

# appendix 3:

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### Aerocylinder Replacement for Single-Action Cylinders

The aerocylinder, a new machinery shock absorber, replaces conventional, single-action compressed-air cylinders in industrial forging, stamping, and welding applications. The aerocylinder has been installed on over 400 stamping and welding presses, primarily in the automotive industry. Using this new system reduces downtime, prolongs equipment life, improves final product quality, and has resulted in an energy savings of more than 340 billion Btu since 1988.

### Aluminum Roofing System

This new technology uses aluminum chips to reflect about 70% of the solar radiation received on asphalt roofs, which reduces building cooling needs. This invention has saved over 635 billion Btu since its introduction in 1984 and is now used on more than 35 million square feet of roofing.

### Arc Furnace Post-Combustion Lance

A new technology was developed that was applied in electric arc furnaces to increase productivity, reduce energy requirements, and improve control. The system consists of a water-cooled lance and controls to inject oxygen to combust the carbon monoxide in and above the furnace's foamy slag. The six installed systems have saved a total of 2.46 trillion Btu of energy.

### Auxiliary Air-Conditioning, Heating and Engine Warming System for Trucks

An auxiliary power unit was developed to maintain cab power in heavy-duty, long-haul trucks when the main engine is not operating. This unit takes fuel from the truck's fuel tanks to heat and air-condition the cab and sleeper, to generate electricity to keep the battery charged, and to furnish hot water to keep the truck's engine warm. Since 1988, more than 3000 units have been installed on trucks and have saved an estimated 19.9 trillion Btu in the form of diesel fuel.

### Biomass Grain Dryer

Originally developed for grain-drying processes, this heat exchanger system later expanded into the furniture industry. By burning husklage, wood waste, or other biomass fuels, the process quickly disposed of combustible waste, provided an alternative energy source, and saved landfilling fees. Used within both the corn and furniture manufacturing industries, this system resulted in a cumulative 1.35 trillion Btu in energy savings and reduced landfill scrap by thousands of tons since being commercialized.

### Biphase Rotary Separator Turbine

A new biphase turbine recovers waste energy from pressurized process streams that separate into liquid and gas when the streams are depressurized. Conventional turbines cannot be used efficiently with two-phase flows because they cannot withstand the forces released during the liquid's rapid evaporation to a vapor. This new turbine is being used by 125 large (500-ton) chillers and is saving 15 kW per chiller, for a cumulative savings of 107 billion Btu.

### Catalytic Distillation

Distillation is one of the most energy-intensive industrial processes, accounting for over 40% of the energy consumed by the chemicals industry each year. This single-stage catalytic reaction/distillation process has become a major commercial success and has improved the energy efficiency and productivity of certain chemical processes, including the production of methyltertiary- butyl-ether (MTBE) and tertiary-amyl-methyl-ether (TAME). Since its introduction in 1982, the 36 units installed in the United States have saved 43 trillion Btu.

### Cement Particle-Size Classifier

A system was developed to control the size distribution of cement particles and to help reduce the current energy-intensive regrinding process. Cement products produced from the improved particle distribution consumed less energy and were of better quality. This system yielded a total of approximately 9.5 trillion Btu in energy savings since its commercialization in 1984.

## Chemical Separation by Fluid Extraction

This technology removes hazardous organic compounds from contaminated solid or liquid waste streams. The technology is more energy efficient than conventional technical hazardous waste treatment methods. The use of this technology has resulted in energy savings of 440 trillion Btu since 1990.

## Cogeneration – Coal-Fired Steam Turbine

Using a coal-fired boiler and turbine exhaust steam system, a cogeneration process was developed for use primarily within the textile industry. The 16 systems installed saved more than 31 trillion Btu of energy/year and significantly reduced emissions due to lower demand for utility-generated electricity.

## Cogeneration – Slow Speed Diesel Engine

This stationary internal combustion, slow-speed, two-stroke diesel engine was developed to accommodate limited space and/or varying load demands. The compact, slow-speed diesel engine has excellent efficiency, greater load flexibility, and lower fuel and maintenance costs than conventional cogeneration options. The three installed units have saved a total of approximately 17.7 trillion Btu of energy.

