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Office of Industrial Programs Research in Progress

U.S. Department of Energy
Office of Conservation
and Renewable Energy
Office of Industrial Programs

This report was compiled for the Office of Industrial Programs from project summaries contained in the Research-In-Progress (RIP) data base of the Office of Scientific and Technical Information, Oak Ridge, Tennessee. The RIP data base describes new and ongoing energy and energy-related research projects carried out or sponsored by the Department of Energy.

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PROGRAM OVERVIEW

The U.S. Department of Energy Office of Industrial Programs conducts industrial energy conservation research and development activities. These activities are focused on achieving the objectives of improving energy use efficiency and providing for fuel flexibility within U.S. industry. To accomplish these objectives, the Office has adopted the basic strategy of identifying, in cooperation with private industry, the technological needs for energy conservation in the industrial sector; identifying what private industry is currently doing or will not do alone; selecting the highest priority targets not being pursued by the private sector; and negotiating cost-shared contracts with private industry, or contracts with universities and government laboratories to carry out the necessary research. Research is developed to the point that the new technology has been proven to work and sufficient "proof" can be disseminated to the private sector end users.

To date, the Office of Industrial Programs has supported over two hundred research and development projects covering a wide spectrum of industrial applications—both generic conservation technologies and energy intensive processes unique to specific industries. Many of these efforts have resulted in the successful resolution of critical technical barriers faced by industry in developing advanced energy conserving processes and technologies.

This report contains summaries for currently active projects supported by the Office of Industrial Programs. The report was prepared from the DOE Research-in-Progress data base maintained by the Office of Scientific and Technical Information.

Director of Industrial Programs
FTS 896-2090, commercial (202) 589-2090.

WASTE ENERGY RECOVERY

Advanced Heat Exchangers

Babcock and Wilcox Company
Lynchburg, VA 24506-1165
R and D Division

1. *R&D of a Ceramic Fiber Composite Heat Exchanger*

Parks, W.P.

This is the second phase of a potential three-phase effort. Phase I involved (1) determining the technical and economic feasibility of an advanced material (ceramic fiber reinforced ceramics) heat exchanger; (2) identifying critical problems relating to development of the heat exchanger; and (3) identifying and detailing Phase II R&D required for the successful design, fabrication, and operation of the critical components. Phase II consists of (1) R&D to solve the critical problems and (2) completing the final conceptual design. Phase III will consist of detailed design and construction of a test module, and its installation and testing in an industrial waste stream. The heat exchanger will be designed for efficient and economic recovery of waste heat from major industrial high-temperature (2000°F) corrosive/fouling gas streams existing in steel soaking pits, aluminum remelt, and glass melting operations. An industrial user will provide a consulting role to provide user perspective of the work.

Oak Ridge National Laboratory
Oak Ridge, TN 37831
Metals and Ceramics Division

2. *Ceramic Materials Support*

Long, E.L.; Moorhead, A.J.; Federer, J.I.

This project provides materials technology support to the Waste Energy Utilization Branch of the Office of Industrial Programs and their contractors in two general categories: (1) recuperator project support and (2) technology development. Recuperator project support involves assistance to DOE contractors in the development of systems for recovery of waste heat from industrial processes. The operating conditions of these systems require qualification of metallic alloys and ceramics for critical components such as heat exchanger tubes, seals, and structural members. The purpose of the project is to identify materials problems that significantly affect performance and reliability and to resolve the problems by application of existing materials technology or by performing the analyses and tests required for material qualification. The technology development portion of this project is focused on materials and processes that enhance industrial acceptance of ceramic recuperators. The cost, performance, and reliability of ceramic materials and components are critical to the overall cost-effectiveness of both current recuperator concepts (emerging systems) and advanced concepts. The objective of this project is to develop improved materials and processes to overcome factors that increase cost (e.g., ceramic powder production and component fabrication) or that limit performance and reliability (e.g., corrosion and toughness).

Babcock and Wilcox Company
Lynchburg, VA 24506-1165
R and D Division

3. *Assessment of Strength-Limiting Flaws in Ceramic Heat Exchanger Components*

Powers, T.

The project objective is to determine if flaw growth occurs in ceramic heat exchange components under industrial operating conditions and the extent it affects ceramic component viability. The first phase investigated specific nondestructive evaluation (NDE) methods to determine their effectiveness in identifying surface loss and characterizing flaw populations in ceramic specimens representative of ceramic heat exchanger geometries. A variety of NDE techniques were investigated and examined to identify techniques applicable to the inspection of SiC heat exchanger components for inherent defects. Four techniques found to be suitable are microfocus radiography, scanning laser acoustic microscopy, pulse echo acoustic microscopy, and acoustic backscattering. The second phase will evaluate the possibility of predicting the minimum lifetime of silicon carbide ceramic heat exchanger tubes from NDE data, using the linear and elastic fracture mechanics concepts. This will be accomplished by determining fracture characteristics of silicon carbide through test samples using induced flaws, then attempting to predict failure in samples machined from silicon carbide ceramic tubes in which flaws have been identified by NDE methods.

Solar Turbines, Inc.
San Diego, CA 92138
Research-Advanced Technology

4. *Development of High-Pressure Heat Exchange Systems (HiPHES)*

Ward, M.E.

The project objective is to develop a high-pressure heat exchange system (HiPHES) based on composite ceramics. The HiPHES should be capable of transferring heat to air at high temperature (above 1500°F) and high pressure (above 100 psia), feeding an indirectly fired gas turbine. The heating source in the air heater will be provided by the exhaust gases from a municipal or hazardous waste incinerator. This will allow higher temperature operation of the gas turbine without introducing corrosive species into the turbine. An industrial host site for field testing was selected. Work is continuing on the preliminary

design of both the indirectly fired gas turbine and heat exchange systems for the HiPHES.

Babcock and Wilcox Company
Lynchburg, VA 24506-0935

5. *Development of High-Pressure Heat Exchange Systems (HiPHES)*
Parks, W.P.

The project objective is to develop a high-pressure heat exchange system (HiPHES) based on composite ceramics. The heat exchanger should transfer heat to air at high temperature (above 1500°F) and high pressure (above 100 psia), feeding an indirectly fired gas turbine. The heating source in the air heater will be the exhaust gases from a municipal or hazardous waste incinerator. This will allow higher temperature operation of the gas turbine without introducing corrosive species into the turbine.

Stone and Webster Engineering Corp.
Boston, MA 02210

6. *Development of High-Pressure Heat Exchange Systems (HiPHES)*
Williams, J.J.

The project objective is to develop an advanced high pressure heat exchange system (HiPHES) for a convective steam reformer integrated with a directly-fired gas turbine cycle. The HiPHES steam reformer is a catalyst-filled tubular reactor that produces hydrogen at elevated pressures for subsequent processing to methanol or ammonia. The HiPHES system should allow reaction temperatures higher than the current state-of-the-art tube outlet temperatures of 1600°F.

Pennsylvania State University
University Park, PA 16802
Department of Mechanical Engineering

7. *Enhanced Tubes for Steam Condensers*
Webb, R.L.

The project objective is to evaluate enhancement of condensation heat transfer on the shell-side and tube-side of an industrial steam condenser. The objective will be met by (1) selecting an optimum enhanced tube geometry and material, (2) measuring heat transfer and pressure drop performance of the enhanced tubes, and (3) determining the tube-side fouling. Work is in progress to obtain enhanced tubes and associated test equipment. In the tube-side enhancement activity we considered potential enhancement geometries, and determined that some form of three dimensional roughness may be quite cleanable using flow driven sponge balls. We designed three possible roughness arrays, which are formed by applying pressure at local points on the external tube surface causing deformation on the inner surface. In the shell-side enhancement activity we are designing the condensing test cell to be installed on the condensation test facility. Possible leaks in the condenser test facility are being checked, because any leakage would prevent its operation at subatmospheric pressure.

Rensselaer Polytechnic Institute
Troy, NY 12180-3590
Mechanical Engineering, Aeronautical Engineering and Mechanics

8. *Enhanced Shell-and-Tube Heat Exchangers for the Industry*
Bergles, A.E.

The project objective is to evaluate enhancement of boiling heat transfer on the outside of tubes. It will address (1) the scaleup of shell-side boiling from a single enhanced tube to a tube bundle, (2) the fouling of the enhanced surfaces, and (3) enhanced shell-side boiling with multicomponent fluids. Rensselaer Polytechnic Institute (RPI) is progressing with single-tube testing, and the construction of apparatuses for bundle test and fouling tests. After completing single-tube testing, final selection of enhanced surfaces for use in bundle testing will be made. Pool boiling testing of Linde High Flux single-tubes with small and large pore sizes were completed. Tests with medium pore size tubes will be made. RPI completed all the work on the tube bundle test chamber. The installation of the plain tubes bundle test in the test chamber and loop modification were to begin at the end of February. RPI updated the data acquisition system program. Power failure warning signals will be installed in series with each cartridge heater.

EG and G Idaho, Inc.
Idaho Falls, ID 83401

9. *Test Fouling and Corrosion Probes in Industry*
Childs, W.F.

The project objective is to develop reliable cost-effective recuperators for high-temperature corrosive fouling industrial waste streams. Activities include: (1) performing waste stream characterization of industrial effluents; (2) conducting state-of-the-art survey of ceramic materials data and designs; (3) developing economic materials synthesis and fabrication methods including joining and sealing techniques; (4) investigating and analyzing novel heat exchanger design; (5) determining system and component quality control and evaluation techniques; (6) analyzing performance and economics; (7) performing hardware fabrication and test. This project provides test data that will link the characteristics of hot, dirty waste gas streams from furnaces of different industries to on-line fouling and corrosion processes for promising materials for the heat transfer surfaces of heat recovery equipment. Probes measure on-line fouling effects and longer duration corrosion, while limited, commercial, state-of-the-art field sampling methods will be used to determine the identifiable constituents of high-temperature waste streams. The resulting data will be used to encourage heat recovery equipment manufacturers and users to use the diagnostic equipment for their own specific applications, and to use the new materials in advanced industrial applications.

Dynatech Scientific, Inc.
Cambridge, MA 02139
Thermal Systems

10. *Development of a Hanging (Plastic) Film Heat Exchanger*

Gilbert, G.B.

The project objective is to investigate the design constraints, performance, and economic viability of the hanging (plastic) film heat exchanger concept. It will (1) analyze the various plastic film and plastic film laminates; (2) design and construct an exchanger and support equipment that will allow the testing of at least two film elements; (3) test various films to determine their resistance to leaching, degradation, and diffusion, using several test fluids; (4) generate a cost estimation method for full-size units; (5) conduct a market survey to determine the numbers and sizes of units with which this type of unit would be competitive; and (6) design, fabricate, and field test a prototype in an industrial environment. Expected results are: (1) a design procedure; (2) knowledge of the limitations of the use of various film materials; (3) a cost estimation procedure; and (4) appreciation of the users for whom these units would be best suited.

Industrial Heat Pumps

Minnesota Mining and Mfg. Co.
St. Paul, MN 55144-1000

11. *Develop a Brayton-Cycle Heat Pump for Volatile Organic Solvent Recovery*

Berry, T.

The project objectives are to develop a Brayton-cycle heat pump solvent recovery system to a production-prototype level, to analyze the market and business potential for adaptation to this solvent recovery system, to evaluate the system first cost and actual annual performance and operating costs, and to field-demonstrate a system to obtain performance/cost data and to identify problems in actual service. The approach consists of four phases of development: (1) system optimization, (2) system design, (3) system fabrication and development tests, and (4) demonstration by industrial facility. The Brayton-cycle solvent recovery system can be used effectively and competitively in a variety of applications, giving it a good market penetration potential. Paybacks of less than two years are predicted for production systems. It also provides industry a means of cleaning the air of pollution. In areas with restricted emission quantities, such as California, it provides increased production.

Argonne National Laboratory
Argonne, IL 60439
Materials & Components Technology Division

12. *Superconductors for Magnetic Heat Pumps*

Uherka, K.L.

The project objective is to assess the use of superconductors in the magnetic heat pump. Magnetic heat pumps use the magneto-caloric effect of ferromagnetic materials such as gadolinium, and offer the potential advantages of: (1) significantly higher efficiencies relative to gas-cycle heat pumps and (2) elimination of chlorofluorocarbon refrigerants that are detrimental to the environment. This project builds on previous DOE-sponsored R&D efforts on magnetic heat pumps for industrial refrigeration applications. Conceptual designs and analytical tools will be developed for improving magnetic heat pump systems through incorporation of superconducting magnet technologies. Phase II includes preliminary design of an integrated magnetic heat pump/superconducting magnetic system, analysis to determine magnetic field configurations for optimized performance/efficiency.

Astronautics Corporation of American
Madison, WI 53716

13. *Development of a Magnetic Refrigerator for the Liquefaction of Hydrogen*

Barkley, J.

Magnetic refrigerators utilize the magneto-caloric effect whereby paramagnetic materials heat up when magnetized by a high-field superconducting magnet and cool down when demagnetized. By cycling the paramagnetic material in and out of the magnetic field a highly efficient refrigeration cycle can be achieved. The development of a magnetic refrigerator to liquefy a precooled hydrogen will be a four phase effort planned to span six years. Phase I is for a final design of a subscale prototype, Phase II is for subscale prototype fabrication and development testing, Phase II is a full scale design of a one-ton-per-day hydrogen liquefier; and Phase IV is the fabrication and test evaluation of the liquefier.

Minnesota Mining and Mfg. Co.
St. Paul, MN 55144-1000

14. *Advanced Brayton Cycle Solvent Recovery Heat Pump*

Nelson, R.

