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THE OFFICE OF INDUSTRIAL TECHNOLOGIES TECHNICAL REPORTS

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Prepared for
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Technical Reports

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Nevada Nuclear Waste Storage Investigations, 1986: An Update. December 1987. 208 refs. DOE/TIC-3406 (Add.1) (DE87012696).

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Yucca Mountain Project Bibliography, January-June 1988: An Update. October 1988. 94 refs. DOE/OSTI-3406 (Suppl.1) (Add.1) (DE88015230).

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Radioactive Waste Management: A Series of Bibliographies

Decontamination and Decommissioning. February 1985. 284 refs. DOE/TIC-3391 (Suppl.1) (DE85003098).

Formerly Utilized Sites: Remedial Action. April 1985. 90 refs. DOE/TIC-3392 (Suppl.1) (DE85008190).

High-Level Radioactive Wastes. September 1984. 1452 refs. DOE/TIC-3389 (Suppl.1) (DE84013656).

Low-Level Radioactive Waste. March 1983. 492 refs. DOE/TIC-3387 (Suppl.1) (DE83007212).

Low-Level Radioactive Waste. May 1984. 636 refs. DOE/TIC-3387 (Suppl.2) (DE84005533).

Nuclear Fuel Cycle: Reprocessing. September 1984. 555 refs. DOE/TIC-3396 (Suppl.1) (DE84013561).

Radioactive Waste Inventories and Projections. January 1986. 31 refs. DOE/TIC-3394 (Suppl.1) (DE86002360).

Spent Fuel Storage. August 1984. 580 refs. DOE/TIC-3395-S1 (DE84005534).

Transuranic Wastes. April 1985. 409 refs. DOE/TIC-3340 (Suppl.1) (DE85006324).

Uranium Mill Tailings. March 1985. 194 refs. DOE/TIC-3393 (Suppl.1) (DE85006278).

Waste Isolation. February 1985. 590 refs. DOE/TIC-3388 (Suppl.1) (DE85003092).

This publication is available as DE92000497.

THE OFFICE OF INDUSTRIAL TECHNOLOGIES TECHNICAL REPORTS

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ABOUT THIS BIBLIOGRAPHY

The U.S. Department of Energy's Office of Industrial Technologies (OIT) conducts R&D activities which focus on the objectives of improving energy efficiency and providing for fuel flexibility within U.S. industry in the area of industrial energy conservation. The Office also conducts programs to reduce waste generation, increase recycling efforts, and improve the use of wastes as process feedstocks. An active program of technology transfer and education supports these activities and encourages adoption of new technologies. To accomplish these objectives, OIT cooperates with the private sector to identify its technological needs and to share R&D efforts. R&D is conducted to the point that a new technology is shown to work and that it can be transferred to the private sector end-users.

To date, OIT has supported more than 300 research and development projects, covering a wide spectrum of industrial applications. The technologies have been both "generic" conservation technologies and energy-intensive processes unique to specific industries. Many of the efforts have successfully resolved critical technical barriers faced by industry in developing advanced energy-efficient processes and technologies.

This bibliography contains information on all scientific and technical reports sponsored by the DOE Industrial Energy Conservation Program during the years 1988-1990. The abstracts are grouped by program subdivision as shown in the Contents. Cross categorization is provided when the report covers more than one topic. Within each group, arrangement is alphabetized by report number in reverse chronological order. Interim progress reports have been excluded when there is a final report on the project. As a result of a 1990 reorganization of the Program, certain areas—Municipal Solid Waste, Solar Industrial, Combustion, Thermal Sciences, Materials, and Bioprocessing—only show work starting in 1990.

Questions pertaining to the technical contents of this bibliography should be addressed to Marsha Quinn (FTS 896-2097), who coordinated this publication.

MASTER

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Industrial Technologies Technical Reports

INDUSTRIAL ENERGY EFFICIENCY

Advanced Heat Exchangers

Refer also to citation(s) 498, 502

1 (ANL-87-28) **A review of two-phase flow-induced vibration.** Chen, S.S. Argonne National Lab., IL (USA). Aug 1987. 54p. DOE Contract W-31109-ENG-38. Order Number DE88001955. Source: NTIS, PC A04/MF A01; GPO Dep.

Two-phase flow exists in many shell-and-tube heat exchangers and power generation components. The flowing fluid is a source of energy that can induce small-amplitude subcritical oscillations and large-amplitude dynamic instabilities. In fact, many practical system components have experienced excessive flow-induced vibrations. To prevent unacceptable flow-induced vibration, we must understand excitation mechanisms, develop analytical and experimental techniques, and provide reliable design guidelines. Thus, we are conducting a comprehensive program to study structural vibration in components subjected to two-phase flow. This report reviews the current understanding of vibration of circular cylinders in quiescent fluid, crossflow, and axial flow, with emphasis on excitation mechanisms, mathematical models, and available experimental data. A unified theory is presented for cylinders oscillating under different flow conditions. Based on the theory, future research needs are outlined. 57 refs., 13 figs., 1 tab.

2 (BAW/LRC-5282) **High-temperature burner-duct-recuperator system evaluation. Annual report, October 1981-September 1982.** Babcock and Wilcox Co., Lynchburg, VA (USA). Lynchburg Research Center. Jan 1984. 563p. DOE Contract FC07-81ID12296. Order Number DE84009627. Source: NTIS, PC A24/MF A01; GPO Dep.

A project to design, construct, install, and evaluate a high-temperature burner-duct-recuperator (HTBDR) system is described. The high-temperature recuperator is to be capable of delivering 2000°F (1800°F minimum) preheated combustion air to a high-temperature burner designed for the combustion system of a steel mill soaking pit. The evaluation site is located at the Koppel, Pennsylvania, steel-making facility of the B & W Tubular Products Group. The purpose of the project is to advance the state-of-the-art in industrial waste heat utilization by developing an HTBDR system that is both technically and economically acceptable to industry. The system designed by B & W intended to operate in flue gas streams of 2500°F (maximum) that contain contaminants from hot topping compounds and scale (iron oxide). This report describes the efforts in the first year of the project, which includes the design of the HTBDR system, flue exposure testing, and an energy audit of the host site. An interactive, interdisciplinary team was utilized to design the HTBDR system. The design effort of each technical discipline is presented in detail in sections 1 to 7 of this report including: ceramic materials characterization; system

mechanical design; process control and instrumentation; thermal and fluid flow; applied mechanics (stress analysis); flow-induced vibration analysis; HTBDR burner development, and HTBDR and energy audit.

3 (CONF-8806363-) **Proceedings of the fouling and corrosion probe workshop, Chicago, Illinois.** Energetics, Inc., Columbia, MD (USA). 23 Jun 1988. 82p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-87CE40762. From Fouling and corrosion probe workshop; Chicago, IL, USA; 23 Jun 1988. Order Number DE89012686. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

This report documents a fouling and corrosion probe workshop held on June 23, 1988 to review and discuss fouling and corrosion probe technologies and test plans. The workshop was sponsored by the US Department of Energy's Office of Industrial Programs and hosted by the Gas Research Institute. The report is comprised of the presentation hardcopies, comments made by workshop participants, final concluding remarks of the participants, and a revision of planned probe tests revised on the basis of the comments received at the workshop. It should be noted that the comments of the workshop participants are not necessarily "consensus" comments and, at time, have been paraphrased.

4 (CONF-880724-14) **Design of a controlled temperature flue gas corrosion probe.** McEvers, J.A.; Federer, J.I. Oak Ridge National Lab., TN (USA). 1988. 7p. DOE Contract AC05-84OR21400. From 25. American Society of Mechanical Engineers/American Institute of Chemical Engineers/American Nuclear Society national heat transfer conference; Houston, TX, US; July 24, 1988. Order Number DE88007480. Source: NTIS, PC A02/MF A01; GPO Dep.

The need to determine suitable materials for use in industrial waste heat recovery systems requires assessment of materials degradation in various flue gas environments. Such an assessment generally involves exposing candidate materials to the environments, then analyzing the effects of the exposure conditions. Degradation of materials is related to flue gas chemical composition, temperature, and thermal cycling behavior. Temperature variations, especially atypical thermal cycling, complicate the task of characterizing such phenomena as corrosion rates and corrosion mechanisms. A relatively constant temperature would allow a more accurate determination of the effects of flue gas chemical composition and temperature. In response to this need, a flue gas corrosion probe has been designed for exposure tests of materials. The probe allows materials to be tested at nominally constant temperatures within a wide span of either constant or changing flue gas temperatures. This paper describes the design and fabrication of the corrosion probe system. 9 refs., 4 figs., 6 tabs.

5 (CONF-881296-Summ.) **Research and development opportunities in supercritical fluid technology: Final report.** EA-Mueller, Inc., Baltimore, MD (USA); Energetics, Inc., Columbia, MD (USA). Aug 1989. 24p.

Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-87CE40762. From Workshop on research and development opportunities in supercritical fluid technology; Washington, DC (USA); 2 Dec 1988. Order Number DE89015320. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

On December 2, 1988, the US Department of Energy (DOE) held a workshop on supercritical fluid technology. The purpose of this workshop was to elicit research ideas from participants representing government, industry, and academia. A special concern was to determine the appropriate level of involvement for DOE and other organizations in order to develop commercial supercritical fluid technology. Group presentations and a general discussion were held to summarize the results. Comments on the general roles of DOE and industry in supercritical fluid R&D included: some industries (e.g., food processing) are already researching this technology; DOE should cooperate with industry in attempting to demonstrate this technology; and direct support of private-sector projects by DOE should be encouraged. It was also noted that productivity benefits may outweigh energy conservation benefits in some application areas. 1 fig., 5 tabs.

6 (CONF-8910120-1) **High-temperature corrosion of heat exchanger materials.** Federer, J.I. (Oak Ridge National Lab., TN (USA)). Oak Ridge National Lab., TN (USA). 1989. 29p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From 1. international ceramic science and technology congress; Anaheim, CA (USA); 31 Oct - 3 Nov 1989. Order Number DE90001963. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Silicon-based and oxide ceramics are candidate matrix materials for ceramic composites for heat exchanger tubes and other critical applications. The corrosion behavior of matrix materials was investigated by exposure tests in industrial furnaces, and composites containing the most corrosion-resistant matrix materials were tested in laboratory furnaces. SiC and Si₃N₄ ceramics corroded severely in industrial furnace atmospheres containing alkali compounds. Oxide ceramics, such as Al₂O₃ and ZrO₂, corroded relatively little in the same atmospheres, but their corrosion increased with increasing SiO₂ content. Most ceramic composites containing hoop-wrapped continuous fiber in Al₂O₃ and stabilized ZrO₂ matrices exhibited dimensional instability during a laboratory corrosion test, but composites containing helical-wrapped fiber were stable. 6 refs., 12 figs., 3 tabs.

7 (DOE/CE/40716-2-Vol.1) **Assessment of high pressure heat exchange systems technology: Volume I, technology assessment and research and development needs.** Mueller Associates, Inc., Baltimore, MD (USA). Oct 1987. 105p. DOE Contract AC01-84CE40716. Order Number DE88012477. Source: NTIS, PC A07/MF A01 - OSTI; GPO Dep.

Research and development appropriate to the Dept. of Energy and to a new generation of advanced heat exchangers which could operate in high-pressure, high-temperature industrial process applications near 2000°F and 1000 psia and often involving corrosive gas streams, is recommended. This study identified and assessed potential applications in power generation using closed-cycle and other gas turbine configurations, steam reforming of natural gas, chemical evaporators for caustics and acids, transfer of heat energy to or from very hot or hostile waste gases, and heat transfer piping for flowing molten metal or liquids. Energy and cost

savings on a process and national basis were estimated. 32 refs., 13 figs., 15 tabs.

8 (DOE/CE/40716-2-Vol.2) **Assessment of high pressure heat exchange systems technology: Volume 2, Appendices.** Mueller Associates, Inc., Baltimore, MD (USA). Oct 1987. 197p. DOE Contract AC01-84CE40716. Order Number DE88012503. Source: NTIS, PC A09/MF A01; GPO Dep.

The industrial applications considered under the HiPHES program span a wide range of operating conditions and materials requirements. The materials of construction for these applications will be subjected to high temperatures and pressures in the presence of a variety of corrosive agents. Design requirements dictate that these materials maintain their high strength and structural integrity over relatively long periods in order to provide the basis for efficiency improvements. An overview and assessment of traditional and novel materials designed for or deemed capable of the best performance under severe service conditions is provided. Generic materials categories included in this review are the metals (alloys and superalloys), monolithic ceramics, and composites.

9 (DOE/CE/40716-3) **Assessment of heat transfer enhancement and fouling in industrial heat exchangers: Final report.** Rebello, W.J. PAR Enterprises, Inc., Fairfax, VA (USA). Nov 1987. 149p. DOE Contract AC01-84CE40716. Order Number DE89005620. Source: NTIS, PC A07/MF A01 - OSTI; GPO Dep.

Since the oil embargo of 1983-1984, energy costs have motivated industry to improve the performance and reliability of heat exchangers by using enhanced heat transfer surfaces. In addition, because of the high economic penalty caused by fouling, research in the area of fouling has increased. In recent years, several international conferences have been held by academia and industry to report on and discuss research opportunities in the area of heat transfer enhancement and fouling. These research opportunities have been prioritized based on the assessment and judgment of the experts in the field. This report, representing a four man-month effort, is an attempt to determine the impacts of heat exchanger enhancement and fouling on energy and capital costs so as to set some priorities for the various research opportunities. As a result of the literature review, a brief overview of enhancement and fouling has been provided and serves as a ready reference. 54 refs., 4 figs., 31 tabs.

10 (DOE/CS/12077-T1) **High-temperature counter-flow recuperator. Final report.** Rudloff, F. Unitex Corp., Salt Lake City, UT (USA). May 1981. 324p. DOE Contract AC07-80ID12077. Order Number DE81031923. Source: NTIS, PC A14/MF A01.

A summary of the work performed to further evaluate the commercial potential of a helical recuperator design in recovering waste heat from industrial furnaces is reported. The helical recuperator concept consists of a cylindrical column with an interior helical interface which separates the preheat air and the combustion gas. The column operates in a counter flow mode and is formed from modular sections. The work was divided into two general activities including a material evaluation and a design optimization. The material evaluation consisted of exposing material samples to a soda-lime glass furnace environment for a fifteen week period. A study of manufacturing was also performed to determine which recuperator designs could be produced and

what their corresponding costs of production would be. The results indicated that of the materials tested, ECP-3, X-81, and Unichrome were the best suited for use in a soda-lime environment. Of the materials tested ECP-3 was the best candidate with respect to manufacturing. In the design optimization, two potential design modifications were identified through theoretical analyses. The modifications resulted in a finned design and a double helix design. The assumptions made in the analyses were checked experimentally. Revised analyses based on the experimental and cost data showed that the prototype design was the most economical producing paybacks of 2 to 3 years for modules made of Siltec and 3 to 5 years for modules made of KT Silicon Carbide. Both of these materials are poor candidates for use in the soda-lime glass environment. For materials that showed the greatest potential for use in the glass environment, the double helix design made from ECP-3 was the most economical producing payback periods of 6 to 14 years.

11 (DOE/CS/40012-1) **High temperature range recuperator. Phase I: materials selection, design optimization, evaluation and thermal testing. Final report, April 1977-May 1978.** Power, D.V. Terra Tek, Inc., Salt Lake City, UT (USA). Jun 1978. 113p. DOE Contract EY-77-C-07-1660. Source: NTIS, PC A06/MF A01.

Initial efforts to develop, test, and evaluate counterflow recuperator designs are reported for the High Temperature Range Recuperator project. Potential materials to withstand glass furnace exhaust environments at temperatures up to 2800°F were evaluated on the bases of material properties, fabrication capability, and relative performance in the flue environment of a day tank glass furnace. Polycrystalline alumina (Vistal), reaction sintered silicon carbide (KT and NC 430), chemically vapor deposited silicon carbide (CVD) and sintered alpha silicon carbide proved most satisfactory in the material temperature range of 2300°F to 2800°F. Relatively pure alumina (AD 998 and AD 94), mullite and cordierite were most satisfactory in the material temperature range of 1700°F to 2300°F. Recuperator designs were evaluated on the bases of cold air flow tests on laboratory models, fabricability, and calculated thermomechanical stress under expected operating conditions. Material strengths are shown to be greater than expected stresses by factors ranging from 2.6 for KT silicon carbide to 16 for cordierite. Recuperator test sections were fabricated from KT silicon carbide and subjected to thermal stress conditions in excess of twice the expected operating conditions with no deterioration or failure evident. A test section was subjected to the thermal shock of instant transfer between room temperature and a 2000°F furnace without damage. Economic analysis based on calculated heat transfer indicates a recuperator system of this design and using currently available materials would have a payback period of 2.3 years.

12 (DOE/CS/40012-2) **High temperature range recuperator. Phase II. Prototype demonstration and material and analytical studies. Final report.** Terra Tek, Inc., Salt Lake City, UT (USA). Apr 1980. 530p. DOE Contract AC07-77CS40012. Source: NTIS, PC A23/MF A01.

A summary of the work performed to fully evaluate the commercial potential of a unique ceramic recuperator for use in recovering waste heat from high temperature furnace exhaust gases is presented. The recuperator concept being developed consists of a vertical cylindrical heat exchange column formed from modular sections. Within the column, the gasketed modules form two helical flow passages - one for high temperature exhaust gases and one for pre-heating

combustion air. The column is operated in a counterflow mode, with the exhaust gas entering at the bottom and the combustion air entering at the top of the column. Activities included design and procurement of prototype recuperator modules, construction and testing of two prototype recuperator assemblies, exposure and mechanical properties testing of candidate materials, structural analysis of the modules, and assessment of the economic viability of the concept. The results of the project indicated that the proposed recuperator concept was feasible from a technical standpoint. Economic analysis based upon recuperator performance characteristics and module manufacturing costs defined during the program indicated that 3 to 10 years (depending upon pre-heat temperature) would be required to recover the capital cost of the system in combustion air pre-heat applications. At this stage in the development of the recuperator, many factors in the analysis had to be assumed. Significant changes in some of the assumptions could dramatically affect the economics. For example, utilizing \$2.85 per mcf for the natural gas price (as opposed to \$2.00 per mcf) could reduce the payback period by more than half in certain cases. In addition, future commercial application will depend upon ceramic component manufacturing technique advances and cost reduction.

13 (DOE/CS/40040-5) **Intermediate- and high-temperature flue-gas recuperators for a variety of industrial-process environments. Project 61006 final report.** Stanton, E.H.; Larson, D.H.; Gawlowski, T.C.; Paul, L.F. Institute of Gas Technology, Chicago, IL (USA). Dec 1981. 177p. DOE Contract AC07-77CS40040. Order Number DE82022029. Source: NTIS, PC A09/MF A01.

Portions of document are illegible.

An industrial recuperator design that uses reradiant heat transfer to achieve improved recovery efficiency was field-evaluated. Modifications were made to an aluminum remelting furnace. Average fuel savings for the recuperated mode was 31%. The internal rate of return for the cash flows calculated for the recuperators with and without the reradiant insert were, respectively, 46.0% and 41.6%.

14 (DOE/CS/40257-1) **High temperature recuperator tests. Final report.** Bjerklie, J.W.; Penty, R.A. Hague International, South Portland, ME (USA). May 1980. 45p. DOE Contract AC02-79CS40257. Source: NTIS, PC A03/MF A01.

A demonstration and test program was conducted on a high temperature, two pass ceramic tube recuperator. Data pertaining to heat exchanger performance characteristics were collected and compared with calculated values. The effect of improved heat exchanger effectiveness on system fuel consumption was demonstrated. Changes in fuel flow as a function of combustion air preheat while maintaining a given heat load were demonstrated. The effects of excess air on fuel consumption with and without system recuperation were demonstrated. A preheat level of 1740°F with a heat exchanger inlet of 2537°F for a recuperator effectiveness of 68% was demonstrated. Comparison of test measurements and calculated heat balance and heat transfer characteristics indicated that the measured effects of recuperation and excess air levels on fuel consumption were close to theoretical values. A post-program examination of the recuperator indicated that no damage to the recuperator occurred that could not be alleviated by minor design modification. The modifications necessary to achieve 1800 to 2000°F preheat with a ceramic tube recuperator of

the type demonstrated were extrapolated from measurements made in this program. The same two pass approach demonstrated in this program can be used. The number of face tubes vs. pressure drop for increased recuperator effectiveness was calculated. Modifications and procedures necessary to achieve a 1800 to 2000°F preheat with furnace temperatures between 2500°F and 2800°F are discussed.

15 (DOE/CS/40330-T1) Technology acceleration program for the GTE ceramic high-temperature recuperator. Final report. Dorazio, R.; Ferri, J.; Fulkerson, W.; Gonzalez, J.; Kohnken, K.; Mahoney, W. GTE Products Corp., Towanda, PA (USA). Chemical and Metallurgical Div.; Par Enterprises, Inc., Fairfax, VA (USA). Mar 1983. 224p. DOE Contract FC01-80CS40330. Order Number DE84007608. Source: NTIS, PC A10/MF A01; GPO Dep.

This TAPHTR (Technology Acceleration Program for high temperature recuperators) final report describes the GTE ceramic recuperator and each of 38 industrial furnace installations and discusses the economics of each installation. In addition, descriptions are provided for other recuperation system components, such as, burners, combustion controls, etc., that were used in this program. A market assessment was conducted to provide information on the possible applications of the GTE ceramic recuperator.

16 (DOE/CS/40331-T1) Technology Acceleration Program high effectiveness recuperators. Final report. AiResearch Mfg. Co., Torrance, CA (USA). 1 Aug 1983. 57p. DOE Contract FC01-80CS40331. Order Number DE84002446. Source: NTIS, PC A04/MF A01.

A six-task program was undertaken to accelerate early use and stimulate overall demand for proven, energy-saving, high-effectiveness, compact metallic recuperators to recover industrial waste heat. The thrust of the program was concerned with seeking out suitable sites for placement of recuperators, placing recuperators at those sites, and then monitoring performance over a suitable period of time. This final report overviews the technology acceleration program in an executive summary and then in greater detail in a program summary.

17 (DOE/ID-10194) High-temperature burner-duct-recuperator (HTBDR) design modification study: Final report, September 1986-May 1987. Huber Construction Co., Inc., Houston, TX (USA). Apr 1988. 43p. DOE Contract AC07-76ID01570. Order Number DE88008308. Source: NTIS, PC A03/MF A01; GPO Dep.

This is a reproduction of a letter report for the design modifications study of a high-temperature burner-duct-recuperator (HTBDR) tested in the Cameron Iron Works, Houston, Texas. The prototype HTBDR was field tested at Cameron, but it was eventually shut down due to the failure of some structural components; not the ceramic heat exchanger tubes. No change was recommended to the original core of the system, i.e., the cruciform (internal fin) silicon carbide tubes. However, the air plenums were changed to a clam-shell configuration that provides higher-pressure sealed manifolds. The various seals between the refractory manifold sections, as well as between the tubes and tube sheets, consist of ceramic fiber sleeves and ropes. The HTBDR was developed by Garret AiResearch under funding from the US Department of Energy, Office of Industrial Programs under Cooperative Agreement No. FC07-81ID12170.

18 (DOE/ID/12138-2) Assessment of gas-side fouling in cement plants. Marner, W.J. Jet Propulsion

Lab., Pasadena, CA (USA). Sep 1982. 100p. DOE Contract AI07-80ID12138. (JPL-PUBL-82-83). Order Number DE83001426. Source: NTIS, PC A05/MF A01.

The purpose of this study is to provide an assessment of gas-side fouling in cement plants with special emphasis on heat recovery applications. Exhaust gases in the cement industry which are suitable for heat recovery range in temperature from about 400 to 1300 K, are generally dusty, may be highly abrasive, and are often heavily laden with alkalis, sulfates, and chlorides. Particulates in the exhaust streams range in size from molecular to about 100 μ m in diameter and come from both the raw feed as well as the ash in the coal which is the primary fuel used in the cement industry. The major types of heat-transfer equipment used in the cement industry include preheaters, gas-to-air heat exchangers, waste heat boilers, and clinker coolers. The most important gas-side fouling mechanisms in the cement industry are those due to particulate, chemical reaction, and corrosion fouling. Particulate transport mechanisms which appear to be of greatest importance include laminar and turbulent mass transfer, thermophoresis, electrophoresis, and inertial impaction. Chemical reaction mechanisms of particular importance include the deposition of alkali sulfates, alkali chlorides, spurrite, calcium carbonate, and calcium sulfate. At sufficiently low temperatures, sulfuric acid and water can condense on heat exchanger surfaces which can cause corrosion and also attract particulates in the flow. The deleterious effects of gas-side fouling in cement plants are due to: (1) increased capital costs; (2) increased maintenance costs; (3) loss of production; and (4) energy losses. A conservative order-of-magnitude analysis shows that the cost of gas-side fouling in US cement plants is \$0.24 billion annually.

19 (DOE/ID/12138-7) Development of a gas-side fouling measuring device. Marner, W.J.; MacDavid, K.S. Jet Propulsion Lab., Pasadena, CA (USA). May 1987. 89p. DOE Contract AI07-80ID12138. Order Number DE87014462. Source: NTIS, PC A05/MF A01; GPO Dep.

A gas-side fouling measuring device has been designed, constructed, and tested in a laboratory setting. The cylindrical probe, made of stainless steel, is cooled with compressed air and utilizes a temperature control system to maintain a constant wall temperature during testing. The design employs a heat flux meter to measure local fouling factors and calorimetric measurements to simultaneously determine average values. Laboratory tests have been carried out using natural gas combustion products doped with slaked lime to serve as the foulant. Local and average fouling factors were obtained over a range of parameters including: inside wall temperature, 270 to 1500°F; gas temperature, 745 to 2214°F; heat flux, 3440 to 40,800 Btu/hr-ft²; and gas velocity, 9.91 to 27.7 ft/sec. Results obtained confirm that the probe is capable of determining local and average gas-side fouling factors under laboratory conditions.

20 (DOE/ID/12170-2) High-temperature burner-duct-recuperator (HTBDR) system low-pressure seal development: Final report. Stillwagon, T.L.; Coombs, M.G.; Kotchick, D.M. AiResearch Mfg. Co., Torrance, CA (USA). May 1987. 144p. DOE Contract FC07-81ID12170. Order Number DE87012055. Source: NTIS, PC A07/MF A01; GPO Dep.

Development has been completed of a ceramic recuperator and its companion high-temperature preheated combustion air burner. The system is designed to operate in

a variety of industrial flue gas streams with exhaust temperatures up to 2500°F. The ceramic recuperator provides combustion air preheated up to 2000°F to the high-temperature burner. Development of low-pressure seals to join the ceramic recuperator components was performed as an integral part of the program. While operating at high temperatures, the recuperator requires seals effective in minimizing both leakage and stress concentrations in the joints between ceramic components. Seal design, composition, leakage performance, and seal characterization were evaluated for cement, glass, and fiber packing seals. Laboratory studies have demonstrated that effective, low-leakage seals were developed and incorporated into the HTBDR industrial design.

21 (DOE/ID/12170-3) High-temperature burner-duct-recuperator (HTBDR) development and demonstration: Final report for the period October 1981-September 1987. Strumpf, H.; Hossepien, G.; Coombs, M.; Kotchick, D. Allied-Signal Aerospace Co., Torrance, CA (USA). AiResearch Los Angeles Div. Dec 1987. 709p. DOE Contract FC07-81ID12170. Order Number DE88006515. Source: NTIS, PC A99/MF A01.

A program has been completed to design, develop, fabricate, install, operate, and evaluate a high-temperature burner-duct-recuperator (HTBDR) system. The HTBDR is used to recover waste heat from industrial furnaces through preheating of the combustion air. The HTBDR comprises a high-temperature ceramic tubular recuperator operating in series with a metallic plate-fin heat exchanger, a high-temperature dual-fuel burner, and the associated ducting, controls, and auxiliary equipment. After generating a full-size preliminary design, a scaled-down prototype HTBDR was designed, developed, fabricated, and successfully tested. The HTBDR produced 2000 F air with exhaust gas at approximately 2350 F. Prototype burners operated with the 2000 F air. Following the prototype test, the full-size final design was prepared. The system was fabricated and installed on a rotary heat treating furnace at Cameron Iron Works, Houston, Texas. The system operated successfully for about 6 months. The HTBDR demonstrated air preheat capability of over 1900 F (with 2100 F exhaust gas). The system was eventually shut down due to the structural failure of a few ceramic components (not the ceramic tubes). Faulty fabrication of the failed parts coupled with severe and numerous thermal cycling was judged to be the source of this problem.

22 (DOE/ID/12222-T2) Assessment, development and coordination of technology base studies in enhanced heat transfer. Final report. Bergles, A.E.; Nelson, R.M.; Junkhan, G.H.; Webb, R.L. Iowa State Univ. of Science and Technology, Ames (USA). Engineering Research Inst. Mar 1984. 150p. DOE Contract FG07-81ID12222. Order Number DE85004130. Source: NTIS, PC A07/MF A01; GPO Dep.

Five tasks were undertaken to advance the understanding and utilization of heat transfer enhancement techniques in commercial heat exchange equipment. Accomplishments in the five task areas are as follows: The technology information base was expanded by increasing the documentation of papers and reports from 1967 to 3045 entries. The US Patent citations were increased from 321 to 454. Bibliographic reports of these two citation data bases have been issued. The third data base consists of a listing of manufacturers and their products related to enhanced heat transfer technology. The present compilation of 221 entries, which updates and expands the previous list of 185 companies, is

presented. A complete list of possible thermal-hydraulic performance evaluation criteria for single-phase enhancement has been developed. Entropy generation has been added to the usual list of constraints and objectives. A computer study narrowed the possible criteria from 237 to 86. Three of the 86 are provisionally recommended as useful criteria for design. A data base was established for single-phase heat transfer and friction performance of spirally fluted (helical repeated rib) tubes. A study was undertaken to clarify the performance and the enhancement mechanism of the commercial T-fin GEWA-T tube. A study of horizontal falling film evaporation on horizontal tubes with smooth and structured surfaces was completed.

23 (DOE/ID/12296-2) High temperature burner-duct-recuperator system evaluation: Second annual report, October 1982-September 1983. Snyder, J. E. Babcock and Wilcox Co., Lynchburg, VA (USA). Research and Development Div. Feb 1986. 308p. DOE Contract FC07-81ID12296. Order Number DE88011186. Source: NTIS, PC A14/MF A01; GPO Dep.

Activities in the second year of a project to develop a high-temperature burner-duct-recuperator are reported. The recuperator is designed to operate in high temperature flue gas streams that contain contaminants and delivers 2000°F preheat air to the combustion system of a steel mill soaking pit. A prototype recuperator was constructed and evaluated. Analysis thermal and fluid flow, flow induced vibration, stress, and materials test data were obtained. Final recuperator system design modifications were made, based on the prototype results, and system fabrication was initiated. Other activities included the development of a high temperature burner, completion of a preliminary economic analysis, and host site preparation.

24 (DOE/ID/12296-3) High temperature burner-duct-recuperator system evaluation: Third annual report, October 1983-September 1984. Babcock and Wilcox Co., Lynchburg, VA (USA). Research and Development Div. 1984. 91p. DOE Contract FC07-81ID12296. Order Number DE88013690. Source: NTIS, PC A05.

The design concept developed to recover the heat in the waste gas stream consists of two ceramic tubes; one tube open on both ends inserted into another tube which is closed on one end, bayonet style. The tubes are suspended vertically from the plenums into the flue of the soaking pit using air-cooled, metallic tube sheets. Combustion air is blown into the upper plenum where it begins the heat exchange process with the hot gases by flowing down the inner tube, turning around at the bottom of the outer tube, and flowing up the outer tube to the lower plenum and out of the recuperator. Combustion air flow direction through the recuperator could also be reversed. The system is called a cross-counter flow heat exchanger. Ceramic fiber insulation is used to line the walls of the plenums and the surfaces of the tube sheets as well as the ducts and burner. Ceramic fiber products are also used to provide individual support sleeves and seals for the tubes. The tubes in this concept rest on the sleeves and seals, and are not constrained from moving due to thermal expansion. This design reduces mechanical stresses on the ceramic tubes. The benefits of the B and W design concept include: no dilution air needed for the flue gas; high operating temperature (2250 F); low flue-side pressure drop (Lo. 1 in. H₂O); unconstrained structural ceramics; and ease of maintenance. 4 refs., 37 figs.

25 (DOE/ID/12296-4) **High temperature burner-duct-recuperator system evaluation: Fourth annual report, October 1984-September 1985.** Babcock and Wilcox Co., Lynchburg, VA (USA). Research and Development Div. 1985. 54p. DOE Contract FC07-81ID12296. Order Number DE88013692. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

The B&W design uses a tube-in-tube bayonet style in the ceramic heat exchanger. This system is described in detail in the previous annual reports. Basically, the ceramic stage consists of fifty outer tubes of siliconized silicon carbide; fifty inner tube (twenty-five recrystallized silicon carbide on the hotter end and twenty-five metallic tubes on the cooler end); two metallic tubesheets insulated with Koawool fiberglass insulation; and associated seals and support sleeves. The sleeves provide support for the tubes but are resilient enough to adjust for thermal expansion. The seals prevent air movement between the combustion air and flue gas streams. In operation, combustion air is driven by a large fan into the metallic heat exchanger, where some heating occurs. Air is then directed through ducting to the ceramic heat exchanger, where maximum preheat occurs. The air moves into the upper plenum, down through the inner tubes, up through the space between tubes, and exits through the lower plenum. Preheated air then moves through larger insulated ducts to the burner. Spent flue gas exits the pit and moves down the flue through first the ceramic tubes and then the metallic tubes before exiting past the damper and out the stack. Benefits of the design concept includes: no dilution air required; high operating temperature; low flue side pressure drop; unconstrained structural ceramics; and ease of maintenance. 39 figs., 1 tab.

26 (DOE/ID/12296-5) **High temperature burner-duct-recuperator system evaluation: Final report, October 1981-August 1988.** Parks, W.P. Jr.; DeBellis, C.L. Babcock and Wilcox Co., Lynchburg, VA (USA). Lynchburg Research Center. Aug 1989. 111p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-81ID12296. Order Number DE89016730. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

The Babcock & Wilcox Company (B&W) has completed a program to design, construct, install, and field test a ceramic-based high-temperature burner-duct-recuperator (HTBDR) in an industrial setting. The unit was capable of operating in corrosive, high temperature (2250°F) flue gas streams. The HTBDR was successfully tested in a steel soaking pit at B&W's Tubular Products Division in Koppel, PA. During the 1400 hour operation prior to plant closing, the ceramic stage performed well with no material related problems or air-to-flue leakage. The maximum preheat air produced was 1425°F with a flue gas temperature of 2170°F. Measured fuel savings of 17-24% were obtained over the previous recuperated (metallic heat exchanger) system. This projects to savings of 41% for an unrecuperated furnace. A simple payback analysis indicated acceptable payback for installation in unrecuperated furnaces but unacceptable payback for recuperated furnaces at today's low gas prices. In both cases return on investment is high over a ten year projected life expectancy. 14 refs., 67 figs., 16 tabs.

27 (DOE/ID/12302-9) **Fluidized-bed waste-heat recovery system development: Final report.** Patch, K.D.; Cole, W.E. TECOGEN, Inc., Waltham, MA (USA). Jun 1988. 386p. DOE Contract FC07-81ID12302. Order Number DE89006888. Source: NTIS, PC A17/MF A01 - OSTI; GPO Dep.

A major energy loss in industry is the heat content of the flue gases from industrial process heaters. One effective way to utilize the energy, which is applicable to all processes, is to preheat the combustion air for the process heater. Although recuperators are available to preheat this air when the flue gases are clean, recuperators to recover the heat from dirty and corrosive flue gases do not exist. The Fluidized-Bed Waste-Heat Recovery (FBWHR) system is designed to preheat this combustion air using the heat available in dirty flue gas streams. In this system, recirculating alumina particles are heated by the flue gas in a raining bed. The hot particles are then removed from the bed and placed in a fluidized bed where they are fluidized by the combustion air. Through this process, the combustion air is preheated. The cooled particles are then returned to the raining bed. Initial development of this concept is for the aluminum smelting industry. In this final report, the design, development, fabrication, and installation of a full-scale FBWHR system is detailed.

28 (DOE/ID/12303-4) **Fluidized bed waste heat recovery system: Annual report March 1, 1984-February 28, 1985.** Aerojet Energy Conversion Co., Rancho Cordova, CA (USA). Jul 1985. 82p. DOE Contract FC07-81ID12303. Order Number DE89002083. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

The continuing Fluid Bed Waste Heat Recovery System (FBWHRs) development progress is reported covering a twelve-month period from March 1984 through February 1985. During this period the advanced, self-cleaning waste heat boiler was constructed, shipped to the test site at Melting Furnace No. 34, ALCOA, Massena, New York, installed and operated. Hot (2200°F), dirty, aluminum melter waste stack gas is used by the FBWHRs to generate plant steam. Several development problems were encountered and overcome. Checkout and development testing per the Test Plan was completed through commissioning and the seven month Evaluation Test was started which is scheduled for completion on 2 September 1985. Operation of the FBWHRs by ALCOA is expected to continue for many years. Four flue gas corrosion and fouling probes were used to characterize the relative corrosion susceptibility of ten selected metal alloys in the same No. 34 Melter flue gas flow. These four probes inserted into the aluminum melter flue were maintained by controlled air cooling at constant respective temperatures of 1100°F, 900°F, 700°F, and 500°F. A Bench Scale (1/30 scale) Test Unit was also fabricated, shipped to Aerojet (Sacramento, California) Test Area "A" and installed. Testing proceeded per the Bench Scale Test Plan through 1100°, 1400°, and finally 1600°F Bench Scale tests. A fouling probe for characterizing the high temperature exhaust gas generated by the Bench Scale burner operating on No. 6 fuel with and without Arol 456SV fuel additive was also provided. 10 refs., 40 figs., 12 tabs.

29 (DOE/ID/12535-1) **R and D Ceramic Tubular Distributor Plate for advanced FBHX. Phase I contract final report, 1 September 1984-30 May 1985.** Hoffman, L.C.; Kreeger, A.H.; Williams, H.W. Aerojet Energy Conversion Co., Rancho Cordova, CA (USA). Aug 1985. 128p. DOE Contract AC07-84ID12535. Order Number DE86004140. Source: NTIS, PC A07/MF A01; GPO Dep.

Aerojet Energy Conversion Company has investigated the use of a Ceramic Tubular Distributor Plate (CTDP) for waste heat recovery. Fluid bed waste heat recovery system (FBWHRs) performance is greatly improved by avoiding dilution

for inlet gas temperature reduction. A CTDp and special refractory inlet plenum make it practical to introduce undiluted 2500°F flue gas directly into the FBWHRs. The engineering definition phase work is reported herein; the work includes methodical selection of the ceramic parts configuration, means for preventing build-up of foulant, refractory inlet plenum and freeboard structures. This Phase I work included an economic (Simple Payback) analysis with projected costs of CTDp manufacturing in production quantities. A Simple Payback of 13 months is projected, which is a 19% improvement over a FBHX with a conventional distributor plate. A Phase II program is defined which takes the CTDp development through Bench Scale testing.

30 (DOE/ID/12535-2) **R and D ceramic tubular distributor plate for advanced FBHX [fluid bed heat exchangers]: Phase 2 contract final report, October 1, 1985-June 30, 1987.** Aerojet Energy Conversion Co., Rancho Cordova, CA (USA). Aug 1987. 219p. DOE Contract AC07-84ID12535. Order Number DE88016673. Source: NTIS, PC A10/MF A01; GPO Dep.

Aerojet Energy Conversion Company has developed a Ceramic Tubular Distributor Plate (CTDP) for waste heat recovery fluid bed heat exchangers (FBHX). Fluid bed waste heat recovery system (FBWHRs) performance is greatly improved by avoiding air dilution for inlet gas temperature reduction. A CTDp and special refractory inlet plenum make it practical to introduce undiluted 2500°F flue gas directly into the FBWHRs. The configuration of the CTDp was actually an assembly of 0.406 inch diameter solid rods of 99+% alumina with 0.010 inch nominal spacing to form the orifice-slots. The engineering design, lab scale development, bench scale cold flow development, and cold flow testing preceded successful combustion gas testing with No. 2 Fuel Oil. Extensive testing progressed through two special CTDp buildups with excellent heat transfer and pressure loss data obtained at 1100°, 1600°, 1900°, 2200°, and 2500°F. Structural limitations in the distributor plate configuration were identified and apparently resolved, although final validation of the durability of the design has not yet been completed. Si₃N₄ hot gas lance for cleaning and fouling prevention was readied for combustion development testing. An economic (Simple Payback) analysis based on projected costs of CTDp manufacturing in production quantities was completed. The simple payback for the CTDp system is projected to be a 22% improvement over a FBHX with a conventional metallic distributor plate. The economic analysis was applied on aluminum remelt furnaces

31 (DOE/ID/12566-2) **Assessment of strength limiting flaws in ceramic heat exchanger components: Phase 2 midcontract summary report, December 4, 1986-November 30, 1987.** Bower, J.R. Babcock and Wilcox Co., Lynchburg, VA (USA). Research and Development Div. Dec 1987. 31p. DOE Contract AC07-84ID12566. Order Number DE88013691. Source: NTIS, PC A03/MF A01; GPO Dep.

Advanced ceramic materials are attractive for use in environments that are too hostile for metals. Unfortunately, acceptance of ceramics in these applications has been limited because ceramics are subject to sudden failure by brittle fracture. The goal of this program is to produce acceptance criteria and appropriate verification tests for one specific component: ceramic heat exchanger tubes. The program has three major parts; NonDestructive Examination (NDE), Linear Elastic Fracture Mechanics (LEFM), and Destructive Testing (DT). Because ceramics are subject to

brittle fracture, the assessment of materials for conditions that could lead to failure is vital. This is the task of NDE. Acceptance criteria must be based on a model that can predict tube lifetime, given operating conditions, material characteristics, and possible flaws present. This is the task of LEFM. NDE examination results need to be compared to failure test results, and LEFM requires test data to create and verify the fracture model. This is the task of DT.

32 (DOE/ID/12566-T1) **Assessment of strength limiting flaws in ceramic heat exchanger components: Phase 1, Final report, September 28, 1984-June 30, 1986.** Powers, T.; Snyder, J. Babcock and Wilcox Co., Lynchburg, VA (USA). Lynchburg Research Center. Oct 1986. 165p. DOE Contract AC07-84ID12566. Order Number DE88004025. Source: NTIS, PC A08/MF A01; GPO Dep.

Assurance of energy efficient design lifetimes of high temperature structural ceramics requires the ability to specify acceptance criteria and to test to those criteria. These criteria will be established through nondestructive testing, to determine which defects are detectable, together with fracture mechanics, to calculate effects of undetectable flaws. The first phase of this program is to examine heat exchanger material with four test methods which have shown promise for use in ceramics; ultrasonic scanning, microfocus x-ray, Scanning Laser Acoustic Microscope, and Acoustic Holography. The capabilities, limits, and potential for improvement of these are presented in this report. Destructive testing, material sectioning, and fractography are included. 24 refs., 68 figs., 6 tabs.

33 (DOE/ID/12772-1) **Evaluation of commercial enhanced tubes in pool boiling: Topical report.** Jung, C. (Rensselaer Polytechnic Inst., Troy, NY (USA)); Bergles, A.E. Rensselaer Polytechnic Inst., Troy, NY (USA). Mar 1989. 135p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-88ID12772. Order Number DE89009028. Source: NTIS, PC A07/MF A01 - OSTI; GPO Dep.

In support of a study of shellside boiling with enhanced tubes, a pool boiling apparatus was developed and used to test single tubes with various structured boiling surfaces in R-113. The basic design of the tube-bundle test section was carried out and certain critical design features were tested experimentally. Copper tubes, 3/4 in. o.d. and 4 in. long, were selected with 1/4 in. diameter cartridge heaters. Four thermocouples were inserted in 3/32 in. diameter, 2 in. long holes. The pool boiling characteristics of a plain tube agree well with previous tests. Wolverine Turbo-B tubes with small, medium, and large features performed identically for a heat flux greater than 20 kW/m². For lower heat flux, however, the Turbo-B S was slightly superior. In general, the Wolverine Turbo-B tubes had more favorable boiling characteristics than the single Wieland Gewa-T tube that was tested. The test procedure is deemed entirely adequate for screening enhanced tubes to see which ones should be used in the tube-bundle test section. Three different ways of mounting the tubes were tested in R-113 at 65°C and 5 bar gage pressure. As all three constructions sealed well, the simplest design is recommended in which a snap ring fixes the tube to the wall and an O-ring seals against the pressure. The general design features of the tube bundle test chamber are also presented. 14 refs.

34 (EGG-CS-5328) **Potential industrial applications for direct contact waste heat recuperator systems. Final report.** Semler, T.T.; Hansen, E.J.; Richlen, S.L. EG

and G Idaho, Inc., Idaho Falls (USA). Feb 1981. 216p. DOE Contract AC07-76ID01570. Source: NTIS, PC A10/MF A01.

A study of the potential industrial applications of direct contact waste heat recuperator systems has been conducted. This study examines the prospects for the use of direct contact waste heat recuperator systems in the major energy consuming industries excluding only the petroleum and chemical industries. Four potential applications have been chosen for economic analysis. They are: (a) stack gas from diesel electric generation, (b) boiler stack gas, (c) waste heat stream from the hydraulic cement dry process dryer, and (d) stack gas from the fire polishing of glass. The waste heat streams studied ranged from 175 to 750°F. A physical analogue of the direct contact waste heat recuperator system has been devised and used for costing purposes. Payback calculations are performed for these applications. Only the stack gas from the fire polishing of glass failed to show significant economic promise. A waste heat stream regime of greater than 10,000 cfm and between 400 and 750°F has been identified as most economically promising for direct contact waste heat recuperation and hot process water delivery.

35 (EGG-CS-5747) **Reradiant recuperator tests.** Richlen, S.L. EG and G Idaho, Inc., Idaho Falls (USA). Mar 1982. 103p. DOE Contract AC07-76ID01570. Order Number DE82012201. Source: NTIS, PC A06/MF A01.

Recuperator tests were conducted at the Alabama Reclamation Plant. During these tests, data were recorded from a radiant recuperator mounted on an aluminum remelt furnace. Two configurations of the recuperator were operated during data collection. During one test, data were collected from the recuperator with a reradiant insert installed. During a second test, the configuration of the recuperator was changed by removal of the insert and no data were collected immediately. About one week later, data were then collected from the recuperator without the reradiant insert. From this data and additional theoretical analysis, it was concluded that the reradiant insert increases the effectiveness of a conventional radiant recuperator and that the increase is relatively insensitive to variations in operating parameters. For the particular recuperator tested, the measured increase in effectiveness due to the reradiant insert was approximately 6%.

