to the paper web. This patented approach could be implemented into new or existing equipment. The GFPD will ultimately help the paper industry (especially drying limited mills) reduce energy use and increase the production rate of paper machines by 10% to 20%.

Laser-Ultrasonic Web Stiffness Sensor
This technology uses noncontact laser ultrasonics to monitor paper mechanical properties (e.g., bending, stiffness, and rigidity) in real-time during the papermaking process. In the past, paper mechanical properties were probed with transducers in direct contact with the web. This approach is no longer used because contact transducers can damage the web, leading to costly production losses. Noncontact monitoring of paper stiffness during manufacture will reduce waste and energy use by using less refining and remanufacturing, make optimal use of pulp feedstock, and reduce production of offgrade paper.

Lateral Corrugator
A new corrugator method increases box strength and reduces drying costs by aligning corrugations with the direction of the paper machine, rather than perpendicularly. With this technology, manufacturers can use thinner paper to produce boxes of equal strength and can reduce drying energy requirements. This technology will also significantly reduce cost and energy use by reducing waste and box plant inventory and by optimizing trim and transportation.

Forest Products
(continued)

Low Temperature Plasma Technology for Treating VOC Emissions
Pulp mills and wood product plants are under increasing pressure to control the emissions of volatile organic compounds (VOCs) generated during their operations. The present-day control technology – regenerative thermal oxidizers – is energy-intensive and depends on combustion technologies that heat the entire waste stream. An emerging technology using nonthermal plasmas can selectively and cost effectively destroy VOCs by producing excited species (free radicals and ions) that oxidize, reduce, or decompose pollutant molecules.

Materials for High-Temperature Black Liquor Gasification
New black liquor gasification technology with combined-cycle cogeneration of steam and electricity can increase energy output for the forest products industry. However, high inorganic salt concentrations and high temperatures significantly degrade refractory materials and metallic components. Improved refractories and wear-resistant nozzle materials are being developed to enable high-temperature black liquor gasification units to attain a longer service life. These improvements will reduce operating downtime and increase energy production capability.

Multiport Dryer
A limited pilot-scale testing of a multiport dryer is being conducted to increase paper drying rates in steam-heated cylinder dryers. Experimental data show that multiport dryers can increase paper production rates by 20% compared with spoiler-bar technology and by as much as 50% compared with conventional technology. The concept involves the steam flowing through multiport passages in proximity to the dryer surface. The multiport design minimizes condensate formation, which reduces heat flow, and maximizes the heat transfer surface area. Commercial benefits include reduced energy consumption, improved productivity, and downsized dryer section.

Forest Products
(continued)

MultiWave™ Automated Sorting System for Efficient Recycling

Clean recycling material streams are critical to efficient and cost-effective recycling efforts and the slow speed of many sorting systems inhibits effective processing. The new MultiWave sensor system incorporates an innovative lignin sensor in addition to color detection and near-infrared detection to effectively detect the presence of paper in plastic recycling streams. The sensor is capable of detecting the paper's unique spectral signature at high speed and can control compressed air jets that then eliminate these materials from the stream. The sensor enables scanning and rejection at speeds of 1200 feet per minute in machine widths up to 96 inches.

Novel Isocyanate-Reactive Adhesives for Structural Wood-Based Composites

Laminated veneer lumber (LVL) is a wood composite that is produced by bonding thin wood veneers together and is used for various wood construction applications. The current LVL manufacturing process is energy intensive, using adhesives that require extensive wood drying (to moisture contents of 6% to 8%) and high-temperature hot-pressing (~200°C). An alternative isocyanate-reactive that cures at room temperature (cold-setting) and is optimized for higher veneer moisture content promises significant energy savings. This new technology will also sharply reduce volatile organic compound emissions and improve product appearance and durability.

Online Fluidics Controlled Headbox

This technology allows for more complete control of fiber alignment on the paper machine, which allows a machine making high performance products (e.g. containerboard, shipping sacks, etc.) to optimize sheet directional properties related to fiber orientation. In many cases, the optimization results in up to 10% reduction in fiber usage for the same product. Also, jet turbulence can be adjusted to optimize formation, thereby affecting not only strength but also properties such as smoothness, appearance, printability and coatability.

Forest Products
(continued)

Oxalic Acid Technology

A short pretreatment of oxalic acid on wood chips saves electrical energy, improves paper strength, and removes hemicellulose along with other wood constituents during mechanical refining. Prior to pulping, the products extracted can be converted into various value-added compounds that can be used for a wide range of industrial applications. Oxalic acid technology provides an effective means of enhancing the physical properties of paper, while reducing the energy requirement in pulp production by at least 25%. The technology also reduces the resin and triglyceride components in the pulp. This technology has been proven in pilot-scale tests.

Residual Solids From Pulp and Paper Mills for Ready-Mixed Concrete

The fibrous residuals from mill processing are typically sent to landfills. These residuals can be incorporated into ready-mixed concrete to improve the strength, durability, and lifespan of concrete structures, especially those exposed to weather. Adding residuals to concrete could increase the lifespan of high-performance concrete from the normal 30 years to up to 100 years. The new technology offers the pulp and paper industry a practical and economical solution for residuals solids disposal and provides the concrete industry with a low-cost source of fibers to produce a better product for its customers.

Screenable Pressure-Sensitive Adhesives

The presence of pressure-sensitive adhesives (PSAs) in recycled paper creates a number of problems for the recycling process, including lost production and diminished product quality. New adhesive materials are being developed that are more effectively removed from the papermaking process during furnish screening. These new adhesives should possess properties that enhance their removal without impacting their performance in PSA products.

Forest Products
(continued)

Steam Cycle Washer for Unbleached Pulp
A new commercial-scale Steam Cycle Washer is being developed to increase profitability by substantially reducing energy consumption, improving fiber and product quality, and ensuring that environmental compliance exceeds current regulations. This steam-pressurized, high-consistency pulp washer will enhance pulp industry profitability by allowing most pulp mills to reduce electrical power consumption for unbleached pulp production by up to 21%, evaporator load by 50%, and plant effluent and fresh-water usage by 45%.

Surfactant Spray To Improve Flotation Deinking Performance
This new technology uses an atomizer to spray frother at the top of the flotation column in the wastepaper flotation deinking process to significantly reduce the loss of fiber and water and the use of chemicals in the process. Frother spray technology will provide on-line control for the frother agent distribution in the flotation slurry. This technology will be easily retrofitted to industrial flotation equipment without significant modifications to existing systems.

Glass

Advanced Combustion Space Model for Glass Melting
Improved understanding and modeling of the combustion process in glass melting will result in innovative furnace designs that will have higher combustion and furnace efficiencies, minimized pollutant formation (primarily NO_X reduction), and improved glass quality.