A second generation heat pump design is being developed to recover and recycle volatile organic compounds (VOC's) from industrial air or gas streams. This technology is an alternative, and more economic (in many cases) means of controlling VOC emissions from industrial processes. Previous research has demonstrated the Brayton cycle heat pump (BCHP) capable of "shock cooling" solvent-laden air streams thus allowing condensation and collection of these solvents. Preliminary economic analyses show

attractive paybacks. Current research involves improvement to the overall heat pump cycle efficiency and the reduction of the capital cost of large scale systems; and the development of smaller capacity heat pump systems that will be marketable to small industrial solvent recovery applications. Specifically, some improvements to the BCHP that have been identified and are under review in the preliminary design phase are (1) an activated carbon solvent concentrator to reduce the turbomachinery size requirements, (2) the utilization of selective adsorption beds to remove water from the solvent gas stream and thus avoid heat exchanger frost-up problems. Present efforts include the design of a mobile BCHP unit to allow field testing at numerous host sites in order to gather design data of larger stationary units.

Mechanical Technology Incorporated
Latham, NY 12110

15. *Advanced Brayton Cycle Solvent Recovery Heat Pump*
Koebbeman, W.F.

A second generation heat pump design is being developed to recover and recycle volatile organic compounds (VOC's) from industrial air or gas streams. This technology is an alternative, and more economic (in many cases) means of controlling VOC emissions from industrial processes. Previous research has demonstrated the Brayton cycle heat pump (BCHP) capable of "shock cooling" solvent-laden air streams thus allowing condensation and collection of these solvents. Preliminary economic analyses show attractive paybacks. Current research involves improvement to the overall heat pump cycle efficiency and the reduction of the capital cost of large scale systems; and the development of smaller heat pump systems that will be marketable to small industrial solvent-recovery applications. Specifically, some improvements to the BCHP that have been identified and are under review in the preliminary design phase are (1) an activated carbon solvent concentrator to reduce the turbomachinery size requirements, (2) the utilization of selective adsorption beds to remove water from the solvent gas stream and thus avoid heat exchanger frost-up problems, and (3) the application of high speed electric motors to reduce turbomachinery capital cost. Present efforts include the design of a mobile BCHP unit to allow field testing at numerous host sites in order to gather design data for larger stationary units.

Kinetics Technology International Corporation
Monrovia, CA 91016
Research and Development

16. *Development and Test of Heat Pumps in New Applications for Industry*
Woinsky, S.G.

The project objective is to identify those industries where heat pump systems will offer significant cost savings. Initial work will involve data collection of specific process information and a PINCH analysis to identify the optimum placement of additional heat exchangers and heat pumps to be installed within the process. Alternative techniques such as boilers, cogeneration, and process modifications will also be considered and compared to the installation of the heat pump system. The PINCH analysis technique offers a means to determine the critical thermodynamic location (the "PINCH" point) within the process where heat may be pumped up to a higher temperature or exchanged down to a lower temperature. Some applications being considered include: synthetic fibers, beer brewing, liquor distilling, wet corn milling, pulp and paper production, fertilizer production, cheese processing, chemical processing, and textile manufacturing.

Southern Co. Services, Inc.
Birmingham, AL 35202

17. *Development and Test of Heat Pumps in New Applications for Industry*
Bowers, K.W.

See citation number 16.

Linnhoff March, Inc.
Leesburg, VA 22075

18. *Development and Test of Heat Pumps in New Applications for Industry*
Spriggs, H.D.

See citation number 16.

Litwin Engineers & Constructors, Inc.
Houston, TX 77079

19. *Development and Test of Heat Pumps in New Applications for Industry*
Pettigrew, M.G.

See citation number 16.

Gulf States Utilities, Co.
Beaumont, TX 77704

20. *Development and Test of Heat Pumps in New Applications for Industry*
Smith, R.C.

See citation number 16.

Oklahoma Gas and Electric, Co.
Oklahoma City, OK 73101

21. Development and Test of Heat Pumps in New Applications for Industry

Prasad, B.H.

See citation number 16.

Duke Power Company
Charlotte, NC 28242
Marketing and Rates Department

22. Development and Test of Heat Pumps in New Applications for Industry

Smith, S.

See citation number 16.

Utah Power and Light, Co.
Salt Lake City, UT 84104

23. Development and Test of Heat Pumps in New Applications for Industry

Drennan, G.B.

See citation number 16.

Rocky Research Corp.
Boulder City, NV 89005
Nevada Division

24. Heat of Reaction, Solid/Vapor Chemical Heat Pump

Rockenfeller, U.

Heat-activated heat pumps are being developed that use complex compounds. The use of complex compounds allows the application of adsorption cycles for industrial applications at temperatures of up to 1500 °F. Both heat amplifier (HA) and temperature amplifier (TA) heat pump cycles are possible. In FY 89 the objectives include (1) screening of a various ammoniated complex compound medium and (2) development and test of a small bench-scale solid/vapor heat pump. High refrigerant energy density of these complex compounds applied to a reactive heat exchanger design offers the potential for the solid/vapor heat pump to reduce capital cost and improve performance over the state-of-the-art industrial heat pump. Potential host sites are presently under review.

Energy Concepts
Annapolis, MN 21401

25. Liquid/Vapor Chemical Heat Pump, Ternary Nitrate (Alkitrate) Fluid

Erickson, D.

A liquid/vapor absorption heat pump is being developed in conjunction with the research on chemical heat pumps in progress at Oak Ridge National Laboratory. An aqueous absorbent is undergoing development which allows an absorption heat pump to operate at up to 260°C (500°F). The absorbent fluid, Alkitrate, is composed of water and (Li, K, Na)NO_3 salts. Testing of the fluid is in a proof-of-concept unit (PCU) in both the heat amplifier and temperature amplifier modes. State-of-the-art Lithium-bromide (LiBr)/water absorption heat pumps, are limited to 170°C because of corrosion considerations. Test data on the Alkitrate fluid, however, show no significant metallurgical corrosive action on nonaustenitic stainless steels at temperatures of up to 250°C. An increase of approximately 80°C to the useful operating temperature and 40°C in the heat pump lift temperature is therefore projected with the new Alkitrate fluid when compared to a LiBr/water absorption heat pump. These improvements will provide not only the enhanced coefficient of performance (COP) of absorption heat pumps but will also increase the number of industrial processes where chemical heat pumps may be economically and technically applied. Host sites to field test this heat pump have been identified and industry response is enthusiastic.

Oak Ridge National Laboratory
Oak Ridge, TN 37831
Energy Division

26. Chemical Heat Pumps

Ally, M.R.

The project objective is to provide the DOE Office of Industrial Programs (OIP) with planning, analysis, experimental, and evaluation support in developing chemical heat pump technology. This technology will reduce industrial fuel consumption by recovering and reducing waste process heat. The amount of industrial waste heat potentially recoverable is estimated to exceed 3 quads. Research is in areas of technology development not likely to be pursued by industry because of high risk or uncertainties in either the economic payback or the proof of concept. The goal is to identify and evaluate chemical heat pump concepts, to develop working fluid experimental data, to carry applied research through the proof of concept, and to estimate the economic payback potential for appropriate industrial applications. This project makes use of the expertise existing in the field of project management, thermodynamics, materials, chemical systems, and heat transfer at Oak Ridge National Laboratory (ORNL).

Improved Combustion Efficiency

Taratec Corporation
Columbus, OH 43215

27. *Study of Combustion Technologies Research Opportunities for Improved Energy Efficiencies in Industrial Applications*

Chace, A.S.

The project objective is to identify critical combustion technology research and development opportunities that can provide energy savings and other process improvements in major industrial sectors. Technologies include mixing and reaction of fuel and air, regulation of stoichiometry, heat transfer to the load, heat loss from the process, combustion control, and diagnostic equipment. Extensive contacts are undertaken with industry to obtain appropriate marketplace perspective on combustion technology requirements. These contacts include site visits and interviews and industry workshops. These activities yield a set of combustion projects recommended to be executed by the U.S. DOE.

Stone and Webster Engineering Corp.
Boston, MA 02210

28. *Assessment of an Industrial Wet Oxidation System for Burning Waste and Low Grade Fuels*

Bettinger, J.A.

The project objective is to develop a wet oxidation system to generate supercritical steam for industrial processes from industrial waste materials and/or low grade fuels excluding coal and municipal waste. The program is divided into four phases: Phase I will involve a review of the state-of-the-art relative to wet oxidation, identification and evaluation of potential fuels, identification and selection of generic industrial applications, development of conceptual designs for each application; and evaluation of each design/application combination. In Phase II, one generic industrial design/application will be selected to prove the concept that wet oxidation is suitable for raising supercritical steam for at least one industrial process. Phase III will involve the design and testing of a pilot scale wet oxidation system for a specific application of the generic design from Phase II. The design will be specific to a host site committed to testing under Phase IV.

University of Wisconsin
Madison, WI 53706
Department of Mechanical Engineering

29. *Evaluation of Polymeric Membrane for Oxygen Enrichment of Air*

Ragland, K.M.

The project objective is to evaluate the performance of two membrane systems for the production of oxygen-enriched air (35%) that could be used in combustion applications. One membrane system will be operated in the pressurized mode, and the other in a vacuum mode. The project will experimentally determine the operating performance of the systems over a range of operating conditions and evaluate the operating costs of membrane oxygen enrichment units for industrial burners sized for 300,000 to 3,000,000 Btu/hr.

Union Carbide Corp.
Tarrytown, NY 10591
Linde Division, Market Development

30. *Industrial Oxygen Enriched Air Production System*

Campbell, M.J.

The project objective is to design, to fabricate, and to provide for evaluation an advanced system for producing an oxygen-enriched air stream of a nominal 100% oxygen in a one ton/day pure oxygen equivalent size. All experimental work has been completed on this project; the final report will soon be published. This report will include details of pressure swing adsorption (PSA) technology, acceptance testing, system economics, and performance testing at the test facility located in Irvine, California and operated by Energy and Environmental Research Corporation (EERC).

31. *Oxygen-Enriched Combustion System Performance Study*

Schroeder, R.W.; Kobayashi, H.

Phase II work includes (1) evaluation of the energy savings and the performance of a full-scale 90 to 100% oxygen combustion system in an on-line industrial glass furnace and (2) evaluation of the performance and cost effectiveness of the oxygen generation system for combustion applications. The oxygen generation system to be used utilizes a pressure swing adsorption (PSA) process. This project was preceded by recently completed Phase I that involved market and technical feasibility assessments using oxygen-enriched combustion.

Vortec Corporation
Collegeville, PA 19426

32. *Coal-Fired Glass-Melting Process Heater Development*

Hnat, J.G.

The objective of this research is to use coal instead of natural gas or oil in a cyclone gasifier/combustor, and to use

the heat in an advanced glass-melting furnace. This is generating the technical, economic, and environmental data needed for private-sector decisions on the feasibility of choosing coal as a fuel. The work will be performed in three phases: (1) technical and economic analysis and pilot facility design; (2) procurement and construction of the pilot facility, and testing of system components; and (3) addition of equipment to obtain an integrated system, and testing of the system. The potential benefits of this technology over present methods are reduced size and capital costs, multifuel capability, integral emission control, rapid start-up and shutdown, rapid product changeover, high thermal efficiency, and fast payback time.

Combustion Engineering, Inc.
Windsor, CT 06095
Kreisinger Development Laboratory

33. *Development of a High-Efficiency Advanced Coal Combustor and Process Heat Retrofit*

Rini, M.J.

The project objective is to develop a high-efficiency advanced coal combustor (HEACC) for retrofit to existing boilers currently firing oil or natural gas. It will develop a retrofitable suspension firing system adaptable to using ultrafine coal–water fuel (with and/or without alkali sorbent) or dry ultrafine coal. The maximum potential of the ultrafine CWF will be realized by using secondary atomization. The project is divided into five technical tasks: (1) cold flow burner development; (2) pilot scale (5 x 10^6 Btu/hr) testing at the Massachusetts Institute of Technology (MIT); (3) demonstration scale (50 x 10^6 Btu/hr) testing at combustion engineering; (4) data analysis and final report; and (5) project management.

Manufacturing and Technology Conversion International (MTCI)
Columbia, MD 21045

34. *Development of a Retrofit (Pulse) Coal Combustor for Industrial Applications*

Durai-Swamy, K.

The project objective is to develop a pulse combustion system for firing both micronized and pulverized dry coals applicable for retrofit to existing boilers currently firing oil or natural gas. The technology also provides an opportunity for combustion staging, NO_x reduction, and sulfur capture by using dry sorbents and efficient ash and spent sorbent rejection. Phase I is comprised of laboratory-scale (2 MMBtu/hr) combustor design optimization, prior to scaleup, and the preparation of a pilot-scale (15 MMBtu/hr) design. Phase II covers development of the pilot-scale pulse coal combustor, preparation of a complete retrofit subsystem, and commercial assessment. Phase III includes field testing.

Surface Combustion, Inc.
Maumee, OH 43537-0428

35. *Development and Evaluation of a Workpiece Temperature Analyzer for Industrial Furnaces*

Schultz, T.J.

The objective of this research is to increase the energy efficiency of industrial heating processes through the development of advanced measurement systems that measure the temperature of the workpiece itself, not the temperature of the gas cavity in which it is located. Workpiece is herein defined as a solid object, either metallic or ceramic. Examples of applications may include reheating, annealing, sintering, soaking, heat treating, thermal setting, and curing or refractories. This analyzer must be a remote (non-contact) system, capable for use in moderate (>1000°F) to high temperature processes in both new and retrofit applications. The temperature profile and surface temperature of the workpiece will be determined either by direct measurement or inferred by calculation from direct measurements. An ultrasonic method of measuring the internal temperature of the workpieces will be developed. The system uses a laser to induce an acoustic wave through the workpiece. The speed of the acoustic wave through the workpiece depends primarily upon the temperature and is calculated by determining both the distance and time of flight of the acoustic wave. The arrival of the acoustic wave at the opposite side of the workpiece is detected by using a laser interferometer. A conceptual design will be developed and an analytical model will be generated which will include all laser, parameters, detection system parameters, workpiece properties, and furnace characteristics. Vendors will be contacted to determine availability of individual system components.