36 (EGG-M-36387) **Field testing of a ceramic heat exchanger for heat recovery application.** Sohal, M.S. EG and G Idaho, Inc., Idaho Falls, ID (USA). [1988]. 29p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-76ID01570 ;FC07-81ID12170. (CONF-880724-29: 25. American Society of Mechanical Engineers/American Institute of Chemical Engineers/American Nuclear Society national heat transfer conference, Houston, TX (USA), 24-27 Jul 1988). Order Number DE90002082. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

AiResearch Company, Torrance, California, developed a 5 MMBtu/hr ceramic-metallic hybrid High Temperature Burner-Duct-Recuperator (HTBDR) system to recover energy from hot (up to 2500°F), dirty, and corrosive glue gas streams and preheat combustion air up to 2000°F. To reduce the cost and size of the ceramic recuperator, ceramic tubes with internal cruciform baffles were developed. The HTBDR system was tested on a 20 MMBtu/hr rotary forging furnace for about 2000 hours. To facilitate tube replacements, final design configuration uses horizontally mounted tubes. A maximum air preheat temperature of about 1916°F was

achieved with a flue gas temperature of 2122°F. This represents fuel savings of about 30 to 50 percent (depending upon the amount of excess air) compared with an unrecuperated furnace. The overall design and operation of the recuperator proved to be successful up to the time of material failure. X-ray diffraction of some failed components indicated that there was some residual Silicon in the interior regions and complete nitriding did not occur during the fabrication process. Degradation of failed components was probably caused by oxidation of residual Silicon and by the stresses caused due to different coefficient of thermal expansion of various compounds during thermal cycling. A combination of severe and numerous thermal cycling coupled with incomplete nitriding was the most likely cause of material failure. 22 refs., 12 figs., 4 tabs.

37 (EGG-M-89039) **Waste heat recovery.** Harkins, B.D. (Solar Turbines, Inc., San Diego, CA (USA)); Ward, M.E. EG and G Idaho, Inc., Idaho Falls, ID (USA); Solar Turbines, Inc., San Diego, CA (USA). [1989]. 16p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-76ID01570 ;FC07-88ID12799. (CONF-891208-15: Winter annual meeting of the American Society of Mechanical Engineers, San Francisco, CA (USA), 10-15 Dec 1989). Order Number DE89016359. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Solar Turbines Incorporated (Solar) is currently participating with the Department of Energy (DOE, Idaho) to develop a High Pressure Heat Exchange System (HiPHES), capable of heating compressed air, 1034 KPa abs (150 psia) to a temperature of 871°C (1600°F). The operating environment for the air heater will be a hazardous waste incinerator with a gas stream temperatures in excess of 1260°C (2300°F). The air heater being design for this project is modular and composed of monolithic and composite ceramics components. The HiPHES air heater being developed by Solar will be integrated into an indirectly heated gas turbine cycle as a method of generating electric power from waste heat gas stream. A project overview is presented, with an emphasis on ceramic component design. 7 refs., 15 figs., 5 tabs.

38 (EGG-SE-6349) **High-temperature waste-heat-stream selection and characterization.** Wikoff, P.M.; Wiggins, D.J.; Tallman, R.L.; Forkel, C.E. EG and G Idaho, Inc., Idaho Falls (USA). Aug 1983. 79p. DOE Contract AC07-76ID01570. Order Number DE83016987. Source: NTIS, PC A05/MF A01.

Four types of industrial high-temperature, corrosive waste heat streams are selected that could yield significant energy savings if improved heat recovery systems were available. These waste heat streams are the flue gases from steel soaking pits, steel reheat furnaces, aluminum remelt furnaces, and glass melting furnaces. Available information on the temperature, pressure, flow, and composition of these flue gases is given. Also reviewed are analyses of corrosion products and fouling deposits resulting from the interaction of these flue gases with materials in flues and heat recovery systems.

39 (EGG-SE-6534) **Evaluation of selected advanced heat exchangers for waste heat recuperation of high temperature streams.** Bliem, C.; Kochan, R.; Mittl, J.; Piscitella, R.; Schafer, J.; Snyder, A.; Wiggins, D.; Zabriskie, J. EG and G Idaho, Inc., Idaho Falls (USA). Feb 1984. 246p. DOE Contract AC07-76ID01570. Order Number DE84016299. Source: NTIS, PC A11/MF A01; GPO Dep.

This document discusses the design, functional and cost requirements for high-temperature, heat recovery systems (recuperators) and describes the state-of-the-art systems, emerging industrial technologies and new concepts developed by EG and G Idaho, Inc. All systems concepts are then evaluated and compared with respect to corrosion, durability, fouling, performance, operation and maintenance, and economics.

40 (ORNL/TM-6227) **Recuperator materials technology assessment.** Tennery, V.J.; Wei, G.C. Oak Ridge National Lab., TN (USA). Feb 1978. 73p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A04/MF A01.

Recuperators are heat exchangers for recovering waste heat from hot flue gases for preheating combustion air or low-joule gases. This report is the result of an assessment of recuperator materials technology conducted between January and August 1977, and includes both metals and ceramics. Creep, corrosion, and oxidation properties of available alloys limit the maximum metal partition temperature to about 980°C. Use of metallic recuperators with higher flue gas temperatures necessitates design for radiation heat transfer and parallel flow of the gas streams. Use of ceramics in recuperator construction could permit the design of recuperators capable of operating with partition temperatures well above the 980°C limit for available alloys and in a gas flow mode able to remove more of the available heat from the waste gas stream. Siliconized and recrystallized types of silicon carbide have shown promising initial results for tubular heat exchanger application. Few data of this nature exist for other candidate ceramic materials. Extended-surface ceramic structures offer promise for use in constructing compact high-temperature recuperators if leakage, fouling, and fabrication costs can be controlled. Fabrication costs of candidate ceramic recuperator materials, their brittleness, their sensitivity to thermal shock fracture, the lack of adequate shop and field joining and repair techniques, generally inadequate nondestructive examination techniques, and the lack of appropriate specifications for structural ceramics for use in recuperators and other heat exchangers were all identified during this assessment as major impediments to more serious consideration of ceramics. 12 figs., 3 tables. (DLC)

41 (ORNL/TM-6794) **Analysis of a cordierite (MAS) recuperator from a molybdenum heat-treating furnace.** Weber, G.W.; Tennery, V.J. Oak Ridge National Lab., TN (USA). May 1979. 48p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A03/MF A01.

Recuperators which can transfer waste heat from industrial furnaces to the combustion air can result in fuel conservation. Available alloys cannot currently satisfy the demand for higher thermodynamic efficiencies from higher temperature recuperated combustion air because of their properties at high temperatures. Therefore, selected ceramic materials are principal candidates for use in waste-heat recovery devices for flue gas temperatures of 1100 to 1650°C. A leading configuration now under investigation is the cross-flow fixed-boundary extended-surface ceramic honeycomb heat exchanger. The need for a material that has both low thermal expansion and high thermal shock resistance and is also fabricable and relatively inexpensive has led to the development of cordierite (magnesium aluminosilicate - MAS). A cordierite honeycomb recuperator was exposed for about 2200 h to representative process temperatures from 1100 to 1650°C in a molybdenum and tungsten reheating furnace. This recuperator performed satisfactorily

for test and exhaust inlet temperatures of 1100 to 1400°C. Electron microprobe and ceramographic examination demonstrated that molybdenum and tungsten carryover in the waste gas stream significantly penetrated the cordierite at temperatures as low as 675°C. The leading edges of the exhaust inlet section showed significant microstructural modification. A subsequent accidental overfiring to 1560°C resulted in slumping of this modified material. Exhaust-to-air channel leakage caused deposits in air channels and modified the microstructure in bonding lines between layers in the honeycomb. Cracking also occurred in the air outlet section. Significant microstructural modification, including coarsening within the walls and glass formation on the air-channel wall surfaces, was observed.

42 (ORNL/TM-6970) **Materials analyses of ceramics for glass furnace recuperators.** Weber, G.W.; Tennery, V.J. Oak Ridge National Lab., TN (USA). Nov 1979. 115p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A06/MF A01.

The use of waste heat recuperation systems offers significant promise for meaningful energy conservation in the process heat industries. This report details the analysis of candidate ceramic recuperator materials exposed to simulated industrial glass furnace hot flue gas environments. Several candidate structural ceramic materials including various types of silicon carbide, several grades of alumina, mullite, cordierite, and silicon nitride were exposed to high-temperature flue gas atmospheres from specially constructed day tank furnaces. Furnace charging, operation, and batch composition were selected to closely simulate industrial practice. Material samples were exposed in flues both with and without glass batch in the furnace for times up to 116 d at temperatures from 1150 to 1550°C (2100 to 2800°F). Exposed materials were examined by optical microscopy, scanning electron microscopy, energy dispersive x-ray analysis, x-ray diffraction, and x-ray fluorescence to identify material degradation mechanisms. The materials observations were summarized as: Silicon carbide exhibited enhanced corrosion at lower temperatures (1150°C) when alkalis were deposited on the carbide from the flue gas and less corrosion at higher temperatures (1550°C) when alkalis were not deposited on the carbide; alumina corrosion depended strongly upon purity and density and alumina contents less than 99.8% were unsatisfactory above 1400°C; and mullite and cordierite are generally unacceptable for application in soda-lime glass melting environments at temperatures above 1100°C.

43 (ORNL/TM-7166) **Corrosion of a stainless steel waste heat recuperator.** Federer, J.L.; Tennery, V.J. Oak Ridge National Lab., TN (USA). Jun 1980. 41p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A03/MF A01.

Waste heat recuperation has significant potential for saving energy in fossil-fuel-fired industrial furnaces. Preheating the air used to burn the fuel can significantly reduce fuel consumption. The US Department of Energy is contracting several high-temperature waste heat recuperation demonstrations with the objective of using successful efforts to stimulate the industrial utilization of these devices. One of the recuperator demonstration contracts has as an objective the successful operation of a concentric-shell radiation recuperator of a new design on aluminum-scrap-remelting furnaces. The design employs type 309 stainless steel radiant inserts within the type 309 stainless steel inner shell to increase heat radiation to the recuperator partition, thereby

increasing the heat exchanger's effectiveness. The first demonstration recuperator in this program was installed on a furnace fired with No. 2 oil and melting about 60 Mg (66 tons) of aluminum per 24-h day. The unit operated for about 30 d and provided air to the burner at 540°C. during this period, a burner control misoperation provided very fuel-rich gases to the base of the recuperator. This fuel combined with safety dilution air at the recuperator base and burned within the recuperator. Also, during this period, air flow loss was detected at the burner. An inspection revealed that this was caused by failure of the partition wall separating the primary and secondary sides of the recuperator. Extensive corrosion of the partition wall and radiant inserts was also observed. The recuperator was removed from the furnace for an analysis of the failure.

44 (ORNL/TM-7306) Technology assessment of ceramic joining applicable to heat exchangers. Brassell, G.W.; Tenny, V.J. Oak Ridge National Lab., TN (USA). Jul 1980. 31p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A03/MF A01.

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As our energy resources become depleted the need for improved energy utilization and conservation becomes increasingly important. Methods of industrial energy conservation presently being explored are waste-heat recuperation and use of high-temperature gas turbines. Recuperators and other heat exchangers that require the use of high-temperature alloys, ceramics, and joining systems include units designed for isolating high-temperature gas turbines from contaminated combustion gases and for recovering waste heat from hot flue gases for preheating combustion air or low-joule gases. Although joining alloys and ceramics to similar and dissimilar materials has received considerable attention in the past decade, most emphasis has been placed on electronic applications having little or no strength and thermal stability requirements in contrast to the very stringent strength and thermal stability requirements of the interfacial joining materials in advanced heat exchanger applications. Thus, we have assessed the joining-bonding technology applicable to high-temperature heat exchangers to identify the status of the ceramic materials joining technology and to determine needs for future research and development. This study, supported by the Electric Power Research Institute, was accomplished through meetings and discussions with personnel in ceramic and electronic firms and with firms conversant with sophisticated heat exchanger technology and through an extensive review of the literature.

45 (ORNL/TM-7553) Analysis of a corroded stainless steel recuperator used on a glass melting furnace. Federer, J.I.; Tenny, V.J. Oak Ridge National Lab., TN (USA). Nov 1980. 29p. DOE Contract W-7405-ENG-26. Source: NTIS, PC A03/MF A01.

A recuperator installed on a natural gas-fired glass melting furnace recovered heat from flue gases to preheat combustion air for the gas burner. The recuperator, which was constructed of type 321 stainless steel, supplied combustion air at about 500°C for about 5760 h (eight months). Although some corrosion of the partition wall in contact with the flue gases was noted during the early weeks of operation, the recuperator continued to supply preheated air at near design temperature throughout the campaign. The partition wall had a 1.5-mm-thick corrosion product consisting of oxides and possible sulfides, and the alloy exhibited a region of grain boundary attack. The thickness of the corrosion product far exceeded that predicted by assuming that

only oxidation occurred at the indicated temperature of 650°C. It was concluded that accelerated corrosion was caused by a sulfidation-oxidation mechanism resulting from carry-over of a sulfur-bearing compound from the glass batch and the fuel.

46 (ORNL/TM-8429) Thermal analysis and air leakage evaluation of a typical container-glass furnace regenerator with a Brayton cycle heat recovery system. Llewellyn, G.H.; Wei, G.C. Oak Ridge National Lab., TN (USA). Nov 1982. 75p. DOE Contract W-7405-ENG-26. Order Number DE83002591. Source: NTIS, PC A05/MF A01.

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A thermal analysis was performed on a typical container-glass furnace regenerator model with a transient heat conduction computer program (HEATING6). The boundary conditions for the two-dimensional checker model were obtained from the Glass Furnace and Regenerator Thermal Analysis Computer Program (GFURN). The objective of these studies was to verify the capability of typical checker bricks for service in a glass furnace regenerator with air pre-heat associated with a Brayton cycle heat recovery system and to determine the effects of air leakage on the system performance. Preliminary calculations indicated that refractory brick upgrading would not be required, although the bricks will be operating at elevated temperatures but well within the allowable temperature ranges. The effects of air leakage in the regenerator, flue, and reversing valve on Brayton cycle heat recovery were evaluated by experimental measurements of air infiltration profiles in two furnace systems, by obtaining data from glass manufacturers, and by computer simulation with GFURN program. Air infiltration in the regenerator typically ranges from 10 to 45%, and air leakage in the reversing valve ranges from 3 to 20%, depending on the operating characteristics, quality of maintenance, and age of the furnace system. The power output of a properly designed Brayton system is relatively insensitive to air infiltration in a typical glass furnace exhaust system having a total leakage of no more than 55%.

47 (ORNL/TM-8819) Corrosion of fluidized-bed boiler materials in synthetic flue gas. Federer, J.I. Oak Ridge National Lab., TN (USA). Nov 1983. 37p. DOE Contract W-7405-ENG-26. Order Number DE84002998. Source: NTIS, PC A03/MF A01.

Candidate materials for components of a fluidized-bed waste heat recovery system (FBWHRS) include plain carbon steel, types 405 and 316 stainless steel, and alloy 800. These materials were exposed to synthetic flue gas at anticipated FBWHRS temperatures and higher for 3000 h to determine corrosion rates. The synthetic flue gas was a combustion atmosphere to which Cl₂ and HCl were added. The projected annual corrosion rate for plain carbon steel is about 0.08 mm/year (0.003 in./year) at 250 to 290°C, but it would exceed 0.5 mm/year (0.02 in./year) at 560°C. The projected annual corrosion rates of the other materials were less than 0.25 mm/year (0.01 in./year) at the maximum test temperatures of 560, 660, and 665°C for type 405, type 316, and alloy 800, respectively. These results indicate that corrosion of candidate FBWHRS materials will not be significant at anticipated operating temperatures for various components unless other factors, not included in this study, cause accelerated corrosion.

48 (ORNL/TM-9677) Analysis of candidate silicon carbide recuperator materials exposed to industrial furnace environments. Federer, J.I.; Tiegs, T.N.; Kotchick,

D.M.; Petrak, D. Oak Ridge National Lab., TN (USA). Jul 1985. 63p. DOE Contract AC05-84OR21400. Order Number DE85018176. Source: NTIS, PC A04/MF A01; GPO Dep.

Several SiC ceramics were exposed to the combustion environment in six industrial furnaces to determine their corrosion resistance. The materials were sintered- α (Hexoloy SA), Sintride, recrystallized (NC-400), CVD SiC coated NC-400, siliconized (NC-430), reaction sintered (SC-X and KT), and Si_3N_4 -bonded (C/75 and CN-178). Tubes of these materials were exposed in two aluminum remelt furnaces, a forge furnace, a steel reheat furnace, and two steel soaking pits at temperatures of 925 to 1250°C for periods of 530 to 5545 h. Significant corrosion occurred in specimens exposed to aluminum remelt furnaces and one of the steel soaking pits, whereas corrosion in the other furnaces was substantially less or negligible. The average C-ring fracture strengths of Hexoloy SA and NC-430, the only materials so tested, were substantially affected by the exposures. The lowest strength in Hexoloy SA occurred in specimens exposed in an aluminum remelt furnace, while the lowest strength in NC-430 occurred in specimens exposed in a steel soaking pit. These results show that SiC ceramics are susceptible to both corrosion and strength degradation when exposed to certain furnace environments.

49 (ORNL/TM-10606) **An investigation of ceramic coatings for protection of SiC from high-temperature corrosion.** Federer, J.I. Oak Ridge National Lab., TN (USA). Feb 1988. 46p. DOE Contract AC05-84OR21400. Order Number DE88007873. Source: NTIS, PC A03/MF A01; GPO Dep.

Silicon carbide (SiC) ceramics are susceptible to corrosion by certain industrial furnace environments. This behavior would limit the use of SiC components in ceramic heat exchangers. Because oxide ceramics corrode substantially less in the same environments, ceramic coatings have been investigated for corrosion protection. Coatings with Al_2O_3 , SiO_2 , or ZrO_2 as the main constituent were applied to sintered α and recrystallized (CS101) SiC substrates. The coated specimens were thermally cycled between room temperature and 1200°C as a test of adherence. Some coatings adhered better to the inherently rougher CS101 SiC; however, most coatings did not adhere to either substrate. Two Al_2O_3 -based coatings developed cracks but remained intact during thermal cycling, and two ZrO_2 -based coatings were adherent without cracks. These four coatings were subjected to corrosion testing at 1200°C in an oxidizing atmosphere containing Na_2CO_3 . None of these four coatings exhibited the desired corrosion resistance in this test. Coated samples, however, corroded less than an uncoated sample, indicating that coatings can improve corrosion resistance. 19 figs., 7 tabs.

50 (ORNL/TM-11029) **High-temperature corrosion of metallic alloys in an oxidizing atmosphere containing NaCl.** Federer, J.I. Oak Ridge National Lab., TN (USA). Feb 1989. 35p. DOE Contract AC05-84OR21400. Order Number DE89010309. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

A particular heat-exchanger application involved metallic alloys exposed to flue gases of an aluminum remelt furnace. Because the flue gases might contain NaCl and other halides, the corrosion behavior of the alloys was to be investigated. Planned direct exposure of candidate alloys to the flue gases, however, was not conducted because of premature termination of the project. Complementary laboratory testing was conducted on seven commercially available

alloys and two nickel aluminides. These materials were exposed to an oxidizing atmosphere containing 0.06 wt % NaCl for 1100 h at 1000°C. Most of the alloy exhibited grain-boundary attack, which resulted in complete oxidation of enveloped grains. The alloys Incoloy MA-956, Incoloy 800, Inconel 625, Inconel 601, Hastelloy X, Haynes 188, and nickel aluminide IC-50 were substantially more corroded than Alloy 214 and nickel aluminide IC-221. The latter two alloys, therefore, would probably be superior to the others in application involving flue gases containing NaCl. Strength fabricability, and weldability, which are briefly discussed, would also affect selection of materials. 8 refs., 12 figs., 5 tabs.

51 **High temperature behavior of pressureless-sintered SiC in a steel soaking pit environment.** Wei, G.C. (Oak Ridge National Lab., TN); White, C.L. *American Ceramic Society Bulletin (USA)*, 63(7): 890-893 (Jul 1984). DOE Contract W-7405-ENG-26.

Sintered- α SiC was exposed for about 800 h at about 1250°C to a steel soaking pit environment. A slag layer consisting of hematite and low cristobalite in an Fe-K-Ca silicate glass matrix was formed on the external surface of sintered- α SiC. No measurable corrosion or loss of material was observed. Large angular pores and depletion of graphite sintering aid, observed in the surface region of the as-received material, resulted in a lower-than-usual fracture strength. The fracture strength increased slightly following the exposure. Auger electron spectroscopic analysis identified oxygen penetration in the near-surface region of the exposed material. The results suggested that sintered- α SiC would be suitable for use as a heat exchanger material in steel soaking pits. 8 references, 8 figures, 1 table.

Industrial Heat Pumps

Refer also to citation(s) 328

52 (CONF-880702-13) **Magnetic heat pumps.** Hull, J.R.; Uherka, K.L. Argonne National Lab., IL (USA). 1988. 28p. DOE Contract W-31-109-ENG-38. From 23. intersociety energy conversion engineering conference; Denver, CO, US; July 31, 1988. Order Number DE88012058. Source: NTIS, PC A03/MF A01; GPO Dep.

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Magnetic heat pumps and refrigerators are potential replacements for vapor-compression devices that use chlorofluorocarbon refrigerants. Several room-temperature designs, using low-temperature superconducting magnets, have reached the experimental device stage. High-temperature superconducting materials may significantly increase the viability of the technology, both by enhancing existing design concepts and by enabling new major design types such as field switching of the superconducting magnets.

53 (CONF-891208-7) **Recent advances in magnetic heat pump technology.** Uherka, K.L. (Argonne National Lab., IL (USA)); Hull, J.R.; Scheihing, P.E. Argonne National Lab., IL (USA). [1989]. 20p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. From Winter annual meeting of the American Society of Mechanical Engineers; San Francisco, CA (USA); 10-15 Dec 1989. Order Number DE89013289. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Magnetic heat pump (MHP)/refrigeration systems, incorporating state-of-the-art superconducting magnet technology, have been assessed for industrial applications ranging from the liquefaction of gases (20°K to 100°K range) to cold storage refrigeration for food preservation (250°K to 320°K range). Initial market penetration of MHP technology is anticipated to occur in the gas liquefaction sector, since the performance advantages of magnetic refrigeration cycles relative to gas compression cycles and other conventional systems are more pronounced in the lower temperature ranges. Design options for rotary MHP devices include alternative regeneration schemes to obtain the temperature spans necessary for industrial applications. The results of preliminary design assessment studies indicate that active magnetic regenerator concepts, in which the magnetic working material also serves as the regenerative medium, offer advantages over alternative MHP designs for industrial applications. 20 refs., 2 figs.

54 (DOE/CS/40033-T5) **Technology-impact study of the MTI high-efficiency industrial heat pump. Draft report.** Sullivan, D. Hittman Associates, Inc., Columbia, MD (USA). Mar 1979. 111p. DOE Contract AC01-78CS40033. (H-C-193-009-79-776D). Order Number DE84000144. Source: NTIS, PC A06/MF A01.

An analysis of a high-efficiency industrial heat pump which uses waste heat both as a heat source for the pump and to produce mechanical work which powers the entire system is presented. The heat pump is designed to recover industrial waste heat at approximately 200°F and to produce low-pressure steam. The overall heat flows through the system are shown. The basic findings of this study are: The system is feasible on technical grounds and does result in substantial energy savings where it can be used. System performance is highly dependent on the temperature of the waste heat available and the pressure at which steam is produced. The profitability of the prototype system is marginal at present although higher future fuel costs will increase the benefits of the device. Also, the case study installation has an exceptionally high first cost due to complicated piping and valving requirements. The system has the potential to save approximately 3 to 5 percent of total industrial energy nationally.

55 (DOE/CS/40262-T1(Vol.1)) **Development of a high-temperature heat pump grain dryer: Volume I. Main body. Final report, September 6, 1979-September 30, 1981.** Hogan, M.R.; Ayers, D.L.; Foster, G.H.; Doering, O.C.; Hawks, K.H. Westinghouse Electric Corp., West Lafayette, IN (USA). Fluid Systems Lab. 1981. 301p. DOE Contract AC01-79CS40262. Order Number DE82012417. Source: NTIS, PC A14/MF A01.

The objective of this work was to develop and test an electrically-driven, high-temperature heat pump grain dryer of a marketable capacity. An economic evaluation of heat pump grain drying was also conducted. The philosophy and constraints which guided the system design are given. A 60-kW maximum electrical demand is the most significant of these and required that the system air cycle be investigated thoroughly. This air cycle analysis and the subsequent results are reported in detail. Selection of the dryer volume, system configuration, and the heat pump design conditions are all affected by the analysis; this too is reported. Each step in the design process, including motor cooling, cold start-up, return air temperature stabilization, system control, and refrigerant distribution and control considerations, is

documented. Field test procedures and equipment, data acquisition, and data reduction methods are documented. The results of the field test are divided into steady state performance and transient performance - the former describes the tests in terms of averaged data and the latter uses temporal comparisons to explain certain observations. The economic analysis is based on life cycle costs and accounts for such parameters as weather, variable energy costs, inflation, and the cost of capital. To put the results into perspective, the life cycle costs of current competitive drying systems are determined and compared to the heat pump. It is concluded that high-temperature heat pump grain drying is technically feasible. Moreover, its on-site energy consumption is from one-third to one-fifth that of liquefied petroleum gas dryers. However, under current and projected economic conditions, the energy savings do not justify the additional capital investment. Consequently, high-temperature heat pump grain drying is concluded to be uneconomical.

56 (DOE/CS/40262-T1-Vol.2) **Development of a high-temperature heat pump grain dryer: Volume II. Appendices. Final report, September 6, 1979-September 30, 1981.** Hogan, M.R.; Ayers, D.L.; Foster, G.H. Westinghouse Electric Corp., West Lafayette, IN (USA). Fluid Systems Lab. 1981. 97p. DOE Contract AC01-79CS40262. Order Number DE82012406. Source: NTIS, PC A05/MF A01.

Appendices are presented to a program designated to design, fabricate, and test a high-temperature, continuous-flow, electrically-driven heat pump grain dryer as an alternative to conventional LPG-fueled units. Detailed information in the appendices include: heat pump design computer program related data; data reduction program listing; drying system specifications and performance information pertinent to the economic analysis; and equipment specification and cost. (MCW)

57 (DOE/CS/40327-2) **Development and demonstration of an electric heat pump for waste heat recovery in industry. System design and test results. Final report.** Moreland, W.C.; Wolfe, R.W. Westinghouse Research and Development Center, Pittsburgh, PA (USA). Feb 1986. 463p. DOE Contract AC07-77CS40327. Order Number DE86014908. Source: NTIS, PC A20/MF A01; GPO Dep.

This report details the design of a prototypical unit planned for the recovery of heat from the vapor effluent of a thermomechanical pulping line in a paper mill. A functional and operational description of the heat pump system is given along with a thermodynamic analysis of the cycle. The various subsystems, controls, and major components are also described and an engineering justification for their selection presented. The computer programs used for determining design performance and in data reduction are included as are the thermodynamic property tables for the working fluid (methanol). Test results showing performance capability over a range of operating conditions are also given as are the results of a short endurance run. These results show that the system performed close to design predictions. At a waste steam pressure of 10 psig the measured output capacity of the unit is 33,000 pounds per hour of 63 psig steam with 20°F superheated at a COP of 4.6.

58 (DOE/CS/40327-T1) **Development and demonstration of an electric heat pump for waste-heat recovery in industry. Topical report No. 2. Design and analysis report.** Moreland, W.C.; Eder, J.S.; Wolfe, R.W. Westinghouse Electric Corp., Pittsburgh, PA (USA). Research and Development Center. 30 Mar 1981. 160p. DOE

Contract AC01-77CS40327. Order Number DE81028751. Source: NTIS, PC A08/MF A01.

Development of a high temperature heat pump for demonstration of waste heat recovery in industry is described. This report outlines the design of a prototypical unit to be used to recover heat from the vapor effluent of a thermomechanical pulping unit in a paper mill. The output capacity of the unit is 30×10^6 Btu/h in the form of process steam delivered at 50 psig with 20°F superheat (318°F). A functional description of the heat pump system is given along with a thermodynamic analysis of the cycle. The various subsystems, controls, and major components are also described and a safety analysis presented. The next step in the program is the procurement of components and fabrication of the heat pump and test loop. A general discussion of the important considerations involved when considering the application of a heat pump to an industrial process is given in Appendix A. Additional information presented in appendices includes an analysis of the hot gas by-pass and control of the intercooler; pressure drops in methanol piping and heat exchangers; and typical liquid nitrogen storage system information.

59 (DOE/CS/40327-T2-Vol.1) **Development of a low-temperature heat-pump grain dryer. Volume I: main body.** Hogan, M.R.; Ayers, D.L.; Schweizer, P.F.; Doering, O.C.; Foster, G.H. Westinghouse Electric Corp., West Lafayette, IN (USA). Fluid Systems Lab. Nov 1979. 244p. DOE Contract AC07-77CS40327. Order Number DE82018807. Source: NTIS, PC A11/MF A01.

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The development of a prototype low-temperature heat pump grain dryer is documented. Previous developmental work, embodied in a heat pump design code and a first generation heat pump dryer, is reviewed in the context of this research. The developed heat pump design philosophy is reported, and each pertinent step in the design process detailed, particularly the computer-generated sealed refrigerant system synthesis. A new, innovative technique for controlling evaporator frost, while maintaining continuous and efficient drying, is revealed. Also presented is a control system which surmounts the difficulties in heat pump operation imposed by an initially cold grain mass in the dryer volume. Fabrication of the developed heat pump dryer is also documented. Also included are details of a comparative field test of the prototype heat pump dryer and a commercial 24 kW electric resistance dryer. Field test instrumentation, preparation, and supervision are reported. Performance data, acquired during the field test, are presented and comparisons between the heat pump and resistance system are performed. Results of an economic analysis of heat pump grain drying as compared to current and contemplated drying alternatives are presented. Conclusions concerning the future viability of heat pump grain drying are drawn and discussed.

60 (DOE/CS/40327-T2-Vol.2) **Development of a low-temperature heat-pump grain dryer. Volume II: appendices.** Hogan, M.R.; Ayers, D.L.; Schweizer, P.F.; Doering, O.C.; Foster, G.H. Westinghouse Electric Corp., West Lafayette, IN (USA). Fluid Systems Lab. Nov 1979. 269p. DOE Contract AC07-77CS40327. Order Number DE82019844. Source: NTIS, PC A12/MF A01.

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Supporting information is given for the design, testing, and economic analysis of the heat pump grain dryer. The appendices include: heat pump design code sample input and output listing; performance and mechanical characteristics of the centrifugal fan selected for the heat pump grain

dryer; characteristics of the line of refrigerant compressors made available to the heat pump design code for selection; variable input data employed in the development of the low-temperature heat pump grain dryer and a compilation of the generated designs; heat pump and electric resistance dryer data reduction code listing; energy and material price forecasts for the heat pump grain dryer economic study; specifications and performance information on the drying systems studied in the economic analysis; estimated costs of a line of low-temperature heat pump dryer units; equipment specification and cost for the system studied in the economic analysis; and a listing of the reduced heat pump-electric resistance field test data. (LEW)

61 (DOE/CS/40327-T3) **Development and demonstration of an electric heat pump for waste-heat recovery in industry. The selection of working-fluid candidates for use in high-temperature industrial heat pumps. Topical report, September 1977-December 1978.** Snyder, P.H.; Moreland, W.C. Westinghouse Electric Corp., Pittsburgh, PA (USA). Research and Development Center. 1978. 104p. DOE Contract AC07-77CS40327. Order Number DE83003725. Source: NTIS, PC A06/MF A01.

The development of a high-temperature industrial heat pump depends upon the identification of an acceptable working fluid. An extensive search was made to select potential candidates meeting certain appropriate physical and hazard requirements. These candidates were then evaluated in detail with respect to their thermodynamic and economic performance as well as their relative health and safety aspects. Four fluids - methanol, thiophene, hexane, and Fluorinol 85 - are recommended as acceptable candidates for high-temperature heat-pump duty over the temperature range of approximately 180 to 330°F (80 to 165°C). Assuming the thermal stability and chemical compatibility of methanol are substantiated in the concurrent materials test program, it is the fluid of choice because its use results in the lowest thermal-delivery cost.

62 (DOE/CS/40327-T4) **Development and demonstration of an electric heat pump for waste-heat recovery in industry. Preliminary design report.** Moreland, W.C.; Eder, J.S.; Wolfe, R.W. Westinghouse Electric Corp., Pittsburgh, PA (USA). Research and Development Center. 30 Mar 1981. 162p. DOE Contract AC07-77CS40327. Order Number DE83003594. Source: NTIS, PC A08/MF A01.

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A high-temperature heat pump is being developed for demonstration of waste-heat recovery in industry. The design of a prototypical unit to be used to recover heat from the vapor effluent of a thermomechanical pulping unit in a paper mill is outlined. The output capacity of the unit is 30×10^6 Btu/h in the form of process steam delivered at 50 psig with 20°F superheat (318°F). A functional description of the heat-pump system is given along with a thermodynamic analysis of the cycle. The various subsystems, controls, and major components are also described and a safety analysis presented.

63 (DOE/ID-10148) **Evaluation of energy efficient distiller/concentrator recovery systems.** Williamson, W.R.; Williamson, R.C. EG and G Idaho, Inc., Idaho Falls (USA); Licon, Inc., Pensacola, FL (USA). 15 Sep 1986. 27p. DOE Contract AC07-76ID01570. Order Number DE88015216. Source: NTIS, PC A03/MF A01; GPO Dep.

A double effect steam fired distiller/concentrator installed at Automatic Electroplating in Newark, NJ is currently being

used to process rinse water from an acid zinc plating operation. LICON approached the Department of Energy in late 1985 about monitoring the installation to make cost comparisons of a steam fired system versus the heat pump evaporators developed under DOE contracts DE-AC07-79CS40290 (Reference 1) and DE-AC07-83CE40629, henceforth referred to as 290 and 629 respectively. As a result of this solicitation, LICON received a purchase order form EG & G Idaho No. C85-100803 to monitor the installation and prepare an informal report of the findings. Except for a few acid zinc installations using energy intensive 20–90 GPH single effect evaporators constructed of borosilicate glass for acid zinc, the only technology available to meet environmental discharge regulations was conventional waste treatment with sludge disposal. These waste treatment systems, due to the rapidly escalating costs of sludge disposal, are causing economic stress in the electroplating industry. This report deals with the economic and thermal efficiency of LICON double effect steam fired climbing film evaporator and compares it to the operation of heat pump and other types of evaporators and to conventional waste treatment systems.

64 (DOE-tr-83-10) **Energy conservation.** USDOE, Washington, DC. 1988. 61p. Translation source information not available. Order Number DE88010203. Source: NTIS, PC A04/MF A01.

Various research programs of energy conservation and materials recovery are briefly described. Topics include food drying, electrolysis, incinerators, optimization of dewatering equipment, membrane technology, and separation processes. Many programs are discussed in these areas. (CBS)

65 (EGG-2539) **A comparative economic evaluation of industrial heat pumps: Part 2, Addendum to report EGG-2408.** Bliem, C.J. EG and G Idaho, Inc., Idaho Falls (USA). Jun 1988. 98p. DOE Contract AC07-76ID01570. Order Number DE88011701. Source: NTIS, PC A05/MF A01; GPO Dep.

This report extends the findings of a study on the cost of delivering process heat with state-of-the-art heat pump systems originally reported in EGG-2408. The original report considered heat pump of a 30 MM Btu/h size, receiving heat from a waste-heat source at 220°. This report extends the work to a 10 MM Btu/h size and to waste-heat sources at 180° and 320°F. Results of the original study are being used to define economic performance which must be met or improved upon by advanced heat pump concepts in order to warrant Department of Energy (DOE) development support. This work will extend the range of applicability to other sizes and waste-heat source temperatures. Sixteen heat pumps systems were configured for relative cost comparisons for each waste-heat source and size. These systems consisted of electrically-driven, prime energy-driven, and waste energy-driven reverse Rankine cycle heat pumps of the open, semiopen, and closed type. In addition, a waste energy-driven absorption heat pump was analyzed. A conceptual design of each system was created using the off-the shelf components generally available to engineering firms. The performance of each system was assessed, the major components sized, and the installed cost determined. Maintenance costs were estimated. Finally, the relative cost of energy delivered by each system was estimated, and the cost of delivery heat with state-of-the-art heat pumps was determined.

66 (EGG-EP-8340) **Solid-vapor complex compound chemical heat pumps for industrial applications: Final report.** Rockenfeller, U.; Kirol, L. EG and G Idaho, Inc., Idaho Falls, ID (USA); Rocky Research Corp., Boulder City, NV (USA). Oct 1988. 59p. DOE Contract AC07-76ID01570. Order Number DE89009743. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

This report briefly reviews complex compound chemistry and heat pump cycles using complex compounds. The proof-of-concept hardware is described and experimental results presented. Finally, the advanced heat exchanger test results and cost estimates are presented. Cost estimates and economic evaluations for complete complex compound heat pump systems are included. 9 refs., 34 figs., 4 tabs.

67 (EGG-EP-8486) **The recovery of volatile organic compounds.** Priebe, S.J. (EG and G Idaho, Inc., Idaho Falls, ID (USA)). EG and G Idaho, Inc., Idaho Falls, ID (USA). Apr 1989. 14p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-76ID01570. Order Number DE89016360. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The objective of this study was to compare the use of Brayton cycle heat pump technology with conventional technologies for the recovery of volatile organic compounds (VOCs) from gas streams. The US Department of Energy (DOE), Office of Industrial Programs has the responsibility to promote the reduction in industrial energy use. The loss of solvents through evaporation from industrial processes represents a significant energy loss and environmental concern. To reduce these problems, DOE has funded the development of a Brayton cycle heat pump capable of removing and recovering a wide range of VOCs. To better understand how the Brayton cycle system compares with conventional VOC recovery technologies, EG&G Idaho, Inc. performed a study of the physical characteristics and the economics of the various systems. This report presents findings from that study. The technologies studied include thermal oxidation, catalytic oxidation, adsorption, condensation by Rankine cycle, and condensation by Brayton cycle. Characteristics of VOCs including, volatility, concentration, miscibility, stability, and value were discussed relative to their impact on the various removal/recovery technologies. Results showed that each technology has a place in the overall field of VOC removal and that no technology is suitable for all cases. 14 refs., 2 tabs.

68 (EGG-M-16887) **Advanced chemical heat pumps using liquid-vapor reactions.** Kirol, L. EG and G Idaho, Inc., Idaho Falls (USA). 1987. 8p. DOE Contract AC07-76ID01570. (CONF-8709166-6: 9. annual industrial energy technology conference, College Station, TX, US, September 16, 1987). Order Number DE88006760. Source: NTIS, PC A02/MF A01; GPO Dep.

Chemical heat pumps utilizing liquid-vapor reactions can be configured in forms analogous to electric drive vapor-compression heat pumps and heat activated absorption heat pumps. Basic thermodynamic considerations eliminate some heat pumps and place restrictive working fluid requirements on others, but two thermodynamically feasible systems have significant potential advantage over conventional technology. An electric drive reactive heat pump can use smaller heat exchangers and compressor than a vapor-compression machine, and have more flexible operating characteristics. A waste heat driven heat pump (temperature amplifier) using liquid-vapor chemical reactions can operate with higher coefficient of performance and smaller heat exchangers than

an absorption temperature amplifying heat pump. Higher temperatures and larger temperature lifts should also be possible. 4 refs., 5 figs.

69 (EGG-M-26787) **Application and technology requirements for heat pumps at the process industries.** Priebe, S.; Chappell, R. EG and G Idaho, Inc., Idaho Falls, ID (USA); USDOE Idaho Operations Office, Idaho Falls, ID (USA). 1987. 8p. DOE Contract AC07-76ID01570. (CONF-8709248-1: 9. annual industrial energy technology conference and exhibition, Houston, TX, US, September 16, 1987). Order Number DE88006740. Source: NTIS, PC A02/MF A01; GPO Dep.

There are basically three categories of equipment used to manage heat energy flows in an industrial process. First, heat exchangers are used to move heat through the process down the temperature gradient. Second, heat pumps are used to move heat through the process up the temperature gradient. Third, heat engines are used to convert heat to shaft power or electricity. The subject here is heat pumps, and they will be discussed relative to their potential for heat energy conservation in industrial processes. The large categories of applications in refrigeration and space heating are not addressed.

70 (ORNL/TM-10392) **Computer simulation of absorption heat pump using aqueous lithium bromide and ternary nitrate mixtures.** Ally, M.R. Oak Ridge National Lab., TN (USA). Jun 1988. 35p. DOE Contract AC05-84OR21400. Order Number DE88013353. Source: NTIS, PC A03/MF A01; GPO Dep.

A new aqueous ternary mixture consisting of 53 wt % LiNO_3 , 28 wt % KNO_3 , and 19 wt % NaNO_3 is available for high-temperature heat pump applications. The pressure-composition-temperature and the specific enthalpy-concentration-temperature data in the form of correlated polynomial expressions are used in a computer program to simulate results of a temperature amplifier heat pump with $\text{LiBr}/\text{H}_2\text{O}$ and ternary nitrate/ H_2O mixtures as working fluids. In the absence of adequate thermophysical data for the fluids, the study serves as a best guess first approximation. The results show that the ternary nitrate mixture potentially has approximately a 10% advantage in COP and a 15% advantage in temperature lifts over aqueous LiBr at high temperatures. Ternary nitrates are hampered by crystallization at low waste heat temperatures and cannot operate competitively in the low lift and waste heat temperature regions. The potential performance advantage at high temperatures for the ternary nitrate mixture is sufficiently attractive to justify additional work to obtain adequate thermodynamic transport and corrosion data. 10 refs., 11 figs.

71 (ORNL/TM-10896) **Corrosion of materials in chemical heat pump working fluids.** DeVan, J.H.; Wolf, J.S. Oak Ridge National Lab., TN (USA). Nov 1988. 41p. DOE Contract AC05-84OR21400. Order Number DE89005687. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

A series of laboratory tests were conducted to evaluate the performance of type A106B and 2.25Cr-1Mo steels, types 304 and 304L stainless steel, and the nickel-base alloy Monel 400 in chemical heat pump environments based on aqueous nitrate salt mixtures. Autoclave screening tests were initially performed to evaluate the stress corrosion cracking (SCC) properties of the materials at temperatures of 170, 210, and 250 C, respectively. In 2-week tests, one of two heats of A106B exhibited cracking tendencies, but all

of the other materials showed no evidence of SCC or significant general corrosion. The cracking tendency of the susceptible steel was associated with an abnormal carbide morphology. A series of 250 C capsule tests, conducted for times of up to 6 months, similarly indicated that neither SCC nor general corrosion was a problem area for these material-environment combinations. General corrosion rates were <0.1 mil/year (mpy). The two materials that performed best, type A106B mild steel and type 304L stainless steel, were tested while being dynamically strained in an 80% nitrate salt/20% water mixture at 250 C. These materials survived the tests with no indication of SCC or other significant corrosion effects. Based on this relatively short-term laboratory test program, type 304L stainless steel and A106B carbon steel can be recommended as candidate classes of structural materials for the nitrate-carrying piping of the chemical heat pump. It is noted that stringent microstructural control may be required in the case of type A106B piping. 2 refs., 14 figs., 7 tabs.

Industrial Combustion Equipment

Refer also to citation(s) 141, 142, 143, 153, 517

72 (CONF-880982-1) **Emissions resulting from the full-scale cofiring of pelletized refuse-derived fuel and coal.** Ohlsson, O.O.; Daugherty, K.; Venables, B. Argonne National Lab., IL (USA). Jun 1988. 8p. DOE Contract W-31109-ENG-38. From 10. annual industrial energy technology conference; Houston, TX, US; September 13, 1988. Order Number DE89000617. Source: NTIS, PC A02/MF A01; GPO Dep.

Full-scale cofiring tests of binder-enhanced pellets of densified, refuse-derived fuel (dRDF) and high-sulfur coal were conducted during June and July of 1987 in Boiler No. 5 at Argonne National Laboratory. These tests were conducted with industry, state, and municipality participation both in critiquing the test plan and in witnessing the actual test runs. Approximately 600 tons of dRDF containing 0%, 4%, or 8% binder were blended with high-sulfur coal at levels of up to 30%, based on the Btu content. This paper describes the dRDF/coal cofiring tests, the emission and ash samples that were taken, the analyses that were conducted on these samples, preliminary test results, and future research plans. 4 refs., 2 figs., 4 tabs.

73 (DOE/CE/40735-1) **Development of a gravel bed combustor for solid fueled gas turbine: Phase 1, Final report, September 1, 1985-January 31, 1989.** Ragland, K.W. (Wisconsin Univ., Madison, WI (USA). Dept. of Mechanical Engineering); Aerts, D.J. Wisconsin Univ., Madison, WI (USA). Dept. of Mechanical Engineering. May 1989. 81p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG02-85CE40735. Order Number DE89009029. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

A novel pressurized combustor operating on wood chips have been built and tested. Air pressurized to 5 atm and preheated to 230 C flows downward through a bed of wood chips supported by refractory gravel. Over 200 hours of combustor tests were performed in a 23 cm i.d. rig using 1.9 cm yellow poplar wood chips. The following correlation for the burning rate per unit bed cross-sectional area ($\text{kg/hr}\cdot\text{m}^2$) was obtained as a function of pressure, inlet air temperature, air to fuel ratio and fuel moisture: $G_f = 0.42 p^{0.816} T^{1.07} (A/F)^{0.816} (100-M)^{0.60}$. Over 50 hours of combustor tests were run with an Allison model 250 gas turbine attached to

the gravel bed combustor. The combustor i.d. needs to be enlarged to more fully load the turbine. A numerical model of the gravel bed combustor was developed which predicts the fuel burning rate and air flow rate for a given set of inlet conditions and excess oxygen in the exhaust. 20 refs., 17 figs., 20 tabs.

74 (DOE/CS/40037-T17) **Pulverized coal firing of aluminum melting furnaces. Final report.** Stewart, D.L. Jr.; Dastolfo, L.E. Jr.; DeYoung, D.H. Aluminum Co. of America, Alcoa Center, PA. Alcoa Technical Center. Apr 1984. 277p. DOE Contract AC07-78CS40037. Order Number DE84013093. Source: NTIS, PC A17/MF A01; GPO Dep.

Significant progress has been achieved in the development of a desulfurizing coal combustion process by the Aluminum Company of America (Alcoa) in a research program funded by the United States Department of Energy. Conceptually, high sulfur coal is burned with additives in a staged cyclone combustor, such that sufficient sulfur to obviate products of combustion (POC) scrubbing is retained in the slag by-product. Bench scale studies conducted during the program have shown that 70% of the sulfur (2.65% sulfur coal) reports to the slag at equilibrium through a 25% addition of iron ore to the coal. Results obtained correlate with published data for similar slag at higher temperatures. In pilot scale combustion tests, equilibrium levels of coal sulfur were retained by the slag (11 to 14%). Equilibrium sulfur capture was limited by low particulate retention and operating temperature higher than optimal. Cost estimates for implementation of the process are included in this report. 28 references, 39 figures, 58 tables.

75 (DOE/CS/40234-T2) **Demonstration of a nitrogen-based carburizing atmosphere. Final report.** Peartree, R.J. Air Products and Chemicals, Inc., Allentown, PA (USA). Sep 1981. 140p. DOE Contract AC07-78CS40234. Order Number DE82004196. Source: NTIS, PC A07/MF A01.