Advanced Oxy-Fuel-Fired Front-End System
A consortium of companies involved in the glass industry has developed the Advanced Oxy-Fuel-Fired Front-End System. A combination of burner modeling and bench trials was used to develop a burner and block that generate the appropriate size and shape of flame for optimal heat transfer distribution. This will result in reduced energy use and decreased CO_2 emissions. The new burner system can be integrated into a front-end system with capital costs that are competitive with a conventional air/gas system. Full-scale installation and testing are under way in a Tennessee glass plant.

Electrostatic Batch Preheater System
The electrostatic batch preheater system is a single-box solution that directs glass furnace exhaust gases through open-bottomed tubes running through a batch/cullet hopper. Direct contact with the hot exhaust gases preheats the batch and cullet before they enter the furnace and cleans SO_X from the exhaust gas stream. A proprietary electrostatic mechanism captures entrained dust and returns it to the batch. The technology reduces furnace fuel requirements by 10% to 15% and cleans the exhaust gas stream of SO_X and dust in accordance with the most stringent regulatory standards.

Enabling Tool for Innovative Glass Applications

Flat architectural and automotive glasses have traditionally been fabricated using technologies that have inherent cutting limitations because they are generally incapable of fabricating glass products with small radii, concave edges, or pierced holes. A new technology uses waste glass as a low-cost media for abrasive water-jet cutting of glass and other materials. This technology can refine and automate the glass manufacturing process while reducing the number of stages and equipment required to produce intricate glass products.

Glass
(continued)

High-Intensity Plasma Glass Melter
A high-intensity plasma glass melter was developed with a square-foot-per-ton-per-day throughput index that is significantly smaller than commercial glass melters. This plasma technology package increases the systems' energy efficiency and reduces emissions. To achieve this high throughput and high quality, the system uses a dual-torch transferred arc-plasma technology, a rotating melt chamber to increase melt rate, skull melting to eliminate the need for a refractory lining and to reduce contamination of the glass from refractory and electrode components, and state-of-the-art control technology to provide stable conditions.

High Throughput Vacuum Processing for Innovative Uses of Glass

A manufacturing process and hardware were demonstrated for cadmium telluride photovoltaic solar cells fabricated on glass substrates. This process has extremely low direct manufacturing costs, low equipment costs, the ability for rapid capacity expansion, and the ability to improve occupational safety. The innovative process uses a proprietary air-to-vacuum-to-air system that allows continuous production of cadmium telluride cells rather than the use of the slower batch process.

Improving Yield in Glass Fiber Drawing
Modeling and improved process control techniques have led to the design of a glass fiber drawing process with reduced break frequency. A pilot-scale drawing tower using a glass marble melter and 200-tip bushing has demonstrated a process with only one break in a six-hour period. The technology is being tested in production.

Manufacturing Ceramic Products from Waste Glass

Ceramic products have traditionally been processed from raw materials that require high firing temperatures and energy-intensive processing steps. A new technology lowers energy costs by substituting raw materials with recycled waste glass. Products manufactured by this new method are less sensitive to contaminants in the glass and can be made from difficult-to-recycle green or mixed-color container glass waste. High-quality ceramic tile has been processed from 92% to 100% recycled glass with a wide range of colors and surface textures. The technology has been applied to several types of glass, including post-consumer container, flat and lamp glass, and industrial fiber-glass waste streams.

Glass
(continued)

Model of On-Line Coating of Float Glass
Strategies, models, and chemical databases are being developed to optimize on-line coating of float glass. Computational models that can predict defects in the coatings are being developed to increase efficiency. Preventing coating defects can reduce the amount of glass to be re-melted and consequently save energy. Model development and trials at manufacturing facilities are ongoing.

On-Line Molecular Analysis for Improved Industrial Efficiency
Research is ongoing to develop an on-line, real-time process analyzer that can monitor or control production on a wide variety of materials. The purpose of the analyzer is to improve product quality, increase manufacturing efficiency, and reduce waste. This analyzer uses transient infrared spectroscopy (TIRS) to determine chemical and physical properties of the material being produced as it moves past the TIRS sensor.

Oxy-Fuel Protocol
By better monitoring and characterizing oxy-fuel furnace operations through advanced measurement techniques and mass and energy balances, glass producers can identify operational inefficiencies and recommend energy-saving changes. An oxy-fuel protocol has been developed to assess the energy performance of an operating furnace. The protocol is intended to identify potential opportunities for energy savings.

Submerged Combustion Melting
A consortium of companies developed a high-intensity glass melter based on the submerged combustion melting technology. This melter serves as the melting and homogenization section of a segmented, lower-capital-cost, energy-efficient Next Generation Glass Melting System. This technology will potentially increase efficiency, lower capital costs, provide more flexible operation, and lower emissions.

ITP Emerging Technologies

IMPACTS

Metal Casting

Cupola Furnace Process Model

A comprehensive mathematical model of the cupola furnace, a type of furnace used to melt iron that is subsequently cast into a variety of products, is being enhanced and updated. The model was incorporated into a user-friendly artificial-intelligence program that can help optimize the temperature, processing time, and other key variables of furnace operation. This improved operation results in energy savings, product quality enhancement, and waste reduction.

Integrating Rapid Solidification Process Tooling and Rapid Prototyping in Die Casting

In this project, a new and unique Rapid Solidification Process (RSP) technology will be introduced to the die casting industry to reduce lead time for prototyping and producing die casting tooling. In addition to increased productivity, the RSP tooling technology also substantially reduces energy use and scrap compared with conventional machining practices.

Lost Foam Casting Technology

Lost foam casting is a highly flexible process suitable for casting metal components with complex geometries. Research supported by ITP has led to a greater understanding of the process and to new control measures. These will increase foundry energy efficiency and reduce scrap. Emerging technologies from the ITP-supported research include: in-plant quality assurance procedures to measure casting parameters; real-time x-ray apparatus which allows visualization of the metal/pattern replacement process; and an apparatus for measuring pattern permeability (fusion) which is a major factor in the replacement process.

New Treatment for Improved Aluminum High-Pressure Die Casting

Traditional components for stamping and cutting functions in the aluminum and other metal industries have limited lifetimes and require periodic replacement to maintain product quality. A new zirconium-based treatment can increase component life by up to 50 times, which reduces process downtime and production costs and increases product quality. Potential applications include metal working, forging, internal combustion and turbine engines, and other high-wear industry processes.

Metal Casting

(continued)

Process to Recover and Reuse Sulfur Dioxide in Metal Casting Operations

Sulfur dioxide (SO_2) is used as a catalyst in forming cold-box molds and cores in the metalcasting industry. The SO_2 is typically used once, scrubbed with a caustic solution, and then discarded (flushed to sewer or sent to a waste treatment facility). This new process recovers the SO_2 for reuse by processing it through a pressure-swing adsorption system that is expected to recover at least 95% of the SO_2. Using this process will reduce energy consumption, eliminate the need for caustic effluent, and pay back costs in less than 1 year.