Acurex Corp.
Mountain View, CA 94042

36. *Development and Evaluation of a Workpiece Temperature Analyzer for Industrial Furnaces*

Dehne, H.

The objective of this research is to increase the energy efficiency of industrial heating processes through the development of advanced measurement systems that measure the temperature of the workpiece itself, not the temperature of the gas cavity in which it is located. Workpiece is herein defined as a solid object, either metallic or ceramic. Examples of applications may include reheating, annealing, sintering, soaking, heat treating, thermal setting, and curing or refractories. This analyzer must be a remote (noncontact) system, capable for use in moderate (>1000°F) to high temperature processes in both new and retrofit applications. The temperature profile and surface temperature of the workpiece will be determined either by direct measurement or inferred by calculation from direct measurements. This project involves the assessment of two optical technologies to measure workpiece surface temperature. Industrial testing will be completed on an optical measurement device developed by Pyrometer Instrument Co., Inc. and called the "Pyrolaser." This system

uses a laser beam directed at and reflected by the workpiece. The surface reflectivity can then be related to emissivity which is used to calculate the surface temperature. Improvements to the Pyrolaser will be recommended to avoid the weaknesses of this technology: (1) effects of background radiation, (2) absorption of the signal by the combustion gases, and (3) indirect measurement of emissivity. The second technology to be evaluated is Raman Spectroscopy in which a laser is used to excite the atoms on the surface of the workpiece and the temperature is determined from the resulting Stokes and anti-Stokes radiation. The laser beam undergoes a change in frequency and a random alteration in phase caused by the vibrational energy (a function of temperature) of the scattering molecules. This technique has the potential to eliminate all the barriers to the Pyrolaser technology. The Raman Spectroscopy system will be evaluated by developing a preliminary concept description and assessment of system economics.

Babcock and Wilcox Company
Alliance, OH 44601-2196

37. *Development and Evaluation of a Workpiece Temperature Analyzer for Industrial Furnaces*

Berthold, J.W.

The objective of this research is to increase the energy efficiency of industrial heating processes through the development of advanced measurement systems that measure the temperature of the workpiece itself, not the temperature of the gas cavity in which it is located. Workpiece is herein defined as a solid object, either metallic or ceramic. Examples of applications may include reheating, annealing, sintering, soaking, heat treating, thermal setting, and curing or refractories. This analyzer must be a remote (non-contact) system, capable for use in moderate (>1000°F) to high temperature processes in both new and retrofit applications. The temperature profile and surface temperature of the workpiece will be determined either by direct measurement or inferred by calculation from direct measurements. An ultrasonic method of measuring the internal temperature of the workpiece will be investigated. The system uses a laser to induce an acoustic wave through the workpiece. The speed of the acoustic wave through the workpiece depends primarily upon the temperature and is calculated by determining both the distance and time of flight of the acoustic wave. The arrival of the acoustic wave at the opposite side of the workpiece is detected by using a laser interferometer. A potential triangulation technique to measure the dimensions of the workpiece (distance of flight) will be investigated. Preliminary concepts and specification will be developed. Laboratory work will be conducted in Phase I to examine major uncertainties identified during concept development.

Surface Combustion, Inc.
Maumee, OH 43537-0428

38. *Research Program for Advanced Combustion Systems Ferrous Scrap Preheating System*

Hoetzl, M.

The proposed scrap preheating system utilizes a unique combustion system called a rich fume reactor (RFR) which provides total independent control of the heating process. The scrap is heated in a charge bucket. Off gases from the bucket are ducted to the RFR where oils and moisture that are normally present on the scrap, are totally combusted providing energy to the process via low oxygen exhaust gases. The hot gases from the RFR pass through the bucket and heat the scrap. The recycle gas loop has a very low oxygen fraction to allow higher preheat temperatures. All gases are incinerated prior to leaving the system. Natural gas supplies any energy not available from the oily scrap. The preheater is decoupled from the arc furnace making retrofit installation practical and process scheduling possible.

Acurex Corp.
Mountain View, CA 94042

39. *Development and Evaluation of a Workpiece Temperature Analyzer for Industrial Furnaces*

Dehne, H.

The objective of this research is to increase the energy efficiency of industrial heating processes through the development of advanced measurement systems that measure the temperature of the workpiece itself, not the temperature of the gas cavity in which it is located. Workpiece is herein defined as a solid object, either metallic or ceramic. Examples of applications may include reheating, annealing, sintering, soaking, heat treating, thermal setting, and curing or refractories. This analyzer must be a remote (non-contact) system, capable for use in moderate (>1000°F) to high temperature processes in both new and retrofit applications. The temperature profile and surface temperature of the workpiece will be determined either by direct measurement or inferred by calculation from direct measurements. This project involves the assessment of two optical technologies to measure workpiece surface temperature. Industrial testing will be completed on an optical measurement device developed by Pyrometer Instrument Co., Inc. and called the "Pyrolaser." This system uses a laser beam directed at and reflected by the workpiece. The surface reflectivity can then be related to emissivity which is used to calculate the surface temperature. Improvements to the Pyrolaser will be recommended to avoid the weaknesses of this technology: (1) effects of background radiation, (2) absorption of the signal by the combustion gases, and (3) indirect measurement of emissivity. The second technology to be evaluated is Raman Spectroscopy in which a laser is used to excite the atoms on the surface of the workpiece and the temperature is determined from the resulting Stokes and anti-Stokes radiation. The laser beam undergoes a change in frequency

and a random alteration in phase caused by the vibrational energy (a function of temperature) of the scattering molecules. This technique has the potential to eliminate all the barriers to the Pyrolaser technology. The Raman Spectroscopy system will be evaluated by developing a preliminary concept description and assessment of system economics. At the close of Phase I, a decision to proceed with an improved Pyrolaser or the Raman spectroscopy technology can be made.

Air Products and Chemicals, Inc.
Allentown, PA 18195

40. *Research Program for Advanced Combustion Systems; Advanced Glass Melting System*

Winchester, D.

The objective of this research is to develop an oxygen-fuel-fired, advanced, glass-melting system that will reduce the industry's energy consumption, capital cost, and impact on the environment. This system will substantially improve the overall thermal efficiency of the melting process, combining the most recent developments in oxygen-enriched combustion with heat recovery and integration techniques. Elimination of nitrogen from the combustion process will allow great reductions in equipment size, while reducing NO_x and particulate emissions. The Air Products advanced glass-melting system will include four primary subsystems: (1) a batch preheater, (2) melter/refiner, (3) oxygen-fuel delivery system, and (4) combustion controls. High heat transfer rates will be achieved with oxygen-fuel combustion above and below the molten bath. The flue gases exiting the melter/refiner will be used to heat the batch (silica sand) or cullet (recycled glass) to temperatures in excess of 1000°F, and potentially up to its melting temperature. Overall thermal efficiencies as high as 60 to 70% are expected.

Alzeta Corporation
Santa Clara, CA 95054-1008

41. *Research Program for Advanced Combustion Systems; Advanced Radiant Combustion System*

Sullivan, J.

The objective of this research by Alzeta Corporation is to develop, test, and demonstrate an advanced gas-fired radiant combustion system for use in industrial manufacturing processes that require very high, controlled heat fluxes at elevated process temperatures ({greater tha}1800°F). The project will undertake the primary objective of extending radiant burner use to higher temperature processes. The system will use high-temperature, fast-response, porous-surface radiant burners combined with advanced combustion controls to allow profiling of radiant output to process load requirements. The proposed initial installation is in a hydrogen-steam-reforming process, whereby hydrogen is manufactured from methane. The combination of high heat flux at a lower uniform temperature means that loads can be heated efficiently in small volumes without being subjected to localized overheating that might produce tube burnout, fluid coking, or material nonuniformities. An added advantage is that the low peak temperatures minimize or eliminate thermal NO_x formation ({less tha}30-40 ppm), resulting in a more environmentally acceptable combustion process.

Babcock and Wilcox Company
Alliance, OH 44601-2196

42. *Development and Evaluation of a Workpiece Temperature Analyzer for Industrial Furnaces*

Berthold, J.W.

The objective of this research is to increase the energy efficiency of industrial heating processes through the development of advanced measurement systems that measure the temperature of the workpiece itself, not the temperature of the gas cavity in which it is located. Workpiece is herein defined as a solid object, either metallic or ceramic. Examples of applications may include reheating, annealing, sintering, soaking, heat treating, thermal setting, and curing or refractories. This analyzer must be a remote (non-contact) system, capable for use in moderate (>1000°F) to high temperature processes in both new and retrofit applications. The temperature profile and surface temperature of the workpiece will be determined either by direct measurement or inferred by calculation from direct measurements. An ultrasonic method of measuring the internal temperature of the workpiece will be investigated. The system uses a laser to induce an acoustic wave through the workpiece. The speed of the acoustic wave through the workpiece depends primarily upon the temperature and is calculated by determining both the distance and time of flight of the acoustic wave. The arrival of the acoustic wave at the opposite side of the workpiece is detected by using a laser interferometer. A potential triangulation technique to measure the dimensions of the workpiece (distance of flight) will be investigated. Preliminary concepts and specification will be developed. Laboratory work will be conducted in Phase I to examine major uncertainties identified during concept development.

ADVANCED INDUSTRIAL COGENERATION

Topping Cycles

Argonne National Laboratory
Argonne, IL 60439
Chemical Technology Division

43. *Atmospheric Fluidized-Bed Cogeneration Air Heater (ACAH) Experiment*

Podolski, W.F.; Myles, K.M.

Argonne National Laboratory (ANL) is conducting materials reliability and performance tests in the DOE-owned 6 x 6 ft atmospheric fluidized-bed combustor (AFBC) unit at Rockwell International, in cooperation with Westinghouse Electric Co., which is currently designing several variations of atmospheric fluidized-bed cogeneration air heaters. The test results will determine the economic viability of these heaters. In support of this program, ANL: (1) established a materials data base; (2) will determine corrosion and erosion rates of selected materials; (3) initiated and monitors a subcontract for the required modification, installation, and experimental testing of tube bundle test sections in the Rockwell International 6 ft x 6 ft coal-fired AFBC and provides an independent data reduction and assessment of tube material performance; and (4) performs management activities. Further effort comprises activities related to the preparation for and presentation of a technology-transfer seminar on the Phase I Generic Studies of Advanced Fluidized Bed Air Heater Technology Project. This seminar is expected to stimulate interest in commercial applications of this technology.

Solar Turbines, Inc.
San Diego, CA 92138
Research-Advanced Technology

44. *High-Performance Steam Proof-of-Concept Phase Cogeneration Service*

Duffy, T.E.

The project objective is to design and develop a high-performance steam system for industrial cogeneration. The system will consist of a steam generator and a steam turbine that operate at 1,500 psia and 1,500°F. The high efficiency of this system will conserve fossil fuel in the industrial sector. The approach is to demonstrate successfully a section of the high-temperature steam generator before building the steam turbine and full-sized steam generator. A successful 4,000 hour test has been completed on a sample tube at 1,500 psia and 1,500°F. A preliminary steam turbine and steam generator design concept has been completed. The expected product is high-efficiency industrial cogeneration equipment in the 4 to 20 MW size range. A laboratory steam generator of 10,000 lb/hr capacity is being built and will be tested. The design of a 5 MW steam turbine is being prepared. A 60,000 lb/hr steam generator will be designed, built, and factory tested. The 5 MW steam turbine will be fabricated and factory tested. With favorable results they will be installed and tested in an industrial site.

University of Wisconsin
Madison, WI 53706
Department of Mechanical Engineering

45. *Gravel Bed Combustor for Solid Fueled Gas Turbine*

Ragland, K.W.

This project will demonstrate that an Allison Model 250 gas turbine rated at 400 hp can be powered directly by a gravel bed combustor using wood chips and crushed coal. Project objectives are (1) to design and construct the pressurized gravel bed combustor, control system, and fuel feed system; (2) to conduct combustion tests of the pressurized gravel bed combustor at 5 atm pressure and 200°C air preheat (using a control valve instead of the turbine to control the combustor back pressure), and to measure combustor performance and ash characteristics (the fuel will be 3/4-in pine chips); and (3) to develop a computer model of the gravel bed combustor that will simulate the combustion rate as a function of fuel properties and air-flow rate, pressure, and temperature. This research will help to promote efficient industrial cogeneration of electricity and process heat without the use of fuel oil or natural gas.

Argonne National Laboratory
Argonne, IL 60439

46. *Oxygen Enriched Combustion Diesel*

Marciniak, T.J.

The objective is development of advanced, high electrical-to-thermal ratio prime movers that increase energy efficiency and provide multifuel flexibility. Phase 1 consists of an assessment of the state of the art. Phase 2 consists of (1) detailed assessment of oxygen enrichment devices; (2) bench tests of oxygen-enrichment devices; (3) computer modeling of the diesel engine; (4) small-scale engine tests; and (5) scale-up tests using a larger diesel engine. In Phase 3 a full-scale cogeneration system utilizing the technology will be designed, built, operated, and evaluated.

Direct Conversion

Ford Motor Company
Dearborn, MI 48121
Advanced Components and Energy Division

47. *One kWe Sodium Heat Engine (SHE) System*

Hunt, T.K.

The project objective is design, construction, and testing of sodium heat engine (SHE) systems of electrical output capacity up to 1 kW and thermal to electric conversion efficiencies up to 25%. Additional goals include (1) improving SHE operational performance, as a result of research into novel electrode materials and methods for their application; and (2) completing application and cost study to assess probable applications. The approach is through the iterative design, testing, and redesign of SHE systems, scaled-up from those investigated under previous efforts. Output power levels of 110 watts have been achieved, and (in separate tests) efficiencies up to 19% have been demonstrated. The work is expected to lead to the demonstration of a SHE system performing at 1 kWe for a period of 50 h while operating at a high temperature at or below 900°C and an exhaust temperature of about 200°C. SHE devices with these performance characteristics can find wide use in industrial and residential cogeneration and for remote power generation in terrestrial and space applications.