A comprehensive energy study comparing nitrogen-based atmospheres to endothermic atmospheres has been completed. Energy savings of up to 18.8% combined with production increases averaging 10% are possible with nitrogen-methane, carburizing atmospheres. Although the economics will vary depending on application and location, these energy savings and production increases are available to the heat treater at costs comparable to traditional endothermic atmosphere. The nitrogen-methanol atmosphere systems are controllable using all of the currently available methods of carbon control.

76 (DOE/ID/12597-2) **Oxygen enriched combustion system performance study: Volume 3, Burner tests and combustion modeling: Final report, Phase 1.** Kwan, Y.; Abele, A.R.; Richter, W.; Chen, S.L.; Payne, R.; Kobayashi, H.; Silver, S.L. Energy and Environmental Research Corp., Irvine, CA (USA); Union Carbide Corp., Tarrytown, NY (USA). Linde Div. Sep 1988. 181p. DOE Contract AC07-85ID12597. Order Number DE89004060. Source: NTIS, PC A09/MF A01 - OSTI; GPO Dep.

Oxygen enriched combustion (OEC) has been shown to have significant energy savings potential in industrial furnace applications. High temperature industrial furnaces, such as glass melting furnaces, appear to be the most promising applications for oxygen enriched combustion. In these applications, the principal energy savings result from minimizing the fuel energy required to heat the diluent

nitrogen in air. The results of technical and economic assessment of OEC and market assessment were reported in Volume 1 and 2 of the current study. This report describes the results of burner evaluation tests over a range of oxygen enrichment and a numerical simulation study. The first part refers to the experimental results of both conventional air-fired burners and specially designed oxygen-fuel burners, evaluated at two scales. Part 2 of this report is concerned with the application of a computer code to extrapolate the results from small scale combustion tests to industrial furnaces. The experiments were designed as a comparative evaluation to: determine the operating range of different burner designs with oxygen enrichment; measure detailed flame characteristics for both air and enriched oxygen conditions; and estimate expected performance from research furnace results to actual industrial applications. 14 refs., 76 figs., 20 tabs.

77 (DOE/ID/12597-3) **Oxygen enriched combustion system performance study: Volume 2, Market assessment: Phase 1, Final report.** Kobayashi, H. Union Carbide Corp., Tarrytown, NY (USA). Linde Div. Sep 1988. 63p. DOE Contract AC07-85ID12597. Order Number DE89004061. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

The technical and economic feasibility of oxygen enriched combustion (OEC) was assessed for twenty-one different types of high temperature industrial furnaces in nine industries. Based on the relative energy savings with OEC, economics and overall consumption of energy, steel heating, glass and aluminum melting furnaces were shown to offer the greatest potential to achieve energy savings by implementing OEC. Detailed analyses for energy savings and economics were conducted for these furnaces. 21 refs., 22 tabs.

78 (DOE/ID/12652-1) **Oxygen enriched air production system.** Lagree, D.A. Union Carbide Corp., Tonawanda, NY (USA). Linde Div. 15 Nov 1988. 58p. DOE Contract AC07-87ID12652. Order Number DE89005746. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

This report summarizes the testing of this advanced Pressure Swing Adsorption (PSA) System used to produce oxygen enriched air (OEA). The objectives of the PSA System were to provide an efficient, flexible, reliable, and cost effective source of oxygen for combustion applications in a simulated industrial furnace. 1 ref., 5 figs., 7 tabs.

79 (DOE/ID/12701-1) **Test and evaluation of polymeric membranes for oxygen enrichment of air: Final report.** Ragland, K.W. (Wisconsin Univ., Madison, WI (USA). Dept. of Mechanical Engineering); Whipple, J.G. Wisconsin Univ., Madison, WI (USA). Jul 1989. 83p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-88ID12701. Order Number DE90000555. Source: NTIS, PC A05/MF A01 - OSTI.

Two A/G Technology hollow fiber polymeric membrane separation modules to produce oxygen enriched air were evaluated. In one module the inlet air was pressurized, and in the other a vacuum was pumped on the permeate side of the membrane. The pressurized module contained three cartridges each 3 in. o.d. by 54 in. long, while the vacuum module contained seven cartridges each 3 in. o.d. by 48 in. long. Laboratory performance tests of the modules were conducted, and an economic analysis of the membrane systems for industrial applications was done. The measured performance data were used along with vendor supplied

compressor, vacuum pump and turbo-compressor data to analyses industrial air enrichment systems producing 1 ton equivalent pure O₂/day and 10 ton equivalent pure O₂/day enriched air at 35% oxygen. Both the pressurized and vacuum systems are economically attractive and provide a simple payback of less than two years when compared to the use of liquid oxygen. The vacuum system provides greater energy savings, while the pressurized system requires less capital investment. New A/G membranes are undergoing further development. 14 refs., 22 figs., 5 tabs.

80 (DOE/ID-12711-1) **Assessment and development of an industrial wet oxidation system for burning waste and low-grade fuels: Final report.** Stone and Webster Engineering Corp., Boston, MA (USA). Sep 1989. 313p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-88ID12711. Order Number DE90003403. Source: NTIS, PC A14/MF A01 - OSTI; GPO Dep.

The DOE Office of Industrial Programs, through the Idaho Operations Office, is sponsoring a program to develop and eventually demonstrate a wet oxidation system for energy production from water borne industrial waste materials and/or low-grade fuels for use in industrial processes. This program is considered a natural extension of previous DOE studies which have evaluated energy production through the wet oxidation of coal and peat. While the results of these studies were favorable for large-scale power generation, the Office of Industrial Programs believes that wet oxidation also has the potential to displace prime fuels on a smaller scale through the treatment of industrial wastes or other low-grade fuels. This report summarizes the feasibility of this program.

81 (DOE/TIC-11124) **Energy-efficient regeneration of granular activated carbon.** Centec Corp., Fort Lauderdale, FL (USA); Centec Corp., Reston, VA (USA). 1981. 17p. DOE Contract W-31-109-ENG-38. Source: NTIS \$8.75.

Major technologies and options available for reducing the energy required by regeneration systems are discussed. The report outlines energy consumption and losses within the regeneration furnace and identifies the energy conservation methods available. Specifically, thermal regeneration of granular activated carbon is considered.

ADVANCED INDUSTRIAL COGENERATION

Topping Cycles

Refer also to citation(s) 361, 362

82 (ANL/CNSV-66) **Viscosity of coal/water slurries at high shear rates.** Sekar, R.R.; Wang, C.S.; Choi, U.S. Argonne National Lab., IL (USA). Aug 1988. 43p. DOE Contract W-31109-ENG-38. Order Number DE89001032. Source: NTIS, PC A03/MF A01; GPO Dep.

The service life of an injector nozzle in a diesel engine fueled with coal/water slurry (CWS) is 2-5 h, which limits the continuous running time of the engine. This study of CWS flow and erosion in injector nozzles was initiated to provide an analytical tool, validated by experiment, for designing a durable injector and predicting long-term wear from limited test runs. The two-phase hydrodynamic theory of solid/liquid slurry flow has been extended to incorporate the constitutive relationship for power-law non-Newtonian behavior. A computer model has been developed to predict

the spatial and temporal variations in solid and liquid velocities, viscosities, and concentrations under the high shear rates encountered in diesel injection systems. The model has been validated using Newtonian, single phase flow data obtained with water or No. 2 diesel fuel and non-Newtonian, two-phase flow data using a CWS. The computed and measured viscosities and shear rates showed good agreement. Viscosities of four micronized CWS samples were measured at shear rates between 3000 and 30,000 sec⁻¹ in a high-pressure/high-shear capillary tube system of a rotational viscometer. The complex CWS flow at high shear depended on coal particle size, temperature, coal loading, additives, and the shear rate. 40 refs., 19 figs., 6 tabs.

83 (ANL/CNSV-TM-87) **Comparison of Rankine-cycle power systems: effects of seven working fluids.** Marciniak, T.J.; Krazinski, J.L.; Bratis, J.C.; Bushby, H.M.; Buyco, E.H. Argonne National Lab., IL (USA). Jun 1981. 88p. DOE Contract W-31-109-ENG-38. Order Number DE82005599. Source: NTIS, PC A05/MF A01.

This study investigates the safety, health, technical, and economic issues surrounding the prime working-fluid candidates for industrial Rankine-cycle power systems in the range of 600 to 2400 kW. These fluids are water, methanol, 2-methyl pyridine/H₂O, Fluorinol 85, toluene, Freon R 11, and Freon R 113. Rankine-cycle power systems using water as a working fluid and boilers burning coal, refuse, oil, or gas - or driven by nuclear energy - have been the mainstay of power generation for about a century. Interest in energy conservation in the industrial sector is now encouraging the development of small Rankine power systems that use heat from a variety of waste streams. The temperature range of interest for industrial applications is from 500°F to 1100°F (260°C to 593°C) for gaseous streams and approximately 300°F (149°C) for condensing streams. At temperatures below about 700°F (371°C), steam systems become less efficient and too expensive to be used. However, other working fluids, usually organic compounds, can be economically attractive at the lower temperatures. This study shows that, at current and projected energy costs, Rankine-cycle power systems using any of the seven working fluids investigated here can exceed the minimum return on investment (ROI) criteria of most industries. The highest ROIs occur for those systems using a 300°F (149°C) condensing stream as the heat source. There appear to be no significant health or safety problems that would prevent the use of any of the candidate working fluids. The only limitation of an organic fluid is its maximum stability temperature, which may prevent its use with high-temperature waste-heat streams.

84 (ANL/CNSV-TM-192) **Organic Rankine-cycle power systems working fluids study: Topical report No. 2, Toluene.** Cole, R.L.; Demirgian, J.C.; Allen, J.W. Argonne National Lab., IL (USA). Feb 1987. 190p. DOE Contract W-31109-ENG-38. Order Number DE88007152. Source: NTIS, PC A09/MF A01; GPO Dep.

The US Department of Energy initiated an investigation at Argonne National Laboratory in 1982 to experimentally determine the thermal stability limits and degradation rates of toluene as a function of maximum cycle temperature. Following the design and construction of a dynamic test loop capable of closely simulating the thermodynamic conditions of typical organic Rankine-cycle (ORC) power systems, four test runs, totaling about 3900 h of test time and covering a temperature range of 600-677(degree)F, were completed. Both liquid and noncondensable-vapor (gaseous) samples

were drawn periodically and analyzed using capillary-column gas chromatography, gas chromatography/mass spectrometry, and mass spectrometry. A computer program that can predict degradation in an ORC engine was developed. Experimental results indicate that, if oxygen can be excluded from the system, toluene is a stable fluid up to the maximum test temperature; the charge of toluene could be used for several years before replacement became necessary. (Additional data provided by Sundstrand Corp. from tests sponsored by the National Aeronautics and Space Administration indicate that toluene may be used at temperatures up to 750(degree)F.) Degradation products are benign; the main liquid degradation products are bibenzyls, and the main gaseous degradation products are hydrogen and methane. A cold trap to remove gaseous degradation products from the condenser is necessary for extended operation. 21 figs., 22 tabs.

85 (ANL/CNSV-TM-202) **Organic Rankine-Cycle Power Systems Working Fluids Study: Topical report No. 3, 2-methylpyridine/water.** Cole, R.L.; Demirgian, J.C.; Allen, J.W. Argonne National Lab., IL (USA). Sep 1987. 284p. DOE Contract W-31109-ENG-38. Order Number DE88012659. Source: NTIS, PC A13/MF A01; GPO Dep.

A mixture of 35 mole percent (mol %) 2-methylpyridine and 65 mol % water was tested at 575, 625, and 675°F in a dynamic loop. Samples of the degraded fluid were chemically analyzed to determine the identities of major degradation products and the quantity of degradation. Computed degradation rates were found to be higher than those for Fluorinol 85 or toluene. For this reason (and other reasons, related to fluid handling), other fluids are recommended as the first choice for service in organic Rankine-cycle systems in preference to 2-methylpyridine/water. 7 refs., 39 figs., 39 tabs.

86 (CONF-870710-3) **Relative importance of economic and engineering factors influencing industrial cogeneration.** Rose, K.; McDonald, J.F. Argonne National Lab., IL (USA). 1987. 14p. DOE Contract W-31109-ENG-38. From 9. international conference of the International Association of Energy Economists; Calgary, CA; July 6, 1987. Order Number DE88002952. Source: NTIS, PC A03/MF A01; GPO Dep.

Industrial cogeneration - the process of generating both electricity and heat from a single energy source at an industrial plant - has been of interest as a way to conserve energy and to decentralize electricity production. We developed an economic model to examine the relative importance of several key economic and engineering factors that firms consider when deciding whether to cogenerate. The model determines the amount of cogenerated electricity produced and the total electricity used by a plant as a function of economic and engineering factors that influence a plant's demand for and marginal cost of electricity. The analytical results suggest that policy actions concerning industrial cogeneration turn on electricity prices and external factors that affect the plant's marginal cost of cogenerating. The buy-back rate, considered by some to be an important factor in determining the amount of cogeneration, was found to be important in determining the amount of cogenerated power only when the plant meets certain economic and engineering conditions. 10 refs., 3 figs., 4 tabs.

87 (CONF-890402-1) **Atmospheric fluidized-bed cogeneration air heater experiment.** Klein, A.; Natesan, K.; Podolski, W.F. Argonne National Lab., IL (USA). 25 Oct

1988. 20p. DOE Contract W-31109-ENG-38. From 10. international conference on fluidized-bed combustion; San Francisco, CA, US; April 30, 1989. Order Number DE89003940. Source: NTIS, PC A03 - OSTI.

The US DOE-sponsored Atmospheric Fluidized-Bed Cogeneration Air Heater Experiment (ACAHE) is intended to assess the performance of various heat exchanger materials in order to establish confidence in the resultant designs of fluidized-bed combustion (FBC) air heater systems. Westinghouse and its subcontractors have specified test conditions and provided test article hardware for the ACAHE. Argonne National Laboratory through a contract with Rockwell International is conducting the tests in the DOE 1.8 m x 1.8 m (6-ft. x 6-ft) AFBC facility in El Segundo, California. This paper presents an overview of the project, a description of the facility and the test hardware, the test operating conditions, a summary of the operation over the first 1000 h. 3 refs., 8 figs., 2 tabs.

88 (DOE/BP/40040-2) **Assessment of commercial and industrial cogeneration potential in the Pacific Northwest.** Techplan Associates, Bala Cynwyd, PA (USA). Mar 1989. 240p. DOE Contract AC79-88BP40040. Order Number DE89010856. Source: NTIS, PC A11/MF A01 - OSTI; GPO Dep.

An assessment is being conducted of the potential for cogeneration in the industrial and commercial sectors in the Pacific Northwest (PNW) region. This assessment is intended to identify the amount of power that could be developed from cogeneration in Bonneville's service area (and also in the entire Pacific Northwest region, which includes all of Montana), given recent changes in costs of fuels and availability of competitive pre-packaged cogeneration equipment. This assessment is also intended to identify the prices of electric power and fuel supply that will induce a significantly greater level of interest in industrial and commercial cogeneration, and to examine the sensitivity of the quantity and rate of expected development to changes in these prices. 3 figs., 18 tabs.

89 (DOE/BP/60288-1) **Assessment of commercial and industrial cogeneration potential in the Pacific Northwest: Final report.** ADM Associates, Inc., Sacramento, CA (USA). Mar 1988. 188p. DOE Contract AC79-86BP60288. Order Number DE88007380. Source: NTIS, PC A09/MF A01; GPO Dep.

An assessment is being conducted of the potential for cogeneration in the industrial and commercial sectors in the Pacific Northwest (PNW) region. This assessment is intended to identify the amount of power that could be developed from cogeneration in Bonneville's service area (and also in the entire Pacific Northwest region, which includes all of Montana), given recent changes in costs of fuels and availability of competitive pre-packaged cogeneration equipment. This assessment is also intended to identify the prices of electric power and fuel supply that will induce a significantly greater level of interest in industrial and commercial cogeneration, and to examine the sensitivity of the quantity and rate of expected development to changes in these prices. 6 figs., 29 tabs.

90 (DOE/CE/40646-T4) **Potential detrimental effects of cogeneration development on utility costs: a preliminary assessment.** Hagler, Bailly and Co., Washington, DC (USA). Feb 1986. 26p. DOE Contract AC01-84CE40646. Order Number DE86008462. Source: NTIS, PC A03/MF A01; GPO Dep.

Of the 13 utilities studied, ten purchased electricity from cogenerators and small power generators. Results of the study indicate that the greatest problem is related to the long-term firm contract price, and that the utilities and their customers should be indifferent in the long run to the amount of cogenerated electricity purchased. (DLC)

91 (DOE/CE/40762-T1) **Summary of R and D program to develop coal/water slurry diesel engine: Final report.** RCG/Hagler, Bailly, Inc., Washington, DC (USA). 8 Jun 1988. 41p. DOE Contract AC01-87CE40762. Order Number DE88013253. Source: NTIS, PC A03/MF A01; GPO Dep.

The overall goal of this R&D program was to provide information that would assist industry in commercializing an energy efficient diesel engine capable of operating on coal-based fuels. DOE focused on proving the feasibility of the concept of coal/water slurry combustion in diesel engines. A slow-speed, two-stroke laboratory unit was used for data acquisition. This included demonstrating that economic conversion efficiencies could be achieved at acceptable power outputs, identifying engine and fuel related problems to be overcome before commercialization, and determining the range of fuel characteristics and specifications that would be technically and economically acceptable. A review of the results obtained by DOE indicates that the CWS-fired diesel engine R&D program was a significant technical success overall. The most important results demonstrated in these tests were: Slow-speed diesel engines can operate on CWS fuels. A total of nearly 50 hours of engine running time was accumulated on the single-cylinder test engine using four selected CWS fuels at a variety of engine loads ranging from 25 percent to 90 percent. Moreover, the hypothesis that engine parameters optimized for one slurry are valid for the other slurries was confirmed. Thermal efficiencies of CWS fuels are comparable to those obtained using No. 2 fuel oil. Emissions are lower when the engine burns CWS than when it burns No. 2 fuel oil. The engine operates more smoothly when burning CWS fuels than when burning No. 2 fuel oil. Economic power conversion efficiencies are obtained when using a CWS containing approximately 50 percent coal. 20 refs.

92 (DOE/CS/4300-1) **Industrial cogeneration optimization program. Final report, September 1979.** TRW, Inc., McLean, VA (USA); Thermo Electron Corp., Waltham, MA (USA). Jan 1980. 526p. DOE Contract EM-78-C-01-4300. Source: NTIS, PC A23/MF A01.

This study program is part of the DOE Integrated Industry Cogeneration Program to optimize, evaluate, and demonstrate cogeneration systems, with direct participation of the industries most affected. One objective is to characterize five major energy-intensive industries with respect to their energy-use profiles. The industries are: petroleum refining and related industries, textile mill products, paper and allied products, chemicals and allied products, and food and kindred products. Another objective is to select optimum cogeneration systems for site-specific reference case plants in terms of maximum energy savings subject to given return on investment hurdle rates. Analyses were made that define the range of optimal cogeneration systems for each reference-case plant considering technology applicability, economic factors, and energy savings by type of fuel. This study also provides guidance to other parts of the program through information developed with regard to component development requirements, institutional and regulatory barriers, as well as fuel use and environmental considerations. (MCW)

93 (DOE/CS/40245-T1) **Feasibility study for non-conventional fuel use for an industrial integrated energy system, La Grange, Georgia.** Birchfield, J.L.; Wade, D.W.; Bulpitt, W.S.; Harris, D.; Muller, J.; Hodges, W.; Robinson, W.; Williams, R.; Lederle, G.; Fenton, D. Georgia Inst. of Tech., Atlanta (USA). Engineering Experiment Station; Sverdrup and Parcel and Associates, Inc., St. Louis, MO (USA); Georgia Forestry Commission, Atlanta (USA). Mar 1981. 258p. DOE Contract AC05-79CS40245. Order Number DE82010086. Source: NTIS, PC A12/MF A01.

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A feasibility study for the construction and operation of a wood-fired combined heat and power production plant has been conducted in conjunction with the development of a 600-acre Industrial Park. Several options are available to system planners which include phasing of the plant in small increments, producing steam as a primary energy source, producing electricity as a primary energy source, and using various local wood resources for fuel. Wood wastes found at wood products industries, sawmills, and residue left in the forest after harvesting are evaluated as a renewable energy source for the central energy plant. Both thermal and electrical energy production are evaluated for its cost effectiveness in the LaGrange situation. Alternative fuel sources including coal, oil, and municipal refuse are also being considered as back-up fuel supplies. Key elements of the study include: (1) a thorough search of literature concerned with wood as an energy source, wood harvesting techniques, and wood combustion equipment; (2) a technical analysis of the industrial park's energy requirements through a survey conducted by Georgia Tech; (3) development of a design criteria for the central energy system along with the investigation of alternative energy supply schemes. To avoid any adverse impacts on air and water quality in the LaGrange area, an investigation of environmental impacts was conducted during the study. In addition, cost analyses including life cycle benefits, operating and ownership arrangements, and alternative financing schemes are explored.

94 (DOE/CS/40362-1) **Industrial cogeneration potential (1980 to 2000) Targeting of Opportunities at the Plant Site (TOPS). Volume I. Executive summary. Final report.** General Energy Associates, Philadelphia, PA (USA). May 1983. 74p. DOE Contract AC01-80CS40362. Order Number DE83013051. Source: NTIS, PC A04/MF A01.

This summary covers: the general methodology, the General Energy Associates Industrial Plant Energy Profile Data Base, the industrial cogeneration potential, and existing cogeneration. (MHR)

95 (DOE/CS/40362-1-Vol.2) **Industrial cogeneration potential (1980-2000): targeting of Opportunities at the Plant Site (TOPS). Volume II. Methodology and data. Final report.** General Energy Associates, Philadelphia, PA (USA). May 1983. 71p. DOE Contract AC01-80CS40362. Order Number DE83013052. Source: NTIS, PC A04/MF A01.

The plant data base used is the GEA/IPEP plant data base. This data base contains detailed plant estimates of steam use, electricity use, and hours of operation for the top 10,000 US industrial plants. Each plant is identified in the data file by name, address, SIC, products and electric utility. Those plants that pass some minimum plant economic return on investment become potential sites. The basic data on ROI distributions is presented and the users of this study can apply their own criteria for penetration of this potential. Detailed, computer based descriptions of sixteen fuel type -

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technology combinations are used to obtain a preliminary design of each cogeneration system in a plant setting. This design sizes the system for the plant based on a heat match and produces a capital cost estimate for the plant. This capital cost is then an input to the economic model which accounts for all cash streams over the life of the equipment. All relevant factors are considered in generating the cash streams. Actual utility costs, PURPA rates and fuel costs are used for the plant. The plant estimate of steam use, electric use, and hours of operation are used to calculate the appropriate cash streams and return on investment (ROI) for the plants. This methodology produces a list of potential sites that have passed the minimum ROI filter.

96 (DOE/CS/40362-1-Vol.3) Industrial cogeneration potential (1980-2000) Targeting of Opportunities at the Plant Site (TOPS). Volume III. Industrial potential cogeneration source book: a geographic-industrial sector profile. Final report. General Energy Associates, Philadelphia, PA (USA). May 1983. 353p. DOE Contract AC01-80CS40362. Order Number DE83013050. Source: NTIS, PC A16/MF A01.

National, regional and state profiles are presented by industrial sector and by size of system for potential cogeneration within the US. For each of the following sections and for each region and state five computer printout tables are provided: (1) potential number of plants with cogeneration potential in each SIC, within specified cogeneration system size (MW) ranges; (2) potential electric power generation (MW) in each SIC, within specified cogeneration system size ranges; (3) potential electric generation (Kwh/yr) in each SIC, within specified cogeneration system size ranges; (4) potential steam generation (lb/yr) in each SIC, within specified cogeneration system size ranges; and (5) potential energy savings (Btu/yr) in each SIC, within specified cogeneration system size ranges. The potential cogeneration profiles presented in the five tables for the national profile and for each of the region and state profiles are for the best system at each plant site having an uninflated ROI > 7%. A national profile for systems with an uninflated ROI > 15% is presented. The definition of each 2 digit SIC group is presented. A correlation between uninflated, constant 1980 dollar ROI and the inflated ROI is presented. The energy savings (Btu/yr) presented in computer printout Table 5 in each section, represents the energy savings at the utility (assuming a utility efficiency of 33%) plus or minus the energy differential between the cogeneration and nocogeneration systems at the plant site.

97 (DOE/CS/40362-1-Vol.4) Industrial cogeneration potential (1980 to 2000) Targeting of Opportunities at the Plant Site (TOPS). Volume IV. Existing cogeneration source book: a geographic-industrial sector profile. Final report. General Energy Associates, Philadelphia, PA (USA). May 1983. 292p. DOE Contract AC01-80CS40362. Order Number DE83013049. Source: NTIS, PC A13/MF A01.

A detailed profile of existing cogeneration is provided. This information is profiled by geographical region, industrial sector and system size. The geographical distributions are developed in the following three sections: national, regional, and state. The industrial sector and size distributions are presented in the tables in each section. The SIC's are defined. For each geographic region (national, regional or state), four computer printout tables are presented for existing cogeneration: number of plants with existing cogeneration by Industrial Sector (SIC) and system capacity size;

total cogeneration capacity (MW) as a function of Industrial Sector (SIC) and system capacity size; total cogeneration of electricity (Kwh/yr) by SIC and size; and total cogeneration of steam (lb/yr) by SIC and size.

98 (DOE/CS/40362-1-Vol.5) Industrial cogeneration potential (1980-2000) Targeting of Opportunities at the Plant Site (TOPS). Final report. Volume V. Industrial manufacturing plant sites. General Energy Associates, Philadelphia, PA (USA). May 1983. 124p. DOE Contract AC01-80CS40362. Order Number DE83013048. Source: NTIS, PC A06/MF A01.

The potential and existing cogeneration sites are listed by a plant identification number to maintain confidentiality of the plant site. They are sorted by state and SIC. The information for the potential plant sites includes the following: plant identification number, state, SIC, and ROI Ratings. In addition to the information developed for the specific plants, a 2 digit SIC distribution of plant average boiler age is provided. The existing cogeneration plants are listed. The information includes the following: plant identification number, state, SIC, cogeneration system type, system capacity (MW), electricity generation (Kwh/yr), and steam generation (lb/yr).

99 (DOE/CS/40402-T3) Assessment of private-sector cogeneration models. Energetics, Inc., Columbia, MD (USA). Jul 1983. 49p. DOE Contract AC01-80CS40402. Order Number DE83016377. Source: NTIS, PC A03/MF A01.

The merits of four cogeneration models were identified, characterized, and evaluated. The models selected were: Pacific Gas and Electric (PG and E) Cogeneration Financial Analysis Models; Electric Power Research Institute (EPRI) Computer Program for Evaluation of Dual Energy Use System (DEUS model); the National Energy Software Center - Argonne National Laboratory Industrial Cogeneration Project (ICOP) Model; and Energetics, Inc. Cogeneration Financial Model (COGEN). Work with the DEUS model was restricted to a qualitative evaluation. The strengths and weaknesses of each of the four models are described in qualitative terms. The characteristics of each of the six test cases are described. The results of the six cases using the PG and E, ICOP, and COGEN models are discussed in detail and compared. (MHR)

100 (DOE/CS/40538-T1) Assessment of electric-utility ownership and operation of industrial-cogeneration facilities. Final report. Hagler, Bailly and Co., Washington, DC (USA). Dec 1982. 151p. DOE Contract AC02-81CS40538. Order Number DE83005494. Source: NTIS, PC A08/MF A01.

To better understand the opportunities for direct utility involvement in the ownership and operation of industrial cogeneration facilities, the Department of Energy requested a study of the factors affecting utility ownership and operation of these facilities. The study team, with the assistance of a utility steering committee composed of representatives of 10 major investor-owned utilities, reviewed pertinent laws and regulations, held discussions with key regulatory personnel, defined prototypical ownership and operating arrangements, evaluated cogeneration facility technical characteristics and financial attractiveness, and determined specific measures designed to encourage greater utility involvement in the ownership and operation of industrial cogeneration facilities. This report discusses factors affecting utility involvement in cogeneration facilities, the positive effects of deregulation on such involvement, measures to improve the regulatory

environment, and measures to improve the financial performance of utility-owned cogenerating facilities. (LCL)

101 (DOE/EA-0145-Rev.3) **Environmental assessment for the alternate energy source project, Pantex Plant, Amarillo, Texas: Revision 3.** USDOE, Washington, DC (USA). Apr 1981. 14p. Order Number DE88004976. Source: NTIS, PC A03.

This Project provides for the construction of a new cogeneration central power plant burning low sulfur coal and producing hot water for heating and cooling. The plant will produce electricity and thereby reduce the amount that is presently purchased from an off-site utility company. Hot water for heating and cooling will be distributed in a new underground system to existing buildings and will serve new hot water heating devices and modified air conditioning equipment in existing buildings. This project will replace the existing natural gas fired steam plant. Possible impacts on water and air quality, land use, soil, etc. are evaluated, as are alternative actions.

102 (DOE/NBB-0057) **Cogeneration handbook for the pulp and paper industry.** Pacific Northwest Lab., Richland, WA (USA). Feb 1984. 152p. DOE Contract AC06-76RL01830. Order Number DE84016307. Source: NTIS, PC A08/MF A01; GPO Dep.

The US Department of Energy (DOE) contracted with Pacific Northwest Laboratory (PNL) to provide the pulp and paper plant manager or company energy coordinator with a framework for making a preliminary assessment of the feasibility and viability of cogeneration at a particular plant. The handbook is intended to provide an understanding of the potential of several standardized cogeneration systems, as well as their limitations. However, because the decision to cogenerate is very site specific, the handbook cannot provide all of the answers. It does attempt, however, to bring to light the major issues that should be addressed in the decision-making process. The decision of whether to cogenerate involves several considerations, including technical, economic, environmental, legal, and regulatory issues. Each of these issues is addressed separately in this handbook. In addition, a chapter is included on preparing a three-phase work statement, which is needed to guide the design of a cogeneration system. Experience has shown that a well-defined work statement can be the key to a rapid and cost-effective design effort. Discussion is presented under the headings: Data Base Development; Matching Cogeneration System Designs; Economic Analysis; Financial Strategic; Environmental Issues; Legal and Contractual Issues; and Three-phase Work Statements. 12 references, 40 figures, 34 tables.

103 (DOE/NBB-0058) **Cogeneration handbook for the textile industry.** Pacific Northwest Lab., Richland, WA (USA). Feb 1984. 143p. DOE Contract AC06-76RL01830. Order Number DE84016308. Source: NTIS, PC A07/MF A01; GPO Dep.

The US Department of Energy (DOE) contracted with Pacific Northwest Laboratory (PNL) to provide the textile plant manager or company energy coordinator with a framework for making a preliminary assessment of the feasibility and viability of cogeneration at a particular plant. The handbook is intended to provide an understanding of the potential of several standardized cogeneration systems, as well as their limitations. However, because the decision to cogenerate is very site specific, the handbook cannot provide all of the answers. It does attempt, however, to bring to light the major

issues that should be addressed in the decision-making process. The decision of whether to cogenerate involves several considerations, including technical, economic, environmental, legal, and regulatory issues. Each of these issues is addressed separately in this handbook. In addition, a chapter is included on preparing a three-phase work statement, which is needed to guide the design of a cogeneration system. Experience has shown that a well-defined work statement can be the key to a rapid and cost-effective design effort. Discussion is presented under the headings: Data Base Development; Matching Cogeneration System Designs; Economic Analysis; Financial Strategies; Environmental Issues; Legal and Contractual Issues; and Three-Phase Work Statements. 18 references, 36 figures, 30 tables.

104 (DOE/NBB-0059) **Cogeneration handbook for the chemical process industry.** Pacific Northwest Lab., Richland, WA (USA). Feb 1984. 160p. DOE Contract AC06-76RL01830. Order Number DE84016310. Source: NTIS, PC A08/MF A01; GPO Dep.

The US Department of Energy (DOE) contracted with Pacific Northwest Laboratory (PNL) to provide the chemical plant manager or company energy coordinator with a framework for making a preliminary assessment of the feasibility and viability of cogeneration at a particular plant. The handbook is intended to provide an understanding of the potential of several standardized cogeneration systems, as well as their limitations. However, because the decision to cogenerate is very site specific, the handbook cannot provide all of the answers. It does attempt, however, to bring to light the major issues that should be addressed in the decision-making process. The decision of whether to cogenerate involves several considerations, including technical, economic, environmental, legal, and regulatory issues. Each of these issues is addressed separately in this handbook. In addition, a chapter is included on preparing a three-phase work statement, which is needed to guide the design of a cogeneration system. Experience has shown that a well-defined work statement can be the key to a rapid and cost-effective design effort. Discussion is presented under the headings: Data Base Development; Matching Cogeneration System Designs; Economic Analysis; Financial Strategies; Environmental Issues; Legal and Contractual Issues; and Three-phase Work Statements. 19 references, 44 figures, 38 tables.

105 (DOE/NBB-0060) **Cogeneration handbook for the petroleum refining industry.** Pacific Northwest Lab., Richland, WA (USA). Feb 1984. 158p. DOE Contract AC06-76RL01830. Order Number DE84016304. Source: NTIS, PC A08/MF A01; GPO Dep.

This Handbook deals only with industrial cogeneration, that is, simultaneous production of both heat and electricity at the industrial plant site. The cogenerator has the option of either selling all cogenerated power to the utility while simultaneously purchasing power to satisfy his plant demand, or directly supplying the plant demand with cogenerated power, thus displacing utility-supplied power. This Handbook provides the refinery plant manager or company energy coordinator with a framework for making a preliminary assessment of the feasibility and viability of cogeneration at a particular plant. The handbook is intended to provide an understanding of the potential of several standardized cogeneration systems, as well as their limitations. However, because the decision to cogenerate is very site specific, the handbook cannot provide all of the answers. It does attempt,

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however, to bring to light the major issues that should be addressed in the decision-making process. The decision of whether to cogenerate involves several considerations, including technical, economic, environmental, legal, and regulatory issues. Each of these issues is addressed separately in this handbook. In addition, a chapter is included on preparing a three-phase work statement, which is needed to guide the design of a cogeneration system. 39 figures, 37 tables.

106 (DOE/NBB-0061) **Cogeneration handbook for the food processing industry.** Pacific Northwest Lab., Richland, WA (USA). Feb 1984. 151p. DOE Contract AC06-76RL01830. Order Number DE84016309. Source: NTIS, PC A08/MF A01; GPO Dep.

The US Department of Energy (DOE) contracted with Pacific Northwest Laboratory (PNL) to provide the food processing plant manager or company energy coordinator with a framework for making a preliminary assessment of the feasibility and viability of cogeneration at a particular plant. The handbook is intended to provide an understanding of the potential of several standardized cogeneration systems, as well as their limitations. However, because the decision to cogenerate is very site specific, the handbook cannot provide all of the answers. It does attempt, however, to bring to light the major issues that should be addressed in the decision-making process. The decision of whether to cogenerate involves several considerations, including technical, economic, environmental, legal, and regulatory issues. Each of these issues is addressed separately in this handbook. In addition, a chapter is included on preparing a three-phase work statement, which is needed to guide the design of a cogeneration system. Experience has shown that a well-defined work statement can be the key to a rapid and cost-effective design effort. Discussion is presented under the headings: Data Base Development; Matching Cogeneration System Designs; Economic Analysis; Financial Strategies; Environmental Issues; Legal and Contractual Issues; and Three-phase Work Statements. 18 references, 40 figures, 38 tables.

107 (DOE/PE/70042-1) **Potential for industrial cogeneration development to defer new-utility electric-power capacity over the next decade.** Resource Planning Associates, Inc., Cambridge, MA (USA). Jun 1983. 126p. DOE Contract AC01-79PE70042. Order Number DE83016643. Source: NTIS, PC A07/MF A01.

Selected utilities in different geographic areas were interviewed to determine the criteria under which they would defer the initiation or completion of central station power plants (essentially, new coal plants) due to projected industrial cogeneration capacity. Using these criteria for the period 1983 to 1993, projected new industrial cogeneration in 28 National Electric Reliability Council sub-regions was assessed against planned new capacity by all the nation's utilities. Further analysis and discussion with utilities in potentially affected regions revealed that only three sub-regions, Middle South Utilities, Gulf States Utilities, and the Texas System, might experience deferrals due to cogeneration. The projected increment of new cogeneration capacity for the period 1983 to 1993 for these three regions is 2720 MW, which is 3% of the 87,000 MW of new coal plants that utilities in the US plan to bring on line in the next decade. In the three sub-regions the projected cogeneration increment for the ten-year period is 15% of the new capacity (18,000 MW) that utilities have planned. To carry out the study, detailed projections were made of new increments of industrial

cogeneration capacity for the five major energy-using industries. It was concluded that about 11,000 MW of new cogeneration capacity could come on line in the period 1983 to 1993.

108 (DOE/TIC-11473) **Utility involvement in industrial cogeneration in the United States and Europe.** Argonne National Lab., IL (USA). Apr 1981. 42p. DOE Contract W-31-109-ENG-38. Order Number DE83012807. Source: NTIS, PC A03/MF A01.

The financial and regulatory constraints impending utility involvement in cogeneration are identified and evaluated. The type of federal and state actions that could mitigate these constraints are identified and evaluated. The constraints to US utility ownership and operation of cogeneration are compared to conditions in Europe. (MHR)

109 (DOE/TIC-11604) **Industrial Cogeneration Optimization Program: a summary of two studies.** Oak Ridge National Lab., TN (USA). Aug 1981. 38p. DOE Contract W-7405-ENG-26. Order Number DE82005587. Source: NTIS, PC A03/MF A01.

Two Industrial Cogeneration Optimization Programs were performed to examine the economic and energy-saving impacts of adding cogeneration to site-specific plants in the chemical, food, pulp and paper, petroleum refining, and textile industries. This booklet first presents an overview of industrial cogeneration in Chapter 1. Chapter 2 provides a description of the two parallel ICOP studies, with Chapter 3 summarizing the major findings and conclusions. Chapter 4 then presents short descriptions of the five industrial sectors, followed by highlights of each of the site-specific case studies. A central conclusion of the ICOP effort was that steam turbine cogeneration systems fired by coal or alternative fuels are generally the most attractive in terms of economic performance and oil/gas savings potential. Of the 15 cogeneration systems selected as optimum in the ICOP studies, 11 were coal- or wood-fired steam turbines. By contrast, gas turbines, combined cycles, and diesel engines, which are currently limited to oil- or gas-firing, are usually less economical.

110 (DOE/TIC-11605) **Handbook of industrial cogeneration.** Oak Ridge National Lab., TN (USA). Oct 1981. 325p. DOE Contract W-7405-ENG-26. Order Number DE82009604. Source: NTIS, PC A14/MF A01.

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The objective of this handbook is to provide sufficient information to permit a decision on whether cogeneration is economically feasible in a particular set of circumstances. Illustrative examples of cogeneration applications drawn from fine industrial plants are used to show the implications of technical, economic, legal, and environmental considerations for specific sites. A compilation of technical cost and cost data for all cogeneration system options, including topping and bottoming cycles, with near term feasibility is presented. A range of industrial cogeneration applications to illustrate the use of technical and cost data in synthesizing cogeneration system conceptual design is described. Industrial fuel and electricity price forecasts and electric utility fuel use profiles are presented. The methodology for analyzing cogeneration economic and energy-savings performance is described and illustrated. (MCW)

111 (HCP/M/8688-01) **Guidelines for developing state cogeneration policies.** Resource Planning Associates, Inc., Washington, DC (USA). Apr 1979. 122p. DOE Contract EM-77-C-01-8688. Source: NTIS, PC A06/MF A01.

This document contains a set of guidelines for use by state decision makers in establishing policies regarding industrial cogeneration. By providing state officials with means of assessing the state potential for future cogeneration development and identifying state actions to stimulate development, these guidelines increase the state decision makers' understanding of the critical issues surrounding cogeneration development in their state. The guidelines address a broad range of topics, including types of cogeneration technologies and their applications, technical constraints to cogeneration development, economic constraints accounting for the regulatory and institutional factors that inhibit cogeneration capital investments, and various ownership and operating arrangements that can promote cogeneration development. The document is structured to reflect a general process that must be followed before effective policy decisions at the state level can be made. Briefly, this process consists of three steps: understanding the concept of industrial cogeneration; assessing the potential for its development without state action; and identifying and evaluating possible actions to stimulate additional development.

112 (MTI-88-TR-10) Heat exchanger development for steam-injected Brayton cycle: Final report for period September 30, 1984 to April 30, 1988. Cain, W.G. (Mechanical Technology, Inc., Latham, NY (USA)). Mechanical Technology, Inc., Latham, NY (USA). Apr 1988. 184p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG02-84CE40690. Order Number DE89012687. Source: NTIS, PC A09 MF A01 - OSTI; GPO Dep.

A steam-injected, externally fired, gas turbine power cycle offers advantages over other cycles for the cogeneration of process steam and electric power, utilizing nonpremium solid fuels. One aspect of this innovative cogeneration cycle gives rise to a need for technology not yet available, heating a mixture of compressed air and steam to 1500 F in an externally fired air heater, prior to expansion through a power turbine. Under this program, funded by the Department of Energy (DOE) and the New York State Energy and Research Development Authority (NYSERDA), Mechanical Technology Incorporated investigated the interaction of common phosphate and hydroxide with typical high-temperature heat exchanger materials in the 1500 F operating environment to determine the expected life of the heat exchanger based on the measured corrosion rate. The program consists of a performance study, a 1000-hr screening test of three heat exchanger materials and three water treatment systems, and a 4000-hr endurance test. This report details the results of the performance study that describes several methods of increasing system efficiency, of the 1000-hr screening test in which 347H stainless steel combined with the coordinated phosphate water treatment system was slightly favored at 1350 F, and of the 4000-hr endurance test in which Incoloy 800H was found to have the least amount of corrosion and erosion at 1500 F. 7 refs., 69 figs., 23 tabs.

113 (N-8233822) The potential for industrial cogeneration development by 1990. Final Report. Resource Planning Associates, Inc., Cambridge, MA (USA). Jul 1981. 158p. (RA-81-1455). Source: NTIS, PC A08 MF A01.

The cogeneration study focused on five industries that constitute three quarters of industrial steam demand: pulp and paper, chemicals, petroleum refining, steel, and food processing. These industries use almost one fifth of the total energy consumed in the United States. The analysis reflected the investment and regulatory concerns in the United

States. The analysis reflected the investment used by industrial and utility managers. Phone discussions were held with approximately 70 companies to verify and augment the process and energy use data for the five industries.

114 (PB-255659) Study of inplant electric power generation in the chemical, petroleum refining, and paper and pulp industries. Final report. Nydick, S.E.; Davis, J.P.; Dunlay, J.; Fain, S.; Sukhuja, R. Thermo Electron Corp., Waltham, MA (USA). Jun 1976. 314p. DOE Contract FEA-CO-04-50224-00. (TE-5429-97-76). Source: NTIS \$9.75.

See also PB-255658.

The maximum thermodynamic and economic potentials for increased inplant electric power generation by steam turbine, gas turbine, and diesel topping and steam and organic bottoming cycles are determined for the chemical, petroleum refining, and paper and pulp industries with and without government sponsored economic incentives. Institutional, legal and regulatory constraints were also assessed.

115 (TID-28853) Commercialization strategy report for cogeneration. Department of Energy, Washington, DC (USA). 1978. 75p. Source: NTIS, PC A04 MF A01.

The commercial readiness assessment for cogeneration is discussed. Technical, market/economic, environmental, and institutional readiness aspects are covered. Benefits analysis is presented. The commercialization strategy for cogeneration is covered by discussing commercialization profile and recommended commercialization approach. The principal technologies currently available for cogeneration include extraction steam turbine-generator, gas turbine system with waste heat boiler, and diesel with waste heat recovery.

Direct Conversion

116 (DOE/CS/05310-01(Vol.1)) Industrial cogeneration optimization program. Westinghouse Electric Corp., Pittsburgh, PA (USA); Gibbs and Hill, Inc., New York (USA). Jan 1980. 226p. DOE Contract EM-78-C-01-5310. Source: NTIS, PC A11 MF A01.

The purpose of this program was to identify up to 10 good near-term opportunities for cogeneration in 5 major energy-consuming industries which produce food, textiles, paper, chemicals, and refined petroleum; select, characterize, and optimize cogeneration systems for these identified opportunities to achieve maximum energy savings for minimum investment using currently available components of cogenerating systems; and to identify technical, institutional, and regulatory obstacles hindering the use of industrial cogeneration systems. The analysis methods used and results obtained are described. Plants with fuel demands from 100,000 Btu/h to 3×10^5 Btu/h were considered. It was concluded that the major impediments to industrial cogeneration are financial, e.g., high capital investment and high charges by electric utilities during short-term cogeneration facility outages. In the plants considered an average energy savings from cogeneration of 15 to 18% compared to separate generation of process steam and electric power was calculated. On a national basis for the 5 industries considered, this extrapolates to saving 1.3 to 1.6 quads per yr or between 630,000 to 750,000 bbl/d of oil. Properly applied, federal activity can do much to realize a substantial fraction of this potential by lowering the barriers to cogeneration and by stimulating wider implementation of this technology. (LCL)

117 (DOE/CS/05310-01(Vol.2)) **Industrial cogeneration optimization program. Volume II. Appendix A. Conceptual designs and preliminary equipment specifications. Appendix B. Characterization of cogeneration systems (near-term technology). Appendix C. Optimized cogeneration systems.** Westinghouse Electric Corp., Pittsburgh, PA (USA); Gibbs and Hill, Inc., New York (USA). Jan 1980. 313p. DOE Contract EM-78-C-01-5310. Source: Dep. NTIS, PC A14/MF A01.

This appendix to a report which evaluates the technical, economic, and institutional aspects of industrial cogeneration for conserving energy in the food, chemical, textile, paper, and petroleum industries contains data, descriptions, and diagrams on conceptual designs and preliminary equipment specifications for cogeneration facilities; characterization of cogeneration systems in terms of fuel utilization, performance, air pollution control, thermal energy storage systems, and capital equipment costs; and optimized cogeneration systems for specific industrial plants. (LCL)

INDUSTRIAL WASTES

Waste Materials Utilization and Conversion: Solid Wastes

Refer also to citation(s) 72, 93, 607, 635

118 (ANL/CNSV-1) **Energy and labor cost of gasoline engine remanufacturing.** Venta, E.R.; Wolsky, A.M. Argonne National Lab., IL (USA). Sep 1978. 46p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A03/MF A01.

This report presents a detailed estimate of the labor and energy, by fuel type, required by the U.S. economy to remanufacture gasoline-fueled automobile and truck engines. The estimate was obtained by combining data provided by several remanufacturers with the results of input-output analysis. A rough estimate of the labor and energy required to manufacture new engines is also given. These estimates suggest that remanufactured engines require 50% of the energy and 67% of the labor that new engines require.

119 (ANL/CNSV-5) **Discarded tires: energy conservation through alternative uses.** Gaines, L.L.; Wolsky, A.M. Argonne National Lab., IL (USA). Dec 1979. 47p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A03/MF A01.