Rapid Heat Treatment of Cast Aluminum Parts

A system that reduces 80% of the time and energy required to heat-treat cast aluminum components is now being demonstrated. Unlike existing technologies where components are stacked in baskets and placed in a convection or vacuum furnace, this new process uses a fluidized bed in a continuous process mode. The fluidized bed is coupled to an automated production line that moves the components through the process. Pulse-fired microprocessor-controlled burners inject heat directly into submerged radiant burner tubes, ensuring precise, even, and rapid heat transfer.

Mining

Belt Vision Inspection System

The Belt Vision system, currently being field tested in underground and surface mines, uses high-speed line scanning cameras and a computer system to monitor mechanical splice deterioration in moving conveyer belts. The computer system, located on the belt or on a remote desktop, digitizes and records continuous imaging of the belt and splices. Mine personnel can review live or historical images several times a day with minimal effort and take action before belt splices fail. The Belt Vision system will help eliminate costly repairs to conveyor belts, keep production running, and help reduce costs.

Dense-Medium Cyclone Optimization

Dense-medium cyclones are used to separate coal or other minerals from waste rock in most modern coal plants and in a variety of mineral plants, including iron ore, diamonds, and potash. A set of engineering tools to improve the efficiency of dense-medium cyclones is being developed and demonstrated. These tools include low-cost density tracers to rapidly assess cyclone performance, mathematical process models to predict the effects of operating and design variables, and a model-based expert system for trouble-shooting cyclone circuits. These tools will successfully improve plant productivity, reduce energy costs, and minimize waste rock generation.

Drill-String Radar Navigation for Horizontal Directional Drilling

Horizontal drilling in a coal seam can relieve methane gas trapped in a coal bed, increasing the safety of coal miners and supplying methane, a desirable resource. Gamma sensors, currently used for horizontal drilling, cannot withstand the vibration of the drill and require additional costly drilling steps. Instead of gamma sensors, drill-string radar transmits radio waves and measures their reflection to identify boundary rocks, reducing vibration sensitivity and allowing real-time measurement while drilling. This technology will reduce the risk, cost, and time required for extraction.

Mining
(continued)

GranuFlow™ Process in Coal Preparation Plants

The GranuFlow technology involves adding a binding agent such as an asphalt emulsion to a slurry of coal and water prior to mechanical dewatering. The binding agent agglomerates the fine-sized coal, increasing its capture during mechanical dewatering, thereby reducing coal loss to impoundments. The GranuFlow treatment also reduces moisture content, alleviating downstream handling, dusting, and freezing problems.

Grinding-Mill Optimization Software

Millsoft 3D is simulation software for visualizing the charge motion in semi-autogenous mills and ball mills used in the mining industry. The software also provides various quantitative information, such as power, forces on the mill lifters, and wear. The three-dimensional code uses the discrete element method to model the individual collisions of ball and rock particles. The software handles mills of all sizes and can be used for shell lifter design and energy optimization of SAG mills.

High-Temperature Superconductors in Underground Communications

Underground communications are important for the mining industry, urban first-responders, and others who frequently work underground. The through-the-earth radio system can increase underground mining production by improving communication and eventually allowing orientation and position information, which can benefit both an individual miner and a mining machine. Most importantly, fast wireless communication improves underground mining safety through early response to problems. A new system has been built using conventional copper and semiconductor designs and higher-performance superconducting designs. Using superconducting materials in underground communications equipment increases the range and clarity of through-the-earth wireless networks.

Magnetic Elutriation Technology for Processing Iron Ore

Magnetic elutriation improves the quality of low-grade domestic iron ore by using an alternating-current pulsed-magnetic field to clean iron ore into a highly refined product. This new continuous countercurrent system is being demonstrated in the field. The technology efficiently separates the tailings and middling particles out of the iron ore without using harmful chemicals.

ITP Emerging Technologies

IMPACTS

Mining
(continued)

Mapping with Natural Induced Polarization

The mining industry uses induced polarization (IP) surveys to locate and characterize mineral resources. Conventional surveys use high-power motor-generator sets to transmit electrical current in the earth through grounded electrodes that are slow and laborious to install. This new natural field polarization survey eliminates the need for these cumbersome transmitters by using the natural electromagnetic fields as the source to collect induced polarization data. The natural fields also provide the benefit of greater depth of exploration than conventional IP surveys. Other benefits of using the natural fields survey induced polarization technique include reduced environmental impact, energy and drilling requirements.

Novel Dry Coal Deshaling Mobile Unit

A new dry deshaling technology removes materials with high-ash content prior to loading and further coal cleaning. The new coal-cleaning unit provides high-density separation near the extraction point or working face of a mining operation. The system requires no water, facilitating easier product transportation and waste material hauling. These features enable mine personnel to remove waste rock and minimize coal losses to the rejection stream. This new method reduces land impacts and waste emissions while lowering capital and operating costs.

Real-Time Coal/Ore-Grade Sensor

Various project partners helped develop a real-time coal content/ore-grade sensor that can be used during exploration, mining, and processing operations. The project used the unique spectral characteristics of coal and ore to quantify coal content and ore grade in real time. The sensor will be suitable for both surface and underground mining operations either at the working face or where mined material is being processed. This feature will allow for greater selectivity and will decrease environmental impacts and energy requirements in exploration, mining and processing activities.

Mining
(continued)

Soft (Unfired) Ceramic Particles via Dynamic Cyclone Classification

Many industrial processes involve the separation of particles from an airstream. The mining industry, in particular, has indicated a need for improved separation methods and reduced waste. In this technology, the particles are separated and transported by boundary layers and induced airflow vorticity near a stack of rotating (slightly separated) disks, which minimizes particle impact and attrition, as well as component wear. The dynamic cyclone classifier offers substantial potential for indirect energy savings by reducing the amount of off-spec product processed to achieve the same amount of product output. Smaller scale devices, operating under the same separation principles, can generate sharp particle classification cuts below 10 microns and are targeted for the pharmaceutical/neutriceutical, food/additives, cosmetic and specialty chemical markets.

Steel

Automated Steel Cleanliness Analysis Tool (ASCAT)

The ASCAT provides steel producers with a rapid, near-real time analysis of inclusions in steel in order to correlate these inclusion measurements at various points in the process with the measured properties of the finished product. This will facilitate the determination of critical process parameters and will permit production of higher quality steel in a more cost effective manner. It has been estimated that the ASCAT has the potential to save the U.S. steel industry more than 2 trillion Btu of energy per year. In addition to energy savings, this technology has the potential to save the US steel industry about $100 million per year.