## Coil Coating Ovens

This system was developed to recover thermal energy previously lost in the solvent-based paint curing/incineration process. Heat, recovered from solvent vapor combustion in zone incinerators, was routed back into the curing oven to vaporize more solvent. The thermal incinerators normally used were replaced by afterburners and a waste heat boiler to produce process steam. A three-fourths reduction in natural gas requirements and a reduction in pollution control energy resulted in over 35 trillion Btu of cumulative energy savings since the system was commercialized. The savings were increased even further as a result of a technology upgrade that eliminated the zone-burning portion of the process.

## Combination Grain Drying

Designed to prevent spoilage during storage and reduce energy consumption, this system used a high-speed dryer and storage bin equipped with a drying fan. The grain was first dried by a high-speed, hot-air dryer, then transferred to a drying/storage bin that delivered ambient air to cool and further dry the grain to a moisture content of around 14%. This combination drying method improved grain quality, increased drying capacity, and reduced propane and natural gas consumption.

## Component Cleaning

A new chemical product for industrial cleaning was developed based on supercritical fluid technology. New equipment was developed that converted carbon dioxide (CO<sub>2</sub>) into a fluid that was used to clean metal, plastics, printed wire boards, etc. This new technology takes the place of chlorofluorocarbon (CFC) solvents in the cleaning process and has reduced the energy needed to evaporate the solvents during the drying process.

## Computer-Controlled Oven

To lower volatile organic compound (VOC) emissions, the computer-controlled oven technology was developed that permits operation at a higher percentage of lower explosive limits, reducing in dilution air requirements and the energy required to heat the high-temperature ovens. Optimizing airflows reduces VOC emissions that, in turn, reduces VOC incineration requirements. Fifteen installations saved a cumulative total of 27.75 trillion Btu of energy since being commercialized in 1982.

## Cupola Stack Air Injection

This process reduced the carbon monoxide (CO) content of the effluents from a cupola furnace and improved the efficiency of combustion in the furnace during production of gray iron. This process eliminated the need for afterburners and the large amounts of energy they used to reduce the CO content in the emissions. By injecting air into the exhaust gases below the furnace charging door, the CO was ignited at temperatures already existing in the stack, with the resulting final exhaust gas having a CO concentration of less than 1%. Cupola stack air injection saved a total of 80 billion Btu of energy before being superseded by more advanced technology.

### Delta T Dryer Control System

This dryer control system significantly improves control capability because it measures moisture content continuously in the dryer rather than only at the exit from the dryer. This more precise temperature control saves 10% to 20% more energy than conventional dryer control systems. Over 200 Delta T control systems have been installed and have saved more than 12 trillion Btu since 1985.

### Direct Source-to-Object Radiant Heating Panels

Radiant heating systems transfer heat directly to a person or object in a manner similar to sunlight, eliminating mechanical heat-delivery requirements. These systems can save up to 50% in heating costs compared with baseboard electric-resistance heating and up to 30% compared with heat pumps. Since 1981, more than 375,000 radiant heating panels have been sold, saving more than 1.45 trillion Btu.

### D'MAND® Hot Water Recirculating and Waste Prevention System

A new system was developed for water heaters to conserve water and energy while providing hot water on demand. The system recycles the hot water that would have remained in the pipes. The primary energy savings are from the reduced amount of energy needed to heat the water returned to the water heater tank. More than 26,000 units have been installed, primarily in residential applications, and have cumulatively saved 386 billion Btu.

### Dye Bath Reuse

To reduce the use of chemicals, water, and energy, two process modifications were developed for batch-dyeing textiles. These modified processes involved reconstituting and recycling the spent dye bath, eliminating the final rinse-water step. These modifications resulted in a cumulative energy savings of 2 trillion Btu prior to being replaced with advanced technologies.

### Electric Tundish

An enclosed and more efficient holding furnace or tundish was developed and demonstrated for the continuous casting of copper alloys. Switching to electricity to heat the tundish rather than gas or oil results in an energy efficiency increase from 20% to 98%. Four tundishes were installed in 1994 and operated until the manufacturing facility closed in 1996.

### Energy-Efficient Canning

A thermal syphon recycle system using a recycling steam jet vacuum compressor and a recirculation pump and heat exchanger outside of the cooker were two methods developed to improve energy efficiency in the canning industry. From the installation of 100 new or retrofitted units, a cumulative energy savings of nearly 3 trillion Btu were realized.