Scrap tires that are not recycled through retreading constitute a serious solid-waste problem, but also offer energy-conservation opportunities through their use as: (1) solid fuel (displaced energy = 15,000 Btu/lb or 35 kJ/g); (2) derived fuel and chemical feedstock (11,000 to 23,000 Btu/lb or 25 to 53.5 kJ/g); (3) virgin rubber compound substitute in traditional rubber products (34,000 to 40,000 Btu/lb or 79 to 93 kJ/g); and (4) asphalt additive for paving applications (90,000 Btu/lb or 210 kJ/g). Both the energy of the displaced fuel and material and the energy consumed preparing the tires for the above uses have been included, where possible, in these estimates. Also provided is a summary of the available data on the cost and requisite scale of operation for the various end use processes.

120 (ANL/CNSV-48) **Opportunities for by-product recovery in synfuel plants.** Gaines, L.L.; Klausmeier, W.H.; Lynch, E.P.; Tevebaugh, A.D. Argonne National Lab.,

IL (USA). Feb 1984. 111p. DOE Contract W-31-109-ENG-38. Order Number DE86000183. Source: NTIS, PC A06/MF A01; GPO Dep.

Emerging synfuel technologies will generate large quantities of solid, liquid, and gaseous wastes that may contain useful by-products. Recovery and sale of such materials could reduce the waste-disposal burden and increase plant revenues; recovery of organic compounds could improve the energy efficiency of the process. At present, the synfuel industry is not yet set in place; therefore now is the best time to investigate potentially useful by-products and methods of recovering them, so that the synfuel plants eventually built can be equipped with appropriate recovery devices. Three major synfuel technologies, each represented by a promising process, were examined with a view to identifying potentially recoverable by-products and evaluating conventional and novel recovery processes that might be useful. The three technologies reviewed are shale oil retorting, represented by the Colony Shale Oil Project (which uses the TOSCO II process); coal gasification, represented by the Great Plains synthetic natural gas facility, and coal liquefaction, represented by the H-Coal Project. Our findings indicate that the members of the synfuels industry are well aware of the potential of the various conventional methods of recovering by-products: for example, sulfur, ammonia, and phenolic compounds. Other opportunities exist, however - some are not cost effective at present, and some are in need of further development. For example, aluminum could be recovered from dawsonite in oil shale; some oil shale deposits also contain nahcolite (a sodium carbonate mineral); the catalysts used in synfuel production contain noble metals that may be worth recovering; and the large volumes of carbon dioxide produced by many synfuel processes may be useful for enhancing the yield of oil fields. 53 refs., 34 figs., 45 tabs.

121 (DOE/CE-0235) **The DOE Industrial Energy Conservation Program: Research and development in waste products utilization technology.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Jul 1988. 31p. Order Number DE89002981. Source: NTIS, PC A03/MF A01; GPO Dep.

This brochure summarizes the research and development efforts undertaken by the Office of Industrial Programs in the area of waste products utilization. The sections which follow are representative of a larger portfolio of projects and provide information on federal industrial energy conservation activities in waste utilization. These sections are: Industrial wastes - a summary of the current status of industrial waste management and of the potential savings associated with industrial wastes; Waste products utilization R & D - a description of waste products utilization R & D projects funded by the Office of Industrial Programs; and R & D data base - a list of contractors, principal investigators and locations for each IP-sponsored project relating to waste products utilization. 15 figs.

122 (DOE/CE/15299-T1) **Development of a liquid jet for disintegration of organic and inorganic materials: Final technical report, September 15, 1986-September 14, 1987.** Mazurkiewicz, M. Incubator Technologies, Inc., Rolla, MO (USA). Nov 1987. 28p. DOE Contract FG01-86CE15299. Order Number DE88003813. Source: NTIS, PC A03/MF A01; GPO Dep.

The work completed for this project includes the development of three working prototypes for disintegration of

materials and the testing of the systems to determine performance characteristics. The material used was waste newsprint, books and fiberboard. This report describes the systems tested, the method of testing and presents results of the testing. 8 figs., 2 tabs. (JDH)

123 (DOE/CE/15367-T1) **High pressure liquid jet for disintegration of wood: Technical progress report for the period May 1988–September 30, 1988.** Incubator Technologies, Inc., Rolla, MO (USA). 1988. 13p. DOE Contract FG01-88CE15367. Order Number DE89003391. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Most newsprint is made of a mixture of seventy to eighty percent ground wood, and twenty to thirty percent unbleached sulphite or semi-bleached sulphate pulp. Presently, spruce is the most desirable species for wood pulp production, with the true firs, western hemlock, and southern pine following in order. It is anticipated that the use of hardwoods in newsprint will increase with time. In the manufacture of wood pulp for paper production, conventional practice is to grind debarked logs using a revolving grindstone. The abrasive stone causes individual wood fibers and fiber bundles to be separated from the log. Water is added to the ground pulp, during grinding, through a shower pipe which sprays water on the periphery of the stone. This water adsorbs the frictional heat generated at the interface between the stone and the wood, washes the fibers from the surface of the stone, and controls the consistency of the resulting pulp. 6 refs., 2 figs., 2 tabs.

124 (DOE/CE/15367-T2) **High pressure liquid jet for disintegration of wood: Technical progress report for the period October 1, 1988–December 31, 1988.** Incubator Technologies, Inc., Rolla, MO (USA). 1988. 15p. DOE Contract FG01-88CE15367. Order Number DE89006088. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Based on the results described in Technical Progress Report No. 1, it was decided to continue with those tests using a combination of mechanical cutting tool with waterjet. The mechanism of cutting wood by mechanical tool, oriented in such a way that the rake angle is negative, creates some kind of analogy to the pulping by grinding. A negative rake angle develops compression stress on a portion of the wood which is in front of the rake face, before the chip is formed. Compression developed on the fibers helps to separate them and form pulp. To check how well it works, a series of tests was carried out for negative rake angle, as well as for cutting tool tip, rounded to radius of 0.125 inches. 5 figs., 2 tabs.

125 (DOE/CE/15367-T4) **High pressure liquid jet for disintegration of wood: Final technical report.** Incubator Technologies, Inc., Rolla, MO (USA). Sep 1989. 32p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG01-88CE15367. Order Number DE89017708. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Preliminary studies carried out at the Rock Mechanics and Explosives Research Center of the University of Missouri-Rolla have shown that high pressure waterjets are an excellent material-disruptive device. Such a capability of the high pressure waterjets arise from the following features: there is a high energy density concentrated on the cutting point; the jet has a high penetration ability into wood, since it exerts very little force outside the impact point; during jet penetration into the material, the radial flow of the jet, upon impact, plays the most important role in separating individual fibers; and using a dispersed jet (or fan jet) single water

particles individually collide with the wood, penetrating into the material, and separate fibers from the solid wood very effectively. Hydraulic wood pulping is used to describe the process when a high pressure waterjet is used to create fibers from a solid piece of wood.

126 (DOE/CE/40556-T2) **Biorefining of selected industrial wastes to liquid fuels and organic chemicals. Final technical progress report for Phase I, June 15–December 31, 1982.** Levy, P.F.; Leuschner, A.P.; Stoddart, J.H. Jr. Dynatech R/D Co., Cambridge, MA (USA). 27 May 1983. 194p. DOE Contract AC02-82CE40556. Order Number DE83013910. Source: NTIS, PC A09/MF A01.

The feasibility of processing industrial wastes to fuels or chemicals by a process incorporating anaerobic digestion and electrolytic oxidation was investigated. The primary objective of this program was the collection and testing of various waste samples for their applicability to the process. Information was gathered to choose the most promising waste material for further development of the process. An effort was also made to solicit industrial interest in this project. A review meeting was held to convey information about the process and as a forum for comments by the industrial participants. In the process, waste material is fed to an anaerobic digester in which methane formation is inhibited. This enhances formation of linear aliphatic carboxylic acids from acetic to hexanoic acid. The organic acids can be removed from the fermenter by liquid-liquid extraction and then converted to the final product by electrolytic oxidation. The product is dependent on the organic acid produced in the digestion step and the conditions of the electrolytic oxidation. The potential process products include linear alkanes (n-octane, n-decane), olefins (propylene, butenes), alcohols (propanol, pentanol), and esters (ethylacetate, propylbutyrate). The process is more sophisticated than methane production, but has a more valuable product. Reduction in wastewater BED and suspended solids (and thus a reduction in disposal costs) is similar to that for methane digestion.

127 (DOE/CE/40586-T1) **Analysis of a new waste paper defibering and deinking process. Final report.** Energetics, Inc., Columbia, MD (USA); Resin Research Labs., Inc., Newark, NJ (USA). Nov 1983. 105p. DOE Contract AC01-82CE40586. Order Number DE84002138. Source: NTIS, PC A06/MF A01.

A new defibering and deinking system was characterized and compared to existing deinking technology to determine potential energy savings. The system consists of two sets of chemical interactions (one for defibering and deinking and one for separation of ink from fiber in suspension) using proprietary chemicals and a process sequence intended to enhance the process chemistry. Front end pulping and washing, which defibers the waste paper and removes contaminants other than ink, is followed by flotation for ink removal and final washing and thickening. Claims for the system include: the capability to remove problem inks, coatings, pigments, etc. other systems cannot; energy conservation due to the use of fewer prime pieces of equipment and more energy efficient ink flotation equipment; equipment cost savings due to the use of fewer prime equipment pieces; and operating cost savings from the use of lower cost paper furnishes. Preliminary findings based on laboratory and pilot testing, and available cost and energy consumption data show these claims to be reasonable. Therefore, full-scale testing of the RRL system is recommended to validate process performance estimates.

128 (DOE/CE/40639-T1) **Pyrolysis of waste plastics to useful energy. Final report, August 29, 1983-December 31, 1984.** Elghossain, M.; Parr, T.R. Proce-dyne Corp., New Brunswick, NJ (USA). Dec 1984. 148p. DOE Contract AC01-83CE40639. Order Number DE85015378. Source: NTIS, PC A07/MF A01; GPO Dep.

This report covers the work completed under United States Department of Energy Contract No. AC01-83CE40639 entitled "Pyrolysis of Waste Plastics to Useful Energy". The objectives of this research and development program were to: determine the applicability of a specific coil pyrolysis process developed under DOE Contract No. AC01-83CE40639 to polyvinyl chloride (PVC) plastic waste; determine the applicability of the same process to polyethylene terephthalate (PET) plastic waste; determine the applicability of this process to mixed waste streams of industrial importance (specifically, the plastic wire insulation and PET beverage bottle streams); and establish the quality and consistency of quality of the pyrolysis products from this process for these applications. It was determined that the coil pyrolysis process is not applicable to PVC conversion to fuel. An alternative pyrolysis approach to PVC was considered and is regarded as potentially feasible. It was determined that the coil pyrolysis process is not applicable to PET conversion. While working on the PET coil pyrolysis process, a PET separation process was developed which offered a commercially feasible route from PET beverage bottles to reusable PET plastic. This development led to a commercial operation of 1500 lb/h plastics recovery in South Windsor, Connecticut. It was concluded that the coil pyrolysis process is applicable to the conversion of the HDPE bases of the PET plastic beverage bottles. It was concluded that the coil pyrolysis process was not applicable to the PET remainder of the beverage bottle or the waste wire stream. An alternate pyrolysis process was considered and is regarded as potentially feasible. It is recommended that development work be continued on these alternative pyrolysis processes.

129 (DOE/CE/40714-T1) **Waste tire utilization.** Hershey, R.L.; Waugh, M.D.; Hanny, E.J. Science Management Corp., Washington, DC (USA). 30 Apr 1987. 39p. DOE Contract AC01-84CE40714. Order Number DE88015215. Source: NTIS, PC A03/MF A01; GPO Dep.

Waste tire accumulations have become an increasingly important problem in recent years. This is of interest to DOE because the scrapped tires represent a large energy resource, and many requests for information have been received. Therefore, this report has been prepared to help in implementing waste tire utilization technologies.

130 (DOE/CS/40160-T1) **Energy-conserving, pollution-free extraction process for the recovery of lead from lead sulfide concentrates. Final report.** Rao, Y.K. Washington Univ., Seattle (USA). Div. of Metallurgical Engineering. Sep 1981. 92p. DOE Contract FC07-79CS40160. Order Number DE82000840. Source: NTIS, PC A05/MF A01.

Research concerned with the development of a new process for the extraction of lead from lead sulfide concentrates is described. The process consists of smelting lead sulfide concentrates with lime and carbon to produce liquid lead. The sulfur in the concentrates is tied up as solid calcium sulfide residue which can be further processed to regenerate lime. No sulfur oxides are generated during the process. The off-gas consist of CO and CO₂. Coke, coal, coal-char or lignite-char may be used as reducing agents. The reduction process can be catalyzed to an appreciable degree by the

addition of small concentrations of catalysts. For the most part, these catalytic substances are either pure or mixed alkali-metal salts. The present process can be applied for extracting zinc from zinc sulfide concentrates and also for the recovery of copper and nickel from their respective sulfide concentrates.

131 (DOE/CS/40192-T1) **Start-up guidelines for the independent remanufacturer.** Lund, R.T.; Skeels, F.D. Massachusetts Inst. of Tech., Cambridge (USA). Center for Policy Alternatives. Mar 1983. 167p. DOE Contract AT01-79CS40192. Order Number DE83016624. Source: NTIS, PC A08/MF A01.

Remanufacturing is an industrial process in which worn-out products called cores are restored to like-new condition. In a typical remanufacturing process, identical cores are grouped into production batches, completely disassembled, and thoroughly cleaned. Component parts are replaced or refurbished as necessary to bring their performance at least back to the level of the product when new. The product is assembled, finished, tested, packaged, and distributed in the same manner as new products. Even the warranty on a remanufactured product is usually similar or identical to the OEM new product warranty. Marketing, technology, economics, legal considerations, and organizational aspects of remanufacturing are discussed.

132 (DOE/CS/40192-T3) **Engineering feasibility study of remanufacture of chain saws.** Lund, R.T.; Skeels, F.D.; Heaton, G.R. Jr.; Grand, R.; Beardsley, D.L.; Gonzalez, T.A. Massachusetts Inst. of Tech., Cambridge (USA). Center for Policy Alternatives. Aug 1982. 281p. DOE Contract AT01-79CS40192. (CPA-82-12). Order Number DE88015218. Source: NTIS, PC A13/MF A01; GPO Dep.

This is the fourth in a series of studies on the subject of manufacturing, conducted by the Center for Policy Alternatives of the Massachusetts Institute of Technology and sponsored by the Alternative Materials Utilization Branch of the Office of Industrial Programs, US Department of Energy. These pioneering studies have served to examine the nature and extent of remanufacturing in the US, the energy and materials conservation potential of this activity, and opportunities for further development of commercially viable remanufacturing enterprises. In this volume we present a preliminary engineering feasibility study of the remanufacture of chain saws, one of the products that had been identified in an earlier study as offering an attractive opportunity for an extension of the remanufacturing concept.

133 (DOE/CS/40202-T16) **Conversion of cellulosic waste to liquid hydrocarbon fuels. Technical progress report, February 1-28, 1985.** Kuester, J.L. Arizona State Univ., Tempe (USA). Dept. of Chemical Engineering. 1985. 4p. DOE Contract AC02-76CS40202. (COO-2982-113). Order Number DE85008100. Source: NTIS, PC A02/MF A01; GPO Dep.

A steam reforming system (nickel oxide catalyst, fixed bed) was installed in the gasification overhead system for the purpose of converting methane to carbon monoxide and hydrogen and thus increasing the amount of reactants (CO + H₂ + olefins) in the synthesis gas. A water gas shift (H₂O + CO → H₂ + CO₂) effect is apparent at temperatures below 1100°F. Above 1100°F, the hydrocarbons (methane, ethane, ethylene) were depleted with a net increase in reactants. 1 fig.

134 (DOE/CS/40202-T19-Vol.1) **Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 1,**

Project overview: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 28p. DOE Contract AC02-76CS40202. Order Number DE87003646. Source: NTIS, PC A03/MF A01; GPO Dep.

An indirect liquefaction approach is used, i.e., gasification to synthesis gas followed by liquefaction of the synthesis gas. The primary virtue of an indirect liquefaction approach for cellulosic type feedstocks is that oxygen contained in the materials is easily separated. Thus the hydrocarbon liquid product is free of oxygenated compounds and can therefore be tailored to match transportation fuel products currently derived from petroleum. Approximately 100 biomass materials were studied as received from private industry, government laboratories and other university laboratories. The feedstock candidates included industrial wastes, agricultural and forest residues and crops that would be deliberately grown for energy conversion purposes. The product of the process is a liquid hydrocarbon transportation grade fuel similar to diesel. This can be upgraded to high octane gasoline via catalytic reforming if desired. The products should be compatible with existing engine designs and fuel distribution and marketing systems. The major virtue of the process is that a renewable, often low valued material is used as the feedstock to produce a quality product.

135 (DOE/CS/40202-T19-Vol.2) Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 2, A kinetic study of the modified Fischer-Tropsch synthesis over an alumina-supported cobalt oxide catalyst: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 505p. DOE Contract AC02-76CS40202. Order Number DE87003647. Source: NTIS, PC A22/MF A01; GPO Dep.

A modified Fischer-Tropsch reaction with the incorporation of ethylene in the synthesis gas has been studied kinetically. The feed mixture was also comprised of methane and carbon dioxide in a proportion similar to a real pyrolysis gas composition. The feed gas was provided by a manifold of compressed gas cylinders. An alumina-supported cobalt oxide catalyst was prepared by an impregnation method and used in the experimentation.

136 (DOE/CS/40202-T19-Vol.3) Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 3, Supervisory control system development for an indirect liquefaction process: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 481p. DOE Contract AC02-76CS40202. Order Number DE87003648. Source: NTIS, PC A21/MF A01; GPO Dep.

A supervisory process control system for the Biomass Indirect Liquefaction Pilot Plant has been developed. A microcomputer, the IBM 9000 system, was utilized for data acquisition, reduction, and adjustment, process modeling, simulation, and off/on-line optimization. The IBM 9000 is interfaced with the process through a front end data acquisition system.

137 (DOE/CS/40202-T19-Vol.4) Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 4, Slurry phase synthesis of liquid hydrocarbon fuels from biomass pyrolysis gas using iron catalysts: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 127p. DOE Contract AC02-76CS40202. Order Number DE87003649. Source: NTIS, PC A07/MF A01; GPO Dep.

An experimental assessment of liquids and iron based catalysts for use in a Fischer-Tropsch slurry reactor has been conducted. The best catalyst/liquid combination was found to be a 48Fe/4.8Cu/47.2Kieselguhr catalyst in Chevron Refined Wax 143. At the optimum operating conditions of 300°C, 200 psig, using a 5 weight % catalyst slurry with a molar H₂/CO feed ratio of 0.5, the yield of product was 118 mg/g-cat/h. Five different catalysts were tested in their ability to produce diesel type fuels from biomass pyrolysis gas. The catalysts tested, in order of decreasing product yield, were: kieselguhr supported, potassium promoted alumina supported, potassium promoted unsupported, unsupported, and alumina supported iron. A two-level factorial study using temperature, pressure, H₂/CO feed ratio, and catalyst concentration in the slurry as factors was also performed.

138 (DOE/CS/40202-T19-Vol.5) Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 5, Microwave heating of fluidized bed reactors: Pyrolysis and calcination applications: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 187p. DOE Contract AC02-76CS40202. Order Number DE87003650. Source: NTIS, PC A09/MF A01; GPO Dep.

A microwave system was designed and built that was capable of reliably and efficiently heating a fluidized bed reactor to elevated temperatures. System applications included pyrolyzing euphorbia lathyris feedstock at 1450°F and calcining 10% cobalt/alumina catalyst at 900°F.

139 (DOE/CS/40202-T19-Vol.6) Conversion of cellulosic wastes to liquid hydrocarbon fuels: Vol. 6, The modeling and design of a staged indirect liquefaction reactor: Final report. Kuester, J.L. Arizona State Univ., Tempe (USA). Coll. of Engineering and Applied Sciences. Nov 1986. 229p. DOE Contract AC02-76CS40202. Order Number DE87003651. Source: NTIS, PC A11/MF A01; GPO Dep.

A staged reactor was designed to convert biomass to useful fuels. The reactor consists of three stages. The first stage is a concentric combustor/pyrolyzer system where the biomass is gasified in a fluidized bed at high temperatures in the absence of oxygen. The second stage is a cyclonic scrubber where particulates and condensable materials are removed from the gas stream while the gas is cooled. In the final stage the gas undergoes a Fischer-Tropsch synthesis in a fluidized bed or slurry reactor. Mathematical models of the system were developed and used to create computer programs that would predict the behavior of the bed. The models were based on fundamental phenomena and were used to predict key dimensions of the staged reactor system. A transparent plastic, full-scale, cold flow reactor simulator was built using the models' predictions. The simulator was used to refine the models and determine the operating characteristics of the reactor. The design was determined to be workable and potentially useful. The reactor was, however, difficult to operate and would require extensive automated control systems.

140 (DOE/CS/40420-T1) In-forest dried (IFD) wood residue fuel technology development. Final report on batch IFD system. Gorham International, Inc., ME (USA). Mar 1986. 86p. DOE Contract FC07-81CS40420. Order Number DE86010582. Source: NTIS, PC A05/MF A01; GPO Dep.

A system has been developed to acquire and process forest residues from logging operations for use as an industrial

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fuel. The Gorham In-Forest Dried (IFD) Wood Residue Fuel System combines several functional elements which are carried out by one of three participants: a logger who harvests the residues of his operation, along with traditional roundwood and sawlog products (co-harvesting); a fuel wood vendor who chips and dries the residues and transports the dry residue chips; and an industrial customer who uses the residue chips (primarily owners of package oil and natural gas fired boilers). The motivation for the system, affecting its overall and specific configuration, is lower capital and operating costs at the user site. The IFD Residue Fuel Technology Development Project has progressed through two phases of work. Overall project objectives included: defining, developing and implementing methods and procedures for small-scale integrated harvesting of roundwood and residues; more fully defining the activities and operations of the fuel wood vendor; adaptation and application of prototype gasifiers to in-forest drying; design and procurement of heat and power and drying equipment; testing and modification of equipment; and examination of issues relevant to industrial use of IFD residue chips.

141 (DOE/ID/12162-T2) **Co-fired oil and tire-derived fuel: waste-tire energy-reclamation project.** Eastern Products Corp., Andover, MA (USA). Apr 1982. 146p. DOE Contract FC07-80ID12162. Order Number DE83007300. Source: NTIS, PC A07/MF A01.

Test results demonstrated that tire-derived fuel (TDF) can be co-fired with oil in a concentration of up to 16% of the Btu input to the boiler. Combustion efficiency was approximately the same as when burning oil only. This efficiency was achieved without making any inlet air optimization adjustments. The data also showed that TDF could be co-fired with oil without air pollution equipment and met Massachusetts pollution standards with proper control of the underfired air supply. Problems with the feed system and the grate are discussed. (MHR)

142 (DOE/ID/12163-1) **Waste tire fluidized bed combustion boiler project.** National-Standard Co., Niles, MI (USA). Mar 1984. 323p. DOE Contract FC07-80ID12163. Order Number DE84008535. Source: NTIS MF A01; GPO Dep.

The objective was to commercially demonstrate a fluidized bed combustion (F.B.C.) system that could convert waste tires into steam energy at a convenience level approximately that of oil or gas-fired boilers. In order to burn tires in a F.B.C. unit, the tires must first be chopped into a maximum size of four inches by four inches. This was readily accomplished in a tire chopper modified for multi-pass operation. The chopper could be mounted on a truck or trailer and use gasoline or other fuels making it suitable for mobile operation. A test program was conducted to determine performance and design criteria, which were used to specify a commercial scale steam generation demonstration unit. It was found that 100% of the heat of combustion available in tires can be released in a F.B.C. unit. Tires must be combusted at $775 \pm 25^\circ\text{C}$ to provide for fiberglass removal. Unburned carbon black along with fiberglass, zinc oxide, bed fines and scrap wire would have to be landfilled. Sulfur dioxide and nitrogen oxide emissions would be below the limits imposed by the Michigan Department of Natural Resources. Particulate emissions downstream of the cyclone would have to be limited by some system such as a bag house. A site was prepared for the pilot model site at National-Standard Lake Street Plant Building No. 6 in Niles,

Michigan. The tire chopper and most of the auxiliary equipment was installed. Before contracts were awarded to construct the F.B.C. unit, a revised financial analysis showed that the investment required for the F.B.C. unit made the entire system uneconomical. Although the operating costs of the waste tire system was considerably less than that of gas or oil fired boilers, the large initial investment for the system made the payback period 12 to 18 years.

143 (DOE/ID/12163-T1) **National-Standard Company waste-tire fluidized-bed-combustion boiler project. Final report.** Kenney, R.; Joyce, J.F. National-Standard Co., Niles, MI (USA). 1981. 324p. DOE Contract FC07-80ID12163. Order Number DE83008108. Source: NTIS, PC A14/MF A01.

The objective of the work reported was to commercially demonstrate a fluidized bed combustion (F.B.C.) system that could convert waste tires into steam energy at a convenience level approximately that of oil or gas-fired boilers. In order to burn tires in a F.B.C. unit, the tires must first be chopped into a maximum size of four inches by four inches. A test program was conducted to determine performance and design criteria, which were used to specify a commercial scale steam generation demonstration unit. It was found that 100% of the heat of combustion available in tires can be released in a F.B.C. unit. Tires must be combusted at $775 \pm 25^\circ\text{C}$ to provide for fiberglass removal. Unburned carbon black along with fiberglass, zinc oxide, bed fines and scrap wire would have to be landfilled. Sulfur dioxide and nitrogen oxide emissions would be below the limits imposed by the Michigan Department of Natural Resources. Particulate emissions downstream of the cyclone would have to be limited by some system such as a bag house. A revised financial analysis showed that the investment required for the F.B.C. unit made the entire system uneconomical. Although the operating costs of the waste tire system was considerably less than that of gas or oil fired boilers, the large initial investment for the system made the payback period 12-18 years.

144 (DOE/ID/12349-T1) **Development of a process to compression dry wood-chip fuels. A laboratory study. Final report.** Haygreen, J.G. Minnesota Univ., St. Paul (USA). Dept. of Forest Products. Sep 1985. 197p. DOE Contract AS07-83ID12349. Order Number DE86002633. Source: NTIS, PC A09/MF A01; GPO Dep.

Because of the promising technical feasibility of compression drying established by this research a preliminary economic analysis was completed. The compression drying process shows the potential to be economically advantageous in many industrial situations where wet wood residues are being purchased as fuels. The most important factors which determine economic payback are the initial moisture content of the fuel and the delivered cost of the fuel. Whenever the green moisture content is in the 53 to 60% range and the delivered cost of the fuel is \$10 or more it appears that compression drying may be justified. When the fuel cost at the boiler is \$15 per ton or more the process looks extremely promising and may pay for itself in less than two years. Other industrial situations using wet residue fuel, where compression drying may be justified, are also identified. Results indicate that compression drying is technically feasible, economically feasible, and can result in a significant conservation of energy. Therefore, compression drying is an excellent candidate for commercialization. Recommendations are given for the design of a prototype, including press size, pressure capability, calculation of through-put,

design of side-plates and other critical elements, as well as sizing the motor/pump system. Also provided are guidelines for the effective operation of a typical compression drying process. 19 figs., 11 tabs.

145 (DOE/ID/12519-T1) **Development of a process to produce chemicals from lignocellulose. Final report.** Allen, B.R.; Dawson, W.J.; Jenkins, D.M. Battelle Columbus Labs., OH (USA). 26 Jun 1985. 42p. DOE Contract AC07-84ID12519. Order Number DE85017028. Source: NTIS, PC A03/MF A01; GPO Dep.

This report is Battelle Columbus Laboratory's (BCL) final report on a research program to investigate the technical and economic feasibility of a conceptual process for the conversion of cellulose and hemicellulose in waste materials to higher value chemicals, such as lactic and acetic acids. The conceptual conversion process was based upon previous studies by Battelle on the conversion of simple sugars to ethanol via a thermochemical process. This process involved the production of lactic acid as an intermediate. The major technical issue of this project, which was not addressed in the previous work, was to determine whether the direct conversion of cellulose and hemicellulose to lactic and acetic acids was technically feasible. This research program was developed to answer the technical feasibility question and to provide a very preliminary evaluation of the process economics. This very preliminary investigation has demonstrated that the conversion process does have technical and economic merit. The major technical goal, that of demonstrating the feasibility of the direct conversion of cellulose to lactic and acetic acids, without first hydrolyzing the cellulose to glucose, was achieved. Direct conversion of waste materials, in yields of about 35 to 40% was achieved and was equal to or higher than the yield from pure cellulose. 2 refs., 8 figs., 9 tabs.

146 (DOE/ID/12560-1) **Recovery and reuse of asphalt roofing waste. Conversion of roofing waste to No. 6 fuel oil. Final report.** Hunt, J.; Shepherd, P. Manville Service Corp., Denver, CO (USA). Research and Development Center. 19 Nov 1985. 42p. DOE Contract AC07-85ID12560. Order Number DE86004899. Source: NTIS, PC A03/MF A01; GPO Dep.

A novel concept for recovering the energy in the asphalt contained in the roofing waste involved dissolving the asphalt in roofing waste in No. 2 fuel oil, separating the solids from the liquid, and concentrating the liquid to No. 6 fuel oil. Experiments showed that this concept would be applicable to both factory and field asphalt roofing waste. Filtration was unsuitable for making the liquid/solid separation. Limited experiments using centrifuging as the liquid/solid separation process indicated that this is feasible. The centrifuging process would be a means for recovery of much of the 7.3×10^{13} Btu represented in the nation's annual roofing waste and would also have a major impact on reducing the six million cubic yards of roofing waste now hauled to landfills each year.

147 (DOE/ID/12560-2-Vol.1) **Recovery and reuse of asphalt roofing waste: incorporation of roofing waste in asphalt paving. Volume 1. Analysis.** Paulsen, G.; Epps, J.A.; Shepherd, P.B.; Powers, T.J.; Albers, J.L. Nevada Univ., Reno (USA). Center for Construction Materials Research; Manville Sales Corp., Denver, CO (USA). Research and Development Center. 15 Sep 1986. 100p. DOE Contract AC07-85ID12560. Order Number DE87000618. Source: NTIS, PC A05/MF A01; GPO Dep.

A prior DOE study on ten candidate methods for recovering the energy resource represented in asphalt roofing waste showed that incorporating this waste in asphalt paving was a potentially viable commercial means for recovering a large portion of the annual 7×10^{13} Btu's in this waste resource. Laboratory tests were designed to investigate this potential and study such variables as waste preparation and amount of roofing waste which might be added to asphalt paving. These laboratory studies reported in Volume II of this report showed that paving mixes can be prepared using hammer milled, worn-out shingles up to about 18 1/2% by weight (30% by volume). The laboratory tests, limited to field waste, showed that the source of waste, size of waste and amount of waste will influence the test response of paving mixes. Preliminary economic projections were made based on the laboratory test results. Adding roofing waste to asphalt paving should prove to be a financially viable means for recovering the energy resource in asphalt roofing waste. Pavement mix cost reductions in the range of 5% to 20% were estimated for the ranges of waste addition tested.

148 (DOE/ID/12560-3) **Recovery and reuse of asphalt roofing waste burning of asphalt roofing waste.** Zolnick, E.L.; Markus, A.R.; Seigfried, J.N.; Powers, T.J.; Shepherd, P.B.; Graziano, G.J.; Battles, R.L. Johns-Manville Sales Corp., Denver, CO (USA). Research and Development Center. 15 Sep 1986. 118p. DOE Contract AC07-85ID12560. Order Number DE87000571. Source: NTIS, PC A06/MF A01; GPO Dep.

The research described in this report was designed to determine the general feasibility and specific requirements for burning asphalt roofing waste and recovering the energy resource as steam. The study combined technical market research with test burning in a three-task program to identify how to use burning as a means for recovering the 7×10^{13} Btu in roofing waste landfilled annually.

149 (DOE/RG/03336-T1) **Waste tires and their utilization: an investigation of trends and obstacles.** Purcell, A.H. Resource Planning Associates, Inc., Cambridge, MA (USA). Jun 1978. 25p. DOE Contract AM01-78RG03336. Order Number DE81023766. Source: NTIS, PC A02/MF A01.

Options that have been developed to conserve the energy and materials investment in tires are discussed. Reduction, the first option, involves finding ways to (a) use less rubber per tire and/or (b) make longer-lasting tires. Reuse of chemically unaltered tire material, in whole tire or other form, provides the second option. Improving long-practiced rubber reclaiming technology is the third area. Recovery encompasses techniques for recovering heat value, constituent materials, and chemicals from waste tires.

150 (DOE/TIC-11431) **Improved combustion of wood waste in industrial boilers. Technology applications manual; technology transfer.** CH2M Hill, Bellevue, WA (USA). 1982. 36p. DOE Contract AC06-76RL01830. Order Number DE81027633. Source: NTIS, PC A03/MF A01.

To provide information on optimum design and operation of existing wood residue fired spreader-stoker boilers, research was conducted on a pilot-scale spreader-stoker boiler. Wood waste combustion was investigated as a function of fuel size, moisture content, species, air:fuel ratios, and type of equipment used. Data collected from the test facility show that distribution of combustion air to the combustion chamber is critical to efficient operation of boilers. The results indicate that more complete combustion of wood

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residue is possible when excess air is reduced significantly below commonly used levels, the underfire air supply is reduced, and overfire air is distributed uniformly over the grate surface. Proper air distribution can increase the combustion by 3 to 8 percent and reduce particulate emissions by 20 to 30% below levels that occur at typical boiler operating conditions. Improved equipment and procedures for burning wood waste in industrial boilers were developed as a result of the tests. These improvements can be used in both existing and new boilers. An economic analysis showed that the improvements can be economically desirable both for retrofit of existing wood fired boilers and for incorporation in new boilers. (LEW)

151 (EGG-M-01987) **Waste tires as auxiliary fuel for cement kilns.** Dodds, J. EG and G Idaho, Inc., Idaho Falls, ID (USA). 1987. 10p. DOE Contract AC07-76ID01570. (CONF-8702171-1: Disposal technology with energy recovery with scrap vehicle tires, Denver, CO, US, February 12, 1987). Order Number DE89010998. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

The subject I have been asked to speak about is the utilization of scrap tires as an auxiliary fuel for cement kilns. My experience with scrap tires began five years ago when we performed a technical and economic evaluation for tire pyrolysis. I work for the Idaho National Engineering Laboratory which is supported by the Department of Energy. My interest in scrap tires continued; in 1984 the Department of Energy and the Portland Cement Association jointly sponsored a conference on the utilization of scrap tires in cement kilns. Most of my remarks today are based upon that conference along with some current information in the US. Mr. Sladek requested that I speak on the combustion process, the progress to date, and the factors that impede or encourage implementation of using scrap tires in cement kilns. For discussion purposes it would help if we had a common understanding of the cement manufacturing process. Cement is made by heating a mixture of finely ground limestone and silica from clay or sand to about 1450°C in a large rotating kiln. The heat causes the limestone to decarbonate and subsequently react with the silica to form calcium silicates. 5 figs.

152 (PNL-4734) **Economic and energy audit of converting waste plastics to oil. Final report.** Machacek, R. Little (Arthur D.), Inc., Cambridge, MA (USA). Jun 1983. 34p. DOE Contract AC06-76RL01830. Order Number DE83015022. Source: NTIS, PC A03/MF A01.

A new technology was developed for converting the waste atactic resin to liquid fuel. The first commercial-scale demonstration/development unit (17 million pounds per year atactic resin feed) was built on a cost-sharing basis by Procedyne, USS Chemicals, and the US Department of Energy at the polypropylene facility of USS Chemicals in La Porte, Texas. The unit has been operating in its present modified form since March 1982. An economic analysis and energy audit on Procedyne Corp.'s pyrolysis process was conducted. The study considered the technical feasibility, reliability, energy savings, and economic incentives of the process.

153 (RLO/2227/T22-1) **Investigation of the rate of combustion of wood residue fuel. First annual report, April, 1976-March 31, 1976.** Junge, D.C. Oregon State Univ., Corvallis (USA). 18 Mar 1977. 11p. DOE Contract EY-76-S-06-2227-022. Source: NTIS, PC A02/MF A01.

A test facility in which to study the rate of combustion of wood residue fuels was designed and constructed. The facility has been started up and is now in process of being calibrated and made ready for data collection. The background, scope and purpose of the project are described. The test facility is illustrated photographically, schematically, and is discussed only in cursory detail. Brief discussion is offered concerning the time framework of the project, the present status of the project, list of project participants, level of financial support and an indication of the interest of agencies and industry in the efforts of this research undertaking.

154 (SAN-1699-T1) **Potential for energy conservation through the use of slag and fly ash in concrete. Final report.** Price, J.D.; Troop, P.; Gershman, H.W. Gordian Associates, Inc., Washington, DC (USA). 29 Dec 1978. 184p. DOE Contract EC-77-C-03-1699. Source: NTIS, PC A09/MF A01.

This study provides an overview of the opportunity for energy conservation through the use of fly ash and glassy (granulated or pelletized) blast furnace slag in the manufacture of blended cement or as ingredients with portland cement in concrete. Hydraulic (portland) cement concrete is the most widely used manmade building material in the world; approximately 700 million tons are used each year in the U.S. alone. Portland cement, the binder in most concrete placed in the U.S., is produced at a great energy cost: the U.S. cement industry consumes about 564 trillion BTUs annually, or roughly 2% of the energy consumed directly in the nation's industrial processes. Certain forms of both fly ash and iron blast-furnace slag can be used as ingredients in portland cement concrete to supplement the cementing action of the portland cement, and effectively reduce the amount of portland cement required as a binder per unit volume of concrete. This report examines the prospects of using the residual byproducts of iron and steel manufacture (blast furnace slag) and electric utility operations (fly ash) to an increasing extent in order to reduce the amount of portland cement required to produce an equivalent amount of concrete. This would reduce the overall energy required to produce that concrete.

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Refer also to citation(s) 63, 318, 338

155 (ANL/CNSV-9) **Energy and materials flows in the production of olefins and their derivatives.** Gaines, L.L.; Shen, S.Y. Argonne National Lab., IL (USA). Aug 1980. 184p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A09/MF A01.

Production of olefins and their derivatives uses almost 3.5% of the oil and gas consumed annually in the United States. It is estimated that their production requires an input energy of 2 Q, which is 50% of the energy used in the production of all petrochemicals. Substantial amounts of this energy could be recovered through recycling. For example, recycling of a single plastic product, polyester soft drink bottles, could have recovered about 0.014 Q in 1979. (About 1.4 Q is used to produce plastic derivatives of olefins). Petrochemical processes use fuels as feedstocks, as well as for process energy, and a portion of this energy is not foregone and can be recovered through combustion of the products. The energy foregone in the production of ethylene is estimated to be 7800 Btu/lb. The energy foregone in plastics production ranges from 12,100 Btu/lb for the new linear

low-density polyethylene to 77,200 Btu/lb for nylon 66, which is about 60% of the total energy input for that product. Further investigation of the following areas could yield both material and energy savings in the olefins industry: (1) recycling of petrochemical products to recover energy in addition to that recoverable through combustion, (2) impact of feedstock substitution on utilization of available national resources, and (3) effective use of the heat embodied in process steam. This steam accounts for a major fraction of the industry's energy input.

156 (ANL/CNSV-44) Energy and materials recovery from industrial wastewaters. Kremer, F.; Broomfield, B.; Fradkin, L. Argonne National Lab., IL (USA). Nov 1983. 263p. DOE Contract W-31-109-ENG-38. Order Number DE84010345. Source: NTIS, PC A12/MF A01; GPO Dep.

The objectives of this study were to identify the larger industries generating wastewaters and to define the properties of their respective effluents, particularly those constituents presenting problems in meeting effluent standards. These constituents were examined to determine their potential for conversion to energy. The following industries were investigated: electroplating, iron and steel, textile, petroleum refining, pulp and paper, food processing, and organic chemical.

157 (ATR-78(7384)-1) Utilization of used oil. Final report. Mascetti, G.J.; White, H.M. Aerospace Corp., El Segundo, CA (USA). Aug 1978. 396p. DOE Contract EY-76-C-03-1101-003. Source: NTIS, PC A17/MF A01.

This report assesses the potential impact of re-refining used automotive and industrial lubricating oils on the national petroleum consumption. The technical base for this assessment is derived from a comprehensive review of the processes utilized in re-refining used oil and those processes used to produce lube oil from crude. Both existing and recently proposed processes are considered. Additionally, an extensive review of processes described in the patent literature is provided. Re-refining processes are surveyed and evaluated. Process descriptions are provided; hardware is identified; and process energy and economic requirements are calculated. Factors affecting the profitability of a re-refining operation are discussed. Economic projections of the demand for lube oil and the ability to satisfy this demand from crude oil are made and the value of lube oil as a vital resource and the need for conservation are addressed. Other factors related to re-refining are discussed, including lube oil characteristics, degradation, lube oil quality and engine sequence testing, and legislative and institutional barriers. Finally, an energy assessment of used oil utilization is made. Two options are considered in this assessment: (1) all used oil is re-refined and recycled back to lube oil; (2) all used oil is burned to recover its heat content.

158 (BERC/RI-75/11) Waste lubricating oil research: geographical and seasonal variations in used lubricating oil basestock composition, part 2. Whisman, M.L.; Cotton, F.O.; Goetzinger, J.W.; Reynolds, J.W. Energy Research and Development Administration, Bartlesville, OK (USA). Bartlesville Energy Research Center. Dec 1975. 22p. Source: NTIS, MF \$4.00.

LUBRICATING OILS/chemical composition; LIQUID WASTES/chemical composition; PHYSICAL PROPERTIES; CHEMICAL PROPERTIES; SEASONAL VARIATIONS; RE-PROCESSING; GOVERNMENT POLICIES

159 (BERC/RI-76/11) Treatment of waste lubricating oil using BERC/ERDA solvent. Corlew, J.S.; Sluski,

R.J. Custom Refining Co., Adams City, CO (USA). 25 Jun 1976. 47p. DOE Contract PO-BE-76-P-1601. Source: NTIS, MF \$4.00.

From data generated in the laboratory and pilot plant studies a quality rerefined oil can be produced via BERC/ERDA solvent extraction and clay treatment. Some of the important processing variables that determine the quality of the finished product are temperature of solvent extraction, type of clay used, temperature and time of clay treatment, and the atmosphere under which the oil is treated with clay. Yields of 75 percent based on water-distillate-free oil can be expected at the conditions used in pilot plant operations. The oils obtained could be compounded to produce a large number of high quality lubricating products. Unlike an acid-clay process where the acid sludges pose an environmental problem, the BERC/ERDA system produces a marketable sludge.

160 (BERC/RI-77/3) Waste lubricating oil research: a comprehensive characterization of five typical re-refinery feedstocks. Part 5. Cotton, F.O.; Whisman, M.L.; Goetzinger, J.W.; Reynolds, J.W. Energy Research and Development Administration, Bartlesville, OK (USA). Bartlesville Energy Research Center. Apr 1977. 23p. Source: NTIS, PC A02/MF A01.

By use of procedures developed previously at this research center, five feedstock samples of used lubricating oil obtained from re-refineries were characterized in detail. A combination of silica-alumina gel and gel permeation chromatography was used to separate the oils into simpler fractions for analysis by low voltage mass spectrometry. The data show the various samples to be extremely similar, implying that an acceptable reclamation procedure should produce consistent re-refinery product with minimal effects from feedstock variations.

161 (BERC/RI-77/11) Predesign cost estimate for re-refined lube oil plant. Bigda, R.J. Bigda (Richard J.) and Associates, Tulsa, OK (USA). Jun 1977. 19p. Source: NTIS, MF \$3.50.

The first estimates for a predesign of the BERC re-refining process are contained in this report. Although many process equipment variables are yet to be resolved, this first estimate indicates the probable viability of the process. Based upon a plant which could process 10 million gallons of waste lube oil a year, the following preliminary conclusions were made: Capital costs would approximate \$2 million. Waste oil purchased at 15 cents/gal could be re-refined into blendable lube oils for 39 cents/gal. Considering a selling price of 47 cents/gal in bulk, the return on investment before taxes would approach 45 percent. The operation is very sensitive to the cost of the used oil. The plant capacity could be doubled or tripled with only a modest increase in cost. These findings and the predesign analysis show areas where more intensive R and D is required. More effort is also apparent to demonstrate the feasibility of economically gathering the waste oil. A larger plant would be more economical, but this must be balanced with the cost of collecting the used oil. In general, the project offers promise as a means of economically and profitably conserving millions of gallons of valuable lube oils.

162 (BERC/RI-77/19) Comparison of BERC re-refining process with acid/clay/distillation process. Bigda, R.J. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Research Center. Sep 1977. 32p. DOE Contract EY-77-X-19-0237. Source: NTIS, PC A03/MF A01.

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This report compares the economics of acid/clay re-refining with the economics of the BERC solvent re-refining process. The costs of re-refining using the BERC process have been studied in a previous report entitled "Predesign Cost Estimate for Re-refined Lube Oil Plant" prepared for the Bartlesville Energy Research Center. Many of the basic assumptions such as plant size, unit capacities, etc. used in that report have been used in this document. Part I of this report compares both technologies with vacuum distillation as is anticipated with the BERC process. The cost of processing a gallon of re-refined oil with acid/clay/distillation technology was found to be 48.7 cents per gallon compared to 40.1 cents per gallon using the BERC solvent/distillation process. Part II of the report compares acid/clay technology as is now commonly used with the BERC solvent system, without using vacuum distillation for either re-refining scheme. Cost for processing a gallon of oil using acid/clay without vacuum distillation was found to be 45.8 cents per gallon compared to 37.9 cents per gallon for the BERC solvent system without vacuum distillation. It should be noted that the BERC process is less expensive than either acid/clay process.

163 (BERC/RI-78-11) BERC re-refining process: comparison of hydrofinishing versus clay contacting. Bigda, R.J. Bigda (Richard J.) and Associates, Tulsa, OK (USA). Jul 1978. 23p. DOE Contract EY-77-X-19-0237. Source: NTIS, PC A02/MF A01.

A comparison between the two possible lube finishing steps, clay contacting or hydrofinishing is presented. It is concluded that the costs of production of either finishing step are nearly the same—about 40 cent per gallon. Variables such as clay and hydrogen costs and waste clay disposal costs are determining factors. Capital costs for a BERC unit with clay contacting is about \$100,000, or 3% cheaper. More highly skilled labor is required for the high pressure hydrofinishing step. The options presented will aid the re-refiners in designing a new facility.

164 (BETC-4343-1) Comparison of sludge separation processes in the BERC used lubricating oil re-refining process. Final report. Benham-Blair-Holway and Spragins, Tulsa, OK (USA). Aug 1979. 34p. DOE Contract EY-77-C-02-4343. Source: NTIS, PC A03/MF A01.