Battelle Memorial Institute
Columbus, OH 43201

48. *Initiative on Ceramic Stationary Gas Turbines*

Anson, D.

The objective of this work is to improve the performance of Stationary Gas Turbines that are used in Cogeneration and Self Generation service. The development will be based on utilization of the newly acquired ceramic technology that has resulted from the High Pressure Heat Exchanger, the Automotive Gas Turbine and the aeroengine programs. An assessment and program plan will be prepared and then a development program will be conducted with one or more domestic gas turbine manufacturers. The components to be improved will be divided into two groups, static and dynamic with the initial emphasis placed on the static parts. There is an existing market for retrofit equipment of approximately 6000 MWe with an annual increment of 800 to 1000 MWe. Fuel efficiencies will increase by 12 to 15%.

WASTE PRODUCTS UTILIZATION

Solid Wastes

Air Products and Chemicals, Inc.
Allentown, PA 18195

49. *Utilization of Waste Tires Using Novel Surface Modification Technology*

Bauman, B.D.

The project objective is to produce novel composite materials by combining surface-modified, ground waste rubber with numerous commercially available plastics. Commercial incentives driving incorporation of surface-modified ground rubber will be manufacturing cost reductions or property enhancements in the composite material. Potential savings of approximately 78,000 Btu can be realized for every pound of surface-modified scrap rubber incorporated in polymer composite systems. Task 1 will involve establishing the concept feasibility basis. In Task 2, the surface modification process will be refined for representative waste tire materials obtained. Pretreatment solvent washing to remove surface oils, surface treatment, chemistry optimization and posttreatment fixing to provide a stable, enhanced adhesion surface are the key steps in this task. In Task 3 the optimal process conditions identified in Task 2 will be used to prepare a sufficient quantity of surface-modified scrap rubber for applications development. In Task 4 applications that can consume significant volumes of surface-modified rubber will be identified and developed. Several approaches will be used including in-house R&D, contract research, and providing samples to prospective end-users. Task 5 will entail evaluation of energy savings potential and environmental impact, and Task 6 will deal with project management and technology transfer.

Oak Ridge National Laboratory
Oak Ridge, TN 37831
Energy Division

50. *Plastics Recycling in the Industrial Sector*

Curlee, T.R.

The project objective is to develop technology to economically convert industrial solid wastes into higher value chemical feedstocks or fuels or recover and recycle contained materials. We will (1) survey and assess opportunities for use of industrial solid wastes; (2) evaluate technologies for the conversion/recycling of solid wastes; (3) develop applicable technologies; and (4) disseminate R&D results to industry.

Solar Energy Research Institute
Golden, CO 80401

51. *Adhesives, Insulation, and Other Higher Value Chemicals from Wood Wastes*

Chum, H.L.

Phenol is a primary component of adhesives for wood products. The potential for energy savings by substituting woody oil extracts for petroleum-based phenol is great, since phenol production is very energy intensive. About one-half of all phenol produced is used to manufacture phenol-formaldehyde resins. Oils produced by the thermochemical conversion of woody materials have a very high content of phenolic compounds. These extracts can be refined to yield suitable feedstocks for the production of p-f resin. A laboratory-scale unit has produced p-f resin and test plywoods that appear to have comparable properties to the existing petroleum-based products, but at a potentially lower cost. The project goal is to produce enough resin for a panel test of the paper, plywood, and wood product. Considerable interest exists in industry to become petroleum independent, using woody sources of energy alone to supply energy.

Manville Sales Corporation
Denver, CO 80217-5108
Research and Development

52. *R&D of Energy Conservation Through Recycling of Factory Asphalt Roofing Waste*

Shepherd, P.B.

The project objective is to obtain process data and to measure shingle quality attributes that will provide a sound technical basis for the commercialization of the direct recycling concept. The recycling will be conducted on a factory scale during commercial production of asphalt shingles and will provide a quantity of product for properties and use testing. Research will include proof testing of the waste processing equipment, optimization of roofing production with scrap, effect on the machinery and plant protocol, evaluation of the product quality, updating of costs of recycling implementation and operation, and analysis of the financial, energy, and environmental benefit to a roofing manufacturer.

Argonne National Laboratory
Argonne, IL 60439
Energy and Environmental Systems Division

53. *Research for Increased Utilization of Scrap Metal*

Wolsky, A.M.; Fraioli, A.V.

This project will perform research to increase utilization of three kinds of scrap metal: aluminum, zinc, and steel. Methods for removing impurities and contaminants that limit the recycling of these materials will be investigated. The scrap aluminum reuse activities involve cooperative efforts with concerned industrial agencies, such as the American Foundrymen's Society (AFS), to determine the separate and combined effects of unacceptable levels of residual elements. Future studies will focus on the removal or neutralization of these residual elements. The scrap steel reuse activities involve removing zinc from steel scrap by electrochemical separation. Argonne National Laboratory Energy and Environmental Systems Division will perform laboratory tests to determine optimal caustic electrolyte composition and cell resistance and to determine the impact of other impurities on the electrowinning of the zinc. A pilot-scale test will involve an industrial firm with an existing technology base in removing zinc-like impurities from scrap metals. System analysis will identify other impediments and alternative strategies to increase scrap metal utilization. Combinations of "identify and separate" and "neutralize or remove" strategies may provide energy and economic benefits when applied at various steps in the recycling chain.

Liquid Wastes

Argonne National Laboratory
Argonne, IL 60439
Waste Management Operations

54. *Energy and Material Recovery from Industrial Wastewaters*

Coleman, R.D.

The objective of this project is to provide cost-effective process options to industry to recover material and fuel constituents from industrial wastewaters having aqueous inorganic–organic and hydrocarbon content. Specific tasks include the following: (1) R&D of novel lactide copolymer with biodegradable–photodegradable links and initial product planning such as lactic acid purity specifications for various end uses; (2) strain improvement of two bacterial strains for D/L isomers lactic acid (yields and tolerances); (3) development of a continuous process: potato → dextrose → lactic acid → polymer sequence, including the patenting of existing saccharification breakthroughs; and (4) exploration of a separation process for lactic acid from the fermentation broth using electrodialysis, liquid–liquid extraction, and esterification to methyl lactate. Potential savings of 30 to 40 trillion Btu per year are possible on potato waste alone at 90% penetration. Total possible impact is in 400 to 500 trillion Btu per year range using other carbohydrate sources such as cheese whey, corn starch, grain sorghum, fruit, and wheat starch. This process will make a biodegradable plastic that can be made into thin film saran-wrap-type products as well as other types of throwaway plastic products. The biodegradability can be tailored to a shelf life of weeks to as long as two to three years. The plastic is nontoxic and is currently applicable for surgery use in degradable supports and sutures, but probably has much larger applications such as controlled release fertilizers and pesticides.

Purdue University
West Lafayette, IN 47907
Purdue Research Foundation

55. *Higher Value Chemicals from Cheese Whey*

Okos, M.R.

The objective of this project is to provide cost-effective process options to industry to recover material and fuel constituents from industrial wastewaters having aqueous inorganic–organic and hydrocarbon content. Specific tasks include: (1) continuing operation and testing to evaluate the 30-inch immobilized cell reactor system at Ft. Wayne, Indiana located at Allen Dairy; (2) conducting laboratory studies to determine the feasibility of several alternate fermentation operations such as production of flavorings and of acetone–butanol–ethanol; and (3) testing the ethanol purification system to aid in the advanced design fermentation-separation systems.

Sawyer Applied Research Co.
Pacific Palisades, CA 90272

56. *Acoustic Sludge Dewatering*

Sawyer, H.T.

The purpose of this project is to test the dewatering performance of an acoustic vibration dewatering device. The primary claim of the uniqueness of the device is that the coupling of the acoustic frequency to the vibrating screen is more efficient because of management of the harmonic characteristics and critical dimensions of the screen. Testing of the device will be performed on several food industry and paper industry sludges. An expert in the technology of creating cavitation as a useful physical phenomenon in dewatering stated that both unbound and much of the bound water can be removed in this manner.

Gaseous Wastes and Waste Reduction

Dow Corning Corporation
Midland, MI 48687-0994
Silicon Research

57. *Pilot-Scale Demonstration of Silicon Furnace Waste Gas Utilization Technology*

May, J.B.

The project objectives are (1) to demonstrate on a pilot scale improved operating efficiencies for the sealed furnace and (2) to recover 80 million Btu's per hour of waste energy in the off-gas stream. The off-gas will also be evaluated for use as a fuel or chemical feedstock. A 200-KVA pilot furnace was designed, constructed, and installed, and will operate to demonstrate the sealed furnace technology. A 75-kW carbon bed reactor has been designed and installed to perform the waste gas recovery analysis.

3M Company Research Labs
St. Paul, MN 55144
Science Research Lab

58. *Waste Gas Minimization: Dual Cure Solventless Coating Process*

Chambers, W.L.

The project objective is to conduct research and development on a dual cure (DC) photocatalyst system for the production of 100% reactive, solventless coatings from urethane and vinyl, and epoxide and vinyl monomer compositions. Testing emphasis has progressed from the baseline DC catalyst system to the three reference DC catalyst systems each of which uses the same cationic organometallic material (1) alone, (2) with the same oxidant used in the baseline system, or (3) with a free radical photoinitiator. Chemical property analysis is continuing. Molecular weight distribution tests were completed on two of three types of gel permeation chromatography. Small angle X-ray and differential scanning calorimetry tests were completed. The transmission electron microscopy tests and the characterization of physical properties are continuing. The complete set of Instron tensile tests are complete. The dynamic mechanical analysis (DMA) tests measure the mechanical response of a material as it is deformed under periodic stress as a function of time, temperature, and frequency, and are the most valuable method for determining the effect of the catalysts on the properties of the cured polymers. The thermogravimetric analysis tests (sample weight as a function of increasing temperature) are complete. Preliminary analyses were completed showing positive results.

Argonne National Laboratory
Argonne, IL 60439

59. *Recovery of Hydrogen and Sulfur from Hydrogen Sulfide Wastes*

Harkness, J.B.L.; Gorski, A.J.

The project objective is to investigate and develop a new concept for recovery of valuable hydrogen and sulfur from gas streams contaminated with hydrogen sulfide. This concept involves using a low-temperature, microwave-generated plasma to dissociate the hydrogen sulfide molecule into its elemental components. This process represents a significant improvement over the current hydrogen sulfide waste treatment technology that loses the hydrogen value as water. The economic benefit of recovering hydrogen and sulfur in a relatively simple, integrated process amounts to a near-term energy savings of over 12 trillion Btu/year. Longer-term savings could amount from 30 to 70 trillion Btu/year. An added benefit of this process concept is its potential for decreasing sulfur emissions from the current hydrogen sulfide waste treatment technology. The project consists of (1) a laboratory effort to verify the technical feasibility of the concept, (2) a systems engineering effort to evaluate the economic potential of the concept, and (3) a technology transfer effort to facilitate industrial acceptance of the process. The laboratory effort will involve experimentally determining the specific energy required to dissociate hydrogen sulfide, as well as the degree of conversion. The engineering evaluation will prepare a detailed, commercial-scale process design and use this design as the basis for an economic evaluation and market study. This study will determine the process sensitivity to the specific energy of dissociation and conversion, and will evaluate alternative applications of the technology. The technology transfer effort established an industry working group to provide technical guidance and to maintain an industrial focus for the laboratory research and the systems engineering.

LOW-TEMPERATURE PROCESSES

Advanced Sensors and Controls

Aguila Corporation
Houston, TX 77043

60. *R&D on a Fertilizer Sensor and Control System*

Colburn, J.W.

The purpose of this project is to determine equilibrium and kinetic chemical reaction relationships of soil nitrogen compounds and to devise mobile sampling probe and sensing techniques applicable as real-time control input to farm-tractor fertilizer spreaders. Computer models and breadboard laboratory experiments will be used to design and develop a mobile probe that will incorporate commercial sensors. The sensor array will be validated for its ability to measure spatial variations of *in situ* nitrate levels in the presence of typical agronomically significant ion interferences. Results are expected to confirm the hypothesis that applying nitrogen fertilizer according to local needs will reduce the waste that results from applying an average value to a field.

National Institute of Standards and Technology
Gaithersburg, MD 20899
Center for Chemical Engineering

61. *Development of Advanced Sensors for the Paper Industry*

Whitstone, J.R.; Semerjian, H.G.

The project objective is to investigate a combustion control sensor designed to measure temperature in the air/fuel reaction zone of a recovery boiler. Temperature is determined nonintrusively in real-time via ultraviolet emission spectroscopy performed through multiple fiber-optic probes. The intensities of two spectroscopic lines present in the reaction zone are measured. The ratio of these concurrently observed intensities uniquely identifies the combustion zone temperature and stoichiometry. Measurement of the consistency of pulp slurries is also of concern to pulp and paper mills since its control directly affects the uniformity of the product produced. Although consistency is defined as the ratio of the mass of fibrous material in a slurry to the total mass of the slurry, consistency transmitters almost universally sense some property of the slurry other than the fiber/total mass ratio. Many consistency sensors use either shear stress or optical transmission measurements. These sensors have been found to be inaccurate in high-consistency flows. Another objective is to develop a more accurate sensor for the high-consistency flow range. In the new operation, consistency is determined nonintrusively in real-time via an electromagnetic technique. Radio frequency energy is input to a pipe carrying the solids–liquid mixture or any mixture having two different dielectric constants. The piping acts as a waveguide; the input radio waves are propagated in a manner that is uniquely determined by medium's solids content (dielectric constant), temperature, and electrical conductivity. Wavelength, frequency, attenuation, and temperature are measured and consistency computed. A prototype unit has been designed and constructed and was evaluated in a pilot plant facility. The unit failed because of air entrainment and additives. Modification is in progress and a new sensor is being designed. Successful development of these sensors could potentially save 0.07 quads annually.