### Energy-Efficient Fertilizer Production (Pipe Cross Reactor)

An ammonia granulation technology was developed to reduce moisture content and energy consumption in the production of pellet fertilizers. The process employed a pipe-cross configured reactor, mounted within a granulator, where liquid raw materials were mixed and then dried via heat from the chemical reaction. Seven reactors were constructed that produced a superior product with a 1% moisture content, reduced pollution, and contributed a cumulative energy savings of 2.6 trillion Btu.

### Fluidized-Bed Waste Heat Recovery System

A self-cleaning waste heat recovery system was developed to replace industrial furnace conventional recuperators. The new system employed finned heat exchange tubes submerged in a bed of spherical alumina particles that absorbed heat from the hot gas and transferred it to the finned tubes. The water flowing through the tubes was converted to steam for use elsewhere in the plants while the alumina particle agitation kept the tubing clean and distributed the heat evenly.

## Foam Processing

To replace the very energy-intensive wet processing of textiles, a process was developed to substitute medium-density foam for some of the water processing. A 50% to 70% moisture retention reduction was realized along with a significant decrease in energy previously required for drying, water usage, and pollution control. This technology, and several similar techniques, achieved a cumulative energy savings of more than 11 trillion Btu.

## Glass Feedstock Purification

A new optical sortation technology, which removes ceramic and other contaminants from glass cullet using optical sensors and computer-controlled jets of compressed air, was developed. This technology was used to recycle 50 tons/day of glass at one plant for two years thus resulting in a cumulative energy savings of 48 billion Btu.

## Heat Exchanger Dryer

This modified multideck dryer that incorporated a heat recovery system, was developed for the wood board products industry. Air-to-air, air-to-water, and air-to-liquid heat exchangers enabled the previously lost heat from exhaust gases to be reused throughout the plant. Three installations yielded nearly 800 billion Btu in cumulative energy savings.

## High-Effectiveness Plate-Fin Recuperator

New materials and fabrication techniques made the previously cost prohibitive plate-fin recuperators more economically feasible for a larger number of industrial applications. The recuperators can recover 90% of the energy from exhaust as hot as 1550°F, are more compact than conventional techniques, and use a flexible flow pattern. Further, the new technology provides more heat transfer surface per cubic foot of volume and is often used in nonfouling heat recovery applications. More than 100 units were installed with a cumulative energy savings of around 5 trillion Btu.

## High-Efficiency Dehumidifier

A new system was developed to recover reheat energy and to control the humidity in all types of buildings. This system uses heat pipe technology to increase the humidifying capacity of air-conditioning equipment and operates without any mechanical or electrical inputs. More than 12,000 units have been sold and have cumulatively 1.38 trillion Btu.

## High-Efficiency Direct-Contact Water Heater

This industrial/commercial water heating system uses a water-cooled burner sleeve and combustion zone to extract all possible energy from natural gas combustion by bringing water into direct contact with a submerged-flame jet-type burner. More than 3,000 units are in use throughout the United States, and have saved a cumulative total of more than 300 trillion Btu in natural gas.

## High-Efficiency Weld Unit

An inverter welding power source that included a multiprocess capability was developed for arc welding processes. Up to 75% smaller in size and weight than conventional units, this system's portability and improved weld quality also provided energy savings of up to 45% over conventional power sources. More than 75,000 units were sold, resulting in a cumulative energy savings of 21 trillion Btu before they were replaced by more advanced welding technology.

## High-Temperature Burner Duct Recuperators

Two ceramic tube recuperators, able to withstand 2000°F+ temperatures, were designed to recover heat from high-temperature industrial furnace exhausts. Used in iron forging and steel production, fuel consumption was reduced by approximately 50%.

## Hot Blast Stove Process Model and Model-Based Controller

A central control system was developed and installed on a blast furnace to optimize the thermal efficiency of the hot-blast stove system. The controller is linked to process optimization algorithms that determine heating fuel rates, thus minimizing fuel requirements and reducing the number of disruptions in iron production. This invention has saved more than 220 billion Btu since its installation in 1998.

