3.4 Industrial

Contents

INDUSTRIAL

3.4.1 TECHNOLOGY SUMMARY

OVERVIEW

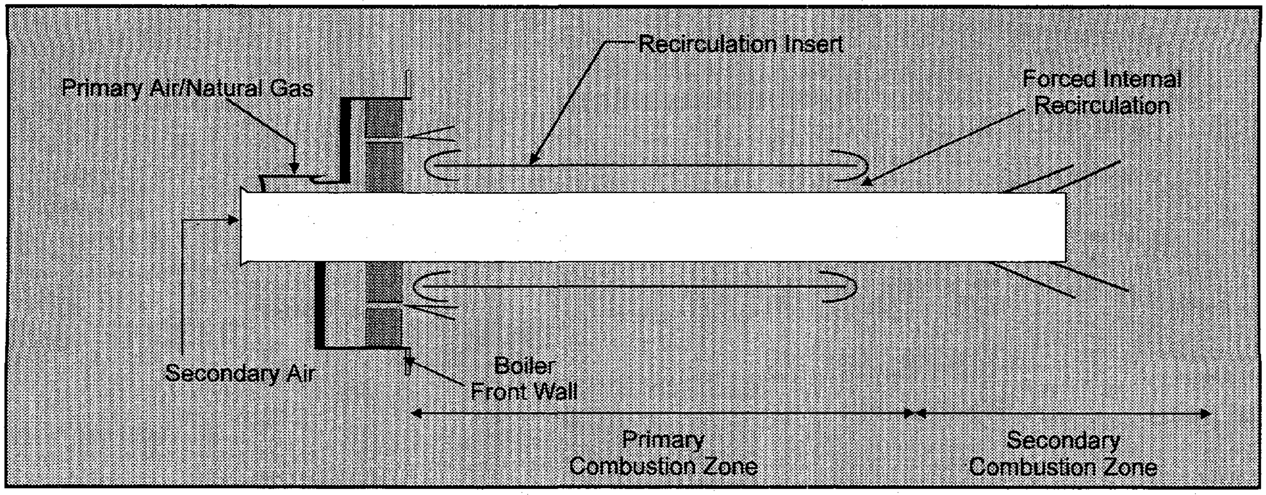
The industrial sector is an important market for the natural gas industry. Eight major gas consuming industries—iron and steel, chemicals, petroleum refining, food processing, textiles, pulp and paper, glass, and aluminum—account for 90 percent of industrial gas consumption. These eight industries represent a wide variety of products, processes, and uses of natural gas.

Natural gas consumption in the industrial sector has been increasing 6 to 7 percent annually since 1986, but slowed to a growth rate of 4 percent, yielding a total consumption of 7.5 trillion cubic feet (Tcf) in 1992. However, in 1993 total consumption reached 7.9 Tcf, an annual increase of 6 percent. Industrial sector consumption in 1993 represented 43 percent of the U.S. gas demand. Much of the increase during the previous six years can be attributed to natural gas consumption by nonutility generators (NUGs).

While natural gas consumption in industry has been increasing, consumption per customer has decreased steadily and dramatically for the past 20 years. Average consumption per industrial customer in 1993 was only 31 percent of the 1973 level. This illustrates the shifting industrial base and decreasing energy intensity of industrial processes.

Natural gas is used both as a raw material in the chemical industry and as a fuel in other industrial applications. Approximately 27 quadrillion Btu of energy were used in manufacturing in 1993, about 80 percent of the amount in all industrial Standard Industrial Classifications (SICs). Within manufacturing, energy use is concentrated in a relatively small number of SICs. Pulp and paper, metals, chemicals and petroleum refining, stone, clay and glass, and food processing account for over 90 percent of all the energy used in manufacturing.

Exhibit 13 - Forced Air Circulation Burner.



The manufacturing sector spent over $130 billion on energy in 1990, and $30 billion on treatment, storage, and disposal of waste. This represents about 6 percent of the value of all manufactured products sold. In the last 10 years, energy has become less important to U.S. industry investment decisions because natural gas, electricity, and imported oil have been readily available at attractive prices, and energy costs have been declining.

Manufacturing industries use the bulk of natural gas in the industrial sector primarily for process heating and steam generation (including cogeneration). Process heating uses of natural gas are extremely diverse, and include glass melting; heating and melting of metals; calcining and drying of minerals, foodstuffs and chemicals; liquid heating; and waste incineration and vitrification. Much of the boiler portion of the steam generation market and some process heat applications, such as fluid heaters in refineries, have dual-fuel capability and are extremely competitive fuel markets.

On the other hand, users prefer natural gas in many process heating applications because it burns cleaner and is easy to use. Investments in technology development are vital to make industry more cost-competitive.

Department-Wide Program

The Office of Energy Efficiency and Renewable Energy (EE) supports research, development, and demonstration (RD&D) efforts that can improve the Nation's energy future. In coordination with the Offices of Fossil Energy, Energy Research, and Policy, EE concentrates its efforts on improving energy efficiency and productivity in the industrial sector of the economy. In order to be certain that its programs continue to be responsive to the long-term needs of its customers, EE has launched the "Industries of the Future" initiative. This initiative strengthens collaboration between industry and government and promotes the leveraging of R&D resources. Industries of the Future is a process in which industry participants, facilitated by DOE, create a vision that reflects the diverse technological, economic, and environmental drivers that are shaping the future of their industries. The vision provides a framework for shaping major advancements in technologies according to their potential for improving industrial efficiency, energy and materials use, and environmental protection.