Alternative methods to separate the sludge from the solvent/oil mixture encountered in the BERC Oil Re-refining Process were investigated in the laboratory and in a centrifuge vendor's pilot plant. The test results indicated that a combination of gravity settling to effect a gross separation and centrifugation of the sludge underflow to increase oil recovery would be the best economical situation. Based upon this process change, the budget estimate for the capital and operating costs were revised for a 10-million-gallon per year plant. The revised economic estimates based upon current conditions showed: (1) the total capital requirements would be approximately \$2.8 million, (2) the total manufacturing cost would be \$0.45 per gallon, (3) the cash flow return on investment before taxes would be approximately 54 percent.

165 (BETC/IC-79/4) Waste lubricating oil: an annotated review. Cotton, F.O. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Dec 1979. 103p. Source: NTIS, PC A06/MF A01.

Because of renewed interest in waste oil, both in terms of energy conservation and as a threat to the environment, there appears to be a need for a systematic compilation of information on the subject. This listing of 486 references

was therefore compiled to address this need. A short summary of the contents of most articles is included. The bibliography is divided into broad subject areas within which the references are listed chronologically, with the most recent articles listed first. Papers covering more than one subject are re-listed under the other subject headings with reference to the original listing. An author and periodical index is also included as Appendix A, listing the senior author only, followed by the section and reference number. Appendix B presents information and addresses for obtaining reprints of some of the references listed.

166 (BETC/RI-78/20) Solvent treatment of used lubricating oil to remove coking and fouling precursors. Brinkman, D.W.; Cotton, F.O.; Whisman, M.L. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Dec 1978. 33p. Source: NTIS, PC A03/MF A01.

Coking and fouling problems encountered with direct distillation of used lubricating oils indicate the need for a pretreatment step in re-refining processes which employ distillation. A systematic, detailed study of pretreatment by solvent precipitation is presented. After many solvents were tested, the optimum system is shown to be a mixture of 2-propanol, 1-butanol, and methylethyl ketone in a ratio of 1:2:1 by volume. The minimum solvent-to-oil ratio is 3:1. Sludge separation and settling rates are noted for static reactors, and data for centrifuged samples are also included. The effects of container shape, pH, and impurities are studied and shown to be minimal. Pilot plant data show this pretreatment to be effective and prove solvents can be recycled for continued use. The solvent pretreatment in conjunction with dehydration, distillation, and a finishing process, produces a high-quality lube oil.

167 (BETC/RI-79/1) BERC re-refining process: an engineering evaluation. Final report. Brinkman, D.W. Benham-Blair-Holway and Spragins, Tulsa, OK (USA). Dec 1978. 25p. DOE Contract EY-77-C-02-4343. Source: NTIS, PC A02/MF A01.

The budget estimate for the design and construction of a used lube oil re-refining plant using the BERC process is contained in this report. Based upon current economic conditions, the following would apply for a 10-million-gallon-per-year plant: the total capital requirements would be approximately \$3 million. The total manufacturing cost would be \$0.42 per gallon. The cash flow return on investment before taxes would be approximately 58%.

168 (BETC/RI-79/5) Clay-contacting re-refined lubricating oils: a parameter study. Reynolds, J.W.; Brinkman, D.W.; Whisman, M.L. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Apr 1979. 14p. Source: NTIS, PC A02/MF A01.

Variation of some parameters involved in clay contacting reclaimed lubricating oil for color and odor improvement has been studied. Laboratory experiments were conducted in which temperature, oil to clay ratio, steam sparge rate, and the amount of acid were varied to determine a set of optimum conditions. 13 figures, 7 tables.

169 (BETC/RI-79/14) Pilot-scale used oil re-refining using a solvent treatment/distillation process. Cotton, F.O.; Brinkman, D.W.; Reynolds, J.W.; Goetzinger, J.W.; Whisman, M.L. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Jan 1980. 46p. Source: NTIS, PC A03/MF A01.

Approximately 1000 gallons of used automotive lubricating oil were collected from service stations in the Bartlesville

region. This oil was then processed using the patented technology developed by the Bartlesville Energy Technology Center (BETC) in earlier work. The resulting lube oil base-stock was tested by both physical and chemical analytical techniques and rigorous engine sequence tests. The end product was a high-quality lubricating oil which passed all requirements for SE service. Analyses of the oil are presented at the end of each stage of processing to demonstrate the effects of that phase. 7 figures, 18 tables.

170 (COO-2983-12) **Energy and protein production from pulp mill wastes. Final report, 15 Jun 1976-14 Jun 1979.** Jurgensen, M.F.; Patton, J.T. Michigan Technological Univ., Houghton (USA). 14 Jun 1979. 60p. DOE Contract AS02-76CS40216. Source: NTIS, PC A04/MF A01.

The goal of this research was to convert the organics and sulfur in sulfite spent liquor (SSL) now classified as pollutants from sulfite pulp mills, into synthetic methane and protein by means of a combination chemical-biological process. Ozonization was used to break the high molecular weight lignosulfonate molecules present in SSL into lower weight fractions which could be metabolized by methane-producing bacteria and protein-producing yeast. Ozonization experiments showed that this treatment is effective in partially oxidizing and fragmenting lignosulfonates into fermentable substrates. This process is initiated at low ozone concentrations and proceeds rapidly until nearly 30% of the Chemical Oxygen Demand (COD) has been consumed. The conditions under which ozonization is conducted greatly affect the degree of oxidation and the molecular weight of the cleaved fragments. In spite of the appreciable oxidative cleavage of the lignosulfonate molecules, continuous-flow fermentation studies showed rather low yields of methane and yeast from ozonated SSL. Under optimum conditions, methane production averaged only 1.7 1/1 of SSL or approximately 3% of the total organics present. Protein production was somewhat more favorable with 6% of the organics being converted to yeast biomass. (6g/1). Neither fermentation fully used all of the oxygenated fragments produced by ozonization, and thus, a two-stage process might yield better results. Although it appears that ozonization is not a viable treatment of SSL under present economic conditions, with increased demand for energy and protein, it could become more competitive in the future. However, of possibly greater importance is the potential use of partial oxidation treatments to improve the biodegradability of organic wastes.

171 (COO-4074-3) **Fleet test of re-refined oil. First annual progress report.** Ulrichson, D.L. Iowa State Univ. of Science and Technology, Ames (USA). May 1977. 11p. DOE Contract EY-76-S-02-4074. Source: NTIS, PC A02/MF A01.

This test is designed to obtain comparative performance data on re-refined and virgin 10W-30 motor oils and hydraulic oils in fleet use. The vehicles are provided by the Iowa Department of Transportation. The re-refined oils are the commercial product from Motor Oils Refining Company, MORCO, and the experimental product from the Bartlesville Energy Research Center, BERC. Forty-six vehicles which include station wagons, pickups, and trucks with hydraulic systems are being operated in normal use with one vehicle on virgin oil for each vehicle on re-refined oil. Oil change samples are being analyzed by standard ASTM methods. 4000, 8000, and 10,000 mile oil change intervals are being used. All vehicles were in operation by September, 1976. All test oils are performing satisfactorily at all three drain intervals. No significant differences have been noted among the

three oils. Twelve of the vehicles on 4000 mile drain intervals have been changed to 8000 mile drain intervals to increase the stress on the oils. Final discrimination among oils will be based on deposit and wear ratings to be made by an independent laboratory and on the accumulated analytical data from oil change samples. 4 tables.

172 (DOE/BC/10008-9) **Engineering design of a solvent treatment/distillation used lubricating oil re-refinery.** Brinkman, D.W. Stubbs Overbeck and Associates, Inc., Houston, TX (USA). Jun 1980. 74p. DOE Contract AC19-79BC10008. Source: NTIS, PC A04/MF A01.

Drawings and specifications were prepared for a 10 million gallon per year used lubricating oil re-refinery based on the solvent treatment/distillation process developed and patented by the Bartlesville DOE Energy Technology Center. In addition, flowsheets were developed for facilities to treat 2, 5, and 20 million gallons per year. Using these drawings and specifications, a detailed capital cost estimate was prepared for the 10 million gallon facilities. Prorated estimates were derived for the other three capacities.

173 (DOE/BC/10044-8) **Feasibility study for the retrofitting of used oil re-refineries to the BETC solvent treatment/distillation process.** Weinstein, N.J.; Brinkman, D.W. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center; Recon Systems, Inc., Somerville, NJ (USA). Sep 1980. 42p. DOE Contract AC19-79BC10044. Source: NTIS, PC A03/MF A01.

Federal policy encourages recycle of used oil, but requires that recycling be done in an environmentally sound manner. In order to encourage such recycling the Bartlesville Energy Technology Center of the US Department of Energy has developed the DOE/BETA solvent treatment/distillation re-refining process. The feasibility of retrofitting existing used oil re-refineries to the DOE/BETC process has been studied in this work. Twelve potential sites were chosen from almost 300 firms thought to be interested in re-refining technology. Three of these twelve sites have been recommended as prime candidates.

174 (DOE/BC/10059-19) **Enhanced utilization of used lubricating oil recycling process by-products. Final report.** Weinstein, K.D.; Myers, T.D.; Craft, S.R. Booz, Allen and Hamilton, Inc., Bethesda, MD (USA); Chromaspec Corp., Houston, TX (USA). Mar 1982. 165p. DOE Contract AC19-79BC10059. Order Number DE82007671. Source: NTIS, PC A08/MF A01.

Portions of document are illegible.

Booz, Allen and Hamilton, Inc. and its subcontractor, Chromaspec Corporation, conducted a study of possible utilization options for the process by-products generated in the re-refining of used lubrication oils. By-product samples from six re-refineries utilizing four re-refining processes were taken. Detailed physical and chemical characterization data on the sample streams and their components were compiled by means of comprehensive laboratory testing. Given the characteristics of the various streams and pertinent regulations that impact possible uses, options for utilization of the by-product streams were derived. The apparently feasible options were subjected to several levels of engineering feasibility testing to determine technical viability. Apparently viable options were found for all byproduct streams, and where data existed, economic analyses were performed. Many of the economic analyses indicate either significant plant savings or increased plant revenues as a result of the implementation of the options. In the case of certain streams

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(fuel strippings, distillation bottoms) there appear to be multiple means of utilization. The only by-product stream for which no options could be found to improve plant economics is wastewater, where treatment and disposal seem the only viable by-product disposition.

175 (DOE/BC/10089-1) **Acid sludge utilization.** Suarez, M. Peak Oil Co., Tampa, FL (USA). Sep 1980. 35p. DOE Contract AC19-79BC10089. Source: NTIS, PC A03/MF A01.

The Peak Oil Company of Tampa, Florida, in cooperation with the United States Department of Energy, has completed an initial study for the incorporation of acid-sludge derived from the rerefining of used lubricating oil into a useful and salable building material. Both bricks and paving materials have been produced using a formulation developed by Peak. Equipment has been designed and constructed for the specific purpose of preparing emulsions containing the acid-sludge, which is a vital ingredient in the final formulation. Testing of products obtained from these initial efforts shows that the acid in the sludge has been effectively neutralized and that heavy metals are not leached from the bricks or paving material in normal testing. While some properties of the building materials that incorporate the acid-sludge by-product are below standards for clay and shale brick, uses are defined for the product as is, and there is some promise of eventual production of building materials that meet all specifications for competitive materials. Initial cost estimations are encouraging, indicating that a profit can be derived by converting a hazardous and noxious by-product of rerefining to a construction material. Acid-sludge has presented a complex and costly disposal problem to the industry resulting in a serious depletion in the capacity for rerefining used lubricating oil.

176 (DOE/BC/10375-6) **Fate of hazardous and non-hazardous wastes in used-oil disposal and recycling. Final report.** Surprenant, N.F.; Battye, W.H.; Fennelly, P.F. GCA Corp., Bedford, MA (USA). GCA Technology Div. Oct 1983. 246p. DOE Contract AC19-81BC10375. Order Number DE84002555. Source: NTIS, PC A11/MF A01.

The primary objective of this program was to identify the hazardous and nonhazardous compounds that might reasonably be found in used oil and to establish their fate under a variety of disposal and recycling scenarios. Those considered were sewer disposal, road oiling, combustion as a fuel, reprocessing by physical methods to produce a specification fuel, and various re-refining processes. A secondary objective was to assess the potential environmental impact of the contaminants in the waste and product streams associated with each scenario. The hazardous and nonhazardous compounds of major interest in waste oil were identified by literature review, interviews with participants in waste oil activities, and by laboratory analysis of 24 samples of waste oils obtained from recyclers and users. The contaminants were prioritized according to their concentrations in the oil and their health impacts, as determined by threshold limit values, drinking water standards, or other measures of multimedia health impacts. The prioritized listing formed the basis for the preparation of the COMPOSITE oil used in the experimental simulation studies of the waste oil disposal and recycling scenarios. The experimental simulation studies were designed to establish the fate, through material balance if possible, of specific contaminants under conditions that were representative of those normally encountered in each situation. In addition to the laboratory simulation studies, computer simulations were conducted to

assess the physical transport of specific compounds during typical re-refining operations such as dehydration, light end removal, and vacuum distillation. 126 references, 15 figures, 93 tables.

177 (DOE/BC/10562-5) **Used lubricating oil re-refining demonstration plant data acquisition. Topical report I. Environmental considerations.** Booth, G.T. III; Odojewski, S.S.; Rakoczynski, R.W. Booth Oil Co., Inc., Buffalo, NY (USA); Waste Resource Associates, Inc., Niagara Falls, NY (USA). Jan 1983. 115p. DOE Contract AC19-81BC10562. Order Number DE83006026. Source: NTIS, PC A06/MF A01.

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Booth Oil Co., Inc. has been involved in used oil collection and reprocessing since 1922. In 1978 due to a number of factors, the company decided to design and build a new re-refining facility. This report describes the multitude of environmental laws, regulations and other considerations which had to be addressed in order to make this decision a reality. The report also details the work performed in assessing the theoretical and actual air emissions emanating from the facility as well as a description of the wastewater treatment system. Much of the work performed during this project may be duplicated by others attempting to enter the re-refining business, so it is documented here to provide a description of what tasks and problems can be expected. This report is the first in a series of three individual topical reports and a final combined report. Subsequent topical reports will address the technical and financial considerations of this venture. 13 figures, 11 tables.

178 (DOE/BC/10826-1) **Hydrofinishing of re-refined used lubricating oil.** Bhan, O.K.; Tai, W.P.; Brinkman, D.W. National Inst. for Petroleum and Energy Research, Bartlesville, OK (USA). 31 Jan 1986. 85p. DOE Contract AC22-84BC10826. Order Number DE86010849. Source: NTIS, PC A05/MF A01; GPO Dep.

This study was conducted to establish hydrotreating as an environmentally attractive and economically feasible waste oil re-refining final process step. The major emphasis of this study was on determining the feasibility of using heterogeneous catalysts for polishing distilled used lube oil. Considerable attention also was focused on reactor corrosion and plugging problems. Armak-840, a commercial Ni-Mo-Al₂O₃ catalyst, was determined to have the highest activity for product liquid color improvement and nitrogen removal among the catalysts we tested. Operating the hydrofinishing reactor at a temperature of 350°C, a pressure of 800 psig, and a space velocity of 1.0 hr⁻¹ produced liquids of acceptable chemical and physical properties. Guard-bed reactors containing high surface area alumina and operated in a temperature range of 285 to 295°C effectively removed all the metals and phosphorus present in the feed liquid. During the extended catalyst life-test study of the Armak-840 Ni-Mo-Al₂O₃ catalyst, severe loss in hydrodenitrogenation activity was observed after 300 hours of oil-catalyst contact. No such decay was observed for the product liquid color. It is argued that the catalysts had not reached their equilibrium activity during the 564 hours of operation. Ammonium chloride, a white crystalline material, formed in the hydrofinishing reactor by the reaction of ammonia and hydrochloric acid, deposited in the reactor exit lines causing severe reactor plugging. Accelerated lowering of the reactor effluent temperature causes the plug to disappear. This problem only occurred in the hydrofinishing reactor. Dark residues

were formed in the guard-bed reactor at temperatures higher than 310°C. Operating the guard-bed reactor in a temperature range of 285 to 29°C suppressed the residue formation. 18 refs., 27 figs., 18 tabs.

179 (DOE/BC/30227-1) **Review of all lubricants used in the US and their re-refining potential.** Bigda, R.J. Bigda (Richard J.) and Associates, Tulsa, OK (USA). Jun 1980. 89p. DOE Contract AT19-78BC30227. Source: NTIS, PC A05/MF A01.

The purpose of this handbook on lubricating oils and their use is to assist those persons in the waste oil collecting and recycling business. Uninitiated persons considering entering this business can get a better understanding of the waste oils and products of this industry from this handbook. The first two sections deal with the processing steps and ingredients of a lubricating oil and their functions. Understanding the fundamental difference between base stocks and additives is essential if the re-refiner is to make a quality product and avoid oils which cause difficulties. The remaining sections are discussions of specific types of lubricant products manufactured in the United States and information is presented about viscosity grades and typical formulations. This will enable a re-refiner to evaluate the potential base oil yields, the value of used oils and the nature of the base oil which can be recovered. The formulations, while not intended as a basis for actual finished product blending, can be used as a guide for preliminary planning. Data and forecasts regarding the consumption and amounts of each type of oil being collected are intended to provide collectors with realistic estimates of the quantities and qualities of oil available for recycling. This study also provides the collector with information on used oil sources, availability and contamination. The problems associated with the collection or handling of some of the products are discussed. There are hundreds of lubricants currently manufactured in the United States and several present difficult problems for a re-refiner. These problems can usually be converted into real opportunities if the re-refiner understands the products he is dealing with. The result is more profit for the re-refiner and improved conservation of a valuable resource.

180 (DOE/BETC/IC-82/4-Rev.) **Waste lubricating oil: an annotated review. 1982 revision.** Cotton, F.O. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Oct 1982. 277p. Order Number DE83001439. Source: NTIS, PC A13/MF A01.

Because of renewed interest in waste oil, both in terms of energy conservation and as a threat to the environment, there appears to be a need for a systemic compilation of information on the subject. This is a revision of the 1979 manuscript (BETC/IC-79/4) reflecting publications of the last three years as well as incorporation of papers that were overlooked. The number of citations has jumped from 486 to 1203, with all previous citations also listed here. The bibliography is divided into broad subject areas. The Introduction gives the history and development of the used oil reclamation industry. The General section includes the comprehensive papers that address several subjects and thus, give a capsulated overview of the used oil situation. Sources of Information and Statistical Treatments of Data tell how to obtain additional and future information and data relating to waste oil and could aid those persons interested in keeping their knowledge current. The Other Lubricating Oils section covers many of the lubricants that have the potential for recycling. The Other Oils section is divided into four sub-sections to aid the reader to find the subject of interest. The

section on Related Subjects includes those sideline areas that could apply to used oil reclamation.

181 (DOE/BETC/RI-80/11) **Environmental, resource conservation, and economic aspects of used oil recycling.** Brinkman, D.W.; Whisman, M.L.; Weinstein, N.J.; Emmerson, H.R. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Apr 1981. 64p. Source: NTIS, PC A04/MF A01.

In order to provide current and updated information, the case for burning used automotive lubricating oil versus re-refining it has been reevaluated based upon the 1980 American economy and energy conservation posture. In these comparisons, the environment is considered within four scenarios ranging from unrestricted burning of used oil without government constraints to complete prohibition of burning thereby funneling all used automotive lube oils to re-refining. Two other areas have been reevaluated in the context of burning versus re-refining of automotive lube oils in the US. These are the material and energy advantages to be realized in terms of resource conservation through either burning or re-refining and an estimation of the economics and profit potential currently available in the disposition of used lube oil. It was found that environmental concerns as presently regulated do not alone provide a persuasive case for re-refining over burning of used automotive lubricating oil. However, in view of the increased use of paraffinic crude oil for the manufacture of automotive lubricating oil, production costs will rise and product yields will be lower. In this context, this study shows that the energy required to produce. As a produce a gallon of lube oil from paraffinic crude oil is greater than that to produce a gallon of lube oil from used lubricating oil. As a result, the re-refining of collectible used automotive lube oil could conserve 43 to 76 trillion Btu's per year, equivalent to 7 to 12 million barrels of imported crude oil worth between a quarter and a half billion dollars. Additionally, this study indicates that new technology such as solvent/distillation re-refining would provide a 26 percent after-tax return on investment based upon 1980 markets and costs.

182 (DOE/BETC/RI-81/1) **Application of the BETC re-refining technology to some state-of-the-art commercial lube oils.** Reynolds, J.W.; Brinkman, D. Department of Energy, Bartlesville, OK (USA). Bartlesville Energy Technology Center. Jul 1981. 14p. Order Number DE81024428. Source: NTIS, PC A02/MF A01.

Five new lubricating oils of the extended drain and/or friction modified-type were charged to vehicles and used. The segregated drainings from each oil were re-refined by the solvent treatment/distillation process developed by the Bartlesville Energy Technology Center. The solvent treatment step of this process failed to desludge these oils significantly, indicating high levels of active dispersant additives remaining in the oils because of insufficient use. The overall process was successful, however, in producing re-refined basestocks of apparent high quality from the used oils. Thus, it would appear that direct distillation without pretreatment would have been adequate for these segregated samples.

183 (DOE/BETC/RI-81/9) **Closed-loop study of the effects of multicycle re-refining of automotive lubricating oil.** Reynolds, J.W.; Goetzinger, J.W.; Cotton, F.O.; Brinkman, D.W.; Whisman, M.L. Department of Energy,

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Bartlesville, OK (USA). Bartlesville Energy Technology Center. Mar 1982. 33p. Order Number DE82005160. Source: NTIS, PC A03/MF A01.

Twenty-five gallons of a hydrofinished virgin lubricating oil basestock was blended with additives into a 10W30 crankcase oil. After the engines had been pruned with a flush oil, 11 vehicles were charged with the blended virgin oil. Mileages ranging from 2000 to over 3000 miles of use were accumulated before the oil was drained, re-refined and recharged to the vehicles. This cycle was repeated until the oil had been re-refined three times. At each stage, detailed analyses and compound characterizations were performed on both the oil being recycled and on the same oil which was re-refined but never charged to vehicles. The data showed no significant change in the composition of the base oil, except for a minor buildup of additive base oil, which was expected.

184 (DOE/CE/40657-1) **Toxic organic chemicals in waste streams: anaerobic bioconversion to methane.** Young, L.Y. New York Univ., NY (USA). Medical Center. 1985. 92p. DOE Contract AC02-84CE40657. Order Number DE86009496. Source: NTIS, PC A05/MF A01; GPO Dep.

Sixteen substituted aromatic compounds were evaluated for their anaerobic biodegradability and toxicity to methanogenesis with two standardized anaerobic bioassays. Each compound was the only added carbon source (20 to 200 mg/L) prepared in prereduced defined medium with a 10% (v/v) inoculum of municipal digester sludge. Four types of responses were observed: (1) all concentrations of benzoate, phenol, dibutyl phthalate and low concentrations (20 mg/L) of dimethyl and diethyl phthalate, 4-nitrophenol and 2,4-dinitrophenol were degraded to CH_4 and CO_2 , attaining 50-100% of the theoretical gas yield; (2) high concentrations (200 mg/L) of diethyl and dimethyl phthalate, and low concentrations of 2-nitrophenol produced methane yields between 10 to 50% of the theoretical; (3) all concentrations of bis(2-ethylhexyl)phthalate, 2,4-dimethyl phenol, 4-chloro-m-cresol, ortho- and meta-cresol, 2-chlorophenol, intermediate concentrations (100 mg/L) of 2-nitrophenol and low concentrations of 4,6-dinitro-o-cresol yielded no more than 10% of the theoretical methane value; (4) high concentrations of 2-nitrophenol, 4-nitrophenol, 4,6-dinitro-o-cresol and 2,4-dinitrophenol exhibited a distinct suppression of methanogenesis from 10 to 90% below that of the background. Acclimation for most of the compounds took several days to weeks before degradation commenced. Thus, many of these compounds are metabolized in anoxic environments. Their fate may be significantly influenced by their concentration and residence time in such habitats. 35 refs., 33 figs., 12 tabs.

185 (DOE/CE/40659-1) **Conversion of food processing wastes into ethanol using a novel biological reactor/separator. Final report, September 1, 1984-September 30, 1985.** Dale, M.C.; Patterson, J.T.; Okos, M.R.; Ladisch, M.R. Purdue Univ., Lafayette, IN (USA). Dept. of Agricultural Engineering. Sep 1985. 110p. DOE Contract AC02-84CE40659. Order Number DE86004952. Source: NTIS, PC A06/MF A01; GPO Dep.

This project deals with scaling up and operating a novel Immobilized Cell Reactor-Separator (ICRS) developed at Purdue University. This reactor uses gas flow through an immobilized cell reactor to remove a volatile product (ethanol) from the fermentation broth. It was found that the life and performance of a small scale reactor could run continuously - 24 hours/day - for a year with no systematic

decay in performance. Some contaminants such as wild yeasts or lactobacillus were able to successfully colonize the reactor causing a performance decay although most contaminants are inhibited by the selective conditions of high acidity, presence of ethanol, and low oxygen tension. Scale-up parameters investigated. Residence time distributions, mass transfer efficiencies, and liquid hold-up as a function of column diameter and operating conditions. It was found that the Peclet number decreased from 122 for a 1 inch column to 58.5 for a 6 inch ID column and finally to 40.6 for a 13 inch ID column. The 13 inch column data should be representative of larger columns as far as the Peclet number, pressure drop, mass transfer and liquid holdup. Process design studies included work with vapor phase dehydration in which it was determined that molecular sieves seem to be the desiccant of choice. We also investigated rectification of the ethanol in the inert gas leaving the ICRS and found that it is quite feasible and that the change in the shape of the equilibrium curve makes it theoretically possible to achieve anhydrous ethanol through rectification alone. 15 refs., 38 figs., 12 tabs.

186 (DOE/CE/40673-T1) **Cosolvent-enhanced critical-fluid extraction of organics from water. Final report, 14 August 1984-14 August 1985.** Kingsley, G.S.; Chung, M.E.; Moses, J.M. Critical Fluid Systems, Inc., Cambridge, MA (USA). May 1986. 115p. DOE Contract FC01-84CE40673. Order Number DE86011472. Source: NTIS, PC A06/MF A01; GPO Dep.

Near-critical carbon dioxide was used in conjunction with cosolvents to efficiently concentrate ethanol and acetic acid from water solutions in a process development unit-scale continuous liquid-liquid extractor. The use of cosolvents has reduced the overall solvent requirements resulting in smaller equipment size and lower costs, and effective use of a vapor recompression cycle in the process design has significantly reduced energy consumption.

187 (DOE/CS-0015) **Used oil recycling kit.** Department of Energy, Washington, DC (USA). Office of Conservation and Solar Applications. Feb 1978. 46p. Source: NTIS, PC A03/MF A01.

Basic facts, ideas, and sample tools necessary to start a communitywide used oil recycling program are provided. (LK)

188 (DOE/CS/40049-1) **Recovery of anaerobic digestion after exposure to toxicants. Final report.** Yang, J.; Parkin, G.F.; Speece, R.E. Drexel Univ., Philadelphia, PA (USA). Dec 1979. 170p. DOE Contract EC-77-S-02-4391. Source: NTIS, PC A08/MF A01.

The concept that methane fermentation cannot tolerate chronic or slug doses of toxicants has almost totally precluded methane fermentation as a viable contender for the treatment of industrial wastewaters. This study assayed a wide variety of toxicants, heavy metals, inorganic salts, organic chemicals, solvents, and antibiotics which are used in industrial processes and, therefore, appear in the industrial wastewaters therefrom. Toxicity was related to the reduction in methane production of a control containing no toxicant. The response of methane fermentation after exposure to a toxicant was assayed with unacclimated cultures as well as cultures which had been acclimated to increasing concentrations of the toxicant over long periods of time. The reversible nature of the toxicants was assayed by adding slug doses to plug flow anaerobic filters and recording gas production prior to, during, and after toxicant addition.

189 (DOE/CS/40258-T1-Vol.2) **Critical-fluid extraction of organics from water. Volume II. Experimental. Final report, 1 October 1979-30 November 1983.** Abboud, O.K.; de Filippi, R.P.; Goklen, K.E.; Moses, J.M. Little (Arthur D.), Inc., Cambridge, MA (USA). Jun 1984. 159p. DOE Contract AC01-79CS40258. Order Number DE84015182. Source: NTIS, PC A08/MF A01; GPO Dep.

Critical fluid extraction has been tested at the pilot plant scale as a method of separating organics from water. The process employed resembles a liquid-liquid extraction in which the solvent is near-critical carbon dioxide and the feed is an organic in aqueous solution. Carbon dioxide's solvent and other thermodynamic properties, and the effective utilization of a vapor recompression cycle in the process design have significantly reduced the energy required for these separations. This process is an energy-conserving alternative to the distillation processes which are currently employed. The objectives of this portion of the project were to demonstrate the feasibility of this technology and to gather the engineering data required to evaluate the process. Three alcohols were tested in these experiments - ethanol, isopropanol and sec-butanol - and were all successfully extracted.

190 (DOE/CS/40288-T1) **Recovery of energy and chrome from chrome tannery wastes.** Muralidhara, H.S.; Maggin, B.; Phipps, H. Systems Consultants, Inc., Washington, DC (USA). 30 May 1980. 131p. DOE Contract AC01-79CS40288. Order Number DE81023699. Source: NTIS, PC A07/MF A01.

An evaluation of the technical performance and cost effectiveness of a low temperature pyrolysis process which uses dry leather tanning wastes to provide energy and chrome tanning liquor for reuse in tanneries is presented. Presently, leather waste is disposed of in landfills, resulting not only in a considerable loss of potential energy (estimated to be 0.7 trillion Btus annually), but an even more significant loss of chromium (estimated to be 1.8 million pounds per year). The pyrolysis process is shown to be technically feasible, economically viable, and can alleviate a leather waste management problem that is becoming increasingly more difficult to handle because of more stringent environmental waste disposal requirements. Leather tanneries can save an estimated \$7 to \$8 million annually by employing this pyrolysis process to conserve energy and chrome in dry tanning wastes.

191 (DOE CS 40290-T3) **Energy effective systems for closed loop treatment of electroplating waste water. Final report.** Williamson, R.C.; Williamson, W.R. Licon, Inc., Pensacola, FL (USA). 17 Mar 1986. 60p. DOE Contract AC07-79CS40290. Order Number DE86007851. Source: NTIS, PC A04/MF A01; GPO Dep.

A closed loop, energy efficient system has been developed for recycling aqueous electroplating wastes. It is termed a distiller concentrator system which uses advanced evaporation technology to reduce capital and energy costs. The closed loop operation resolves water pollution problems with nearly zero discharge, recovers high quality water for rinsing, and recovers plating chemicals at bath strength for reuse. The use of heat pump principles significantly reduces energy requirements. A new heat exchanger design termed BAT (Bayonet Augmented Tube), developed under the contract, provided the high heat transfer rates necessary for high energy efficiency and, when available, waste heat utilization.

192 (DOE/CS/40336-1) **Waste-atactic-to-fuel process/accelerated commercialization program.** Procyne Corp., New Brunswick, NJ (USA). 4 Feb 1983. 116p. DOE Contract FC01-80CS40336. Order Number DE83013134. Source: NTIS, PC A06/MF A01.

It was the objective of the Cost Sharing Program reported here to increase the rate of commercialization of this process to achieve maximum immediate benefit to the national program to reduce fuel oil consumption in the country. Each typical plant installation converts 15 to 25 millions lbs/yr of waste atactic polypropylene to 1.7 to 2.8 million gallons of oil per year. The approach to accomplishing this objective was to provide the major producers of polypropylene with information and documentation on the process, use of the USS Chemicals commercial plant as a demonstration facility, and provide an offer of funded support to two producers willing to invest in commercial size plants. The funded support was limited to pre-startup support activities and operating support activities. The information transfer part of this program was successfully accomplished, however, delays in achieving satisfactory performance of the plant prevented its use as a demonstration facility until the program period plus extensions was over. This prevented achieving the objective of finding two commercial corporations willing to build commercial plants. Since it was concluded that the program could not be effectively accomplished, the expenditures on this program were stopped after the information transfer portion of the program was completed. Approximately 19% of the \$823,965.00 originally funded in this program was spent.

193 (DOE/CS/40338-4) **North Carolina used motor oil - refining program. Final report.** Griffith, W.C. North Carolina State Univ., Raleigh (USA). Dept. of Mechanical Engineering. Feb 1984. 28p. DOE Contract FG01-80CS40338. Order Number DE84009104. Source: NTIS, PC A03/MF A01; GPO Dep.

Experience of the State of North Carolina in acquiring and demonstrating a new type of plant for re-refining used motor oil is documented in a series of publications and summarized in this final report. The recycling program included development of a complete system for collecting used oil, re-refining and drumming operations, and product sales to State and local government agencies. The program was undertaken as a part of the State's overall energy and resource conservation plan. Specifically, the goals were to demonstrate oil re-refining, save energy and a valuable, limited natural resource and by so doing increase public awareness of conservation. Feasibility studies initiated in 1976 suggested that re-refining used motor oil for State and local government vehicle fleets would be technically and economically attractive for a rate of about 500,000 gallons of oil per year using a new process developed by the Phillips Petroleum Company. Executive and Legislative approval was given to purchase a turnkey plant for \$1.4 million. After the first year of operation, a number of changes to procedures and the plant itself were identified as necessary for reaching the desired production rate. Concurrently, the dramatic shifts in world oil prices and availability contributed to a shortage of used motor oil suitable for re-refining. This shortage continued through mid-1983, seriously limiting demonstration of plant performance as modified. The following results of operations for the first two and a half years have been obtained: product quality consistently excellent; cumulative sales approaching 500,000 gallons; average cost of product between \$4 to \$5 per gallon compared to sales price of \$2.57 per gallon; current projections indicate economic break-even at 500,000 to 600,000 gallons per year rate; environmental

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impact of re-refining generally benign, singular events containable; and future operations viable, marginally attractive for private investments. 8 figures.

194 (DOE/CS/40338-5) **North Carolina used motor oil re-refining program. Plant operation and quality control tests. Topical report 4.** Ferrell, J.K.; Schurter, T.L.; Ritchie, M.; Miller, T.M. North Carolina State Univ., Raleigh (USA). Dept. of Chemical Engineering. Jun 1984. 74p. DOE Contract FG01-80CS40338. Order Number DE84014456. Source: NTIS, PC A04/MF A01; GPO Dep.

A cooperative project is described to re-refine used motor oil for use in state-owned vehicles. The re-refining plant has a rated capacity of two million gallons per year for full operation, utilizes up-to-date technology, and is capable of producing a lube-stock product of very high quality. While the overall project has a number of objectives, the objectives of the work described in this report are to investigate the chemistry of the process and to develop and test a set of quality control analyses that will assure that the plant is producing a satisfactory lube-stock product. In addition, a number of tests were also developed to aid in the operation of the plant. This report presents a brief description of the plant and its operation, a discussion of the process and the process chemistry, a description of the tests developed and used, a discussion of sampling and sample locations, and an evaluation of the tests for assuring satisfactory plant operation and quality control of the lube-stock product. 6 references, 4 figures, 15 tables.

195 (DOE/CS/40402-1) **Program guide to used-oil recycling.** Centec Corp., Reston, VA (USA). Jan 1982. 42p. DOE Contract AC01-80CS40402. Order Number DE82010642. Source: NTIS, PC A03/MF A01.

The purpose of the booklet is to provide information and sample tools necessary in starting a much needed community-wide used oil recycling program. This information package includes each of the items listed: instruction booklet - a step-by-step outline on how to proceed; press release - to media and community groups; letter to civic leader - asks civic leaders and others to help; letter to manager - asks service stations to be collection points; letter of thanks - to anyone helping your program; used oil report - DOE background on the national problem; and bibliography - for further reading. Information from the used oil report included with this Guide can prove useful in brochure preparation. A sample press release and letters are provided.

196 (DOE/ID/12502-1) **Development of synergistic waste treatment into applied technology.** Tabor, W.E.; Dempsey, D.G.; Taylor, S.J.; Ervin, A. Enwright Research Corp., Greenville, SC (USA). Jul 1986. 218p. DOE Contract AC07-84ID12502. Order Number DE86014115. Source: NTIS, PC A10/MF A01; GPO Dep.

The contract terms were carried out as specified by DOE with the authors investigating known or practical examples of synergistic and antagonistic effects resulting of mixing of wastewater streams. Databases were compiled on the waste stream characteristics and waste treatment practices of 12 subcategories of the chemical and allied products industry. Both a qualitative and quantitative computer model were developed to select appropriate treatment procedures and to predict the potential interactive effects upon the mixing of two streams; afterward, the data were supplemented by calculation of energy use and calculation of potential savings which could occur from beneficial interactions between

the streams. Results of about seven simulation trials indicate potential energy conservations if the concepts are developed and used. This project has yielded great opportunity for deployment of a new concept in wastewater treatment practices.

197 **Engine sequence testing of re-refined lubricating oils.** Reynolds, J.W. (Bartlesville Energy Res Cent, Okla); Whisman, M.L.; Thompson, C.J. SAE (Society of Automotive Engineers) Preprint (USA), (770431): 5 (1977).

Two oils re-refined by technology developed by the Bartlesville Energy Research Center and one commercially re-refined automotive lubricating oil have been subjected to engine test sequences IIC, IIIC, VC, and L-38. Results of these tests and bench-scale evaluations of some physical and chemical properties of these oils are tabulated.

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Refer also to citation(s) 280

198 (ANL/CNSV-61) **Tests to produce and recover carbon dioxide by burning coal in oxygen and recycled flue gas: Black Hills Power and Light Company Customer Service Center Boiler No. 2, Rapid City, South Dakota.** Kumar, R.; Fuller, T.; Kocourek, R.; Teats, G.; Young, J.; Myles, K.; Wolsky, A. Argonne National Lab., IL (USA). Dec 1987. 69p. DOE Contract W-31109-ENG-38. Order Number DE88005570. Source: NTIS, PC A04/MF A01; GPO Dep.

Experiments were conducted using a modified stoker-fired boiler (2.2 x 10⁶ Btu/h) instrumented to examine the feasibility of producing and recovering carbon dioxide by burning coal in oxygen and recycled flue gas in a utility environment. The tests demonstrated that the boiler can be operated in the oxygen-blown/flue-gas-recirculation mode without any noticeable effects on coal combustion, heat delivery to the water, or the coal-feed or ash-handling systems. Pretest calculations showed that a feasible set of operating parameters for a carbon-dioxide-producing combustor system tightly sealed against air infiltration and containing no more than about 5% O₂ (dry basis) at the furnace exit would be a flue-gas recycling ratio between 0.6 and 0.7 and an oxygen feed rate of 1.17 g-moles per g-atom of carbon, yielding an exhaust gas composition (wet basis) of approximately 46.9% CO₂, 50.6% H₂O, and 2.5% O₂. This composition corresponds to a product gas containing 95% CO₂ and 5% O₂ (dry basis). However, because air leaked into the test combustor and the flue-gas handling system, the highest carbon dioxide concentration achieved in the exhaust gas was 48.5% (dry basis). Major sources of inleakage were the furnace brickwork, the gas-handling system, and the coal-feed and ash-extraction systems. 40 figs.

199 (ANL/CNSV-65) **Carbon dioxide from flue gases for enhanced oil recovery.** Sparrow, F.T. (Purdue Univ., Lafayette, IN (USA)); Wolsky, A.M.; Berry, G.F.; Brooks, C.; Cobb, T.B.; Lynch, E.P.; Jankowski, D.J.; Walbridge, E.W. Argonne National Lab., IL (USA). Jun 1988. 91p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE89014017. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

This report summarizes research to design and develop a new method for recovering carbon dioxide from flue gases. The carbon dioxide could be used to enhance oil recovery

from domestic oil fields. The method would also recover oxides of sulfur and nitrogen, avoiding the emission of these compounds to the atmosphere. The method is now ready to be scaled up for commercial use. When economic incentives are provided for gas recovery either through higher oil prices or the passage of national legislation on acid rain or the greenhouse effect, the research summarized here will make possible the widespread availability of highly concentrated carbon dioxide. In the near term, small ventures may use the method wherever additional carbon dioxide is needed and scarce (e.g., in the Northeast) and a combustor is suitably located. 110 refs., 26 figs., 20 tabs.

200 (ANL/CNSV-TM-168) Experimental evaluation of firing pulverized coal in a CO₂/O₂ atmosphere. Weller, A.E.; Rising, B.W.; Bojarski, A.A.; Nordstrom, R.J.; Barrett, R.E.; Luce, R.G. Battelle Columbus Labs., OH (USA). Oct 1985. 342p. DOE Contract W-31-109-ENG-38. Order Number DE86006168. Source: NTIS, PC A15/MFA01; GPO Dep.

The project discussed herein was conducted in support of Argonne National Laboratory to evaluate the feasibility of economically producing carbon dioxide by firing pulverized coal in conventional boilers in an atmosphere of recirculated carbon dioxide with added oxygen. The excess carbon dioxide generated would be used to enhance oil recovery. It is anticipated that this process could be used where coal-fired utility boilers are in reasonable proximity to an oil field. The major objective of this project was to obtain sufficient experimental data to identify relative differences between coal-air and coal-CO₂-O₂ flames. To achieve this objective, Battelle modified one of its existing coal-fired combustion facilities to permit study of the combustion characteristics of pulverized coal in a CO₂-O₂ atmosphere. This facility was chosen because it simulates many aspects of the coal burning process within large utility boilers and it is of size to be operated economically regarding material and labor costs. The facility and support apparatus were configured to obtain desired data for comparing coal-CO₂-O₂ flames to coal-air flames. The experimental tasks associated with this project included conducting tests at four different operating conditions regarding the oxidant mixture. The basis upon which flames were compared included characteristics such as furnace operating conditions, combustion process characteristics, flame spectral and flow properties, radiant heat transfer, and stack emissions. In general, the tests were successful in providing data for comparing coal-CO₂-O₂ firing with coal-air firing. 10 refs., 36 figs., 31 tabs.

201 (ANL/CNSV-TM-186) Recovery and use of waste CO₂ in enhanced oil recovery: Proceedings. Wolsky, A.M.; Brooks, C. (comps. Argonne National Lab., IL (USA). Jun 1988. 121p. DOE Contract W-31109-ENG-38. (CONF-8703302-- Workshop on recovery and use of waste CO₂ in enhanced oil recovery, Denver, CO, US, March 19, 1987). Order Number DE89002803. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

This report contains eight papers, six of which deal with the use of CO₂ for enhanced oil recovery. Of the remaining two articles, one addresses the impact of coal combustion on acid rain and the greenhouse effect, whereas the other evaluates coal combustion in oxygen and in recycled flue gas mixtures. Individual reports were processed separately for the data base. (TEM)

202 (ANL/CNSV-TM-203) Analysis of gas flows in a new method for carbon dioxide recovery. Berry, G.F.; Wang, C.S.; Dennis, C.B.; Wolsky, A.M. Argonne National

Lab., IL (USA). Apr 1988. 41p. DOE Contract W-31109-ENG-38. Order Number DE88012662. Source: NTIS, PC A03/MF A01; GPO Dep.

The relative size and composition of gas streams concomitant with a new method of carbon dioxide recovery are described and related to each other. This is done for two variations: dry recycle and wet recycle. Calculations performed under the different assumptions of complete combustion and chemical equilibrium are compared. The following fuels are considered: two hypothetical fuels, CH_{0.4} and CH_{0.8}; methane, CH₄; Wyodak coal, CN_{0.013}H_{1.675}O_{0.606}S_{0.004}; and Black Thunder coal, CN_{0.019}H_{1.599}O_{0.539}S_{0.003}. The purity of carbon dioxide from the system exit, the recycle fraction of combustion products, the oxygen concentration at the furnace inlet and outlet, and the excess oxygen at the furnace inlet are investigated. 6 refs., 6 figs., 20 tabs.

203 (ANL/CNSV-TM-204) An experimental program to test the feasibility of obtaining normal performance from combustors using oxygen and recycled gas instead of air. Abele, A.R.; Kindt, G.S.; Clark, W.D.; Payne, R.; Chen, S.L. Argonne National Lab., IL (USA); Energy and Environmental Research Corp., Irvine, CA (USA). Dec 1987. 177p. DOE Contract W-31109-ENG-38. Order Number DE89002383. Source: NTIS, PC A09/MF A01; GPO Dep.

Injection of carbon dioxide (CO₂) can be used to increase the production from oil wells. The recovery of oil is enhanced by pumping CO₂ into oil reservoirs at pressure to dissolve the CO₂ in the oil. This causes the oil to expand as well as decreasing its viscosity and surface tension. The viscous oil can then be more easily recovered from the oil wells. This recovery process requires CO₂ gas that is at least 90 percent pure. One plentiful source of CO₂ is fossil fuel combustion, such as industrial and utility boilers. Ordinarily, the products from the combustion of fossil fuels with air is only about 15 percent CO₂, with the balance being mostly nitrogen, 8-10 percent water vapor, 3-5 percent O₂, and trace quantities of NO_x and SO₂. Conventional approaches to recovering CO₂ from combustion sources utilize various processes to separate CO₂ from the stack gas. Disadvantages to such separation techniques include: (1) the relatively low concentration of CO₂ in the stack gas and (2) the presence of gaseous species (O₂ and SO_x) which may interfere with the separation process. These issues, and the measures to resolve them, tend to increase the cost of the separation process. 8 refs., 44 figs., 32 tabs.

204 (BNWL-2137) Chemical production from waste carbon monoxide: its potential for energy conservation. Rohrmann, C.A.; Schiefelbein, G.F.; Molton, P.M.; Li, C.T.; Elliott, D.C.; Baker, E.G. Battelle Pacific Northwest Lab., Richland, WA (USA). Nov 1977. 289p. DOE Contract EY-76-C-06-1830. Source: NTIS, PC A13/MF A01.

Results of a study of the potential for energy conservation by producing chemicals from by-product or waste carbon monoxide (CO) from industrial sources are summarized. Extensive compilations of both industrial sources and uses for carbon monoxide were developed and included. Reviews of carbon monoxide purification and concentration technology and preliminary economic evaluations of carbon monoxide concentration, pipeline transportation and utilization of CO in the synthesis of ammonia and methanol are included. Preliminary technical and economic feasibility studies were made of producing ammonia and methanol from the by-product CO produced by a typical elemental phosphorus plant. Methanol synthesis appears to be more attractive

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than ammonia synthesis when using CO feedstock because of reduced water gas shift and carbon dioxide removal requirements. The economic studies indicate that methanol synthesis from CO appears to be competitive with conventional technology when the price of natural gas exceeds \$0.82/million Btu, while ammonia synthesis from CO is probably not competitive until the price of natural gas exceeds \$1.90/million Btu. It is concluded that there appears to be considerable potential for energy conservation in the chemical industry, by collecting CO rather than flaring it, and using it to make major chemicals such as ammonia and methanol.

205 (CONF-880348-5) **Microwave plasma dissociation of hydrogen sulfide.** Harkness, J.B.L.; Gorski, A.J.; Daniels, E.J. Argonne National Lab., IL (USA). Jan 1988. 12p. DOE Contract W-31109-ENG-38. From American Institute of Chemical Engineers spring national meeting; New Orleans, LA, US; March 6, 1988. Order Number DE88010086. Source: NTIS, PC A03/MF A01; GPO Dep.