### Humidity Sensor (Optical)

An optical humidity sensor (hygrometer) that determines humidity by measuring the absorption of ultraviolet light was developed for the pulp and paper industry. Replacing less reliable humidity sensors, the hygrometer maximizes drying efficiency by optimizing the balance of exhausted and makeup air. Multiple installations realized a cumulative energy savings of 20 billion Btu.

### Hyperfiltration – Textiles

Hyperfiltration, a membrane-based separation technique, was adapted to treat textile industry wastewater. This process also found widespread use in the food-processing, biotechnology, pharmaceutical, pulp/paper, chemical, electronic, and nuclear industries. Allowing recovery of raw materials and minimizing waste, this process achieved a cumulative energy savings of nearly 1 trillion Btu.

### Hyperfiltration Process for Food

A membrane hyperfiltration process is being used to separate juice into pulp and liquid fractions. This process replaces the energy-intensive thermal evaporation step in the concentration process. This process has been installed in 17 locations and has saved more than 13 trillion Btu since 1989.

### Irrigation Systems

The design of efficient low-pressure impact sprinklers, low-pressure spray heads, and improved drop tubes upgraded center-pivot irrigation systems dramatically. Operating at lower pressures, these systems required 10% less water intake, reduced runoff, and yielded a cumulative energy savings of approximately 49 trillion Btu due to reduced pumping requirements.

### Lightweight Steel Containers

A new process for manufacturing lightweight steel containers uses the container's internal pressure for rigidity rather than a thick wall. The resulting container wall is substantially thinner, which reduces the container's metal content by 40% but provides equivalent or better strength. The process saves energy by using less material in the container, less material processing, and less transportation weight. Two container production lines have cumulatively saved 3 billion Btu.

### Membrane Filtration Technology to Process Black Olives

A zero discharge wastewater purification and reclamation system was installed at an olive production plant. This new system used a cyclone separation system followed by ultrafiltration and reverse osmosis to recycle wastewater back into the plant. Since its installation in 1997, it has saved 100 billion Btu.

### Membrane Separation of Sweeteners

A system to preconcentrate corn steep water was accomplished via a hollow-fiber membrane process. Resistant to fouling, this system extracted more than 50% of the water from the corn steep stream prior to evaporation, thus significantly reducing energy requirements. Additionally, a spin-off technology was commercialized for wastewater treatment.

### Meta-Lax Stress Relief Process

A new process applies subresonant vibrational energy to relieve stress in metal objects. The process replaces heat treating applications and reduces the energy and time needed to heat treat metal. The equipment is portable and treats a wide variety of work pieces in a pollution-free operation. More than 890 units have cumulatively saved 98 trillion Btu.

### Methanol Recovery from Hydrogen Peroxide Production

A new process was developed to recover and clean contaminated methanol for reuse in producing hydrogen peroxide. This process recovers more than 90% of the methanol needed to produce hydrogen peroxide, thereby saving the energy needed to produce virgin methanol. The process also saves energy by reducing the transportation of virgin methanol. The two units using this process have cumulatively saved 244 billion Btu.

### Night Sky-A New Roofing Technology

A natural evaporating roofing/cooling system was developed for flat or slope-roofed commercial buildings to increase the roof's life expectancy and reduce building cooling loads by 50%. This system spray-cools water on the roof at night and then applies the cooled water to reduce subsequent cooling loads. Systems involving more than 95,000 square feet have been installed and have cumulatively saved 2 billion Btu.

## Nitrogen-Methanol Carburization

A system was developed for steel manufacturers that replaced the conventional endothermic atmosphere process with a nitrogen-methanol carburization process. In addition to improving the strength, hardness, and wear resistance of the steel parts, the system proved more reliable and easier to operate. Significant reductions in carbon dioxide and other pollutants were noted along with a cumulative energy savings of 12 trillion Btu.

## No-Clean Soldering Process

After soldering, electronic equipment used to be cleaned using CFC solvents. Changing the soldering technique eliminated the need to use CFC solvents for cleaning, resulting in energy savings and reduced CFC waste. This process has cumulatively saved 3.9 trillion Btu.

## Organic Rankine-Cycle Bottoming Unit

This organic Rankine-cycle system was developed to replace less-efficient, conventional steam Rankine-cycle systems in generating electricity from lower temperature waste-heat sources. It was found to be adaptable to a variety of solar and geo-thermal energy applications as well as suitable for many types of industrial waste-heat streams. The system consists of a standard Rankine-cycle engine, toluene as the working fluid, a waste-heat boiler, a waste-gas flow-control valve, system controls, and an electric generator. The installation of several units cumulatively saved 500 billion Btu of energy.