Industry "Visions of the Future" documents have been developed by the most energy intensive industries in the U.S. These include chemicals, steel, glass, aluminum, metal casting, and forest and paper industries. These industries account for over

90 percent of the energy used in the U.S. manufacturing sector. Each Vision document was developed by an industrial champion and subjected to peer review with others in the industry. These documents characterize the industry today, identify trends and drivers, and characterize the industry 25 years in the future. The Industries of the Future strategy will nurture a more holistic perspective through intra- and interagency alliances within government including the Department of Energy, the National Aeronautics and Space Administration (NASA), Department of Defense (DoD), Department of Commerce (DOC), and Department of Transportation (DOT), as well as State and local governments, and non-government organizations such as the Gas Research Institute (GRI) and the Energy Power Research Institute (EPRI).

Program Activity Summary

Industries of the Future (Energy Efficiency): An objective of this program is to support implementation of high-efficiency natural gas technologies, which provide cost-effective, energy-efficient, environmentally viable solutions for industry to meet new regulations and improve process efficiency. The program has initiated workshops and industrial interactions aimed at identifying research and development activities that will increase energy efficiency and economic competitiveness. Future efforts within Energy Efficiency for industrial utilization of natural gas will be directly related to the "Visions of the Future" strategy for energy-intensive industries. Specific activities are underway for natural gas technology application in aluminum, chemicals, agriculture, forest products, metal casting, glass, steel, and refining.

After each industry prepares its vision and signs the compact with DOE, plans are initiated to develop a technology roadmap that sets milestones for achieving the goals articulated in the strategic vision. The roadmap identifies current technologies and barriers, options and pathways. It lists technical requirements and targets, sets technology priorities, and establishes the research agenda.

The roadmap establishes industry's portfolio of near-, medium-, and long-term technology research, development, and deployment activities to address the challenges and opportunities identified in the strategic vision document.

Improved Combustion Efficiency (Energy Efficiency): The cost-effective minimization of combustion emissions while at least maintaining, if not increasing, the efficiency of combustion from gas-fired combustion systems is the overall goal of industrial combustion research. The program uses combustion fundamentals to address this goal and pursue new combustion concepts with favorable energy and environmental characteristics that can be developed into end-user equipment. Cost-effective minimization of NO_x emissions in the combustion process is the ultimate goal.

Hydrogen Research and Development (Energy Efficiency): Hydrogen is one of the most suitable energy sources for technological and environmental perspectives of the next century. Hydrogen provides a flexible way of storing and using electric energy, diversifies energy supply sources, and can reduce the effects of pollution linked to the use of fossil fuels. The program will develop the concept of absorbing carbon dioxide in the reaction zone of a steam methane reformer using adsorbent material. The objective is to develop high efficiency, lower temperature conversion processes for hydrogen using natural gas as the feedstock to accelerate interest in near- and mid-term energy applications for hydrogen.

Fundamental Chemical Research (Energy Research): The catalytic mechanisms for synthesis of higher molecular weight hydrocarbons and other organic compounds from methane as well as chemical processes on surfaces during combustion are not well understood. The program focuses on supporting fundamental, experimental, and theoretical research on the chemistry relating to catalysis of methane, and the factors affecting combustion of methane in flames, industrial combustors, and internal combustion engines.

Advanced Turbine Systems (Fossil Energy, Energy Efficiency): The program goals are to design, develop, and demonstrate advanced turbine systems that will be ultra-high efficiency, environmentally superior, and will produce electricity costing 10 percent less at the busbar. Improvements in component materials and combustor, and turbine and system design will be integrated into systems utilizing compressor intercooling, high temperature, multi-stage gas turbines and high performance steam generators and turbines. While system design will differ between manufacturer and target application, the program will address aeroderivative and heavy-frame turbine designs. The efficiency goal for the utility class gas turbine is 60 percent for the industrial turbine; an improvement of 15 percent is sought over current models. Emissions of NO_x carbon monoxide (CO), and unburned hydrocarbons are to be reduced to less than 10 ppm.

Cogeneration (Energy Efficiency, Fossil Energy, Energy Research): Gas turbines are used internationally for electrical service, cogeneration, mechanical power drives, and offshore power generation. Nationally, there is about 65,000 megawatts of operating gas turbine capacity. The objective of this program is to insert ceramic components in critical locations of stationary gas turbines for cogeneration service, achieving considerable fuel savings and reduced emissions. Benefits of ceramic components include: more than 40 percent thermal efficiency; ultra-low NO_x potential with a ceramic combustor; engine cost reductions by replacement of cooled single crystal and directionally solidified parts with uncooled ceramics; and lower cost per installed kilowatt of capacity.

Continuous Fiber Ceramic Composites (Energy Efficiency): The objective of this program is to develop advanced structural materials with improved high-temperature, wear-resistant, and noncorroding characteristics that open up new opportunities because of their ability to perform in environments and under operating conditions that would destroy currently available metals and ceramics. Potential benefits include approximately 2.22 quadrillion Btu reduction in the annual national energy consumption, and 0.98 million tons/year of NO_x and 110 million tons/year of carbon dioxide (CO_2) emission reductions.

Advanced Industrial Materials (Energy Efficiency): Materials are necessary in every phase of manufacturing from raw materials through synthesis and processing, to industrial or commercial application, and ending as waste or recycled material for reuse. Advanced materials are not only critical for product development, but are also essential for improving manufacturing processes and reducing energy consumption. Industries engaged in fabrication and assembly of consumer products also will benefit significantly from using advanced materials to improve process efficiency and productivity through reduced life cycle energy use, higher processing temperatures, increased component and system lifetimes, and reduced downtime.