Spectral Sciences, Inc.
Burlington, MA 01803

62. *Economic and Accurate Moisture-Sensing System for Use in Harsh Drying Environments*

Gersh, M.E.

The project objective is to develop an economical and accurate moisture-sensing system (a differential optical attenuation device using ultraviolet light) for use in harsh drying operation environments. The system will be developed to meet the performance and cost requirements of various process drying applications. Accurate moisture sensing and moisture control will achieve energy savings through reduction of overdrying and increase of productivity for industrial processes. The project will consist of three phases. Phase I is a feasibility demonstration of the sensor concept. Phases II and III will result in design, development, and testing of a prototype sensor in an industrial environment.

TransMet Engineering, Inc.
Anaheim, CA 92806

63. *Development of a Heat Flux Dew-Point Hygrometer*

Rall, D.

The project objective is to develop a relatively inexpensive and accurate moisture sensing system (a heat flux dew-point hygrometer) for use in the severe environments typical of drying operations. The sensor employs the latent heat of condensation to determine the instant at which condensation occurs on a cooled surface. The surface temperature of the cooled surface at the instant of condensation is the dew point. To date the concept has been proven. Design of a prototype sensor assembly has been completed, and fabrication of the test hardware is under way.

Jet Propulsion Laboratory
Pasadena, CA 91109

64. *Advanced Sensor Development Program (Process Instrumentation Research) for the Pulp and Paper Industry with Other Generic Applications*

Shakkottai, P.

A primary process parameter in the digestion, washing, and bleaching of wood in paper production is measuring the amount and type of lignin bound to the cellulose. Currently, the concentration of lignin, both in pulp and black liquor, is measured using off-line chemical titration tests, which is time-consuming and subject to error. The Jet Propulsion Laboratory (JPL) is studying the feasibility of a sensor that will be a real-time, on-line lignin analyzer. Using a state-of-the-art mass spectrometer and a probe sample preparation system, the new sensor measures the residual lignin content in digested wood pulp by ascertaining the ratio of differences between the pyrolysis spectra of cellulose and lignin. JPL has tested a prototype of the proposed system. The system has potential for an R&D laboratory or mill application. More testing and correlation needs to be done; an instrument manufacturer needs to repackage the device and commercialize it. The control of humidity and moisture in pulp and paper mills is limited by the quality of the moisture/humidity sensor. From 7 to 20 pounds of air are used for each pound of water evaporated. Enough air must be used to avoid condensation anywhere within the paper machine dryer hood to prevent drips, buildups, and corrosion. At present, humidity sensors are inadequate because of their low survivability rate and accuracy. Current hygrometers either foul too often or damage too easily. The sensor concept developed by JPL includes a tubular flow-through hygrometer comprised of a wire-wound polymer-coated metal cylinder, a power supply and electrometer, a microprocessor computing device, and a digital data logger/readout. The hygrometer will operate based on the sulfonated fluorocarbon polymer's (DuPont's Nafion) changing electrical resistance, which varies as a function of water vapor pressure found in the environment. A prototype has been fabricated, testing in two mills completed, and is ready for repackaging and commercialization. Successful development of these sensors could save 0.05 quads annually. A final technical report has been written.

University of Tennessee
Knoxville, TN 37996
Measurement & Control Engineering Center

65. *Development of an On-Line Chemical Composition Analyzer*

Muly, E.C.

The project objectives are the definition, fabrication, testing, and application development of a composition sensor system suitable for use in industrially important distillation processes. The sensor will be based on laser Raman spectroscopy. The sensor system must perform on-line, real-time data acquisition and analysis with accuracy and reliability sufficient for its inclusion in energy efficient distillation column control systems. The project is divided into three parts: (1) concept development, (2) prototype sensor system development, and (3) industrial testing.

Southwest Research Institute
San Antonio, TX 78284
Department of Electronics and Physics

66. *Development of a Hydrogen Transient Nuclear Magnetic Resonance Sensor for Moisture Measurement*

Nicholls, C.I.

The objective of this project is to develop a hydrogen transient nuclear magnetic resonance (HTNMR) sensor that monitors the moisture content of materials being dried, minimizing drying energy requirements and maximizing process efficiency. Emphasis is on applications involving the drying of processed agricultural products such as corn, wheat, maize, and soybeans as they are converted into commercial items such as animal feed, starch, grain proteins, flour, and so forth. This project involves hydrogen transient nuclear magnetic resonance (HTNMR) sensor development with eventual commercialization of the process. Phase I involves developing the sensor concept and investigating its feasibility, developing the sensor system, and verifying the technical and economic feasibility of the sensor.

Institute of Paper Chemistry (IPC)
Appleton, WI 54912
Paper Sciences Division

67. *On-Machine Sensors to Measure Paper Mechanical Properties*

Hall, M.S.; Habeger, C.C., Jr.

The objective of this research program is to develop a sensor for measuring certain in-plane and out-of-plane mechanical properties of paper on the paper machine in order to provide a continuous record of product quality and ultimately a means for controlling the machine. Fundamental research shows that elastic properties are very sensitive to paper machine process variables and also are highly correlated to paper end use performance. The research will be a vital bridge between fundamental knowledge and its application in the industry. All paper grades are manufactured to some type of mechanical property specification. Mechanical tests are usually destructive and are performed on samples taken from the end of the reel of paper stock. This test made on several square feet of material is the only mechanical property data for the thousands of square feet of stock held on the reel that was sampled. Because no method is available for nondestructive testing of the mechanical properties of the roll stock during the production run, as much as an hour's production can be substandard before a problem is recognized. The loss of an hour's production per day is approximately 4% of the daily machine output. Reprocessing and remanufacture of this material requires about 13.8 million Btu/ton of material stock. Four percent of the 70 million tons of paper product produced annually will generate an energy waste of up to .04 quads of energy. A

major waste reduction and subsequent productivity improvement in the paper manufacturing industry would be attained from a sensor that could provide continuous monitoring throughout a production run in the paper industry.

PEN KEM, Inc.
Bedford Hills, NY 10507

68. *Development of Laboratory and Process Sensors to Monitor Particle Size Distribution of Industrial Slurries*

Pendse, H.P.

A research program is being undertaken to develop new laboratory and process sensors to monitor particle size distributions of concentrated suspensions containing particles with diameters ranging from 0.01 to 1000μm. The need for a particle size distribution monitor has been recognized by process engineers involved in processing industrial slurries. Availability of such sensors will enable one to achieve substantial energy savings through reduction of grinding and/or dryer loads as well as to optimize product characteristics and increase productivity. In Phase I, the research experimentally evaluated a measurement technique based on programmed ultrasonic spectroscopy coupled with a unique, powerful, mathematical model that relates attenuation, corresponding to selected frequencies, to particle size distribution and concentration. In Phase II, tasks related to the development of new transducers and a specialized apparatus will be undertaken. An engineering prototype complete with the software based on an improved mathematical model will be fabricated and tested. In Phase III, efforts will be directed towards development, and associated industrial hardening, of process sensors suitable for use in a process instrument. The emphasis of Phase III will be on conducting a comparative evaluation of the proposed sensor with several currently used sensors on different key applications in pilot as well as in-plant conditions.

LASENTEC (Laser Sensor Technology, Inc.)
Redmond, WA 98052

69. *Development of High Performance Consistency Sensor for Paper Pulp*

Preikschat, E.

This project involves a systematic research and development effort specifically addressed to the pulp and paper industry. The measurement techniques and process control strategies, however, should be applicable to a number of other industries such as food processing, chemicals, pharmaceuticals, plastics, and so forth. Using the scanning laser microscope (SLM) technology, LASENTEC will research and develop a consistency transmitter for the pulp and paper industry that: (1) may be used on most grades of pulp in the presence of a number of variables typically encountered in the pulp and paper industry, (e.g. variable content of fillers, black liquor and air bubbles); (2) will be largely independent of pulp brightness, kappa number, chemical composition of the pulp, and pulp grade; (3) will be compact enough to be insertable through a small ball valve assembly (1 to 2 inches diameter); (4) will be constructed of materials to withstand the entire range of pH levels typically encountered in a pulp and paper mill; (5) will be designed and packaged so that it can operate reliably in the hot, corrosive, and humid mill environment; and (6) will be simply designed, easily manufactured and capable of being marketed at a price of approximately $20,000 or less. To achieve these objectives it is necessary to carefully research how the properties of the SLM are affected by these various parameters, and then to develop special algorithms that can be used with a new sensor design. The new design will use the SLM technology as its basic measuring and discrimination element. This R&D effort will deliver a sensor prototype for testing in the laboratory and at a pilot facility. On successful demonstration of pilot testing, the design will be frozen and packaged for final industrial utilization, application, and commercialization.

Black Liquor Recovery

University of Florida
Gainesville, FL 32611
Department of Chemical Engineering

70. *Characterization of Physical Properties of Kraft Black Liquor*

Fricke, A.L.

The project objective is to develop methods for measurement of rheological, thermal, and surface properties of black liquor, and to develop or improve methods for chemical analysis of black liquor and for molecular characterization of lignin. These will be applied to mill liquors and experimental liquors to develop correlations between properties and composition that can be used to design black liquor recovery systems or to improve operations to increase energy recovery. Results to date demonstrate that the lignin polymer dominates high solids behavior. Properties data can be reduced and correlated by methods that are soundly based on polymer theory. These results represent the first (1) reliable rheological data as a function of solids, temperature, and shear rate; (2) successful correlation for heat capacity at all solids and temperatures; (3) accurate measurements of $\bar{M}_n$ and $\bar{M}_w$; and (4) statistical evaluation of $\bar{M}_w$ of lignin with pulping conditions. Methods and/or data have been used for (1) evaluating new batch pulping to conserve energy, (2) designing three new high solids concentrators, (3) evaluating time trends of black liquor properties, (4) evaluating swings in type of wood and solids limit in firing, (5) evaluating viscosity of polymer-solvent system for new polymer plant, and (6) estimating effects of changes in pulping conditions and liquor viscosity. The final expected product is a set of correlations to be used to predict liquor physical properties from liquor composition. In addition, it will enable mill operator's of recovery boilers to more effectively and efficiently burn black liquor and thus save on energy and reduce material consumption.

University of Maine
Orono, ME 04469
Department of Chemical Engineering

71. *Black Liquor Droplet Formation Study/Nozzle Design*

Stockel, I.H.; Bousfield, D.

This project develops information that can improve nozzle design for Kraft Recovery Boilers. The nozzles are operated to deliver droplets of black liquor with: (1) specified size, velocity, and direction; and (2) within narrow ranges of statistical variation. These parameters will be regulated in the presence of disturbances in the physical properties of black liquor. They are to be capable of control to accommodate changes in furnace conditions and production requirements. The project is an experimental and theoretical study of the formation and initial survival of black liquor droplets from single streams and planar sheets of liquor.

Institute of Paper Chemistry (IPC)
Appleton, WI 54912
Chemical Sciences Division

72. *Fundamental Studies of Black Liquor Combustion*

Grace, T.M.

The project objectives focus on advancing kraft recovery boiler technology by (1) developing continuous flow systems to study both state-of-the-art and advanced recovery processes; (2) applying advanced optical and spectroscopic techniques to study the burning processes; (3) developing a data base of process fundamentals that will bridge and enhance the commercial application of prior and new research findings. These objectives will be accomplished in four phases: (1) in-flight chemical and thermal processes; (2) char-bed processes; (3) inorganic fume formation processes; and (4) recovery-furnace simulation. The research is being conducted at both the Institute of Paper Chemistry (IPC) and at the National Bureau of Standards (NBS). Black liquor combustion technology has evolved mainly through modifications to commercial recovery boiler technology. Two continuous laboratory-scale systems, one at IPC and one at NBS, were developed to study black liquor combustion. The IPC system is used for overall process studies and complete furnace simulation. The NBS dilute-phase system is for instrumentation development and single particle tests. Potential energy benefits from this research could amount to 30 trillion Btu. Energy recovery increases often are an additional benefit from modifications made to increase black liquor throughput. Capacity increases of at least 5 to 10% are often achievable. Increased energy productivity of the kraft chemical recovery boiler will come by incorporation of improved fundamental knowledge into the technology used for boiler upgrades and new boiler construction.

Champion International
Stamford, CT 06921
Energy Management Division

73. *Feasibility of Black Liquor Pyrolysis/Gasification in Combined Cycle Cogeneration*

Kelleher, E.G.; Kohl, A.

The project objective is to perform a feasibility study of kraft black liquor gasification and the use of the product gases in combined cycle cogeneration. The results of a small scale experimental study by Rockwell International Corporation indicated that gasification potentially could offer an alternative to the Tomlinson recovery furnace with its high capital costs, low energy efficiency, and ever-present danger of explosions. Black liquor gasification products fired in a gas turbine cogeneration plant, integrated with a bark and coal-fired combination boiler and steam turbine to form a combined cycle system, had the potential of higher energy efficiency, higher electric power production, and lower cost when compared with a state-of-the-art steam cycle system with a recovery boiler. These results led to a Phase II R&D study to experimentally investigate black liquor gasification further on both a bench scale (additional work) and a pilot scale, to investigate product gas cleaning and other equipment in the system, to analyze the performance of the combined cycle system, and to evaluate the economics of the process. Various black liquors gasified readily and completely to yield product gases with higher bearing values over 120 Btu/scf and reductions of sulfate to sulfide in the melt of over 95%. The performance of the gasifier was independent of melt depth and the results correlated well with the process variables. Overall, black liquor gasification and use of the product gases in combined cycle cogeneration based on gas turbines shows high potential as an alternative to the recovery boiler. It offers higher energy efficiency, lower costs, and safety and environmental benefits. Development of this technology should continue through demonstration on a reasonably large scale. A two-phase demonstration program is recommended.

Manufacturing and Technology Conversion International (MTCI)
Santa Fe Springs, CA 90670
Engineering/R&D

74. *Black Liquor Gasification (Pulsed Combustion)*

Warren, D.W.; Durai-Swamy, K.; Mansour, M.N.