## Oxy-Fuel Firing

This oxygen-enriched combustion system for glass-melting furnaces significantly reduces energy requirements. About one-fourth of all glass-melting capacity in the United States has been converted to oxy-fuel firing. In addition to energy savings, this technology reduces NO<sub>x</sub> emissions by up to 90% and particulates by up to 30%. Since its commercialization in 1990, oxy-fuel firing technology has saved more than 25 trillion Btu.

## Pallet Production Using Postconsumer Wastepaper

A new process produces paper pallets made of 40% postconsumer waste paper. Substituting virgin wood with this recycled product reduces by 60% the energy required to produce pallets, saves landfill space, and decreases air and water pollution. The process has cumulatively saved over 2 billion Btu.

## PET Bottle Separator

Recycling certain plastics for conversion into fuel oil necessitated the development of a separation process that could sort containers of PET (polyethylene terephthalate), high-density polyethylene, and aluminum. One bottling plant using this process recycled 18 million pounds of PET and saved a total of 1.2 trillion Btu of energy.

## Pinch Analysis and Industrial Heat Pumps

Pinch analysis was used to locate the most productive process modifications and heat pump opportunities within a complex process to improve overall process efficiency. A pinch analysis of a wet-corn-milling plant showed that adding two new thermal vapor recompression heat pumps to existing evaporators could reduce overall process fuel use by 33%. These two heat pumps have cumulatively saved 917 billion Btu.

## Plating Waste Concentrator

A low-cost, vapor-recompression evaporation system was developed for the plating and surface-finishing industry to reduce water pollution and recover costly plating chemicals. The waste concentrator was designed with two evaporators, one to concentrate the wastewater and the other to use waste heat as an energy source. Recovery of plating metals, reduced hazardous material treatment costs, and energy recycling all contributed to improved operating costs and energy efficiencies. This technology was used in 62 applications and resulted in a cumulative energy savings of 3 trillion Btu.

### Recuperators

A cross-flow ceramic recuperator made of cordierite (a magnesium-aluminum silicate) was developed to recover heat from exhaust gases in high-temperature (up to 2600°F) furnaces. Corrosion and oxidation resistant, the compactly sized recuperator eliminated the need for a flue gas dilution system. These units cumulatively saved over 24 trillion Btu in energy and reduced both thermal and emissions pollution.

### Retractable® Labyrinth Packing Seals for Turbine Shafts

This invention is a redesigned shaft-sealing ring for utility and industrial steam turbines that self-adjusts from the gap required for start-up to that required for normal operation. The result is less wear damage and improved turbine efficiency. More than 500 of these new seals have been installed and have saved more than 74 trillion Btu.

### Reverse Brayton Cycle Solvent-Recovery Heat Pump

A reverse Brayton cycle heat pump was developed to economically and efficiently recover solvents from numerous industries. This heat pump reduces the demand for new solvents, saving petroleum feedstock and the energy used to produce virgin solvents, and captures for reuse solvents that would have been released to the atmosphere. Ten heat pumps have been installed and have cumulatively saved 4.98 trillion Btu.

### Robotic Inspection System for Storage Tanks

This technology consists of a remotely operated robotic inspection vehicle that is submerged in bulk liquid storage tanks to gather input on structural and corrosion problems. This system replaces the time-consuming conventional inspection process of draining the tank, washing it out, inspecting it, and then refilling it. This technology has cumulatively saved 280 billion Btu.

### Scrap Tire Recycling

This new process converts scrap tires into high-value products, conserving energy and new materials while reducing the amount of scrap tires sent to landfills. This treatment process combines surface-treated rubber particles with other polymers such as polyurethane, epoxy, and polysulfide to form unique composites with improved strength, tear resistance, and resilience. This process has saved a cumulative 0.16 trillion Btu in natural gas.

### Selective Zone Isolation for HVAC Systems

A new method for selectively controlling air flow from a central HVAC system can now fit into ducts that cannot accept conventional dampers because of poor access. The flexible dampers can save 20% to 30% of a typical heating and cooling bill in a large house or commercial building by sealing off unoccupied rooms. More than 4000 systems have been sold and have cumulatively saved 305 billion Btu.