FY 1996-1998 Crosscut Budget Summary ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Continuous Fiber Ceramic Composites (CFCCs)	4.40	4.20	4.20
Aluminum Industry	0.00	0.827	0.961
Chemical Program	13.00	10.00	13.50
Industrial Cogeneration	21.00	25.00	35.00
Glass Combustors Industry	1.60	1.50	0.75
Advanced Combustion Systems	1.30	1.30	1.00
Fundamental Chemical Research Related to Natural Gas	4.80	4.30	4.30
Fundamental Engineering Research Related to Natural Gas	0.20	0.27	0.27
Advanced Industrial Materials Program	8.30	6.30	6.07
Total	**54.60**	**53.70**	**66.05**

Program Schedule

Projects	1997	1998	1999	2000	2001
Industries of the Future					
Hydrogen Research and Development					
Fundamental Chemical Research					
Cogeneration					
Advanced Turbine Systems					
CFCCs					
Advanced Materials					

3.4.2 Project Descriptions

3.4.2.1 Continuous Fiber Ceramic Composites

Background

The U.S. industrial sector has a critical need for materials that are light, strong, corrosion resistant, and capable of performing in high-temperature environments. Although many traditional ceramics perform well at high temperature, they typically fail in a catastrophic manner while in service. Continuous Fiber Ceramic Composites (CFCCs) are being developed to overcome this problem by incorporating continuous ceramic fiber into a ceramic matrix. This results in high strength, high temperature materials that exhibit a tough behavior.

Major Goals

The major goal of the Continuous Fiber Ceramic Composites program is to advance processing methods for reliable and cost-effective ceramic composite materials to a point at which industry will assume the full risk of development and commercialization. Continuous fiber ceramic composites are lighter, stronger, and more damage tolerant than other materials available for high temperature use. Industries that use CFCC components in their applications will realize substantial energy, economic, and environmental benefits, including lower maintenance, faster reaction rates, and decreased operating costs.

DuPont Lanxide Composites Inc., is constructing both silicon carbide CFCC components, using the chemical vapor infiltration process, and aluminum oxide CFCC components for incorporation into a variety of high-temperature, heat management and power generation equipment.

Project Objectives

The CFCC program is a collaborative effort between industry (Allied Signal Aerospace Team, ARC/American Team, Babcock and Wilcox Team, Dow Corning Team, DuPont Lanxide Team, General Electric Team, and Textron Specialty Metals Team), national laboratories, universities, and government to develop advanced composite materials for industrial applications. Participation by industry (which cost shares in this effort 24-35 percent) is vital and ensures the research agenda is based primarily on economic and performance criteria. Projects include:

- Chemical Vapor Infiltration
- Sol Gel Impregnation
- Polymer Impregnation and Pyrolysis
- Heat-Management Equipment
- Directed Metal Oxidation Process (DIMOX)
- Toughened Silcomp
- Gaseous Nitradation

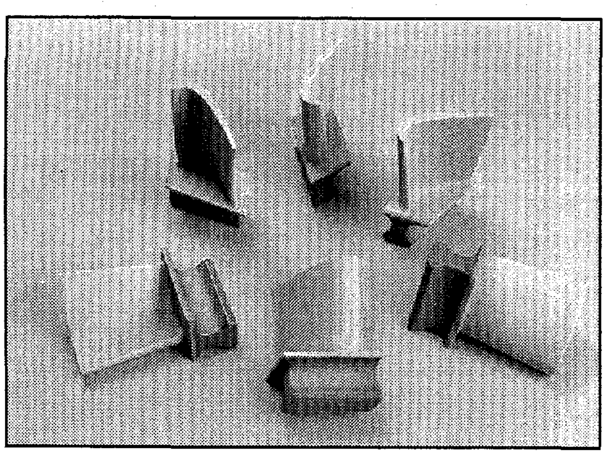


Exhibit 14 - Allied Signal AS800 Silicon Nitride Blades That Have Run 950 Hours in an Industrial Engine Test by Solar Turbines, Inc., ARCO Western Energy, Bakersfield, California.

Expected Benefits

By the year 2010, the CFCC program (as a whole) will provide the following annual benefits:

- 600 trillion Btu of energy savings.
- 980,000 tons of NO_x emissions avoided.
- 119 million tons of CO_2 emissions avoided.
- CFCC component sales of $850 million, adding over 8,000 industrial sector jobs.

Planned Products

- CFCC components for land-based gas turbines.
- CFCC pump components.
- CFCC applications for diesel engine valve guides.
- Hot gas filters.
- Ceramic composite radiant burner tubes.

Strategy (FY 97 Funding: $4.2 Million)

To continue to partner with Industry and material suppliers to develop industrial CFCC applications.

Recent Accomplishments

Porous radiant burners, in contrast to conventional flame-type industrial burner technology, transfer as much as 50 percent of their energy input directly to the process load in the form of infrared radiation.

Hot gas filters are used for high efficiency particulate and contaminant removal in the temperature range of 300ºC to 1,000ºC.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
CFCCs	4.40	4.20	4.20
Total	**4.40**	**4.20**	**4.20**

3.4.2.2 Aluminum Industry

Background

Aluminum is a light-weight, high-strength, corrosion-resistant, and readily recyclable material. It is an essential ingredient for making, maintaining, and improving products that modern society requires and developing nations demand. Aluminum is critical for many markets vital to the U.S. economy. Transportation, aerospace, defense, building and construction, food and beverage packaging, transmission of electricity, consumer durables, machinery and equipment all depend to a significant degree on a consistent supply of competitively priced, technically rich aluminum products.

The aluminum industry comprises three principal sectors. The *raw materials sector* produces alumina (the ore of aluminum) and primary and secondary molten metal and ingot. It is dominated by the Bayer (refining) and Hall-Heroult (smelting) processes. The *semifabricated sector* produces sheet, plate, foil, forgings, castings, wire, rod, bar, extrusions, elemental and alloyed powders, along with a wide variety of alumina-based chemical products. The third sector, *finished products,* uses products from the first two to manufacture a wide variety of consumer/ commercial products, varying from aircraft, automobiles, building curtain walls, windows and doors to fire retardants and packaging for food products.