The MTCI proprietary pulse-enhanced, indirect, steam gasification technology was initially investigated under DOE Small Business Innovative Research grants that limited the work to biomass feedstocks. Based on this work the paper industry was interested in testing this technology with black liquor feedstocks. In order to further develop this technology, waste gasification funding was provided by the DOE, the Weyerhaeuser Company, and the California Energy Commission. The objective of this work is the development and verification of the MTCI black liquor recovery technology, testing of a broad

spectrum of waste feedstocks under varying process conditions, and verification of gasifier scale-up to the 100 to 200 lb/h level. In recent tests, the MTCI gasifier was operated using samples of paper mill sludge waste. Despite high moisture content and the presence of plastic material in these waste products the MTCI gasifier operated without problems. Successful gasification of black liquor at a temperature regime that avoids smelt formation has been verified. Specific gasification rates were measured and found to be consistent with predictions. The producer gas heating value varied fron 240 to 300 Btu/scf and contained 63/65 vol. % hydrogen. The energy density of the producer gas was shown to be several times that achievable by autothermal systems. In addition, and consistent with equilibrium predictions, the gasifier exhibited a high efficiency for sulfate reduction.

Institute of Paper Chemistry (IPC)
Appleton, WI 54912
Chemical Sciences Division

75. *Black Liquor Delivery Systems*
Adams, T.; Malcolm, E.; Grace, T.

The project will research and develop new commercial black liquor delivery systems to allow the pulp/paper industry (ppi) to take advantage of the more fundamental data currently being collected, via DOE-funded programs, regarding molecular structure (physical properties at Univ. of Florida), droplet design (droplet study at Univ. of Maine), and combustion processes (fundamentals of combustion at Institute of Paper Chemistry (IPC)) of black liquor. This procurement will expand on this work in greater detail to characterize large spraying systems in terms of droplet size distribution, velocity, and mass distribution. The first year's work will entail an assessment of the various possibilities for obtaining velocity data and distances required from the nozzle for spraying black liquor. New high-tech, high-resolution, high-speed flash X-ray techniques will be used for the first time in a full-blown series of tests. The results of the X-ray imaging will allow development of the necessary techniques and will process the initial nozzle image. The results of this project will give a deeper knowledge of the liquor spraying operation; improve and control especially older recovery boilers with small modifications; and increase capability of existing recovery boilers. The actual value for a pulp mill with an existing overloaded recovery boiler will be many times greater than the cost of the actual equipment. A high-technology, high-speed, flash X-ray imaging system is being provided via funding from the University Research Instrumentation (URI) grants program at DOE. This flash X-ray system will be a civilian unit comparable to that originally borrowed from the military via Lawrence Livermore National Laboratory (LLNL). LLNL's X ray was used to obtain results that were verified by LLNL as an outstanding technique and method to image liquor sprays, fiber orientation, and so forth for the industrial sector. Industry support includes Weyerhaeuser, Champion International, Potlatch, Georgia-Pacific, HPD, International Paper, Mead, Westvaco, and others. The estimated energy savings is 0.07 quads.

HPD, Inc.
Naperville, IL 60566
Engineering/R&D

76. *Bipolar Electrodialysis for the Recovery of Kraft Black Liquor*
Lynch, J.D.

Work will involve a feasibility study and laboratory evaluation to provide an initial technical and economic evaluation of bipolar electrodialysis for kraft black liquor recovery. The research objectives define a process route or routes for kraft black liquor recovery using bipolar electrodialysis, water splitting techniques. Research will involve obtaining technical and economic data on well-defined commercially available process steps and collecting data via laboratory experiments to define process steps that are not commercially available or where data is inadequate. Assuming that a process route can be defined and can be integrated into an existing kraft pulping flow scheme, the research will enable the construction of a flowsheet and heat balances. Based on the flowsheet and heat balance results, the researcher will be able to conduct a preliminary economic analysis of the process and compare it to the existing kraft process. Finally, the research results will define future work requirements to develop and commercialize the process.

Coating Research

Georgia Institute of Technology
Atlanta, GA 30332
School of Textile Engineering

77. *Application of Chemicals to Substrates Without the Use of Liquids: Solid-on-Solid Processing*
Cook, F.L.

The objective of this research is to develop solid-on-solid (SOS) processing (the application of dry chemicals to dry substrates without use of liquids) to reduce energy consumption and process water volumes in the textile industry. Under development are continuous SOS processes for application of sizes, colorants, and finishes to textile substrates, followed by pilot-scale proof of principle. The systems will be built around electrification of chemical powders, rapid flowing/curing of binders, and dry thermal fixation. Focus is on uniform deposition of the chemicals and control of solid loading. Energy requirements of the SOS concept include generation of electrical fields to charge the chemicals and dry thermal heat to polymerize the binding resin or sublime the solid into the substrate. An estimated 472 Btu/lb of combined electrical/thermal energy will be required by the SOS process. The concept is adaptable to all textile wet processes except singeing, preparation, and mercerization. About 4.84×10^{10} lbs of material are processed each year at an average energy consumption of 4,400 Btu/lb. Maintaining the volume figures and using the projected savings of 3,930 Btu/lb for SOS, a 50% applicability factor yields a national energy conservation potential of 1.66×10^{7} BOE/year. The SOS concept is

built around short high-speed continuous processes, such that even low-yardage lots should be economically processable on the continuous lines. The small number of components proposed for the SOS process and the applicability to low-yardage lots dictate improved productivity for industry, enhancing its global position. SOS offers a dramatic reduction in water requirements and subsequent pollution treatments. The textile industry uses approximately 425 billion gallons of water annually, primarily in wet process. The technology can potentially reduce water/sewer requirements by 213 billion gallons annually.

Separations Research: Membrane

State University of New York
Albany, NY 12222

78. *Energy Efficient High-Crystalline Ion-Exchange Membrane Processes for the Separation of Organic Liquids*

No abstract provided.

Physical Sciences, Inc.
Andover, MA 01810

79. *Application of Fuel Cells to Chlorine-Caustic Membrane Technologies*

Gelb, A.

This project is aimed at establishing proof of concept of combining a membrane alkaline fuel cell with chlorine alkaline production. A systems analysis study was made in Phase I to establish thermodynamic, electrochemical, and cost-effectiveness of a proposed integrated membrane fuel cell chlor-alkali technology. Phase II work will experimentally determine membrane performance characteristics and electrode performance in the alkaline fuel cell environment.

University of Wisconsin
Madison, WI 53706

80. *Colloid-Chemical Approach to Design at Phosphate-Ordered Ceramic Membranes*

The project objective is to produce new and novel ceramic membranes having desired pore size distribution and surface properties by controlling the suspension and interfacial chemistries of these systems. The major objectives are: (1) to understand the major solution variables (pH, ionic strength, specific solute effects, and so forth), controlling sol and gellation chemistries since these sols and gels serve as precursors to ceramic membranes; and (2) to study the effect of these variables and sintering conditions on the final unsupported ceramic membranes. Work also includes experiments with supporting the membranes, a necessity if the membranes are to function in a practically commercial scale unit. Focus is on: (1) the preparation of γ-Al_2O_3 and TiO_2 unsupported ceramic membranes; (2) the production of both γ-Al_2O_3 and clay supports for these membranes; and (3) the construction of an automated BET apparatus for measuring pore size distributions in ceramic membranes.

SRI International
Menlo Park, CA 94025

81. *Hybrid Membrane Systems*

Gottschlich, D.E.

The project objective is to develop guidelines for analyzing and optimizing energy utilization of hybrid membrane separations and to apply these guidelines to recommend specific separation projects suitable for OIP support. Four cases that will be studied are: (1) separation of propane/propylene mixtures by pervaporation and distillation; (2) removal of N_2 from natural gas using gas separation membranes and pressure swing adsorption; (3) concentration of kraft black liquor by reverse osmosis and freeze concentration; and (4) solvent recovery by ultrafiltration and distillation in crude oil deasphalting operations (the Allied/Signal process).

Air Products and Chemicals, Inc.
Allentown, PA 18195

82. *Development of a Novel, Active Transport Membrane Device*

No abstract provided.

Aluminum Company of America
Warrendale, PA 15086
Separations Technology Division

83. *Development of High-Temperature Catalytic Membrane Reactors and Processes for Chemical Production*

Liu, P.K.T.

Ceramic membranes will be used as a catalyst support to enhance the conversion of ethylbenzene to styrene and butene to butadenes. The use of ceramic membrane can perform in-site separation of styrene and butadiene from hydrogen and achieve significant energy savings in the production of these two chemicals.

Idaho National Engineering Laboratory
Idaho Falls, ID 83415

84. *Polyphosphazene Microporous Membranes*
Frank, C.W.

This project consists of two tasks. Task 1 will demonstrate the feasibility of preparing microporous polyphosphazene membranes on ceramic porous supports to perform separations in the 100 to 250°C temperature range. Task 2 will be a detailed assessment of industrial applications for membranes stable at those temperatures. Task 1 activities include: (1) casting existing polyphosphazene materials using solvent/nonsolvent, solvent/dopant, and compression casting methods; (2) optimizing the methods to produce uniform porosity in the membranes; (3) synthesizing new polyphosphazene materials that will inherently lead to microporous structures; (4) studying ceramic support morphology to obtain optimum pore size; (5) casting polyphosphazenes onto porous ceramic supports; and (6) determining membrane separation characteristics, flux, and stability as functions of temperature. (Target process streams include food and sweetening industries.) Task 2 activities include: (1) identifying industrial applications that could use this technology, either as retrofit into existing processes or for new processes; (2) assessing the energy savings and economic impact of this type of membrane material; and (3) reporting on the feasibility study and assessment.

Other Separations Research

Air Products and Chemicals, Inc.
Allentown, PA 18105
Process Systems Group

85. *Corrosion Study on the MOLTOX™ Process*
Brown, W.R.

The objective of the project is to develop the MOLTOX™ process to the point where the process economics, based on the pilot plant operation, can justify proceeding to the next larger scale. New construction materials will be tested for their corrosion rates in laboratory reactors under simulated pilot plant conditions. Concepts for alternative desorber designs will be developed, and the MOLTOX process economics will be updated to reflect the new materials and designs. Test coupons from three types of materials will be prepared or obtained from outside sources. Materials will include: metal alloys such as Cabot 214, coated materials such as MCrAlY, and ceramics such as zirconia. These coupons will be tested in a laboratory muffle furnace and/or batch reactors for preliminary qualitative ranking of corrosion resistance. The most promising materials will be tested in laboratory batch reactors to determine a quantitative corrosion rate under static conditions and as a function of salt velocity. The existing laboratory reactors will be modified as necessary to accommodate the dynamic testing.

Institute of Paper Chemistry (IPC)
Appleton, WI 54912
Engineering Division

86. *Advanced Water Removal Processes for Drying in the Pulp and Paper Industry*
Orloff, D.

The overall objective of this program is to improve "Impulse Drying" an advanced water removal process for paper making, to a level suitable for commercialization. The impulse drying process brings the wet paper stock into contact with a hot metal roll (400 to 700 degrees F) at 400 to 700 psi for 15 to 1500 milliseconds. Energy consumption is 12.5% to 50% of the normal energy requirement of 1600 Btu/lb requirement for conventional paper processes. Commercialization of the impulse drying process is impeded by two process deviations, sheet delamination during drying of heavyweight paper grades, and two-sidedness in lightweight paper grades. The current work will involve further investigation of the drying conditions required for full commercialization of this process for both light and heavy paper grades. Alternative materials for paper rolls which will suppress delamination will be evaluated and tested. Drying conditions required to avoid two-sidedness in lightweight paper grades will be identified. Results to date have shown that impulse drying can reduce the energy requirements for paper drying by one-half to two-thirds. Further savings may result from the ability of impulse drying to improve paper strength by a factor of two or more which would permit increased use of high yield, non-energy intensive pulps and recycled materials.

National Food Processors Association
Berkeley, CA 94710

87. *Separation, Fractionation, Concentration, and Drying of Food Products*
Rose, W.W.

The project develops energy-efficient separation, concentration, and drying processes for food products. Tomato juice will be separated into pulp and serum by three methods. Each fraction will be characterized, concentrated, then recombined. In addition, the serum will be fractionated into components using various ultrafiltration membranes of different molecular weight ranges. Finally, the concept of processing, preserving, modifying, and transporting concentrated, fractionated dried components will be assessed.

Dairy Research, Inc.
Rosemont, IL 60018

88. *Freeze Concentration Fundamentals*

Lucas, A.J.

This project involves research and development of a freeze concentration process for liquid foods (initially dairy products). Efforts will include developing a fundamental understanding of ice crystal kinetics to provide the capability to optimize the process and minimize energy use.

Battelle Memorial Institute
Columbus, OH 43201
Battelle Columbus Laboratories

89. *Development of an Electroacoustic Process for Enhanced Dewatering of Food Suspensions*

Chauhan, S.P.

The objective of this project was to validate the expected technical feasibility and energy conservation/economic benefits of electroacoustic dewatering (EAD) in food processing. Research included selecting, acquiring, and characterizing nine food products. Batch dewatering tests were performed on nine food suspensions while continuous bench-scale tests were conducted on three of the same food products. A preliminary assessment of the effort regarding potential EAD energy savings and process economics indicated that substantial energy savings are attainable and that the technology is economically viable. The objective of Phase II was to obtain data from a proof-of-concept facility to promote adaptation of the technology by the food processing industry. Phase II included design, construction, on-site performance testing of two process research units (PRUs), and four food suspensions.

Purdue University
West Lafayette, IN 47907
Purdue Research Foundation

90. *Design and Control of Energy-Efficient Drying Processes*

Okos, M.R.