The Claus technology and its associated tail gas cleanup (SCOT unit) for hydrogen sulfide environmental control recovers the sulfur contained in hydrogen sulfide wastes but loses the hydrogen as water. The alternative treatment process proposed in this paper uses plasma dissociation to recover the hydrogen in addition to the sulfur, thereby saving a significant fraction of the lost energy. The plasma process also appears to be more economical than the Claus/SCOT process. The total capital required for the plasma facility is projected to be \$14 million, versus \$26 million (including capital cost for the incremental hydrogen generation capacity) for the Claus/SCOT process. Because of energy savings, the annual operating costs for the plasma process are also lower than for the Claus/SCOT process. Assuming a 15% rate of return on capital, the plasma process will produce a net annual profit of \$1.8 million relative to the Claus/SCOT. 4 refs., 6 figs., 3 tabs.

206 (CONF-881120-4) **Coal combustion system analysis for carbon dioxide recovery.** Berry, G.F.; Wang, C.S.; Dennis, C.B.; Wolsky, A.M. Argonne National Lab., IL (USA). 1988. 39p. DOE Contract W-31109-ENG-38. From ASME winter annual meeting; Chicago, IL, US; November 28, 1988. Order Number DE88012054. Source: NTIS, PC A03/MF A01; GPO Dep.

The relative size and composition of gas streams concomitant with a new method of carbon dioxide recovery are described and related to each other. This is done for two variations, dry recycle and wet recycle, of the new method. Calculations performed under the differing assumptions of complete combustion and chemical equilibrium are compared. The following fuels are considered: methane, CH₄; Wyodak Coal, CN_{0.013}H_{1.675}O_{0.606}S_{0.004}; and Black Thunder Coal, CN_{0.019}H_{1.599}O_{0.539}S_{0.003}. The purity of carbon dioxide from the system exit, the recycle fraction of combustion products, the oxygen concentration at the furnace inlet and outlet, and the excess oxygen at the furnace inlet are investigated.

207 (CONF-881120-11) **New method for carbon dioxide recovery from the combustion of fossil fuel.** Berry, G.F.; Wang, C.S.; Dennis, C.B.; Wolsky, A.M. Argonne National Lab., IL (USA). 1988. 13p. DOE Contract W-31109-ENG-38. From ASME winter annual meeting; Chicago, IL, US; November 28, 1988. Order Number DE89000545. Source: NTIS, PC A03/MF A01; GPO Dep.

The relative size and composition of gas streams concomitant with a new method of carbon dioxide recovery are

described and related to each other. This is done for two variations, dry recycle and wet recycle, of the new method. Calculations performed under the differing assumptions of complete combustion and chemical equilibrium are compared. The following fuels are considered: methane, CH₄; Wyodak Coal, CN_{0.013}H_{1.675}O_{0.606}S_{0.004}; and Black Thunder Coal, CN_{0.019}H_{1.599}O_{0.539}S_{0.003}. The purity of carbon dioxide from the system exit, the recycle fraction of combustion products, the oxygen concentration at the furnace inlet and outlet, and the excess oxygen at the furnace inlet are investigated. 9 refs., 8 figs., 4 tabs.

208 (DOE/CE/40646-H1) **Industrial waste gas streams: control technologies and R and D programs. Final report.** Hagler, Bailly and Co., Washington, DC (USA). Jun 1986. 161p. DOE Contract AC01-84CE40646. Order Number DE86014760. Source: NTIS, PC A08/MF A01; GPO Dep.

To reduce industrial process and waste treatment energy consumption, the Office of Industrial Programs of the US Department of Energy supports research and technology/process development for the conversion of industrial wastes to energy or useful products. In this report, Hagler, Bailly and Company investigates current industrial waste gas supply, treatment methods, and R and D programs which attempt to minimize industrial waste gas production or convert the gas streams into energy or useful by-products.

209 (DOE/CS/40177-T2) **COthane, methane from waste CO. Final technical report.** Rabo, J.A.; Frost, A.C.; Elek, L.F.; Risch, A.P.; Yang, C.L. Union Carbide Corp., Tarrytown, NY (USA). Tarrytown Technical Center. Dec 1980. 117p. DOE Contract AC03-78CS40177. Order Number DE81023246. Source: NTIS, PC A06/MF A01.

As the result of early efforts in the fields of catalysis, coal gasification, and methanation, Union Carbide developed a novel process for the direct concentration and conversion of CO in dilute waste streams to high quality methane (SNG). This two bed, two step process was dubbed COthane, a contraction of the feed carbon monoxide (CO) and the product methane. The objectives of this contract were to develop the COthane process up to the large pilot plant stage, to develop an improved catalyst, and to estimate the cost of methane produced by this process. The process development studies yielded all of the design parameters required to design a large scale pilot plant, the catalyst development program produced a catalyst with promising stability, and the economic studies showed that methane production cost would generally be more than \$6/MM BTU. Because this cost is above those for natural gas, further work on this project has been suspended until rising natural gas prices catch up with the more slowly rising COthane production cost.

210 (DOE/CS/40402-T6) **Co-firing of refuse-derived fuel (RDF) with natural gas in a cement kiln: Summary of test results.** Reed, J.E.; Conrad, J.L.; Price, C.D. Energetics, Inc., Columbia, MD (USA). Mar 1983. 101p. DOE Contract AC01-80CS40402. Order Number DE88015217. Source: NTIS, PC A06/MF A01; GPO Dep.

In July of 1986, the Environmental Equipment Corporation, in association with the Portland Cement Association and the Gulf Coast Portland Cement Company, initiated a program to develop and test refuse-derived fuel (RDF) on a commercial scale as a supplemental energy source for the portland cement industry. The objectives of the work

performed were to definitely determine the technical and operational limits on the use of RDF, and to develop and test the equipment and systems required by cement plants to use RDF on a full-time commercial basis. Three extended trial burns were completed with satisfactory results at the Gulf Coast Portland Cement Company's plant in Houston, Texas. Prior to these tests, the kiln was normally fired with natural gas to produce clinker by the wet process. During the trial burns, 20%, 30%, and 40%, respectively, of the heat input was supplied by RDF. Each test lasted approximately three days, in all producing 8500 tons of cement while burning 1338 tons of RDF. Analyses of the cement clinker, kiln feed, flue dust, ash, precipitator dust, and cooler dust by an independent testing authority – the Portland Cement Association – showed acceptable clinker quality and acceptable environmental data. Although some loss of cement product strength was encountered in the third (i.e., 40% RDF) test, this may have been due to an inadvertent, temporary loss of temperature control.

211 (DOE/ID/12379-2) **Membrane research in energy and solvent recovery from industrial effluent streams: Final report, November 1, 1982–November 31, 1987.** Baker, R.W. Membrane Technology and Research, Inc., Menlo Park, CA (USA). Oct 1988. 106p. DOE Contract AC07-83ID12379. Order Number DE89008896. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

This report describes a five-year program to develop a membrane process for separating organic vapors from air. The process uses membranes much more permeable to organic solvents than to air. A vacuum pump on the permeate side of the membrane is used to draw organic vapors through the membrane leaving a solvent-depleted air stream behind and producing a concentrated solvent-containing permeate stream. Solvent is recovered from the permeate stream by cooling and condensation. The program started with basic permeability measurements with thick films to determine suitable membrane materials. The technology required to form these materials into thin composite membranes was then developed and these membranes were fabricated into spiral-wound membrane modules. These membrane modules, containing from 0.3 to 4 m² of membrane, were evaluated with model solvent-containing air streams in the laboratory and in the field. The process appears to be an attractive method of treating air streams containing 0.5 to 5.0% solvent. A number of industrial applications are being investigated and we are currently developing pilot units able to treat 50 to 100 scfm of solvent-containing air for field evaluations. Our goal is to install the first commercial systems in the beginning of 1989. 7 refs., 57 figs., 15 tabs.

212 (DOE/ID/12422-2) **Membrane separation processes in the petrochemical industry: Part 1: Phase 2, Final summary report, October 31, 1985–September 30, 1987.** Li, N.N.; Funk, E.W.; Chang, Y.A.; Kulkarni, S.S.; Swamikannu, A.X.; White, L.S. Allied-Signal, Inc., Des Plaines, IL (USA). 30 Sep 1987. 146p. DOE Contract AC07-82ID12422. Order Number DE89008053. Source: NTIS, PC A07/MF A01 - OSTI; GPO Dep.

This report provides an overview of a DOE-funded project with Allied-Signal which focused on developing new membrane technology with potential for energy conservation in the petrochemical industry. Three applications were investigated. The first is the use of membrane for the bulk removal of CO₂ and H₂S from sour natural gas. The second is membrane technology for separation of polar gases such as H₂S

and NH₃ from H₂. The third process involved a novel ultrafiltration approach for the energy-efficient recovery of solvent from solvent/heavy oil mixtures. This report summarizes laboratory data, field test and pilot plant studies, and economic assessments. 43 refs., 33 figs., 8 tabs.

213 (DOE/ID/12422-2) **Membrane separation processes in the petrochemical industry: Phase 2, Final report, October 31, 1985–September 30, 1987.** Li, N.N.; Funk, E.W.; Chang, Y.A.; Kulkarni, S.S.; Swamikannu, A.X.; White, L.S. Allied-Signal, Inc., Des Plaines, IL (USA). Engineered Materials Research Center. 30 Sep 1987. 116p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-82ID12422. Order Number DE90001600. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

This report provides an overview of a project with Allied-Signal which focused on developing new membrane technology with potential for energy conservation in the petrochemical industry. Three applications were investigated: (1) bulk removal of polar (sour) gases from natural gas using spiral-wound, cellulose acetate membranes; (2) recovery of solvent from solvent/heavy oil mixtures using polysulfone ultrafiltration membranes; and (3) separation of polar gases (e.g., H₂S and NH₃ from H₂) using mixed-matrix, facilitated-transport membranes. This report summarizes laboratory research results performed in an earlier phase of this project and provides results from pilot-scale, field test studies and economic assessments.

214 (DOE/ID/12520-1) **Energy conservation using metal hydrides for hydrogen recovery and steam generation from industrial waste gas streams. Final report.** Goodell, P.D.; Rebello, W.J.; Ally, M.R. PAR Enterprises, Inc., Fairfax, VA (USA); ERGENICS, Wyckoff, NJ (USA). 20 May 1986. 298p. DOE Contract AC07-84ID12520. Order Number DE87001780. Source: NTIS, PC A13/MF A01; GPO Dep.

This report describes development of a conceptual design based on reversible metal hydride formers for recover hydrogen from waste gas streams; it also had intended to generate process steam, but was not successful in this part. A broad range of compositions among AB₅, A₂B, AB₂ and AB compounds were selected for screening based on an extensive literature survey of alloy properties. These were screened over a wide temperature range for tolerance to cycling and poisoning in complex gas streams. No alloy was found satisfactory at process temperatures above about 100°C. Alloys of the La(Ni,Al)₅ family were acceptable for consideration at lower temperatures. Process considerations included analysis of fluid bed handling of the absorber, which proved unsatisfactory. A thermal swing, fixed bed system was adopted and analyzed in relation to several potential industrial waste streams. The absorber alloy was the major cost item since it requires replacement annually. The results were presented as cost of delivered hydrogen, and ranged from \$1.31 to 1.72 per thousand standard cubic feet at a delivery rate of 3 to 15 million standard cubic feet per day. These were well below the cost of manufacturing hydrogen from natural gas, and were also attractive in comparison to some estimates of alternative methods of hydrogen recovery.

215 (ORNL-6169) **Carbothermal synthesis of silicon carbide.** Janney, M.A.; Wei, G.C.; Kennedy, C.R.; Harris, L.A. Oak Ridge National Lab., TN (USA). May 1985.

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60p. DOE Contract AC05-84OR21400. Order Number DE85013546. Source: NTIS, PC A04/MF A01; GPO Dep.

Silicon carbide powders were synthesized from various silica and carbon sources by a carbothermal reduction process at temperatures between 1500 and 1600°C. The silica sources were fumed silica, methyltrimethoxysilane, and microcrystalline quartz. The carbon sources were petroleum pitch, phenolic resin, sucrose, and carbon black. Submicron SiC powders were synthesized. Their morphologies included equiaxed loosely-bound agglomerates, equiaxed hard-shell agglomerates, and whiskers. Morphology changed with the furnace atmosphere (argon, nitrogen, or nitrogen-4% hydrogen). The best sintering was observed in SiC derived from the fumed-silica-pitch and fumed-silica-sucrose precursors. The poorest sintering was observed in SiC derived from microcrystalline quartz and carbon black. 11 refs., 16 figs., 10 tabs.

216 (PNL-3694) Methanol production with elemental phosphorus byproduct gas: technical and economic feasibility. Lyke, S.E.; Moore, R.H. Battelle Pacific Northwest Lab., Richland, WA (USA). Jan 1981. 200p. DOE Contract AC06-76RL01830. Source: NTIS, PC A09/MF A01.

The technical and economic feasibility of using a typical, elemental, phosphorus byproduct gas stream in methanol production is assessed. The purpose of the study is to explore the potential of a substitute for natural gas. The first part of the study establishes economic tradeoffs between several alternative methods of supplying the hydrogen which is needed in the methanol synthesis process to react with CO from the off gas. The preferred alternative is the Battelle Process, which uses natural gas in combination with the off gas in an economically sized methanol plant. The second part of the study presents a preliminary basic design of a plant to (1) clean and compress the off gas, (2) return recovered phosphorus to the phosphorus plant, and (3) produce methanol by the Battelle Process. Use of elemental phosphorus byproduct gas in methanol production appears to be technically feasible. The Battelle Process shows a definite but relatively small economic advantage over conventional methanol manufacture based on natural gas alone. The process would be economically feasible only where natural gas supply and methanol market conditions at a phosphorus plant are not significantly less favorable than at competing methanol plants. If off-gas streams from two or more phosphorus plants could be combined, production of methanol using only offgas might also be economically feasible. The North American methanol market, however, does not seem likely to require another new methanol project until after 1990. The off-gas cleanup, compression, and phosphorus-recovery system could be used to produce a CO-rich stream that could be economically attractive for production of several other chemicals besides methanol.

217 (PNL-3753) Chemical production from industrial by-product gases. Final report. Lyke, S.E.; Moore, R.H. Battelle Pacific Northwest Lab., Richland, WA (USA). Apr 1981. 128p. DOE Contract AC06-76RL01830. Source: NTIS, PC A07/MF A01.

The potential for conservation of natural gas is studied and the technical and economic feasibility and the implementation of ventures to produce such chemicals using carbon monoxide and hydrogen from byproduct gases are determined. A survey was performed of potential chemical products and byproduct gas sources. Byproduct gases from the elemental phosphorus and the iron and steel industries were selected for detailed study. Gas sampling, preliminary

design, market surveys, and economic analyses were performed for specific sources in the selected industries. The study showed that production of methanol or ammonia from byproduct gas at the sites studied in the elemental phosphorus and the iron and steel industries is technically feasible but not economically viable under current conditions. Several other applications are identified as having the potential for better economics. The survey performed identified a need for an improved method of recovering carbon monoxide from dilute gases. A modest experimental program was directed toward the development of a permselective membrane to fulfill that need. A practical membrane was not developed but further investigation along the same lines is recommended. (MCW)

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Refer also to citation(s) 340

218 (DOE/CE/40646-T5) Adhesives for the composite wood panel industry. Final report. Koch, G.S.; Klareich, F.; Exstrum, B. Hagler, Bailly and Co., Washington, DC (USA). 13 Jan 1986. 141p. DOE Contract AC01-84CE40646. Order Number DE86010847. Source: NTIS, PC A07/MF A01; GPO Dep.

Significant energy savings could be realized if current fossil fuel-based resins could be replaced with alternative biomass-derived adhesives. Hence, a program was performed to analyze the current wood panel adhesives market, identify both domestic and international R and D efforts in the area of biomass-derived alternative adhesives that might serve as substitutes for conventional fossil fuel-based adhesives, and assess the technical and economic factors that will influence commercial success of these alternative adhesives.

219 (DOE/CE/40772-T3) The production of chemicals from food processing wastes using a novel fermenter separator: Annual report, October 1986-October 1987. Purdue Univ., Lafayette, IN (USA). Dept. of Agricultural Engineering. May 1988. 18p. DOE Contract FG02-85CE40772. Order Number DE88011556. Source: NTIS, PC A12/MF A01; GPO Dep.

Fermentation costs (which increase with higher product concentration) traditionally must be balanced against product recovery costs (which decrease with product concentration). A novel reactor-separator process has been developed at Purdue University to minimize product inhibition of fermentation rates. This has been shown to exhibit very high productivities - simultaneously producing and removing an inhibitory product while maintaining a high viable cell concentration in the reactor. The objective of this study is to develop an energy efficient and economical process to convert food wastes to usable chemicals. Work is divided into two major efforts (a) an applied phase which involves design and building a whey to ethanol process as well as process design and optimization and (b) a basic phase which involves investigating alternative fermentation systems and fundamental research on immobilized cell reactor systems. Accomplishments are discussed. 116 refs., 80 figs., 22 tabs.

220 (DOE/CS/40214-T1) ARC-coal acetylene process development program. Phase 1B. Final technical progress report, 15 September 1979-31 September 1980. Avco Systems Div., Wilmington, MA (USA). 30 Oct 1980. 528p. DOE Contract AC07-79CS40214. Order Number DE82002844. Source: NTIS, PC A23/MF A01.

For many years, acetylene was a major feedstock in the chemical industry, being used for the manufacture of such important large-volume chemicals as vinyl chloride, vinyl acetate, acrylonitrile, acetaldehyde, and several others chemicals. Since the mid-1960's, however, acetylene has been largely replaced by olefins like ethylene and propylene. These olefins, though sometimes less suitable as feedstocks than acetylene, became more economical as they became readily available at prices considerably lower than acetylene. The successful development of the Arc-Coal process appears to offer a new competitive option to ethylene while reducing the risk of feedstock shortage by relying on the vast coal resources within the US. The Arc-Coal Acetylene process has been tested successfully at both the 100 kW and 1 MW levels, clearly demonstrating that acetylene can be economically produced from coal in a one-step reaction, and that the current reactor design approach is capable of being scaled up to commercial size. The process is shown to be commercially competitive with the currently available process for acetylene manufacture and, more importantly, competes attractively with ethylene in the manufacture of vinyl chloride and vinyl acetate. With the commercial advent of the arc-coal acetylene process, it will become possible to manufacture acetylene more economically than by conventional process. Substantial ethylene price increases tied closely to, and driven by, higher crude oil and natural gas prices are a clear long-term trend which appears certain to continue well into the foreseeable future with periodic market variations. This situation will make the Arc-coal Acetylene process a leading contender for the production of chemicals such as vinyl chloride and vinyl acetate, substituting a coal feedstock process for the current liquid hydrocarbon-fed ethylene-to-vinyl monomers processes.

221 (PNL-6784) **Thermocatalytic conversion of food processing wastes: Topical report, FY 1988.** Baker, E.G.; Butner, R.S.; Sealock, L.J. Jr.; Elliott, D.C.; Neuen-schwander, G.G. Pacific Northwest Lab., Richland, WA (USA). Jan 1989. 21p. DOE Contract AC06-76RL01830. Order Number DE89006396. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The efficient utilization of waste produced during food processing operations is a topic of growing importance to the industry. While incineration is an attractive option for wastes with relatively low ash and moisture contents (i.e., under about 50 wt % moisture), it is not suitable for wastes with high moisture contents. Cheese whey, brewer's spent grain, and fruit pomace are examples of food processing wastes that are generally too wet to burn efficiently and cleanly. Pacific Northwest Laboratory (PNL) is developing a thermocatalytic conversion process that can convert high-moisture wastes (up to 98 wt % moisture) to a medium-Btu fuel gas consisting primarily of methane and carbon dioxide. At the same time, the COD of these waste streams is reduced by 90% to 99%. Organic wastes are converted by thermocatalytic treatment at 350°C to 400°C and 3000 to 4000 psig. The process offers a relatively simple solution to waste treatment while providing net energy production from wastes containing as little as 2 wt % organic solids (this is equivalent to a COD of approximately 25,000 mg/L). This report describes continuous reactor system (CRS) experiments that have been conducted with food processing wastes. The purpose of the CRS experiments was to provide kinetic and catalyst lifetime data, which could not be obtained with the batch reactor tests. These data are needed for commercial scaleup of the process.

MUNICIPAL SOLID WASTE

Contains only reports completed after OIT restructuring in 1990. No abstracts are available for this program area at this time.

SOLAR INDUSTRIAL

222 (SERI/TP-253-3687) **Cleaning up with the sun: Industry's opportunities in the DOE initiative on solar detoxification of hazardous wastes.** Solar Energy Research Inst., Golden, CO (United States). Mar 1990 4p. Source: Solar Energy Research Institute, Golden, CO.

Although the severity of the hazardous waste crisis is undeniable, a promising solution that uses solar thermal technology is emerging from the laboratories of the US Department of Energy (DOE). To move this solution from the laboratory into the marketplace, the office of DOE's Assistant Secretary of Conservation and Renewable Energy recently proposed a new initiative. To encourage your involvement in the initiative effort, this pamphlet will familiarize you with the scope of the initiative and the opportunities it holds for you.

223 **Kinetic and mechanistic overview of TiO₂-photocatalyzed oxidation reactions in aqueous solution.** Blake, D.; Webb, J.; Turchi, C.; Magrini, K. Solar Energy Research Inst., Golden, CO (United States). [1991]vp. Source: Solar Energy Research Institute, Golden, CO.

Destruction of trace organic compounds in water by photocatalytic oxidation over titanium dioxide is the subject of worldwide interest. In this paper we review chemical mechanisms and identify some band gap and thermodynamic limitations that must be considered in limiting a solar-driven process. Recent work will be discussed which tests predictions made by the mechanism concerning dependence of rates of destruction on light flux and on the presence of bicarbonate ion, a known hydroxyl radical scavenger.

224 **Photocatalytic decomposition of organic compounds in aqueous solutions.** Magrini, K.A.; Webb, J.D. Solar Energy Research Inst., Golden, CO (United States). [1991]vp. Source: Solar Energy Research Institute, Golden, CO.

The degradation of aqueous trichloroethylene (TCE) to CO₂ and HCl is accomplished photocatalytically by irradiating TCE solutions, which contain suspensions of anatase TiO₂, with simulated sunlight. Increases in the incident beam energy increase the TCE decomposition rate. Destruction of TCE was demonstrated from initial concentrations of 60 ppm to less than 50 ppB.

225 **Photocatalytic decomposition of aqueous trichloroethylene and direct red-79 with TiO₂ as a function of irradiation intensity.** Magrini, K.A.; Webb, J.D. Solar Energy Research Inst., Golden, CO (United States). [1991]vp. Source: Solar Energy Research Institute, Golden, CO.

The degradation of aqueous trichloroethylene (TCE) to CO₂ and HCl is accomplished photocatalytically by irradiated TCE solutions, which contain suspensions of anatase TiO₂, which simulated sunlight.

COMBUSTION

Engine Combustion Technology

226 (LBL-28270) **A methodology for inhibiting the formation of pollutants in diesel engines.** Oppenheim, A.K. (California Univ., Berkeley, CA (USA). Dept. of Mechanical Engineering); Hom, K.; Maxson, J.A.; Beck, N.J.; Stewart, H.E. Lawrence Berkeley Lab., CA (USA). Jan 1990. 13p. Sponsored by U.S. Department of Defense; US-DOE, Washington, DC (United States). DOE Contract AC03-76SF00098. Contract DAAL03-87-0123. (CONF-9002115-1: Society of Automotive Engineers international congress and exhibition, Detroit, MI (USA), 26 Feb - 2 mar 1990). Order Number DE90011615. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The methodology put forth in this paper stems from the premise that the primary reason for the generation of major pollutants by diesel engines, particulates and nitric oxides, is associated with over-reliance upon diffusion flames to carry out the process of combustion. Specific means are, therefore, proposed to inhibit their formation. This consists of refinements involving the use of either hollow cone spray injectors or air blast atomizers. Concomitantly, the process of combustion is staged by either regulating the rate of injection or employing a number of consecutively activated injectors per cylinder under a microprocessor command, while regions of high temperature peaks are distributed throughout the charge and kept at a relatively low level by exploiting the large scale vortex structure of turbulent pulsed jets combined with residual gas recirculation. Most appropriate for the realization of these concepts is a two-stroke, loop scavenged engine with special provisions included to curb emission of unburned hydrocarbon due to lubricating oil. 26 refs., 13 figs.

227 (SAND-88-1925C) **Gaseous hydrocarbon-air detonations.** Tieszen, S.R.; Stamps, D.W.; Westbrook, C.K.; Pitz, W.J. Sandia National Labs., Albuquerque, NM (USA). 1988. 33p. DOE Contract AC04-76DP00789 ;W-7405-ENG-48. (UCRL-99873; CONF-8810103-1: Fall meeting of the Western State Section of The Combustion Institute, Laguna Beach, CA, US, October 17, 1988). Order Number DE89001042. Source: NTIS, PC A03/MF A01; GPO Dep.

Detonation cell width measurements are made on mixtures of air and methane, ethane, dimethyl-ether, nitroethane, ethylene, acetylene, propane, 1,2-epoxypropane, n-hexane, 1-nitrohexane, mixed primary hexylnitrate, n-octane, 2,2,4-trimethylpentane, cyclooctane, 1-octene, cis-cyclooctene, 1-7-octadiene, 1-octyne, n-decane, 1,2-epoxydecane, pentyl-ether, and JP4. There is a slight decrease in detonation cell width that is within the uncertainty of the data for stoichiometric alkanes, alkenes, and alkynes with increasing temperature between 25 and 100°C. Also there appears to be no effect of molecular weight from ethane to decane, on detonation cell width for stoichiometric alkanes. Molecular structure is found to affect detonability for C₈ hydrocarbons, where the saturated ring structure is more sensitive than the straight-chain alkane. Unsaturated alkenes and alkynes are more sensitive to detonation than saturated alkanes. However, the degree of sensitization decreases with increasing molecular weight. Addition of functional groups such as nitro, nitrate, epoxy, and ethers are found to significantly reduce the detonation cell width

from the parent n-alkane. Nitrated n-alkanes can be more sensitive than hydrogen-air mixtures. The increase in sensitivity of epoxy groups appears to be related to the oxygen to carbon ratio of the molecule. Good results are obtained between the data and predictions from a ZND model with detailed chemical kinetics. 46 refs., 8 figs., 4 tabs.

228 (UCRL-101594) **An experimental and kinetic modeling study of the combustion of n-butane and isobutane in an internal combustion engine.** Wilk, R.D. (Union Coll., Schenectady, NY (USA)); Addagarla, S.; Miller, D.L.; Cernansky, N.P.; Pitz, W.J.; Westbrook, C.K.; Green, R.M. Lawrence Livermore National Lab., CA (USA). 13 Oct 1989. 45p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48 ;AC04-76DP00789 ;FG04-87AL44658. (CONF-8910289-4: Western States Section meeting of the Combustion Institute, Livermore, CA (USA), 23-24 Oct 1989). Order Number DE90002768. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Butane is the simplest alkane fuel for which more than a single structural isomer is possible. In the present study, n-butane and isobutane are used in a test engine to examine the importance of molecular structure in determining knock tendency, and the experimental results are interpreted using a detailed chemical kinetic model. A sampling valve was used to extract reacting gases from the combustion chamber of the engine operated in a skip-fire mode. Samples were withdrawn at different times during the skip cycles, providing a measure of the concentrations of a wide variety of reactant, olefin, carbonyl, and other intermediate and product species. The chemical kinetic model predicted the formation of all the intermediate species measured in the experiments. The agreement between the measured and predicted values is mixed and is discussed. Calculations show that RO₂ isomerization reactions are more important contributors to chain branching in n-butane oxidation is dependent on H-atom abstraction reactions involving HO₂ and CH₃O₂ radicals that occur at higher temperatures than RO₂ isomerization reactions. Therefore, an isobutane mixture must be raised to a higher temperature than a n-butane mixture to achieve the same overall rate of reaction. 48 refs., 3 figs., 2 tabs.

229 (UCRL-102495) **Engine knock predictions using a fully-detailed and a reduced chemical kinetic mechanism.** Cowart, J.S. (Massachusetts Inst. of Tech., Cambridge, MA (USA)); Keck, J.C.; Heywood, J.B.; Westbrook, C.K.; Pitz, W.J. Lawrence Livermore National Lab., CA (USA). 13 Dec 1989. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-900704-2: 23. Combustion Institute symposium on combustion, Orleans (France), 22-27 Jul 1990). Order Number DE90005992. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Two chemical kinetic models are used to interpret engine knock data obtained in a laboratory internal combustion engine. These consisted of a detailed kinetic model and a reduced kinetic model, both calibrated to describe engine conditions. Comparisons of both models with experimental results are discussed. Relationships between the reaction steps of the detailed and reduced models are examined in detail, and the relative strengths and weaknesses of the two approaches are discussed. 15 refs., 2 figs., 2 tabs.

230 (UCRL-102497-1) **Shock tube ignition of isomers of octane.** Burcat, A. (Technion-Israel Inst. of Tech., Haifa (Israel). Faculty of Aerospace Engineering); Pitz, W.J.; Westbrook, C.K. Lawrence Livermore National Lab., CA

(USA). 13 Dec 1989. 23p. Sponsored by USDOE, Washington, DC (United States); United States-Israel Binational Science Foundation. DOE Contract W-7405-ENG-48. (CONF-900704-1: 23. Combustion Institute symposium on combustion, Orleans (France), 22-27 Jul 1990). Order Number DE90005991. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Ignition delay time measurements were carried out behind reflected shock waves for three isomers of octane, including n-octane, 2,2,4-trimethyl pentane, and 2,3,4-trimethyl pentane, and for 1-octene. Initial concentrations of fuel, oxygen, and argon, and the post-shock temperature were varied systematically to establish the influences of these parameters on ignition delay time. A detailed chemical kinetic reaction mechanism was developed to interpret the experimental results. Overall agreement between experimental and computed results was very good, and the model was used to describe the elementary reaction paths by which these fuels ignite and kinetic differences between these closely related hydrocarbon fuels. 22 refs., 5 figs., 3 tabs.

231 (UCRL-102584) **A numerical study of silane combustion.** Britten, J.A.; Tong, J.; Westbrook, C.K. Lawrence Livermore National Lab., CA (USA). Dec 1989. 17p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-900704-4: 23. Combustion Institute symposium on combustion, Orleans (France), 22-27 Jul 1990). Order Number DE90006002. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

A kinetic model of the mechanism of silane combustion has been developed, using a system of 70 elementary reaction steps and 25 chemical species. The model was used to examine silane ignition at ordinary pressures under both shock tube conditions and low-temperature constant-volume conditions. The agreement between model predictions and experimental data is very good, both with respect to shock tube ignition delay times and to the pronounced, nonlinear variation of autoignition time with initial pressure at near-ambient temperatures. The model also reproduces observed trends in H_2/H_2O product yield as a function of the initial SiH_4/O_2 ratio. One key to this mechanism is competition between thermal stabilization and chain-branching decomposition reactions of an excited-state silylperoxy radical, and a second key is the reaction of water vapor with intermediate species containing a $Si=O$ double bond. 27 refs., 4 figs., 2 tabs.

232 (UCRL-102778) **Auto-ignition temperatures of binary mixtures of alkanes in a closed vessel: Comparisons between experimental measurements and numerical predictions.** Griffiths, J.F. (Leeds Univ. (UK), School of Chemistry); Coppersthaite, D.; Phillips, C.H.; Westbrook, C.K.; Pitz, W.J. Lawrence Livermore National Lab., CA (USA) [1990]. 22p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-900704-8: 23. Combustion Institute symposium on combustion, Orleans (France), 22-27 Jul 1990). Order Number DE90007856. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Autoignition temperatures of the binary mixtures methane + ethane and methane + butane in air were measured at atmospheric pressure in a 0.56 dm³ spherical reaction vessel. The method used followed that for standard ASTM and BS tests for gaseous fuels. Fixed proportions by volume of the total fuel in air were studied, which correspond at the extreme of each composition range to the equivalence ratios for methane, ethane and butane of 0.93, 1.63 and 3.04,

respectively. Supplementary experiments were carried out on butane alone under the same conditions, in which its proportion was varied in the equivalence range 0.93-3.04. The autoignition of methane was sensitized by ethane most strongly when the ethane was present at up to 10% of the total fuel. The autoignition temperature ($T_{a,cr}$) was reduced by 40 K with respect to that for pure methane ($T_{a,cr} = 900$ K). There was an even stronger sensitization by similar proportions of butane added to methane, such that $T_{a,cr}$ decreased to 810 K, in neither case were the effects linearly dependent on the proportion of additive. There was an addition sensitive region when butane was present in the proportion 0.5-0.7 of the methane/butane mixture, at which $T_{a,cr}$ fell sharply by 50 K over this limited composition range. Remarkably, except at the leanest mixtures ($C_{butane} < 0.5$), the autoignition temperatures of compositions containing butane alone matched very closely the autoignition temperatures of the equivalent methane/butane mixtures. We believe that this is a new and very important observation in relation to the understanding and interpretation of combustion hazards involving mixtures of fuels. 28 refs., 4 figs.

233 (UCRL-JC-103593) **Modeling of knock in spark-ignition engines.** Westbrook, C.K.; Pitz, W.J. Lawrence Livermore National Lab., CA (USA). [1990]. 10p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-900978-1: COMODIA '90: international symposium on diagnostics and modeling of combustion in internal combustion engines, Kyoto (Japan), 3-5 Sep 1990). Order Number DE90010875. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The chemical kinetic modeling of end gas autoignition leading to knocking behavior in spark ignition engines is discussed. The demands placed upon kinetic models by the conditions of temperature and pressure are examined, and the construction of both highly detailed and of more global or reduce kinetic models is outlined. Methods for including the influences of such factors as fuel molecule size and molecular structure are described for both types of knock model. The results of both types of model analyses are presented, and the strengths and weaknesses of each are discussed. 21 refs., 3 figs., 2 tabs.

234 (UCRL-JC-104065) **A chemical kinetic modeling study of chlorinated hydrocarbon combustion.** Pitz, W.J.; Westbrook, C.K. Lawrence Livermore National Lab., CA (USA). 5 Sep 1990. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9010197-1: American flame research committee 1990 fall international symposium, San Francisco, CA (USA), 8-10 Oct 1990). Order Number DE91000261. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The combustion of chloroethane is modeled as a stirred reactor so that we can study critical emission characteristics of the reactor as a function of residence time. We examine important operating conditions such as pressure, temperature, and equivalence ratio and their influence on destructive efficiency of chloroethane. The model uses a detailed chemical kinetic mechanism that we have developed previously for C_2 hydrocarbons. We have added to this mechanism the chemical kinetic mechanism for C_2 chlorinated hydrocarbons developed by Senkan and coworkers. In the modeling calculations, sensitivity coefficients are determined to find which reaction rate constants have the largest effect on destructive efficiency. 24 refs., 6 figs., 1 tab.

235 (UCRL-JC-105005) **Chemical kinetic modeling of chlorinated hydrocarbons under stirred-reactor conditions.** Pitz, W.J.; Westbrook, C.K. Lawrence Livermore National Lab., CA (USA). 4 Oct 1990. 23p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-7405-ENG-48. (CONF-9010207-2: 1990 combustion institute fall meeting, San Diego, CA (USA), 14-16 Oct 1990). Order Number DE91001751. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The combustion of chloroethane is modeled as a stirred reactor so that we can study critical emission characteristics of the reactor as a function of residence time. We examine important operating conditions such as pressure, temperature, and equivalence ratio and their influence on destructive efficiency of chloroethane and production of other chlorinated products. The model uses a detailed chemical kinetic mechanism that we have developed previously for C_3 hydrocarbons. We have added to this mechanism the chemical kinetic mechanism for C_2 chlorinated hydrocarbons developed by Senkan and coworkers. Some reactions have been added to Senkan's mechanism and some of the reaction-rate expressions have been updated to reflect recent developments in the literature. In the modeling calculations, sensitivity coefficients are determined to find which reaction-rate constants have the largest effect on destructive efficiency. 25 refs., 6 figs., 1 tab.

236 **Chemical kinetic modeling of combustion of practical hydrocarbon fuels.** Westbrook, C.K. (Lawrence Livermore National Lab., Livermore, CA (US)); Pitz, W.J. 14p. Society of Automotive Engineers, Warrendale, PA (USA) (1989). (CONF-8904240-: 40. Society of Automotive Engineers annual earthmoving industry conference, Peoria, IL (USA), 11-13 Apr 1989). Paper 890990.

The development of detailed chemical kinetic reaction mechanisms for analysis of autoignition and knocking of complex hydrocarbon fuels is described. The wide ranges of temperature and pressure which are encountered by end gases in automobile engine combustion chambers result in extreme demands on the reaction mechanisms intended to describe knocking conditions. The reactions and chemical species which are most important in each temperature and pressure regime are discussed, and the validation of these reaction mechanisms through comparison with idealized experimental results is described. The use of these mechanisms is illustrated through comparisons between computed results and experimental data obtained in actual knocking engines.

237 **Kinetic modeling of large hydrocarbon fuel molecules.** Westbrook, C.K. (Lawrence Livermore National Lab., Livermore, CA (US)); Pitz, W.J. pp. 117-120 of 1989 Spring technical meeting on combustion fundamentals and applications. Combustion Institute, Pittsburgh, PA (USA) (1989). pp. 389 (CONF-890446-: Combustion Institute spring meeting: combustion fundamentals and applications, Dearborn, MI (USA), 30 Apr - 2 May 1989).

Hydrocarbon fuels used in practical combustion systems are often complex mixtures of a variety of different molecules, many consisting of large alkane and aromatic species. The authors discuss the importance of fuel molecule size and structure in determining combustion properties. The development of a kinetic model of large hydrocarbon fuel molecules is described.

Continuous Combustion Technology

Contains only reports completed after OIT restructuring in 1990. No abstracts are available for this program area at this time.

THERMAL SCIENCES

Heat and Mass Transfer

238 (ANL-90/19) **Two-phase flow patterns and frictional pressure gradients in a small, horizontal, rectangular channel.** Wambsganss, M.W. (Argonne National Lab., IL (USA)); Jendrzeczyk, J.A.; France, D.M.; Obot, N.T. Argonne National Lab., IL (USA). May 1990. 112p. Sponsored by USDOE, Washington, DC (United States). DOE Contract W-31109-ENG-38. Order Number DE90014802. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

Two-phase flow patterns and frictional pressure gradients in flow in small, rectangular channels are being studied as part of a larger research program addressing phase-change heat transfer of pure refrigerants and refrigerant mixtures in plate-fin heat exchangers. Small rectangular flow channels were selected as representative of plain fin geometries. The particular channel reported herein has dimensions of 19.05×3.18 mm. Adiabatic flows of air/water mixtures, with the flow channel horizontal and the channel exit at near-atmospheric conditions, were utilized in the experiments. Analysis and interpretation of the pressure data relative to observed flow pattern transitions led to an objective method for determining the plug/bubble-to-slug flow transition. This method, together with visual observations, supplemented with photographic data, was used to develop a flow pattern map. A comparison of existing flow pattern maps for circular pipes, capillary tubes, and larger rectangular channels led to the conclusion that, while qualitative agreement exists, these maps are not generally applicable on a quantitative basis to the subject small rectangular channel. Two state-of-the-art correlations for frictional pressure gradient were evaluated, with particular emphasis on the practically important ranges of total mass quality and mass flux, from the standpoint of plate-fin heat exchangers designed as evaporators. Neither correlation was in good agreement over the entire range of interest. A modified, semiempirical correlation was developed to predict, with satisfactory accuracy for design purposes, the measured data of these experiments. 60 refs., 44 figs., 2 tabs.

MATERIALS

Engineered Industrial Materials

239 (CONF-891119-85) **In situ growth of high quality epitaxial $YBa_2Cu_3O_7$ x thin films at moderate temperatures by pulsed laser ablation.** Lowndes, D.H.; Norton, D.P.; McCamy, J.W.; Feenstra, R.; Budai, J.D.; Christen, D.K.; Poker, D.B. Oak Ridge National Lab., TN (USA). Nov 1989. 4p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From Materials Research Society fall meeting; Boston, MA (USA); 27 Nov - 2 Dec 1989. Order Number DE90006629. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

Pulsed KrF (248 nm) laser ablation has been used for in situ growth of smooth, high-quality $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ epitaxial films of variable thickness on SrTiO_3 , KTaO_3 , LaAlO_3 , cubic ZrO_2 , and MgO substrates, at temperatures of ~ 600 – 730 °C, without higher temperature post-annealing. A rotating target pellet, line focusing by a single cylindrical lens, laser-beam scanning over the target, and laser energy densities ~ 2.5 – 3 J/cm² can be combined to yield films of completely uniform composition and with $\sim 25\%$ thickness variation over areas ~ 8 cm². The best films have $T_c > 92$ K and $J_c(H = 0, T = 77 \text{ K}) > 2$ MA/cm². Film-growth procedures are described, together with results of superconducting and normal-state transport measurements. 11 refs., 3 figs., 1 tab.

240 (CONF-891119-88) **In situ growth of epitaxial superconducting $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ films on insulating, semiconducting and ferroelectric $\text{K}(\text{Ta}, \text{Nb})\text{O}_3$ by pulsed laser ablation.** McCamy, J.W. (Tennessee Univ., Knoxville, TN (USA)); Norton, D.P.; Lowndes, D.H.; Boatner, L.A.; Christen, D.K.; Feenstra, R.; Sonder, E. Oak Ridge National Lab., TN (USA). [1989]. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From Materials Research Society fall meeting; Boston, MA (USA); 27 Nov - 2 Dec 1989. Order Number DE90006568. Source: NTIS, PC A02/MF A01 - OSTI.

$\text{K}(\text{Ta}, \text{Nb})\text{O}_3$ (KTN) is an interesting substrate for use in studies of epitaxial superconducting film-substrate interactions because of a moderate lattice parameter mismatch with $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ and great versatility in electrical properties. KTN's properties are easily modified by doping to form an n-type semiconductor and/or a ferroelectric with variable ferroelectric T_c . As an initial step in exploring such studies we have carried out what are believed to be the first epitaxial growth experiments of $\text{YBa}_2\text{Cu}_3\text{O}_{7-x}$ films on insulating, semiconducting and ferroelectric KTN single crystals by pulsed laser ablation. We find that c-axis-normal epitaxial films can be consistently grown with $T_{sc}(R = 0) > 90$ K, $\Delta T_{sc} \sim 1.5$ K, and $J_c > 1$ MA/cm² on semiconducting and/or insulating KTaO_3 . However, growth on KNbO_3 is problematic because of stresses generated by cooling the substrate through first order structural transitions, at even moderate cooling rates. 11 refs., 4 figs.

241 (DOE/CE/90027-1-Rev.1) **Friction and wear of glass carbon in sliding contact: Final report, September 30, 1988–June 30, 1989: Revision 1.** Burton, R.A. (Burton Technologies, Inc., Raleigh, NC (USA)); Burton, R.G. Burton Technologies, Inc., Raleigh, NC (USA). 1 Sep 1989. 43p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-88CE90027. Order Number DE90000743. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The goal of this project is to determine the promise of a new family of self lubricated materials, and to define problem areas for further research. Specifically it is to obtain an understanding of the friction and wear behavior of a promising form of vitreous or glassy carbon in monolithic and reinforced bodies, when run against a representative group of metals and ceramics. This effort serves to evaluate the potential of glassy carbon materials for use in friction and wear applications, through conducting a series of pin-on-disk sliding tests on these materials, and on metals and ceramics which are candidates for similar applications. 13 refs., 5 figs., 9 tabs.

242 (ORNL/FTR-2849) **[Program for measurements and models of grain boundary and surface energies of**

metals and ceramics]: Foreign trip report, March 7–17, 1988. Carpenter, J.A. Jr.; Murr, L.E.; Schneibel, J.H.; Vitek, V.; White, C.L. Oak Ridge National Lab., TN (USA). 18 Apr 1988. 51p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. Order Number DE89017434. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

In a trip to India March 7–17, 1988, the five US travelers collaborated with researchers from three Indian institutions to develop a program for measurements to be made in India of grain boundary and surface energies of metals and ceramics. The Indian institutions were the Indian Institute of Technology of Kanpur, the Bhabha Atomic Research Center at Trombay, and the Indian Institute of Science in Bangalore. The primary purpose of the measurements is to provide a limited but crucial set of updated data for five selected materials systems using modern characterization equipment which data modelers can use to verify or calibrate various "Materials by Design" computer programs envisioned to someday be able to predict properties of "real world" materials or at least make more efficient their experimental development. Fairly extensive collaborations between Indian and American researchers are expected to take place. The five materials systems suggested for study are Ni, Cu, Ni_3Al , Type 316 stainless steel, and Al_2O_3 with various levels of dopants such as S, B, Sb, and Sn. These five systems were deemed attractive for study on the dual bases of being scientifically interesting while also being technologically important.

243 (ORNL/TM-11397) **Models for heat transport through assemblies of uniform-diameter hollow spheres.** Yarbrough, D.W.; McElroy, D.L.; Weaver, F.J. Oak Ridge National Lab., TN (USA). Apr 1991. 139p. Sponsored by USDOE, Washington, DC (USA). DOE Contract AC05-84OR21400. Order Number DE91012998. Source: OSTI; NTIS; GPO Dep.

Uniform-diameter thin-wall hollow ceramic spheres are being developed as a thermal insulating material. The radial heat flow across test beds of the hollow spheres has been measured as a function of interstitial gas pressure and temperature for specimens with either nitrogen or helium as the interstitial gas. This report covers the development of equations used to model the heat flow process. The primary modes of heat transfer in this case are conduction and radiation. Convection transport is a minor but apparently not a negligible part of the overall transport. Three models have been used to describe 17 experimental data sets obtained for combinations of sphere sizes, sphere material, and interstitial gas type and pressure. In each case, the experimental data have been used to determine parameters appearing in the models. In general, the experimental thermal conductivity data for a given bed of spheres can be described to better than 10% over the pressure range investigated. One of the models which includes a pressure explicit function describes the data to set better than 5%. FORTRAN programs have been written to expedite use of the models to describe the data. These programs can be easily modified to produce thermal conductivity predictions for untested combinations of, for example, sphere size, interstitial gas type and pressure, and solid conductivity. The programs have been included in this report. 13 refs., 19 figs., 7 tabs.

Materials Manufacturing Technologies

244 (DOE/CE/15316-T3) **Laser based machine for die and prototype manufacturing: Final report, February**

10, 1987–August 9, 1988. Feygin, M. (Hydronetics, Inc., Chicago, IL (USA)). Hydronetics, Inc., Chicago, IL (USA). 5 Feb 1989. 17p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG01-87CE15316. Order Number DE89009115. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

In his application to the Bureau of Energy Related Inventions Michael Feygin proposed a feasibility study for a new process aiming at completely automated manufacturing of complex and hard to manufacture parts. The technique invented by Michael Feygin is called Laminated Object Manufacturing. It utilizes thin cross-sections of a part, cut by a laser based contouring machine. The part is created by successive deposition and bonding of layers of material. Part geometry is specified by successive cross-sectioning of 3-dimensional images created with a CAD program on a graphic workstation. The Laminated Object Manufacturing system can be thought of as a "three-dimensional-printer" which incrementally stacks two-dimensional images. The ultimate hard copy is produced, the object itself. The laser system is basically an assembly of known technologies: laser cutting, CAD and CAM, brazing or adhesion bonding, and computer controlled mechanical handling of components. It offers a revolutionary new way to produce 3-dimensional objects such as molds, dies, prototypes, models and other items produced in small batches. The research performed on the grant created a foundation for building a successful prototype of a LOM system. The prototype has been built in 1988 using funds of the Illinois Innovation Fund, a state agency independent from DOE. 8 figs., 1 tab.