Project Objectives

Although several of the key drivers may influence each of the three aluminum industry sectors, each possesses unique scientific and technical needs. For example:

- The *Raw Materials sector* is characterized by relatively established underlying processes. Research, development and engineering for this part of the industry is likely to focus on reducing costs via improved operating, energy and environmental efficiencies. Also, some challenging opportunities have been identified for breakthrough primary technologies to improve the century-old Bayer and Hall-Heroult processes.
- The *Semifabricated sector* will likely focus on lowering costs and improving performance, quality and environmental acceptability via the development and application of advanced manufacturing processes and technologies.
- In the *Finished Product sector,* the opportunity may hinge on increased integration of materials and on enhanced process, product design, and enabling technologies to create the products 21st century consumers will demand. A natural gas related effort in this area is the development of an Innovative vertical floatation melter and scrap dryer.

Major Goals

The Energy Research Company (ERCo), and a British company, Stein, Atkins, and Stordy (SAS), started development of a natural gas fired vertical floatation type melter which will increase melting energy efficiency.

Expected Benefits

An increase in melting energy efficiency by 40-80 percent and reduction in emissions of NO_x, SO_x, VOC, particulates, and organics existing in the aluminum scrap.

Planned Products

- Technology Roadmap: The Technology Roadmap identifies performance targets prioritized R&D needs, and timetables segmented by raw materials, semi-fabricated products, and finished products.
- By 2002, a U.S. processing plant owned by IMCO, Recycling Inc., will commercialize the melter in the U.S., while SAS will commercialize the melter in England.

- Air Products and Chemicals, Inc., along with Argonne National Laboratory, Roth Brothers, and Brigham Young University, will develop and demonstrate a novel, high-efficiency, high-capacity, low-NO_x combustion system integrated with an innovative low-cost, on-site vacuum-swing-absorption (VSA) oxygen generation. This integrated burner/oxygen supply system will offer enhanced productivity, high energy efficiency, low operating costs, and low NO_x emissions.

Strategy (FY 97 Funding: $0.827 Million)

To continue to work with industry in defining needs via a technology roadmap and invest in R&D to make their vision a reality.

Recent Accomplishments

SAS provided ERCo with results of their single particles study, using various particles representing aluminum scrap, enabling ERCo to design and probe the operation of the melter. By 1999, these two developers will have completed the design, fabrication, and testing of a pilot scale melter using scrap aluminum and possibly feedstocks from other candidate industries.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Aluminum Industry	0.000	0.827	0.961
Total	**0.000**	**0.827**	**0.961**

3.4.2.3 Chemical Program

Background

The chemical vision focuses on four areas, each of which is developing a technology roadmap. The chemical industry is more diverse than virtually any other U.S. industry. Chemicals are the building blocks of products that meet our most fundamental needs for food, shelter, and health, as well as products vital to the high technology world of computing, telecommunications, and biotechnology. Chemicals are a keystone of U.S. manufacturing and are essential to a large range of industries such as pharmaceuticals, automobiles, textiles, furniture, paint, paper, electronics, agriculture, construction, appliances, and services.

More than 70,000 different products are registered. More than 9,000 corporations develop, manufacture, and market products and processes in the following categories designated as the Standard Industrial Classification 28:

- Industrial inorganic chemical
- Plastics, materials, and synthetics
- Drugs
- Soap, cleaners, and toilet goods
- Industrial organic chemicals
- Agricultural chemicals
- Miscellaneous chemical products

Project Objectives

Natural gas related projects include:

- Advanced membrane devices.
- Polymers for membrane separation in the chemical industry.
- Catalytic membrane for the production of chemicals from natural gas and petroleum.
- Hollow fiber membrane based on encapsulation of novel chemical absorbents for ammonia and acid gases.
- New chemical science and engineering technology.
- Supply chain management.
- Information systems.
- Manufacturing and operations.

Major Goals

- Improve operations, with a focus on better management of the supply chain.
- Improve efficiency in the use of raw materials, the reuse of recycled materials, and the generation and use of energy.
- Continue to play a leadership role in balancing environmental and economic considerations.
- Aggressively commit to longer term investment in R&D.
- Balance investments in technology by leveraging the capabilities of government, academia, and the chemical industry as a whole through targeted collaborative efforts in R&D.

Expected Benefits

Benefits are based upon the portfolio of 21 chemical industry/Office of Industrial Technologies (EE) cost shared projects, based upon the Quality Metrics for the year 2010.

- Energy saved 0.4 x 10^{15} Btu's or $1.48 billion.
- Carbon reduction of 0.4 million tons.

Planned Products

- Include new recycling processes for plastics.
- New bioprocesses for the production of polymers.
- New membranes.
- New catalysis.

Strategy (FY 97 Funding $10.0 Million)

To continue to work with industry to develop a technology roadmap.

Recent Accomplishments

The Chemical Industry Team (CIT) has accomplished much over the past year in addition to supporting the chemical industry's visioning process. *CIT Highlights for 1996* include continuing to help industry articulate its strategic vision in technology "roadmaps." These roadmaps will identify technical pathways from current technologies to advanced technologies needed to achieve the vision; and will serve as the basis for setting priorities and establishing the industry's research agenda. The CIT has also been busy establishing and maintaining numerous R&D partnerships with companies, universities, and other organizations located across the country. This year the CIT projects involved almost 100 working partnerships in over 30 states.

In addition, over the past several years CIT-supported projects have resulted in a number of commercialized technologies. In 1996, the CIT saw completion and commercialization of the "Scrap Tire Recycling" project. This effort developed a new surface treatment for finely ground tire rubber that can be used to manufacture high value composites which, in turn, replace petroleum-derived polymers. This newly treated material greatly increases wheel traction on wet surfaces and will put some of the 70 million scrap tires sent to stockpiles each year to good use.

Schedule

- Chemical Industry solicitation, Summer 1997.
- Roadmap completed, Computational Fluid Dynamics, Fall 1997.
- Roadmap completed, Catalysis, Fall 1997.
- Roadmap workshop, Separations, First Quarter 1998.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Chemical Program	13.0	10.0	13.5
Total	**13.0**	**10.0**	**13.5**

3.4.2.4 Industrial Cogeneration

Background

Gas turbines are used internationally for electrical service, cogeneration, mechanical power drives, and offshore power generation. Nationally, there are about 65,000 MW of operating gas turbine capacity. Upgrading this capacity through routine overhaul of existing equipment or use of ceramics in new gas turbines will have a significant impact on the fuel burned and emissions generated. Efforts include development of an advanced industrial gas turbine, retrofit of ceramic components in an industrial turbine, and advanced materials and manufacturing.