Present drying processes require 2,000 Btu/lb H_2O removed, which is approximately equal to the energy requirements of shipping concentrate. Studies will be performed to combine the basic equipment design principles and advanced moisture measurement methods with a better fundamental understanding of the drying process to design dryers with energy requirements down to 200 Btu/lb H_2O evaporated. A fundamental drying model was developed in Phase I of this project that was applicable for dryer temperatures of 40 to 60°C, but inaccurate at higher temperatures. Since most dryers operate at temperatures above 60°C, the model will be refined to incorporate temperature effects caused by internal temperature gradients. It will also determine additional experimental data required to determine thermal diffusivity and other model coefficients as a function of temperature. Better dryer control could potentially save 20×10^{12} Btu in the food and agricultural industry.

Oak Ridge National Laboratory
Oak Ridge, TN 37831
Chemical Technology Division

91. *Energy Conservation Using Continuous Annular Chromatography in Multicomponent Separations*

Byers, C.H.

Continuous annular chromatography (CAC) is a developing technology that allows truly continuous chromatographic separations. Previous work has demonstrated the utility of this technology for the separation of various materials by isocratic elution on a bench scale. Novel applications and improved operation of the processes are studied in this work, demonstrating that CAC is a versatile apparatus that is capable of separations at high throughput. Three specific separation systems were investigated. Pilot-scale separations at high loadings were performed using an industrial sugar mixture as an example of scale-up for isocratic separations. Bench-scale experiments of a low concentration metal ion mixture were performed to demonstrate stepwise elution, a chromatographic technique that decreases dilution and increases sorbent capability. Finally, the separation of mixtures of amino acids by ion exchange was investigated to demonstrate the use of displacement development on the CAC. This technique, which perhaps has the most potential, when applied to the CAC allowed simultaneous separation and concentration of multicomponent mixtures on a continuous basis. Mathematical models were developed to describe the CAC performance and optimize the operating conditions. For all the systems investigated, the continuous separation performance of the CAC was found to be very nearly the same as the batchwise performance of conventional chromatography. A CAC has been developed at Oak Ridge National Laboratory (ORNL). Its application to copper refining, separating sugars, separating rare earthmetals, and separating amino acids (displacement) is still being studied. It is estimated that a summation of 0.2 quads of energy can be saved in the various industries. The technology appears, thus, to be very promising for industrial applications.

Solar Energy Research Institute
Golden, CO 80401
Solar Fuels Research Division

92. *Sulfur-Free Selective Pulping Process*

Chum, H.L. (SERI); Dimmel, D.R. (IPC)

Cooperative research involving the Solar Energy Research Institute (SERI) and the Institute of Paper Chemistry (IPC), along with various pulp and paper companies that are part of the IPC Project Advisory Committee, will lead to an improved method for producing bleached pulp. Research will focus on developing a cost-effective, quinone-based pulping system. Such a sulfur-free system is expected to be more selective than the conventional kraft pulping process. Higher selectivity will lead to a

more easily bleachable pulp and a simpler chemical recovery system. The impact of all these process advantages is in conservation of wood resources, reduced environmental impact, and a substantial energy savings per unit of product. One can envision about 0.18 quads as potential savings just in the pulping process. Additional savings in energy consumption would be obtained from the simpler chemical recovery system.

HIGH-TEMPERATURE PROCESSES

High-Temperature Sensors and Controls

Battelle Memorial Institute
Richland, WA 99352
Pacific Northwest Laboratory

93. *Development of Process Control Sensors (Aluminum)*

Windisch, C.F.

The project objective is to develop sensors for control of alumina concentration for use with inert anodes. The approach is to analyze cell signals by digital signal analysis (DSA), which is a nonintrusive technique or a pseudo-resistance electrode that monitors the reactions at the anode bath interface. The techniques, when perfected, will allow operation of inert anodes in commercial cells or improve the present cell control practice to provide improved cell current efficiency and energy savings.

94. *In-Plant Testing of a High-Temperature EM Pulsar and EMAT Receiver*

Boyd, D.M.

This project was initiated to aid in the transfer of technology developed during earlier, related research. A noncontact temperature measurement system has been developed and successfully demonstrated in the laboratory. This present research will implement this technology by measuring the temperature of a strand of steel emerging from a horizontal, continuous caster. A secondary goal is to show the position of the liquid–solid interface within the solidifying material. Participants include several steel producers and an equipment supplier.

Advanced Electrode R&D

Battelle Memorial Institute
Richland, WA 99352
Pacific Northwest Laboratory

95. *Development of Inert Electrodes for Aluminum*

Morgan, L.G.

The objective of the scaleup activities is to perform the required research and development of fabrication methods for large anodes and to test the large units in a cell that represents sections of a commercial unit. The approach will be to allow the Pacific Northwest Laboratories (PNL) to perform the required critical path activities while cost share research is pursued with industry through solicitation. Solicitations will cover both materials fabrication and cell application. Results should provide the industry with viable methods for anode manufacture and application.

ELTECH Systems Corporation
Fairport Harbor, OH 44077
Research and Development

96. *Self-Forming Anodes for Aluminum Electrowinning*

King, H.L.

The project objective is to evaluate cerium-oxide-coated ceramic and cermet materials as inert anodes in the Hall-Heroult aluminum electrowinning process. The selected substrates are antimony-doped tin oxide and a copper-containing nickel ferrite cermet developed for DOE by Alcoa. Cerium oxide coatings will be deposited using a proprietary ELTECH process. Laboratory-scale experiments will be conducted using electrodes with surface areas less than 10 cm^2. Cerium oxide coatings will be deposited *in situ* using simulated Hall cell electrolytes. The stability of the coating and substrate will be determined as a function of current density, cerium and alumina concentrations in the melt, and melt chemistry. The use of an inert anode in combination with a wettable cathode would allow the development of a more compact cell with reduced electrode spacing and lower ohmic drop from the electrolyte. The high capital and operating costs associated with the production of prebaked carbon anodes would also be eliminated.

Great Lakes Research Corporation
Elizabethton, TN 37643

97. *Field Testing of Titanium Diboride Cathodes in Commercial Aluminum Cells*

Morris, E.G.

The project objective is to determine the technical and economic viability of graphite-containing titanium diboride materials in low-cost shapes for use as cathodes in aluminum electrolytic cells in an effort to stimulate subsequent demonstration and commercial application. Included are (1) mathematical models for the prediction of cost-reduction cathode shapes, (2) determination of optimum electrode area ratios, (3) voltage reduction and effect on current efficiency by reduced anode-cathode distance, (4) production of cathode shapes using proprietary material processing technologies, (5) commercial and pilot cell operation for data acquisition and cathode longevity determinations, (6) analyses of as-fabricated and as-tested cathodes, (7) failure mechanism evaluation, (8) development of cathode holder/anode stops, and (9) an assessment of energy savings and technical/economic viability.

University of California
Berkeley, CA 94720
Department of Materials Science and Mineral Engineering

98. Physical Modeling of Bubble Phenomena, Electrolyte Flow, and Mass Transfer in Simulated Advanced Hall Cells

Evans, J.W.

The objectives of this project are to define dimensionless group correlations using physical models and selected working fluids, to recommend advanced (low-energy) Hall-Heroult retrofit designs, and to predict operating performance. The University of California, Berkeley, will construct water models for the development of physical data for correlation with a mathematical model. Advanced cell designs based on vertical and horizontal configurations will be evaluated. Predictions of fluid velocities by mathematical model will allow evaluation of proposed large cell and commercial cell designs.

Battelle Memorial Institute
Richland, WA 99352
Pacific Northwest Laboratory

99. Anode Scaleup/Pilot Cell Activities

Morgan, L.G.

The objective of this project is to determine the criteria for acceptable cell operation while using inert anodes. The approach has been to perform bench cell tests on various compositions of cermets of Ni–Fe spinels with copper additions and to determine the effect of different bath chemistries on a standard cermet composition. Operating conditions have been identified that provide low anode wear rates in short-term bench cells. Confirmation tests for the operating conditions and boundary conditions are being performed for practical application of these electrodes in large cells.

High-Temperature Material Processing

Massachusetts Institute of Technology
Cambridge, MA 02139
Materials Processing Center

100. Raman Scattering Studies of Aluminum and Magnesium Electrolysis Cells

Sadoway, D.R.

The objective is to determine *in situ* chemical species in molten salt systems during electrolysis, with the ultimate objective of identifying the mechanisms that decrease current efficiency in primary aluminum Hall cells. The approach is to construct and operate laboratory-scale $MgCl_2$, $AlCl_3$, and cryolite–alumina electrolytic cells. Raman spectra have been taken for the I.G. Farben magnesium electrolysis process and for the Alcoa smelting aluminum electrolysis process. The principal chemical species in the bulk electrolyte have been identified. Efforts are being made to analyze the chemical composition of the cathode boundary layer during electrolysis. Spectra of the Hall cell electrolyte have been taken and laboratory-scale Hall cells have been operated. The results may be interpreted for operational changes that should improve cell yields, thereby decreasing the specific energy requirements to produce these metals.

U.S. Steel Corp. and Bethlehem Steel Corp.
Monroeville, PA 15146
Research Division

101. Thin-Section Casting Project

Moore, M.R.

The project objective is to develop a new continuous casting technology to produce the entire range of hot and cold rolled steel sheet. This new technology, according to 1990 projections of U.S. energy demand, would save 0.191 quads while reducing the capital and operating costs by $35 and $28 per ton, respectively. The approach is to adapt the Hazelett twin belt moving mold continuous casting machine commonly used in the nonferrous industry to the steelmaking process. The caster will produce 1/2- to 1-inch thick slabs at casting rates of 20 to 60 tons per hour per foot of width. The resulting hot band could be sold commercially or hot or cold rolled to commercial specifications. This technology can be retrofitted into integrated steel plants where hot rolling will be done on existing rolling facilities or into minimills where rolling could take place on high reduction reversing or Senzemir or Platzer-type planetary mills. Early casting trials have concentrated on the development of two feeding systems. Feeding is considered the critical technology since the casting machine is believed to have proven its suitability in this application. Other work consisted of material rolling trials, coiling and uncoiling of as-cast slabs to determine the applicability of coilboxes, refractory testing, and process and water modeling studies. Work on this process has been terminated. A final report has been written and technical transfer meetings have been held.

ARMCO, Inc.
Middletown, OH 45043
Research & Technology Division

102. Thin Steel Strip Casting Research

Sussman, R.C.

This project continues the thin strip casting research sponsored by DOE for the past several years. The project objective is to determine which technique, melt overflow or planar flow, is the most appropriate for casting low-carbon steel onto a single wheel substrate. The research will examine substrate effects, dynamic water modeling, and nozzle configurations. After about ten months of experimentation, the research will lead to a decision about whether to optimize the preferred technique.

Lawrence Livermore National Laboratory
Livermore, CA 94550
Engineering Sciences Division

103. Development of Superplastic Steel Processing

Goldberg, A.

This project is part of the Steel Initiative, the goal of which is to develop energy efficient steel processes. This immediate research is directed toward the production of superplastic steels on a large-scale basis using ultrahigh carbon (UHC) steels. These steels have shown superplastic behavior after controlled processing in the laboratory. The project team consists of a steel producer, a forging producer, and an end user of impression die forgings. Current efforts are underway to identify a preferred alloy analysis that overcomes the constraints inherent in the compositions used in the laboratory study. Later efforts will be directed towards the successful casting of the alloy through a continuous caster and the subsequent production of forging stock. Eventually closed die forgings will be made from the superplastic steel and compared with commercially available forgings.

Carnegie-Mellon University
Pittsburgh, PA 15213
Department of Metallurgical Engineering and Materials Science

104. Removal of Copper from Scrap

Fruehan, R.T.

The project objective is to prove that liquid sulfide treatment can be effective in removing copper from scrap and the sulfide matte can be separated from the metal. Two processing concepts are: (1) feeding the scrap and sulfide into the rotary kiln that heats the scrap and matte and mixes them to provide intimate contact of the matte with the copper in the scrap and (2) simple submersion of heated scrap into a large container filled with the liquid sulfide matte.

American Iron and Steel Institute
Pittsburgh, PA 15235

105. Development of Direct Steelmaking

Aukrust, E.

This project is part of the Steel Initiative, the goal of which is to develop energy-efficient steel processes. This work is expected to lead to a continuous steel making process that eliminates the need for coke. Current efforts are under way to conduct a fifteen-month experimental program after a pilot plant is started up. In addition to the pilot plant program, supporting university research and large scale tests are being concurrently conducted. Eventually a new process to continuously produce liquid steel will be developed.

American Foundrymens' Society
Des Plains, IL 60016

106. Development of Precision Evaporative Casting Technology

Twarog, D.L.

The project objective is to further develop and optimize Evaporative Pattern Casting (EPC) technology for a broad based application. Sand flow and compaction will be evaluated. Factors that influence the dimensional precision of castings produced via the EPC process will be evaluated. Critical process parameters and system properties that control the dimensional precision of the evaporative casting process will be identified. Compaction of granular materials, heat transfer, thermodynamics, casting defect detection by various methods, refractoriness of coating materials, dimensional analyses, glue formations and principles of vibration compacting are involved.

107. On-Line Process Modeling of a Cupola Furnace

Twarog, D.L.

The project objective is to develop a model to optimize the process control and the efficiency of the cupola furnace as a foundry melting unit. The process model would permit control of cupola operation in order to meet the desired product quality with optimum efficiency and permit menu driven, user friendly, off-line studies to be made for determining process and cost impacts of intended changes in process inputs. The work involved consists of a critical review of literature and information available on existing cupola and blast furnace models to apply available technology. Thermochemical and kinetic data bases will be developed and a critical review of currently available sensors will be performed to recommend sensor development activity not included in the scope. Conceptual models of heat transfer-fluid flow and heat and mass balances will be developed including equation statements. Industry review will be obtained prior to verification of the model with operational data to compare computational results with actual cupola data. An expert system scoping study will be conducted to integrate the cupola model into a broader foundry model. The results will be discussed with the foundry community.