Cost-Effective, Energy-Efficient Steel Framing

The construction industry has used steel framing in residential construction for several years. However, designs for minimal energy code compliance have not always been cost-effective or practical. This project focuses on overcoming the major performance and cost barriers that prevent many builders from using steel framing. The project considers thermal performance and installed cost to determine designs for steel-framed residential and light commercial construction that are energy-efficient and meet applicable building codes.

High Quality Iron Nuggets Using a Rotary Hearth Furnace

A new process, that was demonstrated in a pilot plant, is an iron making technology that uses a rotary hearth furnace to turn iron ore fines and pulverized coal into iron nuggets of similar quality as blast furnace pig iron. The new technology will be able to effect reduction, melting, and slag removal in only about 10 minutes. The process is a simple one-step furnace operation that requires less energy, capital, and operating costs than existing pig iron technology. Consequently, high-quality iron product can be produced at a substantially lower cost.

Steel

(continued)

Hot Oxygen Injection into the Blast Furnace

A new injection system has been developed to directly inject hot oxygen in blast furnace tuyeres. Material and energy balances on the blowpipe/raceway zone of the blast furnace have shown that injecting ambient temperature oxygen offers little overall benefit, whereas injecting hot oxygen offers several mechanisms for improving burnout. This process increases coal injection rates and reduces coke consumption. Consequently, direct injection of hot oxygen into blast furnace tuyeres improves operating cost, energy consumption, and emissions.

Laser-Assisted Arc Welding

Applying this new process to steel welding will meet the needs for a new joining technology. The benefits of combining laser- and arc-welding processes will ease the current requirement for precise fit when laser welding alone. Using filler metals in the arc-welding component of the process will result in greater flexibility in the choice of materials that are joined. The process could easily be applied to nonlinear joint geometries. This process will increase the welding throughput and productivity over either laser or arc welding alone.

Life Improvement of Pot Hardware in Continuous Hot Dipping Processes

Coating steel sheets by continuous hot dipping in a molten metal bath of a Zn/Al melt is an efficient and economical method of protecting most steel sheet compositions from corrosion. Dynamic corrosion, wear, and dross buildup of galvanizing bath hardware lead to frequent downtime of production lines and consequent severe reduction of energy efficiency. A new generation of bath hardware materials provides ten times the corrosion and wear resistance in the Zn/Al bath compared with baseline materials. This new generation of bath hardware includes several entirely new materials, such as a cobalt-based super alloy (T400C) and an iron-based super alloy (MSA 2012). These materials were demonstrated at two steel company facilities with galvanizing lines where extended production was achieved.

IMPACTS

Steel
(continued)

Magnetic Gate System for Molten Metal Flow Control
This project is developing an electromagnetic flow control unit that improves the quality and productivity of the continuous casting process. The dc axisymmetric flow control device has the potential to overcome the disadvantages of high-frequency, high-power electric currents that have been tried previously. The device's configuration allows it to be used around conventional ceramic pouring tubes.

Method of Making Steel Strapping and Strip

A new continuous process has been developed that produces high quality steel strapping and strip from rod stock produced from scrap steel. The process yields a higher quality, less expensive, product while increasing the amount of recycled steel in the finished product. The continuous process has lower processing and capital costs than the conventional production method while increasing the strength of the final product.

Modeling of Post Combustion in Steelmaking
Currently, many furnaces used for molten steel production employ post-combustion technology to transfer heat to the molten steel bath. For typical electric arc furnaces and basic oxygen steelmaking furnaces, a significant amount of CO is available during the steelmaking process. Combustion of a portion of the available CO to CO_2 (post-combustion) can release heat energy above the molten steel bath. Efficient transfer of the heat energy from the post combustion gases to the molten steel bath can reduce steel production costs, save energy, and improve productivity. To optimally design the injection parameters for post combustion, modeling the injector location, geometry, and oxygen flow rates before plant trials is more cost effective, thereby minimizing operational problems associated with high temperatures (e.g., failed lances and burned hoods). The technology developed from this project enables a modeling program to be conducted in a fraction of the time it would take to start the program from scratch.

Steel
(continued)

Non-Chromium Passivation Techniques for Electrolytic Tin Plate
Two previously identified nonchromium passivation treatments for electrolytic tin plate are being compared in a plant trial to determine their commercial viability. These new techniques will replace the existing cathodic dichromate treatment method that is facing environmental use restrictions. In addition, continued use of chromate treating solutions will result in ever-increasing operating costs.

Optical Sensor for Post-Combustion Control in Electric Arc Furnace Steelmaking
This project is developing an optical sensor for electric arc furnace steelmaking based on measuring off-gas temperature and carbon monoxide, carbon dioxide, and water vapor concentrations. The remote-sensing optical instrument is based on tunable infrared-laser technology and will provide input signals for control and optimization of oxygen use and post-combustion emissions. This new technology will also address needs for improving energy use and developing automated process controls.

Oscillating Combustion
Oscillating combustion creates successive fuel-rich and fuel-lean zones within the flame. This technology reduces the formation of NO_X and increases the heat transfer from the flame to the load. Oscillating combustion is easily retrofitted to existing burners since no modifications to the burner or the furnace are necessary. Only the addition of oscillating valves, a valve controller, and assoicated piping changes are required.

Processing Electric Arc Furnace (EAF) Dust into Salable Chemical Products
This unique technology will hydro-metallurgically process EAF dust into saleable products. EAF dust is oxidized and digested in acid and then treated by a series of individual steps to isolate and retrieve individual components of the dust.

Steel
(continued)

Regeneration of Hydrochloric Acid Pickling Liquors

The PHAR® hydrochloric acid regeneration system is an innovative method of regenerating spent hydrochloric acid from steel pickling. Conventional pickling technology generates 1.5 billion gallons of spent pickle liquor nationwide each year, resulting in costly and energy-intensive handling, treatment, and disposal. This new technology eliminates the disposal problem, significantly reducing operating, environmental, and capital costs. The process uses sulfuric acid to restore hydrochloric acid for reuse. Salable ferrous sulfate heptahydrate is a by-product.

Single-Ended Infrared Emission Sensor

Newly developed laser-based sensors measure infrared emissions from the particles in the basic oxygen furnace offgas. These sensors will provide an early and direct indicator of when the steelmaking process is complete. The process uses an infrared laser beam fired across the mouth of the vessel to a spectrometer that detects molecular interference with the beam. The instantaneous analysis of CO, CO_2, and water in the gases indicates the carbon level of the bath with a high degree of accuracy, while reducing oxygen and improving furnace yield.