Project Objectives

To complete development and demonstration of ultra-high efficiency natural gas turbine systems for commercial offering to electric utilities, independent power producers, and industries by 2000.

Major Goals

- Boost system efficiency to 60 percent (LHV) or above for utility combined cycle systems and 15 percent over existing industrial systems.
- Reduce cost of electricity by 10 percent compared to conventional systems.
- Lower nitrogen oxide emissions to 8 parts per million (ppm), and less than 20 ppm carbon monoxide without the use of post-combustion emission controls.
- Offer reliability-availability-maintainability (RAM) that equals or exceeds current turbine systems.

Expected Benefits

The partnership of industry, government and universities created by the ATS program provides a blend of technical know-how, market understanding, research capabilities, and financial resources required to make revolutionary advances in gas turbine technology. These advances will yield significant benefits to the nation, including:

- Cleaner air emissions.
- Reduction of 52 tons/year of greenhouse gases.
- Lower carbon monoxide and unburned hydrocarbon emissions per MW.
- Reduced fuel consumption.
- Higher efficiencies will save an estimated 1 Tcf of natural gas annually, providing a lower cost of electricity. A single percentage point increase in fuel efficiency can reduce lifecycle operating costs of a typical 400-500 MW combined cycle plant by $15 to $20 million, lowering the cost of electricity by as much as 10 percent.
- The worldwide market for industrial gas turbine systems (3 to 20-MW) has doubled since 1985. Market growth of this rate is expected to continue at least through 2010.
- Rising demand for electricity both here and around the world places gas turbines in a crucial position. Expectations are that a large portion of new electric and cogenerating capacity additions will be gas turbines. The domestic market potential for advanced gas turbine systems could be as high as $5 billion/year after 2000 and the total world market could reach $1 trillion annually by 2010.

Planned Products

- Development of a new generation of gas turbines for cogeneration, utility, mechanical drive, and small power production applications (2001) (joint program with Fossil Energy).
- Ceramics for stationary gas turbines.
- Advance materials thermal barrier coatings.

Strategy (FY 97 Funding: $25 Million)

The program consists of three phases and features industry led development teams, including ceramic component manufacturers, end-users of gas turbines, and university and National Laboratory support activity.

Recent Accomplishments

Phase II has been completed. Allison Engine Company, Solar Turbines, Westinghouse and General Electric have been selected to develop prototype engines for testing during Phase III.

Solar Turbines with Allied Signal, and Dupont Lanxide has completed 744 hours of a 2,000-hour test of ceramic components in an industrial gas turbine [1850 ºF Turbine Rotor Inlet Temperature (TRIT)] at full load at Solar Turbines California facility. To date, this has been the longest test of ceramic components in an industrial gas turbine. Parts tested included a CFCC combustor liner and silicon nitride blades. Unoptimized NO_x levels were typically around 15 ppm and CO less than 5 ppm. A 4,000-hour test at 2,050 ºF TRIT is scheduled for the Fall of 1997.

Program Funding

DOE Historical Spending ($ in Millions)

Cost share is approximately 45 percent averaged over the life of the program.

Projects	FY 1996	FY 1997	FY 1998
	21.0	25.0	35.0
Total	**21.0**	**25.0**	**35.0**

Schedule

Projects	1997	1998	1999	2000	2001	2002
ATS	━	━	━	━	━	━
Ceramic	━	━	━	━	━	━
Materials	━	━	━	━	━	━

3.4.2.5 Glass Combustion Industry

Background

The U.S. glass industry is an important component of the U.S. economy. It employs more than 150,000 workers in skilled jobs, and generates 21 million tons of consumer products each year with an estimated value of nearly $24 billion. This industry is broken into four distinct segments: flat, container, fiber, and specialty. The glass industry includes both major corporations and small family businesses that are spread out across the Nation, with a strong presence in California, Illinois, New York, West Virginia, Pennsylvania, and Ohio.

The glass industry vision identified four areas for technology development: production efficiency, energy efficiency, environmental protection and recycling, and innovative uses. The glass industry has set up a committee structure for implementing the vision, with subcommittees for each of the four areas.

The efforts specifically addressing natural gas utilization are:

- High heat transfer natural gas combustion system
- Oxygen-enriched air-staging (OEAS) technology for glass furnace combustion space models
- An integrated batch and cullet preheater system

Project Objectives

High Luminosity Low-NO_x Burner: The Institute of Gas Technology is developing a high-luminosity low-NO_x burner that internally modifies the fuel prior to combustion, as well a controls fuel/air mixing to substantially increase the formation of soot within the flame. This process enhances the luminosity of the flame, thereby increasing heat transfer rates and decreasing flame temperature. Consequently, the furnace production rate and thermal efficiency are increased and NO_x formation is reduced.

OEAS Technology for Sideport Furnaces: Oxygen and air-staged combustion are two methods that the industry typically uses to reduce NO_x. While oxygen use eliminates nitrogen which can form NO_x, it is costly and can increase energy consumption. The air staging method costs less, but is less effective.

The Institute of Gas Technology has developed OEAS technology, an advanced combustion modification technique which combines the two methods to control NO_x formation. By reducing the oxygen available in the flame's high-temperature zone and improving flame temperature uniformity, NO_x formation is controlled and heat transfer to the glass is improved, without interrupting furnace operation or adversely affecting product quality. By injecting oxygen near the exit port, complete combustion and heat release within the furnace are assured.