### SIDTEC™ Condenser Maintenance Program

A new on-line condenser tube cleaning system uses ultra-high molecular weight polyethylene tube cleaners to remove both soft and hard deposits. The system maintains system efficiency and keeps the thermal power plant operating. Eleven power plants have used the new system and have cumulatively saved 97 trillion Btu.

### Slot Forge Furnace/Recuperator

A high-performance slot forge furnace design that incorporated a ceramic shell-and-tube recuperator was developed to recover approximately half of the heat energy previously lost in the furnace exhaust gases. Additionally, modified recirculation burners, improved temperature and air/fuel ratio controls, and lightweight furnace wall insulation reduced energy requirements per pound of steel by approximately 4100 Btu. The use of this technology resulted in a cumulative energy savings of 13 trillion Btu.

## Solar Process Heat

This project was developed to expand the use of solar process heating systems primarily within the government and institutional sectors. Reducing the need for fossil fuels, solar heat supplies water preheating, process hot water, and steam as well as process hot air, cooling, and refrigeration.

## SolaRoll® Solar Collector System

A flexible rubber tubing solar collector system was developed to be used to heat hot water, swimming pools, and building heating systems. The collectors are an extrusion of ethylene-propylene-diamine rubber and are primarily used for heating swimming pools. The new systems replace conventional natural gas or electric heat pump systems. More than 35 million square feet of SolaRoll® have been sold and have saved more than a cumulative 25 trillion Btu of energy.

## SOLARWALL® Air Preheating System

A newly developed solar air heating system heats incoming ventilation and makeup air using a metal cladding system installed on the south-facing wall of a building. This system also reduces a buildings heat loss in the winter and lowers the cooling loads in the summer by preventing solar radiation from striking the south wall of the building. More than 40 systems with over 200,000 square feet of wall are operating in the United States and have cumulatively saved 76 billion Btu.

## Solvent Recovery from Effluent Streams

A membrane system was developed for recovering volatile organic compounds and chlorofluorocarbons from petrochemical waste streams. This new system allows solvents to be recovered from waste streams that are too diluted or too concentrated with solvents to use other methods. In addition to eliminating the environmental release of these solvents, the 27 units in operation in the United States have saved more than 15 trillion Btu since 1990.

## System 100® Compressor Controls

A compressor control system was developed that allows the operation of both pipeline and process compressors to operate efficiently without surge or recycle. The compressors are usually powered indirectly by natural gas (steam for process compressors and gas-powered turbines for pipeline compressors). Energy savings are typically in the 5% to 10%

range. Total sales of the control systems were more than 3600 units and they have cumulatively saved more than 400 trillion Btu.

## V-PLUS™ Refrigerant Oil Cooling System

The V-Plus system injects refrigerant liquid into the outlet stream of a screw-compressor for industrial refrigeration and cooling systems. The result is increased system capacity, extended system lifetime, and energy savings. Over 200 units have been installed and have saved more than 750 billion Btu since 1982.

## Wallace Energy Systems Solar Assisted Heat Pump Water Heater

A new system was developed for extracting heat from a source (air or water) and applying this heat to water. The heat pump water heater provides both water heating and space cooling. The new systems can be used in applications that need large amounts of hot water and cooling, such as laundries and schools. More than 103 units are in use and have cumulatively saved 118 billion Btu.

## Waste Atactic Polypropylene to Fuel

This pyrolysis process converted a polypropylene plastic by-product, called atactic polypropylene, to fuel oil and gas. A total of 17 million pounds/year of atactic polypropylene was pyrolyzed into 2 million gallons/year of commercial-grade fuel oil that yielded a cumulative energy savings of 500 billion Btu.

## Waste Energy Recovery

Two waste-to-energy plants were constructed, one in Honolulu, Hawaii and one in Tacoma, Washington, that burn the combustible portion of municipal solid waste (MSW). The combustible MSW materials are burned to produce steam, which in turn, is used to power a conventional steam turbine/generator to produce electricity. These plants reduce the amount of electricity that must be produced by fossil fuels, as well as the amount of MSW that must be disposed of in landfills. These two installations have yielded more than 35 trillion Btu of energy since being commercialized.