SQA™: Surface Quality Assured Steel Bar Program

The Surface Quality Assured (SQA) system is intended to alleviate surface quality problems faced by the special quality steel bar and rod industry and their customers, the forging industry. Surface defects in hot rolled bars is one of the most common quality issues faced by the American steel industry, accounting for roughly 50% of all steel bar rejects. The SQA system will minimize surface defects in hot rolled steel products by using process sensors to identify online automatic root causes to detect surface defects and by applying advanced diagnostic methodologies to analyze the data. The SQA system will detect these defects in real-time to mark them for downstream removal.

Steel
(continued)

Steel Foam Materials and Structures

Metal foams with high levels of controlled porosity are an emerging class of ultra-lightweight materials receiving increased attention for a broad range of applications. Steel foams produced via a powder metallurgy process are about 50% lighter than conventional steel materials and can be produced as monolithic foams, as foam-filled tubular structures, and in sandwich panel geometries. The efficient energy-absorption characteristics of steel foams can increase safety in commercial and military vehicles. The light weight can improve operational efficiency and competitiveness in shipbuilding and rail systems. These foams can also be recycled and reproduced, as well as produced from recycled metal scrap. Additional process scale-up development is required to position steel foams for production readiness and commercialization.

Submerged Entry Nozzles That Resist Clogging

Clogged nozzles in the steelmaking industry slow production and must be frequently replaced to enable a consistent flow of molten metal. A comprehensive refractory research program is providing the data necessary to define the mechanisms controlling nozzle accretion, which will form the basis for developing new technologies for reducing or eliminating nozzle clogging.

IMPACTS

Crosscutting Technologies

A Hybrid Integrated Model for Gas Metal Arc Welding

This project is attempting to completely optimize the welding process, the process parameters, and the welding consumable selections. A hybrid integrated model for Gas Metal Arc Welding (GMAW) is being developed to combine both the fundamental approaches based on physical science, where feasible, and the artificial neural networks based on industrial experimental data. The model will have direct immediate benefit in optimizing the welding processes using both solid- and cored-wire Fe-C-Mn-Si electrodes. The technology will minimize the extent of expensive trial-and-error experimentation typical of weld processes and consumables development for new steels and advanced materials.

Advanced Weld Overlay Alloys

A new advanced weld overlay alloy uses pure aluminum wire to make welds on carbon steel or nickel-based alloy substrates. Welding with pure aluminum wire results in a weld overlay deposit with typical aluminum content from 8% to 10%. Such a weld overlay offers a unique combination of oxidation, carburization, and corrosion resistance. This technology can be used in weld overlays for corrosion resistance in basic oxygen furnace hoods used in steelmaking. Various types of alloys are also being considered for that application.

Carbon Films for Next Generation Rotating Equipment Applications

A super-low-friction carbon film, Near Frictionless Carbon (NFC), and a carbon conversion film, Carbide Derived Carbon (CDC), have been combined to achieve extended wear life and higher energy savings in rotating-equipment applications, including mechanical seals, sliding bearings, and shafts. Adherent, low-friction, wear-resistant coatings for silicon carbide and other metal carbide ceramics for rotating seal applications have been developed.

Crosscutting Technologies
(continued)

Chromium Tungsten Alloys for Use as Reaction Vessels

Chromium-tungsten alloys are a new class of steels having the unique properties of strength, toughness, and stability when subjected to thermal cycling. These properties are a function of the alloy's microstructure, which results in highly favorable material properties. Chromium-tungsten applications include reaction vessels where significant reductions in plate thickness (by up to one-half) are expected and heat-transfer tubing applications where thinner-walled tubes will significantly improve heat transfer.

Continuous Fiber Ceramic Composite (CFCC): Combustion Liner

Two classes of continuous fiber ceramic composite (CFCC) materials were developed for gas turbine combustors and other stationary hot section components (e.g., transition pieces, shrouds, and nozzles). One class of CFCCs consists of continuous silicon carbide fibers in a matrix of silicon carbide, and a second class consists of oxide fibers in an oxide-based matrix. The CFCCs provide oxidation resistance and thermal and mechanical properties in air. However, silicon carbide-based CFCCs suffer degradation from water vapor attack in the hot section of gas turbines operating at high firing temperatures and pressure ratios. To improve their environmental resistance, Environmental Barrier Coatings (EBCs) were applied to the silicon carbide-based CFCCs. While the oxide-based CFCCs do not require EBCs, their mechanical properties are improved by applying thermal protection coatings to the surface. Field testing of CFCC liners in gas turbines has been ongoing in California and Massachusetts since 1997.

Diagnostics and Control of Natural Gas Fired Furnaces via Flame Image Analysis

A real-time multi-sensor expert system using vision technology and artificial intelligence techniques is being developed. This new system uses furnace video images to provide input to three independently operating sensors: 1) a flame sensor, which includes a flame detector and a flame analyzer; 2) a temperature profiler; and 3) a feed batch-line detector for glass melting furnaces. The expert system output can be integrated with a furnace control system in real time or used as a diagnostic tool for manual control adjustment by an operator. This technology can improve furnace thermal efficiency and product quality and lower NO_x and CO emissions.

Crosscutting Technologies
(continued)

Diode Laser Sensor for Combustion Control
A sensor system based on using tunable diode lasers will allow in-situ determination of the concentrations of CO, oxygen, and water vapor as well as gas temperature in harsh industrial furnaces. The chemical species targeted are key to controlling combustion for improved energy efficiency, reduced pollutants, and improved process quality.

Distributed Wireless Multisensors for Reducing Motor Energy Use
Motors consume an estimated 63% of all electricity used in industry. To reduce plant power consumption, sensors are often used to monitor the efficiency of motors used in industrial applications but deploying sensors for continuous monitoring of noncritical motors is costly. Distributed wireless technology offers continuous monitoring to both smaller and less critical motors through low-cost, distributed, multi-measure, wireless sensors. Reducing the cost and complexity of sensor deployment is anticipated to allow continuous monitoring to become pervasive, which will allow industries to better maintain and improve the efficiency of their electric motor assets.

Energy-Savings' Model for the Heat Treatment of Aluminum Castings
A research program is extending the understanding of the evolution of microstructures during the heat treatment of complex, multi-component alloys and will develop quantitative relations among process, microstructure, and properties applied to aluminum castings. The methodology developed, Integrated Heat Treatment Software (IHTS), will serve as a framework to develop quantitative process models for other alloy systems, including ferrous alloys. Compared with the current technology that specifies heat treatment cycle and furnace loadings based on prior specifications and historical "rules of thumb," IHTS is expected to reduce solutioninzing heat treatment times by 50% to 80%, leading to 25% to 50% reductions in cycle time and energy consumption and 50% indirect reduction in non-energy environmental impacts and variable costs.