The OEAS technology has been successfully retrofitted to several endport furnaces in the U.S. and has achieved NO_x levels below 2 lbs. per ton (50-70 percent reduction). Efforts have now been initiated to apply the OEAS technology to sideport glass melting furnaces, which are used for 65 percent of U.S. glass production. The OEAS technology is being demonstrated on a six-port pair sideport furnace at Owens-Brockway's Vernon facility.

Integrated Batch and Cullet Preheater System: Corning will demonstrate and test the technical viability, system reliability, and economic benefits of batch and cullet preheating oxy-fuel combustion furnaces. An advanced raining bed technology developed by Tecogen/Thermo Power Corporation will be tested to preheat batch and cullet and to recycle condensables and particulate matter in the exhaust stream.

Two commercial demonstrations will be performed — one in a 5 tons-per-day specialty glass furnace and another in a 175 tons-per-day soda lime furnace producing consumer ware. In addition, conceptual designs will be prepared for batch and cullet preheat systems in fiberglass, container glass, and flat glass furnaces.

Major Goals

- Production costs at least 20 percent below 1995 levels.
- Process energy use reduced from present levels by 50 percent towards theoretical energy use limits.
- Recycle 100 percent of all glass products.
- Recover 100 percent of reasonably available consumer glass.
- Reduce air/water emissions by a minimum of 20 percent.

Expected Benefits

High Luminosity Low-NO_x Burners: These burners offer many benefits to the glass industry:

- Reduced Emissions — Even when utilizing lower-cost industrial oxygen, NO_x emissions could be reduced up to 90 percent.
- Reduced Costs — The burner provides cost-effective compliance with emissions regulations. Additionally, existing furnaces can be retrofitted without major modifications.
- Increased Efficiency and Productivity — While improving furnace control, production rate and system thermal efficiency could be increased up to 20 percent.
- Reduced Space Requirements — The technology provides a compact furnace system for glass melters, and smaller flue gas cleaning equipment.

The high-luminosity low-NO_x oxygen/natural gas burner technology will be applicable to high temperature heating and melting systems in energy-intensive industries including glass, iron and steel, non-ferrous metals, and cement.

OEAS Technology: Oxygen-Enriched Air Staging technology for sideport furnaces offers the glass industry important advantages in the face of increasingly restrictive regional emissions regulations. Currently, regenerative glass melters use very high air-preheat temperatures, which result in extremely high NO_x levels. While there are no federal regulations on NO_x at this time, these melters are increasingly being placed under strict regional regulations. To enable glass producers to meet these regulations, the OEAS project is working to reduce the NO_x emissions from regenerative sideport glass melting furnaces from 10 lbs. per ton of glass produced to below 3 lbs. per ton. Without such a cost-effective solution, companies may be forced to shut down additional facilities.

The OEAS technology will benefit the glass industry by achieving:

- Reduced Waste — Total waste production is expected to be reduced by 10 thousand tons per year, a 31 percent reduction.
- Energy Savings — IGT estimates saving 28 percent of the energy used in conventional technology, representing 150 million Btus per year.
- Reduced Emissions — NO_x levels will be reduced by 50-70 percent, thereby enabling glass producers to meet the most stringent environmental regulations through the year 2000.
- Reduced Costs — This is a highly cost effective means of meeting emission regulations without increasing fuel consumption. Capital and operating cost are moderate compared to competitive technologies. Additionally, the technology will reduce oxygen production costs.

The OEAS technology has applications for regenerative glass melting furnaces in the container and float glass industries, as well as for other high-temperature processes such as metal melting.

Integrated Batch and Cullet Preheater: The Corning integrated batch and cullet preheat system can help the glass industry maintain the lowest possible production costs while achieving stringent emission standards. This system offers both of these benefits and more:

- Energy Savings — Since the batch and cullet is partially heated when introduced to the furnace, less energy must be added. Analysis reveals an estimated 15 percent increase in energy savings (natural gas), a total of 3 billion Btu, per year.
- Reduced Waste — Combustion-related waste will be reduced by an estimated 17,500 tons per year. Through increased unit life, the annual non-hazardous waste from spent refractories will also be reduced.
- Reduced Emissions — Lower product costs through lower energy costs will increase market share and job demand. Additionally, existing furnaces are easily retrofitted.
- Increased Efficiency — This unit contains no inventory of batch material within the heat exchanger. Material falls freely through the system, eliminating the possibility of plugging.

Batch and cullet preheating (Exhibit 15) can be applied to furnaces in all four glass market sectors: float, container, fiber, and specialty. Corning Engineering, which is responsible for internal and external implementation, will introduce the preheater technology to U.S. manufacturers once it is demonstrated. Initially, Corning will apply the technology to oxy-fuel installations. As the technology is proven and process benefits quantified, it may be applied to conventional air-fuel furnaces.

Strategy (FY 97 Funding: $1.5 Million)

Continue to work with industry on R&D needs to realize their vision.

Recent Accomplishments

Glass roadmapping workshop report.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Glass Combustion Industry	0.161	1.500	0.750
Total	**0.161**	**1.500**	**0.750**

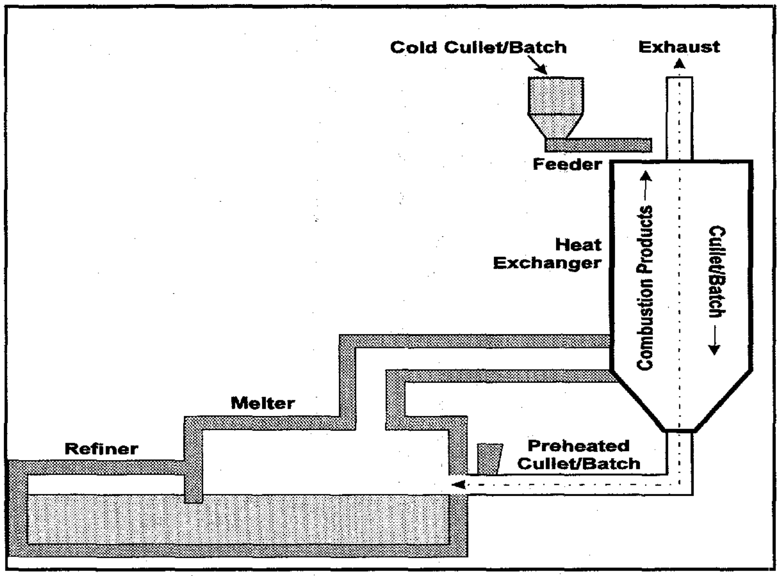


Exhibit 15 - Integrated Batch and Cullet Preheater.