245 Synthesis of sinterable SiC powders by carbothermic reduction of gel-derived precursors; and pyrolysis of polycarbosilane. Wei, G.C. (Oak Ridge National Lab., TN); Kennedy, C.R.; Harris, L.A. *American Ceramic Society Bulletin (USA)*, 63(8): 1054-1061 (Aug 1984). DOE Contract W-7405-ENG-26.

Silicon carbide powders were synthesized by 1) carbothermic reduction of carbon-doped silica gel derived from colloidal silica or methyltrimethoxysilane and 2) pyrolysis of polymeric SiC precursors. Powder characteristics, including sinterability, depended on the type and composition of the precursor. The colloidal silica-sucrose and -pitch SiC powders doped with boron and carbon were sintered to 95% to 96% of theoretical density at 2100°C in argon. The microstructures of these sintered SiC bodies consisted of mixtures of elongated grains (up to 50 μm) and equiaxed grains ($\approx 10 \mu\text{m}$) with residual pores (up to 8 μm) at grain boundaries or inside grains. 12 references, 7 figures, 2 tables.

246 Beta SiC powders produced by carbothermic reduction of silica in a high-temperature rotary furnace. Wei, G.C.T. (Oak Ridge National Lab., TN). *Journal of the American Ceramic Society (USA)*, 66(7): C111-C113 (Jul 1983). DOE Contract W-7405-ENG-26. (CONF-8210286--: 35. American Ceramic Society annual Pacific Coast Regional meeting, Seattle, WA, US, October 27, 1982).

Sinterable β -SiC powders were synthesized by carbothermic reduction of silica with carbon in a high-temperature rotary furnace. The powders were characterized as to sinterability, surface area, particle size, and morphology.

Bioprocessing

Contains only reports completed after OIT restructuring in 1990. No abstracts are available for this program area at this time.

SENSORS AND CONTROLS

Advanced Sensors and Controls

Refer also to citation(s) 3, 4, 19, 426, 427, 443, 444, 445, 460, 465, 466, 467, 512

247 (CONF-8611136–) Proceedings of the DOE/Industry Research and Development Sensor Working Group meeting, Chicago, Illinois: [Final report]. Emerson, D.B.; Whitworth, B.A. Energetics, Inc., Columbia, MD (USA). 14 Nov 1986. 200p. DOE Contract AC05-85CE40741. From DOE/Industry Research and Development Sensor Working Group meeting; Chicago, IL, US; November 14, 1986. Order Number DE87006159. Source: NTIS, PC A09/MF A01; GPO Dep.

This report gives summaries and working group comments on the following pulp and paper sensor projects: in-situ combustion control, pulp consistency meter, lignin mass spectrometer for kraft cooking liquor, lime kiln temperature sensor, submillimeter laser for moisture and basis weight, capacitive dew point sensor, acoustic steam flow meter, and real-time, noncontact optical surface motion monitor. A caucus report on these projects and presentation aids are included. (DLC)

248 (CONF-8711169–) Proceedings of the DOE/Industry Advanced Research and Development Sensor Working Group meeting, Phoenix, Arizona. Emerson, D.B. Energetics, Inc., Columbia, MD (USA). 13 Nov 1987. 350p. DOE Contract AC05-85CE40741. From DOE/industry advanced research and development sensor working group meeting; Phoenix, AZ, US; November 13, 1987. Order Number DE88007713. Source: NTIS, PC A15/MF A01; GPO Dep.

This document includes the minutes and presentation aids of this meeting and covers: In-Situ Combustion Control; Consistency Meter; Lignin Mass Spectrometer; NBS Consistency Meter and JPL Lignin Mass Spectrometer Testing; On-Machine Sensors to Measure Paper Mechanical Properties; Modelling, Optimization and Control of Complex Physical Systems; Real Time, Non-Contract Optical Surface Motion Monitor; and DOE/Industry Sensor Working Group Caucus Report.

249 (CONF-8804220–) Proceedings of the DOE/Industry advanced research and development Sensor Working Group meeting, Appleton, Wisconsin. Emerson, D.B. Energetics, Inc., Columbia, MD (USA). 21 Apr 1988. 232p. DOE Contract AC05-85CE40741. From DOE/industry advanced research and development sensor working group meeting; Appleton, WI, US; April 21, 1988. Order Number DE89002943. Source: NTIS, PC A11/MF A01 - OSTI; GPO Dep.

The Department of Energy/Industrial Program (DOE/IP) pulp and paper sensor program undertakes long-term, high risk, applied research and exploratory development activities to expand the generic technology base that supports initiatives by both the DOE end-use conservation programs and

private industry, to improve the efficiency of energy conversion and utilization systems. The DOE/IP pulp and paper sensor research program is distinct from other research programs in that: (a) it undertakes directed basic research that is problem oriented; (b) it focuses on solving problems common to more than one energy-consuming sector in anticipation of technology needs that impede achievement of efficiency improvements; and (c) it seeks out, encourages and supports innovative ideas/concepts that: (1) show technical promise; (2) show cost effective potential; (3) are too long-term for industry to pursue on its own; and (4) are capable of engaging industry interest for future investment in further development if successful at the proof-of-concept stage.

250 (DOE/BP/18944-T1) **Simplot potato processing plant energy conservation study: Appendices.** Seton, Johnson, and Odell, Inc., Portland, OR (USA). [1988]. 136p. DOE Contract AC79-84BP18944. Order Number DE89005585. Source: NTIS, PC A07 - OSTI.

Handwritten manuscript.

This group of appendices, B-G, of the "Simplot Potato Processing Plant Energy Conservation Study", covers processing equipment, refrigeration equipment, water systems, air conditioning systems and lighting systems. Data on these systems related to cost and energy consumption are given. (JF)

251 (DOE/BP/71980-T1) **Calibration of irrigation flow meters.** Trimmer, W.L. Oregon State Univ., Corvallis (USA). Dept. of Agricultural Engineering. Feb 1988. 50p. DOE Contract A179-86BP71980. Order Number DE88010992. Source: NTIS, PC A03/MF A01; GPO Dep.

Several meters working on the Doppler principle were tested. The Doppler meters depend on reflections from particles or bubbles in the fluid to measure velocity. Although they were linear, they were too inaccurate and inconsistent. Two meters working on the transit time principle were tested and worked very well. These meters measure upstream and downstream transit times for signal reflections from the inner pipe surfaces. However this type of meter is available at present only for permanent installations, not as a survey meter. Finally, the currently used Hall meters were calibrated and recommendations were made as to their proper use. The report recommends that an effort be made to develop a transit time meter in a portable configuration for irrigation survey work. 14 figs., 5 tabs.

252 (DOE/CE/15401-T4) **A miniature inexpensive oxygen sensing element: Quarterly review.** Arenz, R.W. (CeramPhysics, Inc., Westerville, OH (USA)). CeramPhysics, Inc., Westerville, OH (USA). 30 Jun 1989. 5p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG01-88CE15401. Order Number DE89014439. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

MEASURING INSTRUMENTS/design; PROGRESS REPORT; OXYGEN; SEALING MATERIALS; SEALS; CERAMICS; JOINING; DESIGN

253 (DOE/CE/40715-T1) **Process sensor availability and needs: a review of equipment available to the pulp and paper industry. Final report.** Emerson, D.B. Energetics, Inc., Columbia, MD (USA). Jun 1986. 106p. DOE Contract AC01-84CE40715. Order Number DE86012858. Source: NTIS, PC A06/MF A01; GPO Dep.

This report presents the summary findings of a study undertaken to determine the current status of pulp and paper

industry process control sensor and instrumentation technology for use in identifying where further federal R and D might be appropriate. Instrumentation manufacturers were contacted to obtain information regarding the current market status and capabilities of available equipment. Subsequent discussions with pulp and paper mill personnel were used to characterize industries' view of available equipment and to qualitatively identify existing technology weaknesses and needs.

254 (DOE/CE/40777-T1) **On-machine sensors to measure paper mechanical properties, Report No. 1.** Hall, M.S.; Habeger, C.C. Jr. Institute of Paper Chemistry, Appleton, WI (USA). Oct 1988. 61p. DOE Contract AC05-86CE40777. Order Number DE89005579. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

This project is a four-year program which began October 1, 1986. The work may be separated into two distinct parts and four phases. Part I (Phases 1 and 2) is being emphasized to date, and Part II (Phases 3 and 4) will be initiated upon successful completion of Part I. Part I of this project is specifically concerned with the development of a sensor to make on-machine measurements of elastic stiffness in the thickness direction of the paper and the integration of this sensor with an appropriate in-plane sensor. Upon completion of Part I (Phases 1 and 2), we expect to be able to independently monitor the effects of refining, jet-to-wire speed ratios, and draws (and the related drying restraints) on paper properties. This means that we should be able to control these three machine variables continuously and independently during the manufacturing process. Part II of the project will then be concerned with the development of algorithms, hardware, and software necessary to control these variables on the paper machine in the machine direction (Phase 3) and the cross-machine direction (Phase 4). Project objectives call for a successful demonstration of the sensor and control scheme on a laboratory scale paper machine. Success would lead to further work on a pilot scale and eventual scale-up to a full size paper machine. 22 refs., 19 figs., 5 tabs.

255 (DOE/CS/40023-T3) **Highly efficient welding power supply. Topical report, May 1, 1978-October 12, 1978.** Thommes, J.M. Cyclomatic Industries, Inc., San Diego, CA (USA). Nov 1978. 55p. DOE Contract AC03-78CS40023. Source: NTIS, PC A04/MF A01.

Selecting the best circuit approach for development of the highly efficient welding power supply is described. Arc characteristics and process demands were discussed in Section 2 concerning some testing results on the constant current mode and the constant voltage mode. Cost versus performance trade-offs are considered along with power supply line compatibility and expandability in Section 3. Specific approaches considered in Section 4 include power architecture, switch devices, control circuits, frequency and filtering, and packaging. Existing technology is reviewed in Section 5 and cost estimate is summarized in Section 6. Information on power supply specification goals, power circuit approaches, control circuit interface and approaches, and a detailed cost estimate of material is presented in appendices. (MCW)

256 (DOE/CS/40150-1) **Impact on energy conservation of automatic control systems utilization in the US pulp and paper industry.** Fam, S.S. Thermo Electron Corp., Waltham, MA (USA). 1978. 87p. DOE Contract AC02-78CS40150. Source: NTIS, PC A05/MF A01.

This study is concerned with the energy and other resource benefits resulting from the computerized automation of processes in the US pulp and paper industry. The primary objectives were to characterize the state of the art of computer controls in the industry and to pinpoint the problem areas that limit their further use. The study lasted approximately 4 months. An exhaustive survey of all the possible technologies in use, or under development, was not possible. The main conclusions are that the pulping and recovery operations offer the greatest potential for reducing energy use by computer control, and that effective hierarchical control at the plant level requires the integration of these operations into one or more control loops. No control system has been found that provides reliable, fully automated control of recovery boilers for an extended period of time. The total technical potential for fuel savings was estimated at 0.2 quadrillion Btu's a year, or the equivalent of 94,000 barrels of oil per day.

257 (DOE/CS/40152-T1) **Investigation of motor characteristics when connected to a Nola controller.** Colorado Univ., Boulder (USA). Dept. of Electrical Engineering. 31 Dec 1982. 217p. DOE Contract A101-79CS40152. Order Number DE83011696. Source: NTIS, PC A10/MF A01.

Tests performed on Nola-type power factor controllers for induction motors are described. Emphasis on energy conservation during the past two years has prompted many manufacturers to apply to NASA for licenses to produce both single-phase and three-phase controllers of this type. Claims have been made extolling the energy savings possible through the use of these devices. Units have been produced to operate with motors from fractional horsepower size up to at least one hundred horsepower. It was the purpose of this investigation to examine the behavior and efficiency of representative controllers for motors of single-phase fractional horsepower and three-phase up to 25 horsepower. In so far as possible, normal installation and operating conditions were simulated. The controllers were initially adjusted according to manufacturer's instructions and tests were run under various conditions of load and input voltage to determine their operating characteristics. Most of the controllers tested were purchased at random from representative manufacturers. However, during the period of the investigation, several manufacturers loaned controllers to the project to be tested. Some of the controllers operated reasonably well while others could not be stabilized at all. Operating data have been included for those units which were stable and mention has been made of those which were not. No tests were made at other than normal laboratory ambient temperature of approximately 20°C nor were any tests performed to check the possibility of resonance with other devices due to the harmonics induced in the voltage and/or current by the operation of the controller.

258 (DOE/CS/40402-16) **Assessment of energy-efficiency improvements for paint spray booths.** Centec Corp., Reston, VA (USA). Mar 1983. 73p. DOE Contract AC01-80CS40402. Order Number DE83016680. Source: NTIS, PC A04/MF A01.

The purpose of this report is to inform industry and industrial associations of the economic and technical benefits achievable through spray booth control. A discussion of the energy use and potential for conservation in spray booths is presented. Descriptions, costs, and payback potentials of several spray booth control system concepts are provided. In addition, the technological barriers and the R and D needs to overcome these barriers are identified and discussed.

259 (DOE/ID-10155) **Rapid in-process analysis of melts: Final report.** EG and G Idaho, Inc., Idaho Falls (USA). Feb 1987. 54p. DOE Contract AC07-76ID01570. Order Number DE88014872. Source: NTIS, PC A04/MF A01; GPO Dep.

A system was investigated and developed to provide on-line analysis of molten steel for the purpose of decreasing energy use by reducing the time to maintain a steel melt during analysis. The system consists of: (1) a probe to produce a representative powder by gas nebulization of the melt and rapid cooling of the particles, (2) a transport system to deliver, concentrate, and control the quality of the powder, and (3) an inductively-coupled plasma analysis system to determine the elemental composition of the powder. The system was tested with a tin alloy and to a lesser extent with steel alloys. For industrial purposes the system can be fully automated via minicomputer monitoring and control of various system operating pressures. 7 refs., 18 figs., 6 tabs.

260 (DOE/ID/12136-T1) **Automated energy control of integrated pulp and paper mills. Final report - Phase I.** Hunt, S.E. Saint Regis Paper Co., West Nyack, NY (USA). Technical Operations Div. 15 Apr 1983. 220p. DOE Contract FC07-80ID12136. Order Number DE83013888. Source: NTIS, PC A10/MF A01.

The test site selected for the project is the St. Regis Ferguson Mill in Monticello, Mississippi. The objective of the project is to evaluate the technical and economic feasibility of a mill-wide Automatic Control System (ACS) with primary emphasis on reduction of specific energy consumption in an integrated mill. The proposed system for proof-of-concept testing will employ one computer system for mill-wide optimization and a number of unit process control computers as required for this mill-wide optimization task. All control functions will be divided into modular components throughout this computer hierarchy to facilitate project management and mill utilization of the system. A systems philosophy will be employed to insure the functional integration of these components into a unified whole. The principal R & D feature of the project is that the energy consumers (e.g., paper machines, digesters, etc.) as well as the energy generators (e.g., boilers and turbine-generators) are being optimized. To date only optimization of the energy generators has advanced to the proof-of-concept stage and beyond.

261 (DOE/ID/12138-3) **Survey of gas-side fouling measuring devices.** Marner, W.J.; Henslee, S.P. Jet Propulsion Lab., Pasadena, CA (USA); EG and G Idaho, Inc., Idaho Falls (USA). Mar 1984. 125p. DOE Contract A107-80ID12138; AC07-76ID01570. (JPL-PUB-84-11). Order Number DE84014595. Source: NTIS, PC A06/MF A01; GPO Dep.

A survey of measuring devices or probes, which have been used to investigate gas-side fouling, has been carried out. Five different types of measuring devices are identified and discussed including: heat flux meters, mass accumulation probes, optical devices, deposition probes, and acid condensation probes. A total of 32 different probes are described in detail and summarized in matrix or tabular form. The important considerations of combustion gas characterization and deposit analysis are also given a significant amount of attention. The results of this study show that considerable work has been done in the development of gas-side fouling probes. However, it is clear that the design, construction, and testing of a durable versatile probe - capable of monitoring on-line fouling resistances - remains a formidable task.

262 (DOE/ID/12463-2) **Development of spectral flame analyzer for individual burner control in boilers: Final report.** Metcalfe, C.L.; Cole, W.E. TECOGEN, Inc., Waltham, MA (USA). Nov 1987. 104p. DOE Contract AC07-83ID12463. Order Number DE88016692. Source: NTIS, PC A06.

Optimum continuous combustion control of a multiple burner system can be achieved only if each individual burner can be continuously checked. The most promising method to achieve individual control is based on spectral emission from each burner flame. The intensity of certain emissions from chemical species formed during combustion are indicative of the fuel-air ratio of the burner. An optical monitor tuned to these emission bands provides the needed burner control signal. Tests were conducted to develop this technology. The first tests were conducted using laboratory scanning radiometers to look at the spectral emissions. These tests clearly showed the active wavelength bands and how the intensity varied with excess air level, firing rate, swirl, and fuel type. This information was used to upgrade a prototype analyzer previously built and tested. This analyzer was installed on a 1000-lb/hr package boiler and operated for four months. Results showed a response to excess air level, swirl, and firing rate.

263 (DOE/ID/12557-2) **Development of a prototype ultraviolet absorption hygrometer for industrial dryers: Phase 2: Final report.** Gersh, M.E.; Domingue, R.P.; Matthew, M.W.; Richtsmeier, S.C.; Bangert, M.; Lowe, R. Department of Energy, Idaho Falls, ID (USA); Idaho Operations Office; Special Sciences, Inc., Burlington, MA (USA); Pacer Systems, Inc., Billerica, MA (USA). Jun 1987. 59p. DOE Contract FC07-85ID12557 (SSI-TR-123). Order Number DE88011631. Source: NTIS, PC A04 MF A01; GPO Dep.

The motivation for this program is the observation that the use of reliable and accurate hygrometers to monitor or control the processes in industrial drying chambers could result in a significant reduction in the energy usage of the United States. At the present time, there are no commercially available hygrometers which have the required characteristics of a measurement capability at simultaneously high temperature and humidity, along with the ability to operate for long periods in a severely contaminating and/or particle-laden environment. The goal of this program is the development of an industrial hygrometer which can be employed to monitor the humidity during industrial drying operations. This requires a device which can operate at temperatures up to 250C, at high humidity (50-100%), and in environments containing particulates and/or fouling or corrosive vapors. 9 refs., 23 figs.

264 (DOE/ID/12557-T1) **Development of an ultraviolet absorption hygrometer for industrial dryers. Phase I. Final report.** Gersh, M.E.; Matthew, M.W.; Bien, F.; Lear, A.M.; Handy, R.; Bangert, M. Spectral Sciences, Inc., Burlington, MA (USA); Pacer Systems, Inc., Burlington, MA (USA). Nov 1985. 63p. DOE Contract FC07-85ID12557. Order Number DE86014902. Source: NTIS, PC A04 MF A01; GPO Dep.

The breadboard version of the UVAH was successfully designed and fabricated. During this process, tests were performed on the components and assemblies in order to assure the validity of the design concepts. A performance model of the UVAH was developed on the SSI computer, in order to guide the design, assess the performance, and analyze the data of the UVAH. The success of the design effort

was demonstrated by the results of the system performance tests. These tests demonstrated that the UVAH could measure the absolute humidity of a (clean) test chamber between temperatures of 50 to 90°C and relative humidities of 50 to 90%. An auxiliary test demonstrated operation under 100% relative humidity. The performance tests also demonstrated that the UVAH could measure the absolute humidity of a test chamber containing (silica) dust concentrations up to 7.8 g/m³, with air flow velocities up to 8.9 m/s. Model predictions showed that there was no fundamental limitation that would prevent the UVAH from performing measurements up to a relative humidity of 100% at 150°C. Finally, a preliminary market survey was performed in order to assess whether there was a potential demand for the UVAH in industries that could employ it in their drying operations. It appears that a primary market exists in the pulp and paper industry and that additional markets exist in the softwood lumber and grain industries. If the UVAH were widely used by these three industries in their drying operations, the potential energy savings could be more than 0.03 quad per year.

265 (DOE/ID/12558-2) **Improved industrial humidity sensor: Final technical report.** Honeywell, Inc., Plymouth, MN (USA). Solid State Electronics Div. Apr 1988. 126p. DOE Contract FC07-84ID12558. Order Number DE89002378. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

The objective of this project was to develop an economic and accurate moisture sensing system; a capacitive dew point hygrometer for use in harsh drying operation environments. The system was developed to meet the performance and cost requirements of agricultural grain drying and other process drying applications. Accurate moisture sensing and control using this sensor may achieve energy savings through reducing overdrying and increasing productivity of agricultural and industrial drying processes. This report describes the results of the dew point sensor development effort. 45 figs.

266 (DOE/ID/12558-T1) **Improved industrial humidity sensors and control systems. Dew point hygrometer. Phase 1. Final report.** Sulouff, R.E.; Randazzo, T.A. Honeywell, Inc., Plymouth, MN (USA). Solid State Electronics Div. Nov 1985. 119p. DOE Contract FC07-84ID12558. Order Number DE86011052. Source: NTIS, PC A06/MF A01; GPO Dep.

A capacitive dew point hygrometer was designed, fabricated, and tested for applications in industrial grain drying environments. This report describes the system development and the results of the fabrication and sensor evaluations. The dew point sensor was fabricated on silicon to provide a capacitive condensate detector that could detect liquid water or ice on the surface. The change in capacitance occurs due to the higher dielectric constant of water over air and results in an increase of capacitance from 25 pF dry to 40 pF completely wet. An integrated permalloy resistance temperature device (RTD) was also present on the surface of the sensor.

267 (DOE/ID/12559-1) **Development of a heat flux dew-point hygrometer for harsh and fouling environments: Final report.** Trans-Met Engineering, Inc., Anaheim, CA (USA). Jun 1988. 36p. DOE Contract FC07-85ID12559. Order Number DE89008082. Source: NTIS, PC A03 MF A01 - OSTI; GPO Dep.

The program summarized in this report was initiated for the purpose of developing a practical economic hygrometer

for use in high temperature harsh and fouling industrial driving environments. The need for such a sensor was based on the fact that a successful measurement of the moisture content of the air in such environments could greatly improve drying efficiencies with attendant significant energy saving. At the time of the initiation of the program there were no sensors commercially available for such measurements. 4 refs., 9 figs.

268 (DOE/ID/12559-T1) **Development of a heat flow dew-point hygrometer. Phase I. Final report.** Argonne National Lab., IL (USA). Reactor Analysis and Safety Div. Mar 1986. 32p. DOE Contract FC07-85ID12559. Order Number DE86014899. Source: NTIS, PC A03/MF A01; GPO Dep.

Tests included simulated fouling of the sensing surface with lint and resin, silicon grease, salt and corn starch. The prototype instrument was capable of measuring dew-point to within $\pm 4.5\%$ of theoretical over the range of interest for both clean and contaminated sensors. All tasks of the Phase I project were completed and all objectives met. This report is a description of the work completed, results obtained, and an analysis of these results.

269 (DOE/ID/12726-T1) **Advanced moisture sensor research and development: Quarterly progress report, SwRI Project 15-2236.** Nicholls, C. Southwest Research Inst., San Antonio, TX (USA). 30 Jul 1988. 11p. DOE Contract FC07-88ID12726. Order Number DE88015257. Source: NTIS, PC A03/MF A01; GPO Dep.

During the first quarter of this program we have been addressing the objectives of Task 1 which are to develop a moisture sensor based on the proposed nuclear magnetic resonance (NMR) concept and to investigate feasibility. This task is divided into four subtasks covering: a literature search of existing sensors, the definition of processes for which a NMR sensor is suitable, the definition of a development plan and the selection of an industrial collaborator. The collaborator would help in defining the sensor specifications and would ultimately provide a field site at which tests of a fullscale version of the sensor could be tested. 27 refs.

270 (DOE/ID/12726-T1) **Advanced moisture sensor research and development: Quarterly progress report.** Nicholls, C. Southwest Research Inst., San Antonio, TX (USA). 31 Jan 1988. 6p. DOE Contract FC07-88ID12726. Order Number DE89006502. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

During the third quarter of this program we have collected data to enable the design of our sensor, designed the sensor and the test plan. Thus Tasks 1a through 2c have been completed. We have submitted the test plan for DOE approval prior to continuing. The long delay in finding a suitable industrial collaborator has required us to request a six month no-cost time extension, as was anticipated in the previous quarterly report. 2 figs.

271 (DOE/PR 06010-T33) **Advanced sensor development program for the pulp and paper industry. Annual report.** National Bureau of Standards, Washington, DC (USA). 1984. 95p. DOE Contract A101-76PR06010. Order Number DE84008548. Source: NTIS, PC A05/MF A01; GPO Dep.

A program is described for the development of measurement science and technology for on-line measurement of process variables in the pulp and paper industry. Four research projects are currently in progress: (1) combustion control sensor, (2) pulp consistency sensor, (3) steam flow sensor, and (4) lignin sensor.

272 (PNL-6742) **Test of dip cup instrumentation.** Brenden, B.B. Pacific Northwest Lab., Richland, WA (USA). Nov 1988. 18p. DOE Contract AC06-76RL01830. Order Number DE89004423. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Instrumentation has been developed which will measure the alumina content of cryolite baths based upon the detection of a thermal arrest in the cooling curve when a small sample is pulled from the bath using a graphite cup. Detection of the temperature at which thermal arrest occurs is automatic, and an alumina content is automatically calculated and displayed. Recent measurements at a production plant indicate a standard error of 0.38% or less in the determination of alumina content based upon a set of 9 measurements. The time required for a single measurement is less than 5 minutes. No further development of the technique of instrumentation is planned at the present time. 1 ref., 2 figs., 4 tabs.

Coating Research

Refer also to citation(s) 49

273 (CONF-880724-19) **An investigation of ceramic coatings for protection of SiC from high-temperature corrosion.** Federer, J.I. Oak Ridge National Lab., TN (USA). 1988. 11p. DOE Contract AC05-84OR21400. From 25. American Society of Mechanical Engineers/American Institute of Chemical Engineers/American Nuclear Society national heat transfer conference; Houston, TX, US; July 24, 1988. Order Number DE88011023. Source: NTIS, PC A03/MF A01; GPO Dep.

Silicon carbide ceramics are susceptible to corrosion by certain industrial furnace environments. This behavior would limit the use of SiC components in ceramic heat exchangers. Because oxide ceramics corrode substantially less in the same environments, ceramic coatings have been investigated for corrosion protection. Coatings with Al_2O_3 , SiO_2 , or ZrO_2 as the main constituent were applied to sintered alpha and recrystallized (CS101) SiC substrates. The coated specimens were thermally cycled between room temperature and 1200°C as a test of adherence. Some coatings adhered better to the inherently rougher CS101 SiC; however, most coatings did not adhere to either substrate. Two Al_2O_3 -based coatings contained cracks, but remained intact during thermal cycling, and two ZrO_2 -based coatings were subjected to corrosion testing at 1200°C in an oxidizing atmosphere containing Na_2CO_3 . None of these four coatings exhibited the desired corrosion resistance in this test. Coated samples, however, corroded less than an uncoated sample, indicating that coatings can improve corrosion resistance.

274 (CONF-890468-6) **Evaluation of ceramic coatings on silicon carbide.** Federer, J.I.; van Roode, M.; Price, J.R. Oak Ridge National Lab., TN (USA). 1989. 32p. DOE Contract AC05-84OR21400. From 16. international conference on metallurgical coatings and equipment exhibit; San Diego, CA, US; April 17, 1989. Order Number DE89010321. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Ten ceramic coatings were plasma sprayed onto a sintered alpha silicon carbide (SiC) tube to determine if the coatings would protect SiC from high-temperature corrosion. Several coatings consisted of mullite or mullite-zircon. Others had base layers of mullite or mullite-zircon, transition layers with increasing amounts of alumina (Al_2O_3), zirconia (ZrO_2), or yttria (Y_2O_3), and outer layers of these last three

oxides. Mullite and mullite-zircon coatings, which have coefficients of thermal expansion (CTE) near that of SiC, survived 60 thermal cycles between 300 and 1300 C without apparent damage. Coatings have Al_2O_3 and Y_2O_3 layer cracked, while those with ZrO_2 layers cracked and spalled. Survivors were corrosion tested at 1200 C in an oxidizing atmosphere containing Na_2CO_3 , which corroded uncoated SiC at a rate of ≈ 21 mm/y. The coatings protected SiC for up to 500 h, but degraded because the atmosphere penetrated and reaction product. Denser coatings are needed for extended protection. 10 refs., 4 figs., 2 tabs.

275 (DOE/CE/90041-1) **Tool wear modelling/life prediction: Final report for the period September 1, 1986-February 29, 1988.** Kramer, B.M. George Washington Univ., Washington, DC (USA). Dec 1988. 14p. DOE Contract AC02-86CE90041. Order Number DE89005818. Source: NTIS. PC A03/MF A01 - OSTI: GPO Dep.

A calibrated analytical model of cutting tool wear has been developed to allow for the prediction of the wear rates of potential coatings for cutting tool materials. The model has been used to select coating compositions which may provide improved performance, as compared to existing titanium nitride based coatings. The model predicts that the wear resistance of the IVB nitrides will increase in the order TiN, ZrN and HfN. In addition, it predicts that the wear resistance of the binary nitride (Ti,Hf)N will be greater than that of either of the component mononitrides under the cutting conditions which are commonly used in the machining of steel with high speed steel tooling. 7 refs., 6 figs.

276 (DOE CS 40009-T1) **Demonstration of a fuel-saving system for paint-curing ovens.** Jensen, W.P. (comp.). EG and G Idaho, Inc., Idaho Falls (USA). Dec 1980. 115p. DOE Contract AC07-76CS40009. Source: NTIS. PC A06/MF A01.

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Two curing ovens at Roll Coater, Inc. (the Greenfield, Indiana plant) were retrofitted to save fuel and cost. Included in the fuel conserving retrofit was the design, fabrication, and installation of an afterburner for each of the two ovens, piping their combustion products to each of two commonly housed waste heat boilers before discharge from those units to the atmosphere at about 450 F. Depending on the product being run and the coating applied, natural gas requirements have been reduced by 45 to 65% with operation of the zone incinerators only and by as much as 65 to 85% including the effects of both the zone incineration and heat recovery by means of the afterburners and waste heat boilers. A demonstration program on conversion work at the No. 3 line at Greenfield and results are described in Section 2. Section 3 describes the retrofit design and the system construction. System performance (tests and measurements, qualitative performance, maintenance factors, and economic performance) is described in Section 4. Conclusions and recommendations are summarized.

277 (DOE CS 40210-T2) **Ultraviolet-radiation-curable paints.** Grosset, A.M., Su, W.F.A., Vanderglas, E. Westinghouse Electric Corp., Pittsburgh, PA (USA). Research and Development Center. 30 Sep 1981. 168p. DOE Contract AC01-79CS40210. Order Number DE82015717. Source: NTIS. PC A08/MF A01.

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In product finishing lines, ultraviolet radiation curing of paints on prefabricated structures could be more energy efficient than curing by natural gas fired ovens, and could

eliminate solvent emission. Diffuse ultraviolet light can cure paints on three dimensional metal parts. In the uv curing process, the spectral output of radiation sources must complement the absorption spectra of pigments and photoactive agents. Photosensitive compounds, such as thioxanthenes, can photoinitiate unsaturated resins, such as acrylated polyurethanes, by a free radical mechanism. Newly developed cationic photoinitiators, such as sulfonium or iodonium salts (the so-called onium salts) of complex metal halide anions, can be used in polymerization of epoxy paints by ultraviolet light radiation. One-coat enamels, topcoats, and primers have been developed which can be photoinitiated to produce hard, adherent films. This process has been tested in a laboratory scale unit by spray coating these materials on three-dimensional objects and passing them through a tunnel containing uv lamps.

278 (DOE ID/12138-6) **Corrosion-resistant amorphous metallic coatings: Engineering development: Progress report, October 1, 1985-October 1, 1986.** Fitzgerald, D.J., DiStefano, S., Rameshan, R. Jet Propulsion Lab., Pasadena, CA (USA). 01 Dec 1986. 106p. DOE Contract AI07-80ID12138. Order Number DE87012744. Source: NTIS. PC A06/MF A01: GPO Dep.

Objective is to use sputter-deposited amorphous metallic coatings on alloys in heat recovery systems in power plants. It was found that chromium could be used as a substitute for ruthenium in MoRuB. The new alloy, MoCrB, has corrosion current two orders of magnitude lower than MoRuB. The effort to develop the parameters for depositing FeCrPC on steel was frustrated by a persistent pinhole problem. Two titanium-based alloys were developed which are equal to or better than the optimized FeCrPC alloy in terms of corrosion resistance. The potentiodynamic polarization characteristics of MoCrB and TiCrBC were measured over a range in temperature from 25 to 100°C. The corrosion current increased with temperature as predicted by theory. The corrosion characteristics of MoCrB and TiCrPC were also tested in 1.0N HCl. Cost analysis of the magnetron sputtering coating process indicates that the process cost is in the range of \$2.50 to \$3.00 per square foot steel.

279 (TID-28705) **Oven curing: energy conservation and emission control in coil coating. Technical briefing report: technology transfer.** Centec Consultants, Inc., Fort Lauderdale, FL (USA). Aug 1978. 35p. DOE Contract W-31-109-ENG-38. Source: NTIS \$8.75.

Paint coating is a key manufacturing step between the production of sheet metal and the manufacture of consumer products. Natural gas is used in 95% of the nation's paint-curing processes, with total annual energy use for curing estimated at approximately 196 trillion Btu in 1976. As environmental regulations are enforced and more energy is required to reduce emission of solvents from curing processes, total usage could increase to 232 trillion Btu. Zone incinerators which can reduce the energy required in the sheet metal coil coating process are described and evaluated. The zone incinerators, which can be retrofitted to existing curing ovens, recover a significant amount of the energy previously lost in oven exhaust gases and reduce the energy penalty associated with environmental control systems. Data are presented on the operation, performance, economics, environmental effects and uses of this heat recovery equipment (LCL).

280 (TID-28706) **Coating industry: energy savings with volatile organic compound emission control.** Centec

Consultants, Inc., Fort Lauderdale, FL (USA). 1979. 113p. DOE Contract W-31-109-ENG-38. Source: NTIS \$10.75.

This Technology Applications Manual presents technical and economic data to enable engineers and managers in the coating industry to evaluate the energy-conservation opportunities for installation of solvent emission-control systems. Although the properties of the solvents vary considerably, the information contained in the report serves to improve the ability of the engineer to make quick estimations of energy savings, energy rates, economics, and performance of control systems and heat-recovery options. The emphasis is directed to a discussion of add-on devices, such as thermal and catalytic incineration. New technologies, such as the one recently demonstrated by the Department of Energy in cooperation with industry and the National Coil Coaters Association, are highlighted. Extensive graphics and illustrations show energy use, savings, and economics; these are supplemented by calculations to be used by each plant to determine site-specific data.

281 (UCRL-98343) **A novel approach to abrasion resistance.** Steele, W.A.; Mohr, P.B.; Leider, H.R.; Hirschfeld, T.B. Lawrence Livermore National Lab., CA (USA). Mar 1988. 12p. DOE Contract W-7405-ENG-48. (CONF-880885-2; IECEC '88, Denver, CO, US, August 1, 1988). Order Number DE88014180. Source: NTIS, PC A03/MF A01; GPO Dep.

The high abrasion and impact loads characteristic of many technologies require frequent maintenance or special materials. Conventional approaches to protection have used either extremely hard coatings or compliant elastomeric coatings. The former are typically ceramic or ceramic-like surfaces produced by direct deposition or by in situ formation by oxidation, carburization or nitriding. Ceramic coatings are very good against abrasion, but are vulnerable to impact damage. Elastomeric coatings have excellent impact resistance and are capable of withstanding deformation; however, they are limited in thermal range and chemical resistance. It is possible to combine the desirable properties of both types by using "hair," a structure in which an extremely hard material can be simultaneously elastic and compliant by virtue of a very high L/D ratio. We have demonstrated the good performance of carbon fiber "hair" in resisting damage from impacting particles and have identified a probable failure mechanism. 7 refs., 6 figs., 1 tab.

Separation Systems

Refer also to citation(s) 186, 189, 513, 534

282 (BSDF-38-4Q-80) **Evaporation by mechanical vapor recompression. Final report, September, 1979 - October 31, 1980.** Iverson, C.H.; Coury, G.E.; Fischer, J.H. Beet Sugar Development Foundation, Fort Collins, CO (USA). 1980. 208p. DOE Contract AC03-79CS40208. Source: NTIS, PC A10/MF A01.

A review of existing technology and application of the mechanical vapor recompression and falling film evaporation in both the sugar and non-sugar industries, and the potential of application to the domestic beet sugar industry is made. Upon assimilating the information gathered, certain design guidelines were established, possible candidate factories for a demonstration project were identified, and a preliminary technical and economic evaluation of the sites was made. The Nampa, Idaho plant of the Amalgamated Sugar Company was selected as the most amenable from the standpoint of technical compatibility, the most attractive on

investment and the enthusiasm of the management. Preliminary engineering was done for the Nampa site, permitting a reasonably definitive installed cost estimate to be made. Based upon a synthetic energy balance, the steam savings were calculated and translated into dollars using 1980 fuel costs escalated to 1982 at 12% per year. These efforts generated a gross return on investment calculation of 40.7% based upon fuel savings divided by capital cost. The estimate included adequate instrumentation for the monitoring and measuring of all the process parameters for the purpose of assessing the performance of each component. A complete testing program for accomplishing this evaluation was developed. Additional information is presented in 7 appendices.

283 (BSDF-39-8Q-81) **Technical and economic feasibility of membrane technology. Final report, September 17, 1979-November 16, 1981.** Beet Sugar Development Foundation, Fort Collins, CO (USA); American Crystal Sugar Co., Moorhead, MI. Research Center. 1981. 50p. DOE Contract AC03-79CS40213. Order Number DE82019045. Source: NTIS, PC A03/MF A01.

Portions of document are illegible.

The first phase of the project involved the development of a literature survey relative to the state-of-the-art for reverse osmosis (RO), electrodialysis (ED), and ultra filtration (UF). A comprehensive examination of both domestic and foreign literature provided a basis for selection of membrane candidates evaluated in Phase II and III of the project. In addition, an investigation was conducted identifying the development of other commercial membrane materials for use other than in the sugar industry (cheese industry). During Phase II, selected membranes were evaluated using a prototype mounting configuration, different temperatures, pressures, feed streams as well as some preliminary testing on ED and UF. The feed streams evaluated included diffusion juice, thin juice, hot Steffan waste, and ion exchanged purified effluents. Replicated runs were performed on several different batches of membranes and feeds to establish significant differences. The activity conducted during Phase III consisted of evaluating selected membranes over a long-term performance basis, i.e., pilot plant evaluation. Membrane material were mounted in pilot hardware for testing purposes. Determinations of membrane life cycles were made as well as establishing the preliminary economics of the operation as related to replacement module service life and on-line operating characteristics.

284 (CONF-841264-) **Black Liquor Research Program symposium: proceedings.** Emerson, D.B.; Whitworth, B.A. Energetics, Inc., Columbia, MD (USA). Mar 1985. 177p. DOE Contract AC01-84CE40716. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. Order Number DE85010244. Source: NTIS, PC A09/MF A01; GPO Dep.

In the paper pulp industry's recovery boilers, black liquor is sprayed in through nozzle guns near the top of the furnace. This report includes eight papers. (DLC)

285 (CONF-841264-, pp. 5-10) **Program overview.** Raymond, D.R. (Weyerhaeuser Co., Tacoma, WA). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings.* 5-10p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The Black Liquor Program is reviewed from an industry perspective. The key Black Liquor research needs are listed and the activities necessary to improve energy recovery boiler operation are summarized.

286 (CONF-841264-, pp. 11-38) **Freeze crystallization of Kraft Black Liquor.** Davis, H.E. (Concentrex, Inc., Andover, MA). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 11-38p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The freeze crystallization method for concentrating Black Liquor is discussed. Freeze concentration is a generic process that is suitable for concentrating many materials, including Black Liquor. The advantages of freeze concentration are improved quality, energy reduction, and longer cycles between cleaning. The following types of freezing processes are discussed: secondary refrigerant, vacuum, and indirect.

287 (CONF-841264-, pp. 39-63) **Gasification of Black Liquor.** Kelleher, E.G. (Champion International, West Nyack, NY). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 39-63p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The feasibility of gasifying Black Liquor is discussed. The feasibility of replacing the Tomlinson recovery boiler with a gasification-based combined cycle plant was studied. The study was based on a limited number of experiments. The results of the experiments were used to do some energy cycle analyses and economic analyses. These studies demonstrated the feasibility of a gasifier approach to replace the Tomlinson boiler. Data are included from the bench-scale Black Liquor gasification tests.

288 (CONF-841264-, pp. 64-112) **Characterization of physical properties of Kraft Black Liquor.** Fricke, A.L. (Univ. of Florida, Gainesville). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 64-112p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The fundamentals of Black Liquor are discussed and an effort to relate the physical properties of the liquor to composition in the simplest manner possible is described. If the work is successful, it should be possible to predict the properties of liquors from the Kraft process. The interest is in defining Black Liquor properties as functions of the processing variables, such as temperature, composition, concentration, shear rate, etc. To do this pulping experiments have been designed with slash pine. The liquors from the pulping experiments are being used to measure the physical properties of these liquors.

289 (CONF-841264-, pp. 113-122) **Ultrafiltration of Kraft Black Liquor.** Hill, M.K. (Univ. of Maine, Orono). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 113-122p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The ultrafiltration of Black Liquor is discussed. The idea in ultrafiltration of the liquor is to set up conditions to minimize concentration polarization by using turbulent flow across the

membrane and by regulating the pressure and other properties of the system that influence the gel layer formation. The feasibility and economics of the ultrafiltration process for the removal of lignin from the liquor are discussed.

290 (CONF-841264-, pp. 123-131) **Computer model of single droplet flight patterns.** Shick, P.E. Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 123-131p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The control of Black Liquor droplet size in recovery furnaces is discussed. Droplet flight patterns and a broad range of droplet sizes were studied. A computer program that assists in these studies permits one to enter the width of the furnace, the height of the nozzle, and the height of the bed. The use of the computer program is discussed.

291 (CONF-841264-, pp. 132-140) **Droplet formation research program.** Stockel, I.H. (Univ. of Maine, Orono). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 132-140p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The formation of Black Liquor droplets from single jets is described. The formation of droplets is a key component of many commercial processes and applications. The objective of this work was to determine the ranges of operation within which droplets of the desired size can be formed from Black Liquors. The properties of today's Black Liquors and the likely characteristics of future Black Liquors are considered.

292 (CONF-841264-, pp. 141-143) **Black Liquor droplet stability task.** Pendse, H. (Univ. of Maine, Orono). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 141-143p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The formation of uniform size droplets from Black Liquors is discussed. A literature search indicated that at present the theoretical framework is not sufficiently sophisticated enough to allow an estimate of droplet stability behavior corresponding to high liquid viscosities and thermal shock to be made. Physical property data necessary to analyze the experimental data from droplet formation and droplet stability studies are discussed.

293 (CONF-841264-, pp. 144-155) **Fundamentals of combustion - Part 1.** Clay, D.T. (Institute of Paper Chemistry, Appleton, WI). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 144-155p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The fundamentals of Black Liquor combustion are discussed. Some of the process studies that were done and preliminary tests to develop a basis for reactor design are described. The three major objectives of this project were to: develop a Black Liquor combustion reactor; apply advanced spectroscopic techniques to better understand the mechanisms of the process; and review and analyze data on improving present processes or better understanding advanced processes such as a gasification.

294 (CONF-841264-, pp. 157-170) **Fundamentals of combustion - Part 2.** Semerjian, H. (National Bureau of Standards, Gaithersburg, MD). Energetics, Inc., Columbia, MD (USA). Mar 1985. From Black liquor research program symposium; Washington, DC, US; December 12, 1984. In *Black Liquor Research Program symposium: proceedings*. 157-170p. Order Number DE85010244. Source: NTIS, PC A09/MF A01.

The fundamentals of Black Liquor combustion are discussed. The preliminary work depended on the use of an auxiliary reactor that will eventually become part of the final reactor assembly. An auxiliary reactor was constructed that allows studies of the following to be made: fluid dynamic effects, introduction of droplets, effect of initial velocity profile, particle trajectories, design of char catcher, and diagnostic techniques. The results of these studies are presented.

295 (CONF-8707139-) **Proceedings of the black liquor research program review fourth meeting held July 28-30, 1987.** Emerson, D.B.; Whitworth, B.A. Energetics, Inc., Columbia, MD (USA). Oct 1987. 413p. DOE Contract AC01-87CE40762. From 4. black liquor research program review meeting; Gaithersburg, MD, US; July 28, 1987. Order Number DE88004597. Source: NTIS, PC A18/MF A01 - OSTI; GPO Dep.

Research programs, presented at the black liquor review meeting are described. Research topics include the following: Cooperative Program in Kraft Recovery; Black Liquor Physical Properties; Viscosity of Strong Black Liquor; Ultrafiltration of Kraft Black Liquor; Molecular Weight Distribution of Kraft Lignin; Black Liquor Droplet Formation Project; Fundamental Studies of Black Liquor Combustion; Black Liquor Combustion Sensors; Flash X-ray Imaging of Black Liquor Sprays; Laser Induced Fluorescence For Process Control In The Pulp and Paper Industry; Recovery Boiler Optimization; Black Liquor Gasification and Use of the Products in Combined-Cycle Cogeneration; Black Liquor Steam Plasma Automization; The B and W Pyrosonic 2000R System; Monstera's Boiler Control System; and Cooperative Program Project Reviews. Individual projects are processed separately for the data bases.

296 (CONF-8806321-) **Proceedings of the black liquor research program review fifth meeting.** Energetics, Inc., Columbia, MD (USA). Sep 1988. 245p. DOE Contract AC01-87CE40762. From 5. black liquor research program review meeting; Charleston, SC, US; June 14, 1988. Order Number DE89007108. Source: NTIS, PC A11 - OSTI.

On June 14-17, 1988 the participants and invited guests of the Cooperative Program in Kraft Recovery gathered in Charleston, South Carolina to review progress on four major black liquor research programs being executed at the Institute of Paper Chemistry, the University of Maine, the National Bureau of Standards, and the University of Florida. These programs include: (1) Black Liquor Properties; (2) Black Liquor Droplet Formation; (3) Black Liquor Nozzle Evaluation; and (4) Black Liquor Combustion. In addition to the objectives of previous meetings, this meeting made a direct attempt to gather ideas on how to improve our ability to move from new technology concepts to commercial implementation. Also attached is the agenda for the Charleston meeting. The first two days were involved with updates and reviews of the four major black liquor programs. A half day was spent discussing pathways to implementation and developing thoughts on what industry, DOE and academia could do to facilitate commercial implementation of the

research results. This publication is a summary of the presentations made in Charleston and the industry responses to the research work. Readers are cautioned that the contents are in-progress updates on the status of the research and do not represent referred technical papers. Any questions regarding the content should be referred to the principal investigators of the project.