Crosscutting Technologies
(continued)

Enhancement of Aluminum Alloy Forgings
The forging process creates parts that are stronger than those manufactured by any other metalworking process. Unfortunately, the grain growth in the material prior to forging can be significant, which subsequently affects the fatigue properties of the final part. The infrared technology being developed uses tungsten-halogen lamps as the heating source for the heat flux used to preheat aluminum billets prior to forging into various shapes. The technology will result in higher-quality forgings, longer fatigue life, finer grain size, and less energy consumption.

High-Density Infrared Transient Liquid Coatings
The high-density infrared (HDI) process provides a rapid, localized heating method that will allow the use of advanced cermet-fused coatings on many industrial products. This technology is currently being used to produce wear- and corrosive-resistant coatings on a variety of surfaces including current research into coatings for aluminum dies used in the automotive industry.

High-Temperature Coating for Gas Turbine Components

A new high-temperature coating material for gas turbines has been developed as a replacement for existing coating materials Coatings made from this new material provide superior cracking resistance and enhanced oxidation protection to the hot-section components of gas turbines and better adhesion for thermal barrier coatings, while reducing manufacturing cycle time and cost. In addition, the process for applying the new coating material is more environmentally friendly than some of the current techniques.

High Temperature Refractory Ceramic

A new castable refractory liner material to be used in high temperatures has been developed. The capabilities of this new ceramic liner will be a 200°C improvement in maximum allowable operating temperatures, an operating life extension of five times, and additional cost savings in installation.

IMPACTS

Crosscutting Technologies
(continued)

Insert Drill Having Three or More Flutes

A newly developed, patented drill concept uses a three-fluted design to lower horsepower requirements by allowing smaller inserts and producing smaller metal chips. For through-hole drilling, a metal slug is not ejected as the drill exits the drilled hole. This design results in a smooth finished hole eliminating the need for two or more machining operations.

Intensive Quenching Technology for Heat Treating and Forging Industries

Intensive quenching technology (IQT) for steel products was developed as an alternative way of quenching steel parts. While conventional quenching is usually performed in environmentally unfriendly oil, the IQT process uses environmentally friendly water or low-concentration water/mineral salt solutions. Complete development and commercialization of IQT in heat-treating, powder metal, and forging industries will significantly reduce energy consumption and environmental impacts, thus enhancing the economic competitiveness of the domestic steel, metal casting, and mining industries.

Iron Chromium Alloys for Use in Corrosive Environments

A new alloy (Fe-35Cr-2.5%Si) has significant potential for applications in the glass and chemical industries. The alloy is based on a sufficient level of chromium to resist aqueous corrosion and the required silicon content for the formation of SiO_2 on the surface for high-temperature oxidation resistance. This alloy is castable by conventional commercially available processes; it can be hot-formed (forged, rolled, or extruded); has limited cold formability and can be welded in thin sections without pre- and post-weld heat treatments. The alloy has been recently formed into a prototype for testing as a water cooler for refractories used in a glass-melting furnace.

Crosscutting Technologies
(continued)

Miniature, Inexpensive, Amperometric Oxygen Sensor

A new sensor to measure oxygen partial pressure from parts-per-million levels to 100% oxygen has been developed. It has particularly good sensitivity in the combustion range of 0.1% to 5% oxygen partial pressure. The new amperometric sensor, which is a multi-layer ceramic capacitor, is ideal for inexpensive mass production. The large reduction in cost of the sensor will economically allow any combustion process, including industrial, commercial, and residential furnaces and boilers, to be more closely monitored and controlled, thus saving energy.

On-Line Laser-Ultrasonic Measurement System

An on-line laser-based ultrasonic measurement of thickness and eccentricity was purported to improve the productivity of seamless mechanic steel tube making by 30% to 50% through reduced setup time, reduced out-of-specification products, and improved material use. The gauge used in the measurement also would help reduce energy consumption and pollutant emissions. The gauge has been in service since March 2002; succeeding models have added features including adjustment for variation in tube position and extension of the inspection range to smaller diameters and wall thicknesses. The original installation had an estimated annual energy savings of about 5%, or 23 billion Btu, primarily from increases in efficiency (target size is achieved faster) and quality (record low tube wall scrap rates were reached).

Particulate Ejection Coal Fired Turbine

A sub-scale prototype of a medialess inertial rotary disk filter was successfully evaluated to operate at the high temperatures/pressures typically found in coal-fired gas turbine generators. This technology demonstrates 98% to 99% coal ash removal efficiency without fouling, thus reducing the need for conventional disposable porous ceramic candle filters for hot gas filtration. Constant filtration efficiency and non-varying pressure drop across the all-metal filter eliminates brittle ceramic failures and allows operation at higher gas temperatures, which eliminates gas reheating and improves energy efficiency. The continuously self-cleaning technology may also eliminate landfilling of spent/replaced ceramic candles.

Crosscutting Technologies
(continued)

Portable Parallel Beam X-Ray Diffraction Systems
Real-time, nondestructive in-line measurements of material properties are needed for process control in metallurgical, thin film materials, and pharmaceutical manufacturing. By incorporating newly developed X-Beam®, x-ray diffraction systems can be used to identify structural phases, determine grain size, and measure stress and texture of materials in line. This parallel beam x-ray diffraction technology uses a polycapillary collimating optic to collect x-rays over a large solid angle from a low-power x-ray source to form an intense quasi-parallel beam. This technology reduces or eliminates errors from sample misalignment and surface roughness, reduces power consumption, and improves measurement efficiency.

Process Heater System
A new generation of process heaters has been developed and demonstrated that is extremely low in emissions. This innovative system incorporates several advanced technologies: 1) ultra-low-emission (ULE) burners; 2) a specially designed fired heater with enhanced heat recovery, optimized for use with the ULE burner systems; and 3) on-line tube metal temperature sensors and burner control system to optimize heater operation, reduce maintenance costs, and increase run lengths. The technology will have applications for a broad range of refining and chemical processes. The advanced heater components will be developed for new design and retrofit applications.

Radiation Barrier Heating Mantle for High-Temperature Furnaces

Retort furnaces, which consist of a heating-mantle jacket surrounding a retort vessel, are widely used to generate high temperatures for the metal-processing, chemical-processing, and heat-treating industries. A new porous wall radiation barrier (PWRB) heating mantle represents a breakthrough in heating mantles that significantly increases heat-transfer rates over both the existing gas-fired heating mantle and the electrically heated mantle. This unique development results in a heat-transfer rate in the 1,800°F to 2,400°F range that is 2 to 4 times greater than electric and conventional gas-fired mantles.

Crosscutting Technologies
(continued)

Rotary Burner

A new rotary burner that provides ultra-low combustion emissions along with significant fuel and electricity savings has been developed and field-tested. The novel technology uses a process that allows for expansion of pressure energy in a rotary burner, meaning that combustion air needs can be satisfied and inherently coupled to match the fuel demand to ensure the desired air-to-fuel ratio. Its compact size ensures ease of retrofit to existing installations.