3.4.2.6 Advanced Combustion Systems

Background

The cost-effective minimization of combustion emissions, while at least maintaining, if not increasing, the efficiency of combustion from gas-fired combustion systems, is the overall goal of industrial combustion research. The program uses combustion fundamentals to address this goal and to pursue new combustion concepts with favorable energy and environmental characteristics that can be developed into end-user equipment.

Project Objectives

Develop a new generation of burners capable of realizing single-digit NO_x emissions without post-combustion control, while keeping all emissions low. The efficiency will be equal to or better than today's best. The natural gas related projects include:

- Radiation stabilized burner.
- Vortex inertial staged air (VISTA) burner development for very low NO_x emissions in furnaces and boilers.
- Forced internal recirculation burner.
- Dilution of oxygen combustion.

Major Goals

Each of the four projects is using one or more approaches to realize the single-digit NO_x target. In general, they are:

- Demonstrating the selected approaches using laboratory scale facilities,
- Scaling-up to pilot size, and for some projects using actual operating industrial boilers and furnaces, and
- Demonstrating or operating industrial systems.

Expected Benefits

The combustion systems being developed are expected to reduce NO_x emissions by over 110,000 tons/year and capital costs by nearly $3 billion relative to meeting the same emissions targets using post-combustion systems.

Consequently, greenhouse gases will be reduced. For example, up to 8 percent less CO_2 will be produced due to increased efficiency, and because there is no need for an ammonia based add-on NO_x control system, there will be no N_2O emissions.

Planned Products

New low-emission burners will be developed for specific boiler or furnace markets serving the refining, chemical, steel, aluminum and other industries.

Strategy (FY 97 Funding: $1.3 Million)

The strategy includes: (1) utilizing recently identified high heat burner materials that can survive the high temperature industrial process environment, and increase overall process efficiency while significantly reducing emissions; and (2) retrofitting this new burner type to current generation industrial heaters and conduct a demonstration to show industry the value of this concept.

Recent Accomplishments

- Achieved 4,000 hours with half-scale burners (over five months) at steam reformers temperature without significant degradation.
- Completed design of burner controls.
- 6 ppm NO_x realized in developmental test on working boiler.
- Obtained approval of design, field test plan, safety plan, and all requirements for installation of burners in host site (Air Products) reformers.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Advanced Combustion	1.30	1.30	1.00
Total	**1.30**	**1.30**	**1.00**

Schedule

- Complete developmental test: December 1997.
- Start host site demonstration: April 1998.
- Complete host site demonstration: September 1998.

3.4.2.7 Fundamental Chemical Research Related to Natural Gas

Background

The catalytic mechanism for synthesis of higher molecular weight hydrocarbons and other organic compounds from methane are not sufficiently understood for optimal use of methane as a resource for liquid hydrocarbon fuels and chemical feedstocks. More detailed information is required on methane dissociation, partial oxidation, and molecular fragment recombination reactions to effectively utilize catalytic processes.

Chemical processes on surfaces during combustion are poorly understood and rarely investigated. Semi-empirical theories are needed to represent complex combustion reaction mechanisms by simplified, but fundamentally correct, representative metareactions. Such chemical theories will be incorporated into fluid dynamic models of combustion.

Project Objectives

To conduct fundamental investigations relating to catalysis of methane, partial oxidation, and factors affecting combustion of methane in flames, industrial combustors, and internal combustion engines.

Major Goals

- Characterize activation of carbon-hydrogen bonds by metals and metal complexes as a function of their electronic properties and structure.
- Characterize reactive pathways of radical intermediates in oxidation and coupling reactions and develop predictive theories for enabling the suppression of radical intermediates in partial oxidation of methane for portable transportation fuels and as a feedstock for Fischer-Tropsch synthesis.
- Develop semi-empirical theories for representation of complex reaction mechanisms by prototypical metareactions, and for temperature and pressure dependence of their rates.
- Develop general theories, principles, and methods of measurement for characterizing the reactions of prototypical combustion species at surfaces, temperatures, and pressures characteristic of combustion systems.

Expected Benefits

- Allows chemistry to be more readily incorporated into turbulence and mixing models through the use of semi-empirical theories for simpler and more reliable description of combustion and complex chemical processes.
- Allows design decisions on combustion devices for minimizing emissions of unwanted byproducts and maximizing combustion efficiency by characterizing surface combustion processes.
- Allows more efficient discovery of new catalytic systems for more optimal use of natural gas resources through theories for C-H activation and molecular fragment recombination at surfaces.

Planned Products

Development of critical data, descriptive and predictive theories, and measurement methods for fundamental processes in catalysis and combustion. These will be conveyed to DOE technology programs through jointly sponsored workshops, contractor meetings, personnel exchanges, and reports, and to the broad technical community through publication in the archival, peer-reviewed literature.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Fundamental Chemical Research	4.8	4.3	4.3
Total	**4.8**	**4.3**	**4.3**

Strategy (FY 97 Funding: $4.3 Million)

The program strategy will focus on supporting fundamental, experimental, and theoretical research at universities and National Laboratories. In general, proposals are unsolicited and are prepared by individual investigators. A major effort on fundamental combustion science is underway at the combustion research facilities at the Sandia and Livermore National Laboratories.