Vesuvius Crucible Corporation
Arlington, VA 22204

108. Molten Steel Temperature Measurement

Phillippi, R.M.

This project is a follow-on development of a DOE effort that identified a sheath material suitable for using within a steel bath, namely boron nitride. The purpose of the present research is to assess the performance of the selected material in an operating melt shop environment. Thermocouples protected by the boron nitride sheaths will be tested to destruction in a continuous caster tundish. The results will be compared with the use of less expensive, but short-lived, disposable thermocouples.

SMALL BUSINESS INNOVATIVE RESEARCH

OPTRA, Inc.
Peabody, MA 01960

109. Real-Time, Noncontact Optical Surface Motion Monitor

Wyntjes, G.J.

Monitoring of surface motion, velocity, net displacement, unit length produced, and differential motions (e.g., across a web of material) is essential in certain manufacturing processes. OPTRA, Incorporated, is currently developing a noncontact optical surface motion monitor for multiple industrial applications. The system works in reflection as well as transmission and works with only a minimal amount of light scatter from materials. The prototype's remote, passive optical laser probe is satisfactory for measuring surface motions in a variety of industries. The monitor system is currently undergoing further laboratory experimentation. OPTRA has also developed a paper pulp velocity sensor. A breadboard prototype for feasibility demonstration at a pulp and paper mill has been designed, fabricated, and tested in-house. Demonstration of the device is in progress. Major work was expended in designing, fabricating, and testing a breadboard prototype of Laser Doppler Velocimeter (LDV). The Laser Doppler Velocimeter sensor is portable and meets the requirements of the physical test environment of the laboratory at this ppi facility. The device can be affixed on an operating paper machine for testing. The Laser Doppler Velocimeter breadboard was designed to serve as a research tool as well as a demonstrator. The device was used initially to characterize light scattering and Doppler modulation from a variety of solid surfaces mounted to a constant velocity DC motor.

Intelligent Dynamics Systems, Inc.
Conyers, GA 30207
Research Division

110. Hierarchical Intelligent Control of Industrial Processes: An In-Parallel Lime Kiln Application

Davey, K.R.; Vachtsevanos, G.

The project objective is to develop a hierarchical intelligent controller and to implement a computer simulation of the strategy in parallel with a lime kiln. A lime kiln is a chemical reactor designed to regenerate lime from lime mud using hot combustion gases and is an integral part of all pulp and paper mills. Because the kiln process is complicated, involving interactions of flow and composition variations in the lime mud as well as fuel and air flow rates, even the most experienced operator skills are taxed heavily. When conventional control strategies are incorporated into the decision process, wide swings in kiln inlet and exit temperatures occur because of the slow response time of the kiln. This research proposes a control strategy that realizes operational autonomy using the hierarchical intelligent controller. This controller will realize optimum performance for the lime kiln, fault diagnostic capability, and system reconfiguration during off-normal conditions. In so doing, it has a direct impact on the kiln process in reducing the energy consumption, increasing performance productivity, and enhancing a plant's competitive edge for the manufacture of its product. The objectives of the hierarchical control strategy being developed are (1) minimizing fuel/lime ratio; (2) maximizing lime quality; (3) minimizing dust loss; and (4) minimizing air pollutants. It is estimated that for a 1,000 ton/day mill at 350 days/year, a 4% increase in lime yield saves $138,600/year, assuming $0.60/gallon fuel and an average energy expenditure of 7.2 MMBtu/ton. Development of the hierarchical control strategy requires a sophisticated analytical model of the kiln, which is currently under development. The model contains the following basic elements: (1) energy balance (convective, radiative, and conductive transfer); (2) mass balance; (3) chemical kinetics (reaction rates and enthalpy changes); and (4) temporal and spatial changes.

KSE, Inc.
Amherst, MA 01004

111. Reaction-Enhanced Extraction of Aromatics

Kittrell, J.R.

The total U.S. commercial jet fuel market is about 11 billion gallons annually, and is forecast to grow at a rate of 3% per year. Approximately 50% of the current jet product is limited by aromatics content and/or smoke point. Future demand growth and trends in crude oil quality will require efficient processes for aromatics removal. Conventional extraction or catalytic hydrogenation processes exhibit deficiencies for this application, except in special circumstances. The project objective is to evaluate the technical feasibility of a unique reaction-enhanced extraction process. The enhanced distribution coefficient permits extraction with higher yields and a reduced solvent to oil ratio, with associated cost and energy savings compared to alternative processes. This process appears to be economically viable, to provide substantial energy savings, and to provide a coproduct of high-end use value. This project could provide energy savings of 1.7 trillion Btu annually, and could grow to 12 trillion Btu in the next decade. It will benefit the refining industry through improved profitability, employment, and energy savings.

Advanced Fuel Research, Inc.
East Hartford, CT 06108

112. Low-Cost, Versatile Instrumentation for Improved Process Control

Morrison, P.W., Jr.

An important aspect of many energy intensive processes is the ability to have on-line monitoring. This ensures minimum downtime of the plant as well as operator and environmental safety. Consequently, there is a great need for diagnostic instruments for multiphase media that can

function in difficult environments. The goal of this Phase II project is the development of a rapid, rugged, and automated Fourier transform infrared (FTIR) spectrometer for monitoring process streams. The Phase I project has demonstrated that the FTIR monitor can measure the concentrations and temperatures of gases and particles generated within a coal/water combustor and in the stack of the combustor. The sensitivity to CO, CO_2, SO_2, NO_x and unburned hydrocarbons is at the ppm level. Phase I has also successfully tested both infrared fiber optics and process control using the FTIR monitor. The above results confirm that the E/T FTIR process monitor is technically feasible at a reasonable cost. Phase II research will implement and field test a single FTIR coupled directly or by fiber optics to multiple points in a plant. Phase II will focus on developing improvements to the FTIR system and will field test the monitor in three important industries: combustion, paper manufacturing, and semiconductor processing. The improvements will encompass both hardware and software modifications. This research will produce a generic process monitor consisting of an FTIR, coupling optics, fiber optics, analysis software, and control software that an engineer can easily modify to meet specific needs of an industrial control problem. The result of Phase II will be a second generation design suitable for commercialization in Phase III. Commercial applications include the control of combustion processes, paper manufacturing, semiconductor device manufacture, municipal or hazardous water disposal, distillers, evaporators, dryers, and a variety of other industrial processes.

Spectral Sciences, Inc.
Burlington, MA 01803

113. Development of a Solvent-Absorption Fiber-Optic Explosive Range (SAFER) Sensor

Gersh, M.E.

Solvent evaporation in industrial drying chambers is an energy-intensive process that currently uses energy in a very inefficient manner. This is because these dryers typically operate at solvent vapor concentrations on the order of 7% of the lower explosive limit (LEL) in order to ensure safe operation. However, if a continuous vapor concentration monitor and safety interlocks were installed, the solvent concentration could be allowed to approach 50% LEL. Operation at high solvent concentrations produces significant, direct energy savings, and it results in additional economic benefits of improved drying equipment productivity and reduction of size and cost of solvent recovery equipment. This proposal addresses the development of a Solvent Absorption Fiber-Optic Explosive Range (SAFER) sensor that would provide a sensitive, real time measurement of the solvent concentration in industrial dryers and that could be used in a process/safety control system. The SAFER instrument would use an innovative combination of proven sensor head on new IR fiber-optic technologies. This combination permits the SAFER sensor to perform its measurements directly in the contaminating environment of the solvent dryer, thereby eliminating the problems of fouling and sample line delays that have restricted the utility of currently available sensors. The objective of the proposed project is the development of a commercial sensor for monitoring and controlling the concentration of solvent vapors in industrial drying chambers. As a first step toward this goal, in Phase I a laboratory breadboard will be constructed to investigate the sensitivity and dynamic range of this technical approach, as well as the effects of sample temperature. In phase II, a brassboard SAFER instrument will be constructed and tested in an industrial solvent drying chamber. The successful development of a SAFER sensor would represent a major advance in the monitoring and control of solvent vapor concentrations in industrial dryers, thereby promoting increased productivity, energy savings, and safer operating conditions. It is anticipated that the SAFER instrument will find its initial applications in the industrial production of plastics, tapes, and coatings.

OPTRA, Inc.
Beverly, MA 01915
Research & Development

114. Noncontacting Dimensional Profiler

Hercher, M.

This project concerns a method for very rapidly obtaining complete and acccurate digital contour information (i.e. dimensional profiling) for diffusely reflecting objects. The proposed technique combines a number of recently developed technologies (high-power laser diodes, CCD-array vidicons, high-speed data processing in an inexpensive computer, low-cost frame-grabbers), with a novel hardware configuration and data-processing algorithm. The noncontact dimensional profiler (1) will be relatively inexpensive, fast, and versatile; (2) will be ideally suited for on-line quality control (QC) applications; (3) will improve manufacturing throughput, reduce waste and energy consumption, and save time; and (4) can be applied to tasks as diverse as monitoring the shape of formed sheet-metal panels, measuring the flatness of processed silicon wafers, or checking the surface contour and volume of candy bars. Convenient trade-offs between measurement range and precision can easily be achieved, and in one proposed configuration a dynamic range (i.e., ratio measurement range to minimum resolvable height increment) of more than 5,000:1 can be achieved. The technology will make possible the rapid and accurate profiling of diffusely reflecting surfaces and objects. By using standard components, the cost of the instrument can be kept low. Commercial applications will center on quality control, where the low cost and high throughput of the noncontact dimensional profiler will allow 100% inspection. This, in turn, will provide better products and reduce wastes of materials, labor, and energy.

Manufacturing and Technology Conversion International (MTCI)
Santa Fe Springs, CA 90670
Engineering/R&D

115. An Advanced Sensor for Monitoring Slagging and Fouling in Black Liquor Boilers

Warren, D.W.

Black liquor recovery boilers use black liquor as a primary fuel that contains large amounts of lignin, sodium carbonate, sodium sulfide, and small amounts of sodium sulfate. Downtime, costly repair, and even fatal explosions have been encountered in the operation of these large recovery boilers. Slagging and fouling of the boiler, and in some instances corrosion damage, frequently occur unless careful operation is maintained at all times because of the black liquor characteristics with large amounts of sodium-based chemicals. In phase I we experimentally verified the feasibility of the acoustic deposition monitor (ADM) to use the dynamic response signatures of black liquor recovery boilers to determine the rate and location of slag deposition during boiler operation. This on-line monitoring technique provides a method for the timely identification of boiler slagging and fouling and the early and effective application of cleaning techniques, thereby reducing boiler downtime and the risk of catastrophic boiler failure. In Phase II, we will identify and experimentally characterize high-temperature sensing devices and methods for applying ADM technology to the operating environment of a commercial recovery boiler. The ADM system requires the development of analytical software to reduce the complex spectrum data collected into an image of the deposits mass distribution on the heat transfer surfaces of the boiler. Testing under hot conditions representative of a real boiler environment will reveal solutions to logistics concerns and provide the confidence necessary to design a prototype system. In conjunction with the Weyerhaeuser Company, we will prepare the preliminary design of a prototype system for a phase III field test at a Weyerhaeuser commercial facility. The results and potential applications would represent a significant cost savings to the pulp and paper industry. Following the near-term introduction in the black liquor recovery boilers, where the need is the greatest, the system can also be adapted and introduced in coal-fired boiler systems.

Spectral Sciences, Inc.
Burlington, MA 01803

116. Development of a Fiber-Optic Laser-Absorption Water Sensor (FLAWS)

Bien, F.

Industrial drying operations are major users of energy, representing approximately 4 to 6% of total energy use by U.S. industry (or approximately 1.2 to 1.8 quads per year). Significant fractions of this drying energy are used by industries that are capable of using sophisticated control systems for their drying processes, such as pulp and paper, food, textiles, and lumber. In addition, the use of hygrometers by these industries to monitor the humidity in their drying chambers and provide real time process control information is a route to both significant energy savings and improved product quality. In order for these hygrometers to be useful to the above industries, they must be able to measure humidity reliably at temperatures up to 450°C, at high humidity (50 to 100%), and in environments containing particulates and/or fouling or corrosive vapors. This proposal addresses the development of an innovative multiple sensor hygrometer permitting measurements of the absolute humidity in the types of industrial environments discussed above and which could be used in a process control system. It would use a combination of proven sensor head and innovative near infrared diode laser technologies. This combination permits operation of several sensor heads connected by optical fibers to a single laser/detector/electronics package, which potentially offers lower sensor costs (and, thereby, applicability to a wider range of industrial users) than existing designs. The objective of the proposed project is the development of a commercial sensor for monitoring and controlling humidity in industrial drying chambers. As a first step toward this goal, in Phase I a laboratory proof-of-concept breadboard will be constructed to investigate the fundamental limitations on sensitivity, selectivity, and linearity for water vapor detection. In Phase II, a brassboard FLAWS instrument will be constructed and tested in an industrial drying chamber, probably in the pulp and paper industry. The successful development of the FLAWS instrument would represent advances in the monitoring and control of humidity in industrial dryers, as well as in the utilization of diode laser technology for the quantitative detection of gaseous species. It is anticipated that the FLAWS instrument will find its initial applications in the pulp and paper, food, and textile industries, with subsequent applications to drying in the lumber and agricultural products industries.

INSTITUTION INDEX

This index lists the institutions responsible for the projects cited in this publication. The corporate names are entered in standardized forms found in the authority listing EDB Corporate Author Entries (DOE/TIC-4585). Each entry includes the project title and citation number.

INVESTIGATOR INDEX

Investigators' surnames are indexed in the form appearing in the citation; given names generally have been reduced to initials. For projects with multiple investigators, each name is indexed. Accent marks are not input because of computer alphabetization. Spelling and transliteration follow standard conventions.

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See references guide users from synonymous terms to the descriptors selected for the concept. *See also* references indicate subject concepts that are more specific than a particular descriptor. To gain complete subject coverage, all such terms should be reviewed.

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