Self-Dressing Resistance Welding Electrode

The project is designed to produce an electrode from a unique metal-matrix composite material that employs a ceramic substrate, which enhances the themal resistance properties of the composite material, as the load-bearing element. The composite material also uses a metal matrix as the conduit for the electric current flow. The project will be carried out in four separate tasks, consisting of material selection, design development and optimization, fabrication and model verification, and performance test and evaluation.

Sensing and Control of Cupola Furnaces
This project is developing an intelligent, integrated industrial process sensing and control system to optimize the performance of cupola furnaces. This system regulates the melt rate, temperature, and iron composition of the furnace. Successful control of furnace variables will increase energy efficiency, furnace yield, and productivity and will reduce environmental emissions.

Super Boiler
The Super Boiler concept using ultra-high-efficiency, ultra-low-emission steam generation technologies is targeted for broad industrial applications over the next 15 to 25 years. The concept combines a suite of enabling technologies such as a staged intercooled combustion system with forced internal recirculation, high-intensity heat transfer surfaces, an advanced transport membrane condenser, and a smart control system in an integrated package. The performance goals include 94% fuel efficiency, 5 vppm NO_x and CO, and 50% size and weight reduction compared with a conventional firetube boiler.

IMPACTS

Crosscutting Technologies
(continued)

Thermal Imaging Control of High Temperature Furnaces
The near-infrared thermal imaging system fine-tunes the main furnace controller for improved combustion performance. The system uses multiple infrared wavelengths combined with a periscope probe to map the full field of combustion space during furnace operation. Control algorithms minimize differences between measured field temperatures and temperature set points and send output signals to the main furnace combustion control. Optimizing the combustion process has been shown to decrease the total fuel use by at least 5%, with a corresponding decrease in airborne emissions.

Thermoelectric Generator for Diesel Engines

This new technology generates electric energy from waste heat and has many applications in the power industry, as well as in the chemical and petroleum industries. One possible application is as an array on the exhaust of the gas turbine to increase efficiency. Heavy earth moving equipment for mining presents another potential application. A prototype generator is being tested by a truck manufacturer and has been driven on their test track for 500,000 miles to demonstrate the ability to endure shock and vibration.

Tough-Coated Hard Powders

Revolutionary tough-coated hard powder (TCHP) pseudoalloys combine the highest extremes of fracture toughness, hardness, wear resistance, light weight, low coefficient of friction, and thermal properties ever known. Designed nanostructures are created by nano-encapsulating extremely hard micrometer-scale core particles (e.g., diamond) with very tough materials (e.g., tungsten carbide and cobalt), which in the consolidation process become the contiguous matrix. As many unique properties can coexist in a TCHP variety as there are different core particle materials present in the uniform tough substrate. Extreme strength, double-digit component and tool life multiples, and reduced friction and thermal losses combine to enable tens of billions of dollars in annual cost, energy, and environmental impact improvements.

Crosscutting Technologies
(continued)

Ultrananocrystalline Diamond Coatings
Ultrananocrystalline diamond (UNCD) coatings can be grown on various substrates by using emerging microwave plasma chemical vapor deposition technology. The coatings exhibit a unique microstructure that provides superior mechanical (high hardness), tribological (low coefficient of friction), chemical (inertness to chemical attack), and electronic (wide range of conductivity via doping) properties. Multipurpose mechanical pump seals will be the first to benefit from these coatings.

Variable Speed, Low Cost Motor for Residential HVAC Systems

Existing variable-speed motors cost at least four times as much as single-speed motors and thus are currently used in only 5% of residential HVAC systems. A revolutionary low-cost, brushless, variable-speed motor technology uses solid-state switches on the rotating armature to control motor torque and speed. It will shortly be tested by a dozen major HVAC suppliers. A variable-speed motor running continuously at half speed compared with a single-speed motor running at full speed but half the time uses 25% of the power to move the same amount of air in an HVAC blower, thus saving energy.

Wear Resistant Composite Structure of Vitreous Carbon Containing Convoluted Fibers

A novel method makes a composite material consisting of a vitreous silicon/carbide matrix containing carbon fibers. The resulting product has better wear resistance, lower fade, and higher electrical conductivity than competing materials. The material is being developed for use in cable and third rail electric transportation systems, such as light rail.

Crosscutting Technologies
(continued)

Wireless Sensor Network for Motor Energy Management
Energy use of large motors (over 200 hp) has already been reduced with advanced monitoring and diagnostic systems served by conventional field wiring. Deploying monitoring systems on smaller motors could further reduce motor energy use by 18% but is not cost-effective with conventional wiring and thereby does not promote the identification of energy savings and opportunities to improve uptime. Wireless sensors that monitor voltage and current and integrate with advanced energy and inferential condition management software are being developed to serve this need. The research effort will focus on developing smart sensors with embedded intelligence as well as network system robustness to ensure system security, self-configuration capability, cost effectiveness, and the ability to accommodate plant complexity.

Wireless Sensors for Process Stream Sampling and Analysis
Sensing and control of manufacturing present unique problems associated with effective sampling in harsh environments and real-time control. Several promising wireless technologies are being explored as systems most likely to meet the demanding requirements of industrial control of manufacturing processes. Wireless sensors for sampling and analyzing process streams will be tested at multiple sites to see how well they satisfy the key considerations of operational reliability, sustained performance in harsh environments, invulnerability to interference, security and bandwidth efficiency, and other factors that are critical for the ultimate wide-spread deployment of robust wireless sensor networks in manufacturing. In addition to production line measurement and control, the anticipated low cost of this technology will enable wireless sensors to be used to determine energy- and environmental-related process parameters that are not traditionally monitored.

Other Industries

BEI Cellulose Hydrolysis Process
The BEI Dilute-Acid Cellulose Hydrolysis (DACH) Process and Reactor System uses a double tubular reactor system in two stages, which is automatically controlled to continuously convert cellulose feedstock into fermentable sugars solution products. The second stage of the BEI-DACH process reactor system recovers excess and surplus process heat and acid-chemicals for reuse in the first stage, providing exceptional energy and acid efficiencies and related economic savings. The BEI-DACH reactor system process hydrolyzes cellulose into a pentose, hexose, and glucose sugars solution at the point of use. These DACH sugars may then be yeast-fermented into ethanol and/or single-cell-protein and into other organic chemicals as commercial products.

Biofine Technology
The Biofine technology can convert low-grade cellulose-containing wastes from paper mills, municipal solid waste plants, logging and agricultural operations, and other sources into levulinic acid, a versatile platform chemical that is an intermediate to several high-value chemical and oxygenated fuel products. Cellulose is converted to levulinic acid using a novel, high-temperature, dilute acid hydrolysis reaction system.