3.4.2.8 Fundamental Engineering Research Related to Natural Gas

Background

To conduct fundamental studies on transportation and other processes involving natural gas, which may lead to improved design methodologies.

Project Objectives

Improved analysis of flows in pipelines and heat exchangers with high heat fluxes.

Major Goals

This research is a facet of a broad-based engineering research program emphasizing heat and fluid transport, process diagnostics and control, and engineering analysis. Specific goals are:

- Determine dryout limits for heat exchanges applicable to power plants using heated tubes with natural gas as the heat source; and
- Improve modeling of pipeline flows of gases and liquids.

Expected Benefits

- Improves models of chemical, mass, and heat transfer processes suitable for systems applications, testing, and evaluation.
- Develops capabilities for enhanced design and operation of pipelines and power plants utilizing natural gas.

Planned Products

- Publication of scientific and technical reports in the professional literature.
- Development of patents.
- Completion of new technology transfer to the private sector.

Strategy (FY 97 Funding: $0.270 Million)

The program strategy is to conduct studies combining computational modeling with experiments designed to test and refine modeling methodologies. Specific research topics include Gas-Liquid Flows in Pipelines, and Dryout in Horizontal and Almost Horizontal Heated Tubes.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Gas-Liquid Flows in Pipelines	0.100	0.120	0.120
Dryout in Horizontal/ Heated Tubes	0.100	0.150	0.150
Total	**0.200**	**0.270**	**0.270**

3.4.2.9 Advanced Industrial Materials Program

Background

The program goal is to support development and commercialization of materials to improve productivity, product quality, and energy efficiency in major process industries.

Project Objectives

The advanced industrial materials program investigators in the DOE National Laboratories are working closely with approximately 100 companies, including 15 partners in CRADAs. Research and development is being performed in a wide variety of materials technologies, including intermetallic and metallic alloys, ceramic composites, metal composites and polymers.

The program supports the Industries of the Future effort of Office of Industrial Technologies (OIT) including the major energy consuming process industries-aluminum, chemicals, forest products, glass, metalcasting, refineries, and steel. Recently, the Advanced Industrial Materials program began working with carbon products forging, heat treating, and welding cross-cutting industries. Each of these industries has decided to develop a vision, roadmap and implementation plan, and OIT is working on ways to integrate these industries into the "Industries of the Future."

Major Goals

- To expand the applicability of this technology, better characterize the process and facilitate further industrial applications of the technology.
- To determine causes of failure of composite tubes in Kraft recovery boilers and to develop new materials to eliminate failures. This work addresses a critical technical problem for reasons of productivity, energy efficiency and worker safety.
- To further develop and commercialize the use of nickel aluminide in furnace furniture and thereby provide advantages of increased furnace furniture life and higher permitted operating temperatures.
- To develop centrifugally cast nickel aluminide for transfer rolls in steel reheat furnaces. This is another application in which the excellent high-temperature properties of the nickel aluminide material family offer advantages.
- To enable boiler operators to mitigate damage to their systems and to estimate the extent of damage associated with a given set of operating conditions.

Expected Benefits

- In the first year, a set of experiments will be performed to characterize variability in material/process interactions and their role in process control.
- Efforts will focus on corrosion and residual stress determination of the behavior of various materials for applications in digestors and boiler components, including composite tubes and splash plates of black liquor injector nozzles.
- Nickel Aluminide castings for heat treating trays will be prepared and evaluated under a CRADA with GM Saginaw.
- A subcontract will be issued to Stanford Research Institute for development of flexible mullite coatings for application on metal, ceramic, glass, or polymer substrates.

Planned Products

Assessments of materials needs and opportunities in the process industries are being made to improve the relevance of materials research. The assessments are being used for program planning and setting of priorities; this is being followed by support work to satisfy those needs.

Strategy (FY 97 Funding $6.3 Million)

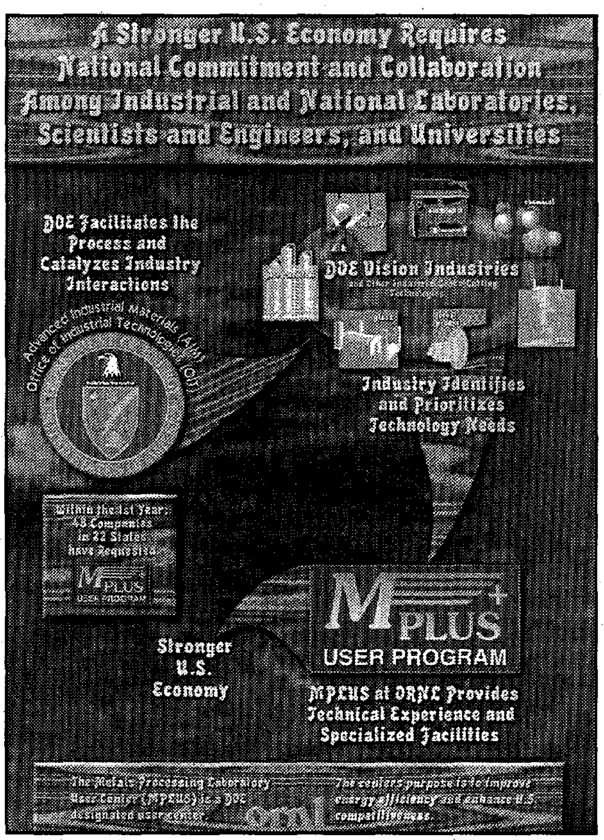
Continue to work with Industry on R&D needs to realize the vision.

Program Funding

DOE Historical Spending ($ in Millions)

Projects	FY 1996	FY 1997	FY 1998
Advanced Industrial Materials Program	8.30	6.30	6.07
Total	**8.30**	**6.30**	**6.07**

MPLUS User Program Pamphlet



Metals Processing Users (MPLUS) Center is Located at DOE's Oak Ridge National Laboratory