Clean Energy from Biosolids
The innovative and unique SlurryCarb™ process receives waste as a slurry and subjects it to heat and pressure in a reactor unit to rearrange the slurry molecularly. This step produces a homogeneous, clean fuel with an energy density significantly greater than untreated material. The high-energy renewable "E-Fuel" can be used efficiently in conventional combustion equipment as a substitute for fossil fuel.

Deep-Discharge Zinc-Bromine Battery Module
A new zinc-bromine battery is being demonstrated that increases load-leveling efficiency and offers longer cycle life with less weight than conventional lead-acid batteries. This new battery is applicable to electric utilities and industrial companies. The modular construction allows for sizing and portability of the system to suit multiple applications and needs. This technology allows customers to purchase lower-cost power and then use it for reducing peak-power purchases.

IMPACTS

Other Industries
(continued)

Distillation Column Flooding Predictor

A new control technology more accurately identifies incipient floods in petrochemical distillation and separation columns. The Flooding Predictor, a patented pattern recognition technology, allows a column to be operated at or near the incipient flood point. The technology identifies patterns of transient instabilities that occur just before flooding events. Identifying the incipient flood point allows the control objective to be shifted from delta-pressure to the actual flood point. Shifting the control objective virtually eliminates column flooding events, while increasing throughput.

Distributed Optical Fiber Sensors for Continuous Liquid Level Tank Gauging

The Noverflo Multipoint Tank Gauging (NMTG) system is a family of fiber optic sensor arrays designed for the oil and gas, transportation, and food/beverage processing industries. Compared with similar products, the NMTG offers a simple design that allows both low and high accuracy measurements to be made at a very low cost. The system can make accurate measurements in liquids of shifting densities and performs continuous density measurements at any tank level. A new data acquisitions system allows the NMTG to monitor hundreds of sensors and numerous external-switching devices without any upgrades to existing systems.

Float Zone Silicon Sheet Growth

This innovative technology consists of a process to develop crystalline silicon sheet from a polycrystalline silicon source. Its primary goal is the efficient, low-cost production of high-quality crystal silicon sheet for the solar and electronics industry. Development of this process will provide several important benefits, such as high production rates, low cost in terms of material and energy input, good dimensional control, improved crystal quality, and remarkable purity the same as the source material.

Other Industries
(continued)

Forging Advisor

The forging advisor (also called the near net shape process selection advisor) is a manufacturing process selection system that allows engineers to rapidly analyze trade-offs with respect to geometry, performance, and cost among a series of manufacturing processes. The processes chosen for implementation in the advisor include three types of investment casting, rough machining, forging, and laser enabled net shaping. The system also provides input on best practices for the design of forgeable parts.

High-Intensity Silicon Vertical Multi-Junction Solar Cells

A new solar cell combines high voltage with low series resistance operation to create efficient concentrated solar power conversion at low cost. Output power densities exceeding 1000 times that of conventional solar cells have been demonstrated. The simple design of the new cell results in lower manufacturing costs and robust reliability compared with existing concentrator cells. Basically, the new solar cell technology enables high intensity photovoltaic concentrator systems that provide considerably lower $/watt cost than conventional photovoltaic modules. Immediate applications include large-scale electric power generation (>100 kW) in sunny regions of the world.

Hydrodyne Process for Tenderizing Meat

The hydrodyne process offers a unique way of tenderizing meat, particularly tougher meat with less fat. The innovative new technology reduces beef tenderization time from weeks to a fraction of a second by using hydrodynamic shock waves. The process can increase beef tenderness in tougher meat cuts by as much as 72% without changing natural appearance, texture, or flavor.

Novel Membrane-Based Process for Producing Lactate Esters

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

Other Industries
(continued)

Petroleum Fouling Mitigation
In refinery process units, fouling is a deposit buildup that impedes heat transfer, increases pumping power, decreases equipment reliability, and results in a leading cause of diminished efficiency and productivity in refineries. The increasing use of crude oils with high concentration of naphthenic acid and sulfur content is causing refinery equipment to corrode. Furthermore, the corrosion product (iron naphthenate) is causing high iron-sulfide induced fouling/coking. Research and development is urgently needed for on-line monitoring and effective mitigation techniques to reduce fouling problems. A threshold-fouling model and fouling test units were developed for establishing operating procedures to allow refineries to operate heat-exchange equipment (heat-exchangers and fired heaters) below threshold fouling conditions. The refinery industry will use these tools to determine the root cause of fouling and to evaluate cost-effective mitigation techniques. Real-time fouling monitoring and root-cause analysis provide the basis for the condition-based maintenance of heat-exchange equipment.

Plastics, Fibers, and Solvents from Biosynthetically Derived Organic Acids
Biologically-derived succinic acid is produced by fermenting sugar derived from grains and other biomass. After separation and purification, the succinic acid is used as a chemical intermediate that is converted into a wide assortment of products such as plastics for automobiles and household items, fibers for clothing, food additives, solvents, deicers, agricultural products, ink, and water treatment chemicals.

Pulsed Laser Imager for Detecting Hydrocarbon and VOC Emissions

A new hydrocarbon detection device, the pulsed laser imager, uses the principles of infrared spectroscopy to locate and measure the extent of hydrocarbon leaks and emissions of volatile organic compounds (VOCs). The imager's main advantage over its competitors is its remote-sensing feature that does not require an air sample. The imager detects hydrocarbon leaks from a safe distance by analyzing the electromagnetic spectra of the compounds. Both the short- and long-range versions of the pulsed laser imager are flexible, sensitive, accurate, and intrinsically safe and provide a cost-effective solution to hydrocarbon detection.

Other Industries
(continued)

Soy-Based 2-Cycle Engine Oils
A new soy-based biodegradable lubricant called AquaLogic 460 has been developed to replace petroleum oils used in 2-cycle marine engines for outboard and personal watercraft. The new product is greater than 80% biodegradable, produces lower emissions, and extends engine life.

SO_3 Cleaning Process in Semiconductor Manufacturing


A new process is being demonstrated that removes photoresist from semiconductor wafers by exposing the wafers to SO_3 gas followed by a deionized water rinse. Hardened photoresist must be thoroughly cleaned from very small crevices on the wafer at various stages in the manufacturing process. This process is anticipated to substantially replace damaging dry stripping and wet stripping that produces hazardous waste in the semiconductor manufacturing industry.

Thermophotovoltaic Electric Power Generation Using Exhaust Heat

This new technology produces electricity directly from furnace exhaust waste heat by using infrared-sensitive photovoltaic cells. The cells are mounted inside ceramic tubes that are heated in the high-temperature exhaust stream from furnaces. This technology allows on-site generation of electricity from waste heat in industrial or residential applications.