297 (CONF-891013-3) **Preparative-scale proteins separations by continuous annular chromatography.** Bloomington, G.F. (Virginia Univ., Charlottesville, VA (USA). Dept. of Chemical Engineering); Bauer, J.S.; Carta, G.; Byers, C.H. Oak Ridge National Lab., TN (USA). 1989. 30p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. From 6. symposium on separation science and technology for energy applications; Knoxville, TN (USA); 22-27 Oct 1989. Order Number DE90001954. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The use of continuous annular chromatography (CAC) for the separation of protein mixtures is studied in a preparative-scale CAC unit. S-Sepharose, a strong-acid porous cation exchange resin is used as the separation medium mixtures of albumin, hemoglobin, and cytochrome-C are used as a model separation system. Equilibrium and mass transfer parameter are developed for this system on the basis of fixed-bed chromatograph experiments. A mathematical model is then successfully used in conjunction with these parameters to simulate the performance of the CAC separations. 11 refs., 11 figs., 3 tabs.

298 (COO-2870-2) **Upgrading existing evaporators to reduce energy consumption.** Centec Consultants, Inc., Reston, VA. 1977. 96p. DOE Contract EY-76-C-02-2870. Source: NTIS \$10.50.

This manual is intended to assist the evaporator engineer who will be performing the technical and economic analyses to determine the most suitable evaporator upgrading technique for his particular plant. Information is included on potentials for upgrading evaporators; correctable operating factors; heat recovery and other improvements in energy use with minor capital investments; upgrading through major capital investments; guidelines for formulating an upgrading program; and new technologies encompassing advanced designs, use of solar and low-grade heat sources, and heat transfer enhancement. A 36 item bibliography is included. (LCL)

299 (DOE/CE/15193-T1) **Separation of kraft lignin from kraft black liquor: Final report, July 1984-April 1987.** Kurple, K.R. Kurple (Kenneth R.), Anchorville, MI (USA). 15 Apr 1988. 24p. DOE Contract FG01-84CE15193. Order Number DE88009270. Source: NTIS, PC A03/MF A01; GPO Dep.

All the objectives were accomplished: a high-quality kraft lignin containing less than 50 ppm sodium was separated into a solvent phase (freon) from as much as 1000 lb kraft black liquor. Supporting data (infrared spectra, chemical analyses, etc.) are included. (DLC)

300 (DOE/CE/15193-T2) **Separation of kraft lignin from kraft black liquor: Final report, July 1984-April 1987.** Kurple, K.R. Kurple (Kenneth R.), Anchorville, MI (USA). 15 Apr 1988. 19p. DOE Contract FG01-84CE15193. Order Number DE88011806. Source: NTIS, PC A03/MF A01; GPO Dep.

The importance of this work is related to the fact that with over 16 million tons of kraft lignin available annually, practically all of it is burned just for its heat value. In essence, kraft lignin has no real value except its heat value. The major accomplishments of this research has shown that it is possible to produce high purity kraft lignin from kraft black liquor. This patented technology represents a way of producing a material that can be utilized in a wide variety of markets. Kraft lignin that was produced using this technology was sent to major corporations who used this kraft lignin as a starting material in their chemical processes. 3 figs.

301 (DOE/CE/15296-T1) **Cocurrent distillation: Final report, September 17, 1986-September 30, 1988.** Trutna, W.R. Trutna (William R.), Pasadena, TX (USA). 30 Jan 1989. 109p. DOE Contract FG01-86CE15296. Order Number DE89007092. Source: NTIS, PC A06 - OSTI.

This report covers the major categories of research and design information needed for the development of the Cocurrent Process. The Cocurrent Process is a new and completely different distillation process, and has the potential for a large reduction in capital expenditures and energy consumption. The report covers Laboratory and SRP Hydraulic Performance, Engineering Prototype Mass Transfer, Capacity Tests, Comparative Performance, Cost Comparison, Mechanical Design and Costs, Distributor Design, Channel-Skirt Heights, Vent Flows and Downcomer Area. 58 figs., 21 tabs. (JL)

302 (DOE/CE/40544-1) **Pilot plant development of chemical air separation process: Report of period 1 October 1984-30 September 1986.** Dunhobbin, B.R.; Brown, W.R. Air Products and Chemicals, Inc., Allentown, PA (USA). Feb 1987. 93p. DOE Contract AC07-82CE40544. Order Number DE87010080. Source: NTIS, PC A05/MF A01; GPO Dep.

The overall objective of this program was to develop the economic viability of a new air separation process for oxygen production, termed the MOLTOX system. This report presents the results of the completion of Task 1, which confirmed market predictions for the MOLTOX system and showed a significant need for new oxygen plants. The MOLTOX system can compete for 80% to 90% of the total projected markets. The report also includes the results from Task 2. Pilot Plant Construction and Operation. Pilot plant operation began in December 1985, and several experimental runs have been completed. Run I was instrumentation and control and hydraulic testing of the plant before oxygen production, and Run II was a low-temperature oxygen generation trial. Runs III and IV were "proof of concept" runs, which were intended to demonstrate operation of the plant at base-case absorber column and desorber design conditions. Results indicate that the process chemical performance essentially meets all expectations and confirms predictions. The corrosion results show that the materials of construction are generally adequate, except at high-temperature, two-phase flow locations, namely the oxygen desorption heat exchanger, and in regions of high fluid velocity.

303 (DOE/CE/40606-T1) **Physical properties of kraft black liquor. Final report. Phase I.** Fricke, A.L. Maine Univ., Orono (USA). Dec 1983. 169p. DOE Contract AC02-82CE40606. Order Number DE84006996. Source: NTIS, PC A08/MF A01; GPO Dep.

Methods were selected, equipment installed, and procedures developed for determining rheological properties; for determining thermal properties (stability, density, thermal

expansion, and heat capacity); for purification and characterization of lignin (glass transition, stability, weight average molecular weight, and number average molecular weight); and for performing chemical analyses (negative inorganic ions, positive inorganic ions, acid organic salts, lignin, and total solids). A strategy for pulping to supply test liquors was developed, and a statistically designed pulping experiment was specified for a Southern softwood species. Arrangements were made for performing initial pulping work in an industrial pilot plant, and a preliminary set of pulping experiments were conducted. Liquors from the preliminary pulping experiments were used to test procedures and to determine reproducibility of the experiment. Literature was also surveyed and preliminary selection of designs for a pilot digester, and for equipment to determine surface tension were made.

304 (DOE/CE/40606-T3) **Ultrafiltration of Kraft Black Liquor. Final report, Phase I.** Hill, M.K. Maine Univ., Orono (USA). Oct 1985. 109p. DOE Contract AC02-82CE40606. Order Number DE86005233. Source: NTIS, PC A06/MF A01.

Kraft Black Liquor (KBL) is ultrafiltered to favorably affect the properties of the KBL permeate. The major property to be changed is viscosity. If the high molecular weight lignin is removed by ultrafiltration, the KBL permeate should show a significant drop in viscosity. An objective of the work reported was to examine how much KBL viscosity is lowered relative to membrane and membrane pore size used in the ultrafiltration. Another objective was an initial evaluation of ultrafiltration equipment and membranes. Operating characteristics were determined for selected equipment and membranes. Decreases in KBL permeate viscosity were indeed seen. (LEW)

305 (DOE/CE/40606-T4) **Ultrafiltration of Kraft Black Liquor: Phase II, Final report.** Hill, M.K. Maine Univ., Orono (USA). Sep 1987. 186p. DOE Contract AC02-82CE40606. Order Number DE87013555. Source: NTIS, PC A09/MF A01; GPO Dep.

The major justification for examining ultrafiltration was to lower the viscosity of the Kraft Black Liquor by recovering it as an ultrafiltration permeate from which the highest MW lignin had been removed. The liquor could then be concentrated to a higher percentage solids before firing into the recovery boiler. Consequent energy savings for the 1000 ton/day pulp mill would be 2.05×10^{10} Btu/y for each percentage increase in TDS (total dissolved solids) to the recovery boiler. This Phase II report gives data on viscosity with percentage solids of KBL permeates. Another favorable effect of ultrafiltration on the permeate properties is disproportionate removal of multivalent ions including the major scaling ion Ca^{2+} . If this high-viscosity high-Ca retentate could be treated to lower its viscosity and to release the Ca in a non-scaling form, this would enhance the possibility that ultrafiltration might be useful in a mill situation. Included in this report are data on the results of treating the retentate fraction. Other justifications for this program included further information in KBL properties: lignin MW in the KBL at high pH; elemental and sugar analyses; and differential properties of lignins in the retentate and the permeate fractions. A preliminary economic analysis of ultrafiltration is contained in this report. These analyses indicate that with flux rates now attainable, ultrafiltration would not be economically justified at this time if the only justification is to lower KBL viscosity. For certain situations where high Ca liquors present a scaling problem, especially in an evaporator-limited mill, the

economics are more favorable. There are also unsolved problems relating to the use of the high viscosity retentate.

306 (DOE/CE/40606-T5) **Physical properties of kraft black liquor: Summary report, Phases 1 and 2.** Fricke, A.L. Florida Univ., Gainesville, FL (USA); Maine Univ., Orono, ME (USA). Sep 1987. 310p. DOE Contract AC02-82CE40606 ;FG02-85CE40740. Order Number DE88002991. Source: NTIS, PC A14/MF A01; GPO Dep.

Since 1981, a research program has been in progress to determine the physical properties of kraft black liquors and to develop methods for reduction of data and correlation of properties with pumping conditions. The basic premise that has been used to direct the research program is that kraft black liquor behaves as a polymer solution, particularly at high solids, and that the behavior is dominated by the characteristics of the lignin present. This premise is proving to be correct, and the principles that follow from this premise are proving to be successful for data reduction and correlation. The research has been a complex program involving experimental pulping, chemical analysis, lignin separation and characterization, thermal analysis, rheological measurements, and considerable equipment and methods development. Due to the complexity of the program, the unforeseen need to expend a great deal of effort in development of experimental techniques for analysis, and the fact that our liquors proved to be unstable at high temperatures and solids, all of the original objectives could not be accomplished. However, our program has added substantially to the body of knowledge of physical properties of black liquor. Our results indicate that the goal of developing correlations for physical properties of kraft black liquor is practical and can be realized through extension of the present work.

307 (DOE/CE/40606-T7) **Ultrafiltration of kraft black liquor: Final report, Phase 3.** Hill, M.K. Maine Univ., Orono, ME (USA). Apr 1988. 61p. DOE Contract AC02-82CE40606. Order Number DE89008221. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

Since 1981, a research program has been in progress to determine the physical properties of kraft black liquors and to develop methods for reduction of data and correlation of properties with pumping conditions. The basic premise that has been used to direct the research program is that kraft black liquor behaves as a polymer solution, particularly at high solids, and that the behavior is dominated by the characteristics of the lignin present. This premise is proving to be correct, and the principles that follow from this premise are proving to be successful for data reduction and correlation. The research has been a complex program involving experimental pulping, chemical analysis, lignin separation and characterization, thermal analysis, rheological measurements, and considerable equipment and methods development. Due to the complexity of the program, the unforeseen need to expend a great deal of effort in development of experimental techniques for analysis, and the fact that our liquors proved to be unstable at high temperatures and solids, all of the original objectives could not be accomplished. However, our program has added substantially to the body of knowledge of physical properties of black liquor. Our results indicate that the goal of developing correlations for physical properties of kraft black liquor is practical and can be realized through extension of the present work. 21 refs., 32 figs.

308 (DOE/CE/40626-T1) **Research on droplet formation for application to Kraft black liquors. Technical**

report No. 1. Stockel, I.H. Maine Univ., Orono (USA). Mar 1985. 127p. DOE Contract AC02-83CE40626. Order Number DE85014493. Source: NTIS, PC A07/MF A01; GPO Dep.

Two regimes of droplet formation from nozzles have been identified: a chaotic regime in which fragmentation of liquid results from the combination of initial liquid turbulence and viscosity of the surrounding gas medium; and an ordered regime in which droplet formation results from surface tension of the liquid, density of the gas medium and uniform oscillations in flow from a nozzle. Fragmentation and subsequent droplet formation in the chaotic regime result in a broad range of droplet sizes which is assumed to be undesirable for best operation of a Kraft Recovery Boiler. Production rates in the ordered regime are limited by transition into the chaotic regime. This project is concerned with droplet formation from jets and sheets of high solids black liquors in which large amplitudes of oscillatory flow can be applied which can assist the ordered fragmentation process to produce uniform droplets at higher production rates.

309 (DOE/CE/40626-T2) **Research on droplet formation for application to kraft black liquors: Technical report No. 2.** Stockel, I.H. Maine Univ., Orono (USA). Oct 1986. 146p. DOE Contract AC02-83CE40626. Order Number DE87003169. Source: NTIS, PC A07/MF A01; GPO Dep.

The Department of Energy and the American Paper Institute joined in supporting research at the Chemical Engineering Department of the University of Maine at Orono to develop a fundamental understanding of the liquid droplet formation process with particular emphasis on kraft black liquors. The five year program is divided into five tasks. Work began on October 1, 1983. Tasks I and II have seen significant progress and are the primary topics of this report: droplet formation from single jet, and measurement of surface tension. The overall objective of this program is to develop a fundamental understanding of the droplet formation process at conditions relevant to the processing of kraft black liquors. Goal is to develop new knowledge which can result in the design of better spray nozzles for more energy efficient and productive operation of kraft recovery boilers.

310 (DOE/CE/40626-T3) **Measurement of black liquor surface tension: Technical report No. 3.** Krishnagopalan, J. Maine Univ., Orono (USA). Sep 1987. 262p. DOE Contract AC02-83CE40626. Order Number DE88015384. Source: NTIS, PC A12/MF A01; GPO Dep.

Surface tension and density of two kraft black liquors were measured at a series of temperatures, from a minimum value when gas bubbles can be blown into the liquor to a maximum value near the elevated boiling point of a particular sample. Available methods for the measurement of surface tension were evaluated critically and, as a result, the maximum bubble pressure method was selected. Varying the flow rate of the gas changes the frequency of bubble formation and thereby the age of the surface. The parameter has been utilized by many researchers to monitor the diffusion of low surface energy components (e.g., surfactants) to the liquid/air interface. The effect of bubble frequency when tested with a few pure liquids, indicated that the dynamics of bubble formation had to be further examined to separate out inertial and viscous effects from purely surface tension related pressure. The pressure versus flow rate data were extrapolated to zero flow rate and surface tension and density were calculated using these extrapolated values. As

expected, surface tension decreased with increasing temperature for all the samples. Surface tension decreases with increasing solids content (when compared with the value for water) to a certain level (about 20%) and it starts to increase again. The decrease in surface tension in the dilute black liquor, is probably due to the decrease in the concentration of water, which has a high surface tension value. The occurrence of the minimum is probably due to the effect of inorganic components dominating over the effect of surfactants and other components. Reduction in the solubilities of the inorganics, promotion of micelles of the surfactants and reduction in the diffusion of surfactants to the surface, also could contribute to this phenomenon. 54 refs., 54 figs., 12 tabs.

311 (DOE/CE/40626-T4) **Research on droplet formation for application to kraft black liquors: Final report: Tasks I and III, report No. 4.** Stockel, I.H. Maine Univ., Orono (USA). Oct 1988. 204p. DOE Contract AC02-83CE40626. Order Number DE89001755. Source: NTIS, PC A10/MF A01 - OSTI; GPO Dep.

The overall objective of this project is to generate technical data with which to design nozzles for kraft black liquor recovery boilers which can reduce under and over size droplets and adjust for changing black liquor properties and production requirements. The research is organized into five tasks: Droplet formation from a single jet, theoretical and experimental-ambient gas medium; Surface tensions of black liquor; Aerodynamic/hydrodynamic stability/instability of droplets once formed; Black liquor droplet formation from a single jet-furnace gas medium; Prototype of a new nozzle design. 88 figs.

312 (DOE/CE/40637-T1) **Fundamental studies of black liquor combustion. Report No. 1 - Phase 1, October 1983-September 1984.** Clay, D.T.; Semerjian, H.G.; Grace, T.M.; Kapheim, R.J.; Macek, A.; Charagundla, S.R. Institute of Paper Chemistry, Appleton, WI (USA); National Bureau of Standards, Washington, DC (USA). Jan 1985. 146p. DOE Contract AC02-83CE40637. Order Number DE85013773. Source: NTIS, PC A07/MF A01; GPO Dep.

This five-year research program conducted at the Institute of Paper Chemistry (IPC) and the National Bureau of Standards (NBS) focuses on fundamentals of kraft black liquor combustion. The burning processes of drying, pyrolysis, gasification, oxidation, reduction, and fuming will be simulated in two laboratory-scale flow reactor systems. Industry-wide use of the developed fundamentals will improve the energy efficiency and productivity of kraft chemical recovery boilers. This progress report describes the needs, a four-phase experimental program developed to meet these needs, and the design of required experimental systems. Preliminary combustion test results needed to complete the final system designs are also presented. The report covers the first half of Phase 1 work. The IPC system will focus on process issues and be capable of complete process simulation. Its nominal black liquor solids capacity will be 10 lb/h (4.5 kg/h). The complementary NBS dilute-phase reactor system will concentrate on mechanistic issues, instrumentation diagnostics, and development. This system will study flowing single particles and gas phase intermediates. Phase 1 construction of the two systems will be completed during 1985. The reactors are under construction. Both are required before laboratory-generated knowledge can reliably be implemented to improve operating recovery boilers.

313 (DOE/CE/40637-T2) **Fundamental studies of black liquor combustion: Report No. 2, Phase 1 (October 1984-November 1986).** Clay, D.T.; Lien, S.J.; Grace, T.M.; Macek, A.; Semerjian, H.G.; Amin, N.; Charagundla, S.R. Institute of Paper Chemistry, Appleton, WI (USA). Chemical Sciences Div.; National Bureau of Standards, Washington, DC (USA). Chemical Process Metrology Div. Jan 1987. 240p. DOE Contract AC02-83CE40637. Order Number DE88005756. Source: NTIS, PC A11/MF A01; GPO Dep.

The fundamentals of kraft black liquor combustion are being studied in a five year project. This report covers the second and third years of work by The Institute of Paper Chemistry (IPC) and the National Bureau of Standards (NBS) for the US Department of Energy. The burning processes are being studied in two continuous flow reactor systems designed to both study overall process and single particle phenomena. Black liquor burning is divided into four distinct phases: drying, volatiles burning, char burning, and smelt coalescence. Phase 1, In-flight Processes, is the main focus of this report. In-flight processes include mainly the stages of drying and volatiles burning. Testing results in both flow reactors and in two specially designed single particle reactors are presented. Dynamic droplet velocity and swelling have been measured for the first time. A direct link between initial liquor viscosity and burning behavior in the early stages has also been identified. During the fourth year Phase 1 will be completed and Phases 2 (Char Burning) and 3 (Fume Processes) will begin.

314 (DOE/CE/40637-T3) **Kraft black liquor combustion: Advancement in fundamental understanding.** Clay, D.T. Institute of Paper Chemistry, Appleton, WI (USA). Oct 1987. 6p. DOE Contract AC02-83CE40637. (IPC-3473-6). Order Number DE88015981. Source: NTIS, PC A02.

Self-generated fuel streams plus purchased fossil fuel and power supply the pulp and paper industry with its energy requirements. The total industry energy use for 1986 was approximately 2.3 Quad (2300 trillion Btus). Self-generated and residue fuels accounted for 57% of the energy requirements. Spent pulping liquors provide the single largest self-generated energy source, approximately one Quad (900 trillion Btus). The pulp and paper industry also leads the nation in cogeneration performance. In 1986 eighty-nine percent (89%) of the 46 billion KWHs generated were produced by cogeneration. Spent pulping liquors supply the single largest fuel source (35%) to these cogeneration facilities. Spent pulping liquors consist of solubilized wood organics, spent inorganic chemicals, and water. Since kraft pulp dominates the North American market, 74%, kraft black liquor is the dominant spent pulping liquor. Effective recovery of high level energy and chemicals from black liquor contributes heavily toward dominance of kraft pulping. The kraft chemical recovery cycle centers around the recovery boiler. Kraft recovery boilers have been commercially available for over 50 years. The potential still exists, however, for significant improvements in energy recovery and black liquor throughput. Potential energy benefits from black liquor combustion research amount to 30 trillion Btus. Energy recovery increases often are an additional benefit from modifications made to increase black liquor throughput. Capacity increases of at least 5% 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. 5 refs., 9 figs.

315 (DOE/CE/40637-T7) **Fundamental studies of black liquor combustion: Report No. 3, Phases 1, 2, and 3, December 1986-December 1987.** Clay, D.T. (Institute of Paper Chemistry, Appleton, WI (USA). Chemical Sciences Div.); Lien, S.J.; Grace, T.M.; Macek, A.; Semerjian, H.G.; Amin, N.; Charagundla, S.R.; Brown, C.N. Institute of Paper Chemistry, Appleton, WI (USA). Chemical Sciences Div.; National Inst. of Standards and Technology, Gaithersburg, MD (USA). Chemical Process Metrology Div. Apr 1989. 164p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-83CE40637. Order Number DE89014547. Source: NTIS, PC A09/MF A01 - OSTI; GPO Dep.

The fundamentals of kraft black liquor combustion are being studied in a five year project. This report covers the completion of Phase 1 (In-Flight Processes) and initial results on Phase 2 (Char Burning) and Phase 3 (Fume Processes). The primary in-flight processes are drying and volatiles formation. Drying rate data could be interpreted with sample heat transfer models. Expansion of the drops during drying is significant and has a strong influence on drying rate in a high temperature environment. Char bed burning was studied using a char burning furnace module interfaces with the in-flight module on the IPC flow reactor. Initial experiments were characterized by a lack of a steady-state burning period and by O₂ stoichiometric control of the burning rate. Means for overcoming these problems were defined. A nonintrusive laser polarization ratio technique to measure fume particle size was successfully demonstrated. 40 refs., 70 figs., 41 tabs.

316 (DOE/CE/40685-T1) **New concepts in wet pressing. Final report.** Sprague, C.H. Institute of Paper Chemistry, Appleton, WI (USA). Mar 1986. 88p. DOE Contract AC02-84CE40685. Order Number DE86008553. Source: NTIS, PC A05/MF A01; GPO Dep.

This is the final report in a small, year-long project to investigate two subjects: the technical feasibility of displacement pressing and the factors causing the differences in water removal between a laboratory compression tester and a pilot press. (DLC)

317 (DOE/CE/40691-1) **Hyperfiltration/reverse osmosis: a handbook on membrane filtration for the food industry.** Merlo, C.A.; Pedersen, L.D.; Rose, W.W. National Food Processors Association, Berkeley, CA (USA). Western Research Lab. Jul 1985. 78p. DOE Contract FG01-84CE40691. Order Number DE86006737. Source: NTIS, PC A05/MF A01; GPO Dep.

The four chapters are titled: hyperfiltration/reverse osmosis technology, membranes and systems, energy recovery through renovation and recycle of hot water, and other applications of membrane technology in the food industry. (DLC)

318 (DOE/CE/40691-T1) **Hyperfiltration as an energy conservation technique for the renovation and recycle of hot empty container wash water. Final report.** Merlo, C.A.; Rose, W.W.; Pedersen, L.D. National Food Processors Association, Berkeley, CA (USA). Jul 1985. 43p. DOE Contract FG01-84CE40691. Order Number DE86006964. Source: NTIS, PC A03/MF A01; GPO Dep.

This report details the investigation of using hyperfiltration to recover hot water (~0°C) from an empty container washer within a food plant. The current study followed previous feasibility testing of this application. Thin film composite membrane modules in spiral wound configuration (0.5 to 1

m²) were tested. Testing consisted of single pass, recirculation, or modified recirculation modes. A preliminary test was run at 27.6 bar for 355 h with hot water followed by discharge from a container washer. A long-term test was run for 767 h with discharge from a container washer, followed by a simulated solution of discharge. Operating pressure began at 6.9 bar and was gradually increased to 12.0 bar as the flux declined with operation. Final fluxes after cleaning were 4' and 25 L/m²h.

319 (DOE/CE/40725-1) **Economic evaluation of kraft black liquor freeze concentration for the pulp and paper industry: Final report.** Coleman, T.C. Main (Charles T.), Inc., Boston, MA (USA). Sep 1986. 134p. DOE Contract AC01-85CE40725. Order Number DE87009325. Source: NTIS, PC A07/MF A01; GPO Dep.

The system was conceptually incorporated into several paper mill liquor concentration systems. Three fundamental scenarios were considered: a small, sulphite mill expansion comparing freeze concentration to evaporators and vapor recompression; a "greenfield" mill which evaluated the use of a freeze concentration process to achieve varying degrees of liquor concentration before achieving final concentration using traditional evaporation; and a kraft mill expansion which explored the use of freeze concentration to achieve a mill capacity expansion using a freeze concentrator in tandem with an existing evaporator set. The performance of these various scenarios were evaluated using a heat balance analysis and the comparative net present value of each arrangement was determined using a traditional evaporator system as a reference. Results indicate that generally the freeze concentration process is not economically attractive relative to traditional evaporator systems at the present time. At a fuel cost of \$28.77/barrel, the freeze concentration process becomes attractive. However, this study was performed considering a fuel oil cost of \$23.63 per barrel and the world fuel oil price has declined markedly since then.

320 (DOE/CE/40738-T2) **High-intensity drying processes impulse drying: Report two.** Lavery, H.P. Institute of Paper Chemistry, Appleton, WI (USA). Feb 1987. 86p. DOE Contract FG02-85CE40738. Order Number DE87004107. Source: NTIS, PC A05/MF A01; GPO Dep.

Impulse drying is under study as an alternative to conventional cylinder drying of paper and paperboard. Work over the past year has found the following: Impulse drying reduces drying energy requirements to as little as 500 Btu per pound of water. The specific energy requirement decreases with increasing initial sheet moisture content. Water removal rates are far greater than attainable with conventional drying. Impulse drying produces substantial increases in density. Impulse drying improves strength properties. The increase in tensile strength and STFI compressive index for recycled fiber and high-yield pulp linerboard is particularly significant. The z-direction density profile produced by impulse drying can offset the decline of certain properties such as opacity and tear strength which would be expected from increases in average density. A pilot roll impulse dryer has been designed and is presently under construction.

321 (DOE/CE/40738-T3) **High-intensity drying processes—Impulse drying: Report 3.** Lavery, H.P. Institute of Paper Chemistry, Appleton, WI (USA). Feb 1988. 85p. DOE Contract FG02-85CE40738. Order Number DE88016462. Source: NTIS, PC A04/MF A01; GPO Dep.

The past two years of Department of Energy supported research on impulse drying have established the process as

one of the most promising alternatives to conventional cylinder drying of paper and paperboard. The early work on impulse drying, documented in the first Progress Report in this series, identified the potential of the process as part of a study of several novel drying and pressing technologies. The second year's work, which is summarized in Progress Report Two included an extensive study on the response of several commercially important grades to impulse drying. The excellent performance of the process in terms of water removal, energy use and properties development was demonstrated during these studies. The present Progress Report covers work completed between October, 1986 and September, 1987. The principal project activity during that period was the design, construction, and preliminary testing of a pilot-scale roll impulse dryer. In addition to this significant equipment development task, experiments were performed to evaluate the effects of impulse drying on very wet sheets and to further develop mechanistic understanding of the process.

322 (DOE/CE/40740-T4) **A comprehensive program to develop correlations for the physical properties of kraft black liquors.** Fricke, A.L. Florida Univ., Gainesville, FL (USA). Jul 1989. 110p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG02-85CE40740. Order Number DE89016404. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

The major accomplishments during the period extending from August 1, 1987 to July 1, 1989 were design and construction of a pilot plant building; design, fabrication, installation, testing, and initial operation of a 3.5 ft³ digester system for kraft pulping and a large scale evaporator system for liquor concentration; specification, purchase, and installation of new instruments for lignin characterization; major revision of rheological instruments; specification, purchase, installation, and initial operation of instruments for determining heats of combustion and heats of dilution; extensive revision of techniques for thermal studies; and staff development. Laboratory and pilot scale facilities for conducting experimental kraft pulping, for concentrating experimental and mill liquors for research for complete analysis of liquors, and for rheological and thermal properties measurements for kraft black liquors are now completed. 44 figs.

323 **Kraft recovery boiler physical and chemical processes.** Adams, T.N. (Adams Terry N.), Tacoma, WA (USA); Frederick, W.J. 256p. The American Paper Institute, Inc., New York, NY (1988). Sponsored by USDOE, Washington, DC (United States). DOE Contract FG05-88CE40835.

The focus of this book is on the recent research into the physical and chemical processes occurring in and around a black liquor recovery boiler. Almost all of the detailed technical information in this book has previously appeared in the open literature. The purpose here is not to present research for the first time, but to present it in a context of the other processes occurring in recovery boilers. Topics covered include: general characteristics of recovery boilers; black liquor thermal and transport properties; black liquor droplet formation and combustion; recovery boiler char bed processes; flow and mixing in Kraft recovery boilers; entrainment and carryover in recovery furnaces; fume formation and dust chemistry; deposits and boiler plugging; and recovery boiler thermal performance. 257 refs., 102 figs., 38 tabs.

324 (DOE/CH/10093-57) **Membrane separation processes for liquid hydrocarbons and gases in the petrochemical industry: A technical case study.** Solar

Energy Research Inst., Golden, CO (USA); Energetics, Inc., Columbia, MD (USA). Sep 1989. 13p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC02-83CH10093 ;AC01-87CE40762. Order Number DE89009464. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

OIP and Allied Signal Corporation have completed a joint project exploring new applications of membrane separation technology for the petrochemical and related industries. These applications have the potential for major energy savings compared to more traditional distillation and chemical absorption processes. This technical case study provides an overview of the DOE-Allied Signal membrane development project. It highlights the field testing of modified cellulose acetate membrane systems for acid gas removal at two commercial natural gas plants. The document is aimed at making field test and data analysis results available to other researchers and private industry in a timely manner. This case study discusses project status; summarizes field testing efforts; and reviews potential technology impacts in terms of applications, energy savings, and preliminary economics.

325 (DOE/CS/4431-T1) **Energy conservation: a route to improved distillation profitability. Executive briefing report, technology transfer.** Radian Corp., Austin, TX (USA). 1980. 29p. DOE Contract W-31-109-ENG-38. Source: NTIS \$8.75.

The savings potential of energy-conservation measures applied to distillation is examined. The document catalogs all of the various energy-conservation options applicable to distillation; categorizes the options by investment required; and describes in detail the options having a significant potential to reduce distillation energy requirements economically. A technology applications manual designed to assist distillation process engineers who will perform technical and economic analyses to determine the conservation measures most suitable for their particular plant is also available (DOE/CS/4431-T2).

326 (DOE/CS/4431-T2) **Energy conservation in distillation: a technology applications manual.** Radian Corp., Austin, TX (USA). May 1980. 54p. DOE Contract W-31-109-ENG-38. Source: NTIS \$9.25.

Distillation is the most widely practiced technique for separating mixtures of chemical species, but it is an energy intensive process. A 10% reduction in distillation energy consumption would effect a significant savings. On a national basis this would be an annual savings of 200 trillion Btu, or the equivalent of 36.5 million barrels of oil per year. Technology to achieve these savings in distillation energy is available and measures are presented to assist process engineers in technical and economic analysis of the energy conservation measures most suitable for particular distillation applications. The manual catalogs all of the energy conservation options applicable to distillation and the options by the investment required; describes in detail the options having a significant potential to reduce distillation energy requirements economically; provides guidelines that will allow the plant engineer to quickly screen each option for his application; and provides short-cut calculation procedures for use in a preliminary economic analysis of promising options.

327 (DOE/CS/40033-T2) **Concentration processes for the beet-sugar industry.** Curran, H.M. Hittman Associates, Inc., Columbia, MD (USA). May 1978. 41p. DOE Contract AC01-78CS40033. (H-C-193/200-78-730D). Order Number DE84000148. Source: NTIS, PC A03/MF A01.

One part of the beet sugar processing plant operation, namely the juice concentration process, is presented. The concentration processes discussed could have applications in beet sugar processing plants other than juice concentration, but these are not considered. Basic energy considerations and concentration processes are discussed. The applicability of these concentration processes are considered for electrodialysis, freezing process, vapor recompression, and reverse osmosis. Three unsolicited proposals submitted to DOE are described briefly. (MHR)

328 (DOE/CS/40033-T3) **Analyses of industrial energy-conservation alternatives: technology impact. Final technical report.** Hittman Associates, Inc., Columbia, MD (USA). Jun 1979. 38p. DOE Contract AC01-78CS40033. (H-C-0193/100-79-892F). Order Number DE84000141. Source: NTIS, PC A03/MF A01.

The objectives and conclusions resulting from the eight technologies studied are summarized. The technologies are: concentration processes for the sugar industry, spectral fuel conservation system for low excess air combustion, high temperature recuperation for steel mill soaking pits, B.E.S.T. thermal sludge drying process for the pulp and paper industry, automatic imaging pattern recognition system for pulp fiber characterization, leaf protein concentrate extraction from alfalfa, MTI high efficiency industrial heat pump system, and hot slab inspection systems for steel mills.

329 (DOE/CS/40033-T4) **Impact assessment of the B.E.S.T. thermal sludge drying process in the pulp and paper industry. Draft final report.** Hittman Associates, Inc., Columbia, MD (USA). 4 Dec 1978. 118p. DOE Contract AC01-78CS40033. (H-C-193/500-78-755FD). Order Number DE84000147. Source: NTIS, PC A06/MF A01.

The Basic Extractive Sludge Treatment (B.E.S.T.) drying process is being examined as an energy-saving alternative to flash drying of partially dewatered sludge produced by wastewater treatment in the pulp and paper industry. The B.E.S.T. process relies on the low 133 Btu/lb heat of vaporization of the solvent triethylamine (TEA), and on the action of TEA as a sludge conditioning agent in mechanical dewatering, to produce almost completely dry solids from input sludges of 6 to 30% solids. The dried solids may be sold as fertilizer (e.g., 7% Nitrogen, 3% P_2O_5) or burned to raise steam (e.g., 9500 Btu/lb volatiles, 20% ash). In this study, costs and energy usage were developed for sludge disposal process trajectories used or potentially used in the pulp and paper industry. Evaluations were performed on trajectories, or series of processes, in order to establish common grounds for comparisons, such as similar starting and finishing points in sludge treatment. The amount of sludge of the type which might require a thermal drying process was projected through the end of the century. Costs and energy usage for complete disposal process trajectories were compared assuming 100% saturation of the estimated market. A preliminary toxicity analysis was performed on the TEA solvent used in the B.E.S.T. process.

330 (DOE/CS/40034-T1) **Investigation of freeze concentration as a process for industrial energy conservation in black liquor, acetic acid, and citrus juice applications. Final report.** Concentration Specialists, Inc., Andover, MA (USA). Jul 1979. 173p. DOE Contract AC01-78CS40034. Source: NTIS, PC A08/MF A01.

One of the largest consumers of energy in industrial processing is the equipment that concentrates weak aqueous

solutions to stronger more sellable or reusable concentrations. The technical and economic feasibility of applying freeze concentration (that is, crystallization and removal from solution of pure solvent - water) as an alternative to heat evaporation (or distillation) to three industrial applications is established. For each of the applications - pulp mill black liquor concentration, acetic acid recovery and orange juice concentration - the economic analyses indicate that the energy savings achievable by freezing justify the respective capital investments with pay out periods of generally one to three years. Past freeze concentration operations have been in the 10,000 to 100,000 gallons per day range for sea water desalination. Research and development work will be required to adapt this work to the three industrial applications.

331 (DOE/CS/40034-T3) **Freeze crystallization technology for black liquor concentration. Second interim report.** Concentration Specialists, Inc., Andover, MA (USA). Jul 1983. 84p. DOE Contract AC01-78CS40034. Order Number DE84001110. Source: NTIS, PC A05/MF A01.

The pulp and paper industry is one of the largest consumers of energy. Concentration of black liquor (the stream resulting from the chemical separation of wood fibers in the pulping operation) uses 25% of the purchased energy to produce pulp, an equivalent of 33 million barrels of oil in 1982. Here it is shown that freeze concentration, an emerging concentration technology, has the potential of reducing the energy consumption by at least 45%. This amounts to a cost savings of \$5 to \$15 per ton of pulp depending on the cost of energy, geographical location, and method of application.

332 (DOE/CS/40034-T4) **Freeze crystallization technology for Kraft black liquor concentration. Third report.** Johnson, W.E.; Rhodes, C.R. CONCENTREX, Andover, MA (USA). Apr 1985. 107p. DOE Contract AC01-78CS40034. Order Number DE85013081. Source: NTIS, PC A06/MF A01; GPO Dep.

About 25% of the purchased energy in the pulp and paper industry is used to concentrate black liquor. The technical feasibility of using freeze concentration to supplement evaporation has been successfully demonstrated, and results indicate that energy consumption can be reduced 45%. After compiling a considerable data base on the characteristics of black liquor at low temperature and after developing a computer program to aid analysis, the process chosen was vacuum freezing-vapor absorption (VFVA). A pilot plant was built and operated; however, due to problems with crystallization of the absorbent and contamination, it was found that maintaining the conditions necessary for a continuous process was not practical at the present state of development. Therefore, indirect freezing was used for all subsequent work. This required the design and fabrication of a simple shuttle crystallizer to replace scraped surface units conventionally used. CSI also developed an integrated ice separation column that combined crystal growth, a concentration gradient, and washing all in one unit. Finally, extensive heat transfer coefficient data were collected so that a preliminary design could be completed for a 350 TPD industrial freeze concentration unit. An economic analysis was calculated in order to compare using evaporation and freeze concentration to process the increased liquor flow from a pulp mill expansion. A 200,000 lb/hr freezing unit used to preconcentrate the mill's entire stream up to 18.7% solids would save \$10 to \$16 per ton of pulp.

333 (DOE/CS/40056-T4) **Application of foams to the processing of fabrics. Final report, October 1, 1977-September 30, 1981.** Namboodri, C.G. United Merchants Research Center, Langley, SC (USA). Oct 1981. 73p. DOE Contract AC02-77CS40056. Order Number DE82011717. Source: NTIS, PC A04/MF A01.

The primary objective of this project was to reduce the energy consumed in the wet processing of fabrics where wet processing encompasses those processes used to convert loomstate (greige) goods to finished textile products. This includes desizing, scouring, bleaching, dyeing, printing, and finishing of fabrics. The energy intensive step in most of these processes is drying the fabric. By having less water on the fabric as it enters a drying oven, proportionately less energy is consumed in drying the fabric. The specific route used in this project to accomplish this objective has been to use air to distribute the finish, dye or printing ink onto the fabric. Rather than saturating the fabric with a dilute finish formulation, a concentrated formulation is mechanically foamed, air serving as the diluting medium and the foam applied to the fabric. In this manner, the water content of the fabric as it enters the drying oven is reduced by as much as 80% thereby leading to a corresponding reduction in the energy required to dry the fabric. Details on the procedure are presented and experimental results are discussed. (MCW)

334 (DOE/CS/40056-T5) **Pilot implementation of the Impact Scoreboard System: Appendix 2, Textile foam finishing: Final report.** Systems Consultants, Inc., Washington, DC (USA). Jan 1980. 132p. DOE Contract AC02-77CS40056. Order Number DE87013931. Source: NTIS, PC A07.

A large amount of energy is used by the textile "wet processing" industry in bleaching, dyeing, printing and finishing. A process which could reduce the need to have large quantities of liquid media would not only reduce energy needs but would help solve an environmental waste problem. In a new process developed by United Merchants and Manufacturers, Inc. (UM & M), a concentrated solution of fabric-treating chemicals, foaming agents and stabilizers are mechanically foamed to incorporate 50 to 95% air. The foam is applied to a fabric and then the foam is collapsed by mechanical pressure. Conventional means are used to dry and fix the treated fabric. This report concentrates on the commercially available foam finishing process for characterization. The Impact Scoreboard System (ISS) is used to monitor (track) and display the market penetration and energy savings of government-sponsored industrial energy conservation technologies as they are installed as commercial units in industry.

335 (DOE/CS/40060-T1) **Energy conservation in grain (corn) drying with combination high-temperature, low-temperature methods. Final report, July 1, 1978-September 30, 1980.** Morey, R.V.; Gustafson, R.J.; Cloud, H.A.; Walter, K.L. Minnesota Univ., St. Paul (USA). Agricultural Experiment Station. Jan 1981. 53p. DOE Contract AS02-78CS40060. Source: NTIS, PC A04/MF A01.

Field drying experiments were carried out during the 1975 through 1978 harvest seasons at the University of Minnesota Rosemount Experiment Station. Several combination drying experiments were conducted each season along with a control (conventional drying) experiment. Based on the results of the field experiments, comparisons of energy requirements for combination and conventional drying were made. Performance of the low-temperature, in-storage phase of combination drying was evaluated using computer

simulation. Drying performance using ambient air was compared to performance when small amounts of supplemental heat were added, either solar or constant source heat. Long term weather records were used to evaluate variations in performance from year to year.

336 (DOE/CS/40064-1) **DOE wet pressing project. Progress report, October 1979-October 1980.** Ceckler, W.H. Maine Univ., Orono (USA). 10 Nov 1980. 17p. DOE Contract AS02-78CS40064. Source: NTIS, PC A02/MF A01.

A computer model has been developed to predict water removed in the wet press section of a paper machine. When experimentally determined values for permeability and compressibility of the paper sheet are used the model predicts press behavior that agrees quite well with laboratory dewatering tests on the same type of paper. The results of permeability tests on a variety of papers are presented along with the effect of changes in fiber concentration for each of these materials. The design and performance of a laboratory compression tester is discussed along with results of compression tests on saturated and unsaturated samples of paper. Plans for both the pilot plant tests and mill trials which will be used to refine and test the final computer simulation model are discussed.

337 (DOE/CS/40064-4) **Wet pressing behavior of newsprint and linerboard. Phase II, final report.** Ceckler, W.H.; Thompson, E.V.; Jewett, K.B. Maine Univ., Orono (USA). May 1984. 188p. DOE Contract AC02-78CS40064. Order Number DE85009862. Source: NTIS, PC A09/MF A01; GPO Dep.

Results of the Phase II project indicate that both newsprint and linerboard can be successfully modeled using the Phase I simulation model and computer program, although an alteration is required for the linerboard case as this material represents a composite structure. Since newsprint represents compression-controlled dewatering, while linerboard flow-controlled dewatering, the success of the model shows its validity over the entire range of pressing performance. In comparing the model prediction of consistency leaving the final press to the actual value measured at the mill, the following values were obtained: for newsprint, 42.2% (simulation) and 41.7% (mill); and for linerboard, 40.7% (simulation) and 41.0% (mill). Effects of changes in operating variables or press configuration were explored: increased loading on each press separately, and all presses together; increased line speed; increased temperature into each press separately, and all presses together; and substitution of an extended nip press for the last press of the press section. Substantial dryness increases are realized using the extended nip press for both newsprint and linerboard. A new, channeling phenomenon was discovered, which is associated with the dewatering of heavy basis weight sheets of both linerboard and newsprint, and is manifested in higher than expected dewatering and nonclassic flow controlled behavior.

338 (DOE/CS/40081-T1) **In-plant demonstration of energy optimization in beck dyeing of carpet. Final report, June 1, 1979-January 1, 1980.** Tinscher, W.C. Georgia Inst. of Tech., Atlanta (USA); Salem Carpet Co., Chickamauga, GA (USA). 1980. 130p. DOE Contract AS05-76CS40081. Source: NTIS, PC A07/MF A01.

Several energy-conservative technologies have been successfully combined and transferred to a commercial carpet finishing plant to optimize beck dyeing. The technology of

bump-and-run, in which the dyebath temperature was allowed to drift for the last 85% of the hold time instead of being maintained by active steam sparging, reduced the energy consumption by 38% with negligible capital investment required. Merging of dyebath reuse with bump-and-run only marginally increased the energy consumption (to 39%), but substantially lowered the plant's finishing costs further by directly recycling dyes, auxiliary chemicals, and water. Final optimization, which merged a technique whereby the carpet was pulled directly from the hot bath with bump-and-run and dyebath reuse, further improved the economics by drastically reducing water/sewer requirements by 90% and eliminating the holding tank/pumping assembly as a reuse requirement. From a carpet industry viewpoint, the demonstrated modifications have a direct energy conservation potential of 2.4×10^5 barrels of oil equivalent per year assuming the technology is directly transferable to similar atmospheric dyeing processes, e.g., beck dyeing of nylon and polyester fabrics, the potential to the entire textile industry is 2.6×10^6 BOE/year. Economically, total potential savings for the carpet industry on reuse incorporation was $\$1.2 \times 10^7$ /year, based on a 2.3 cents/lb. savings figure. When the allied fabric industry was included, the national potential was raised to $\$1.0 \times 10^8$ /year. These figures include cost savings due to materials recycled (water, auxiliary chemicals and dyes) as well as energy conservation.

339 (DOE/CS/40081-T2) Development and demonstration of energy-conserving drying modifications to textile processes. Part II, Phase III. Final report, December 1, 1978-November 30, 1979. Brookstein, D.S.; Carr, W.W.; Holcombe, W.D. Georgia Inst. of Tech., Atlanta (USA). School of Textile Engineering. 1980. 133p. DOE Contract AS05-76CS40081. Source: NTIS, PC A07/MF A01.

Research was conducted to develop and to expand procedural and engineering modifications to textile drying processes in order to reduce energy requirements. Research was concentrated on: an investigation of the potential of a Machnozzle as a fabric predrying device and a program to optimize textile can drying with respect to energy consumption. Results demonstrated that the Machnozzle can significantly reduce the moisture content in fabric. The energy consumption of the Machnozzle compares favorably with that for steam can drying. An economic analysis of the Machnozzle as a predrying device was made using the Internal Rate of Return. Results showed that the economic feasibility of using the Machnozzle was dependent on the cost of energy and process operating conditions. (MCW)

340 (DOE/CS/40081-T3) In-plant demonstration of dyebath reuse applied to hosiery dyeing. Part I, Phase III extension of DOE contract. Interim report, June 1, 1978-September 30, 1978. Combes, R. Georgia Inst. of Tech., Atlanta (USA); Adams-Millis Corp., High Point, NC (USA). 1978. 17p. DOE Contract AS05-76CS40081. Source: NTIS, PC A02/MF A01.

Progress is reported on a project to dye 30 batches of pantyhose from reused dyebaths, randomly switching fiber type from Nylon 6 to Nylon 66 and also switching 5 shades. Complete energy, mass, and time balances will be obtained on both the conventional and modified processes. The necessary monitoring and analytical equipment to conduct the in-plant demonstration has been purchased, installed, and checked out for proper operating efficiency. The holding tank/pumping assembly has been installed and inspected for correct operation. Monitoring of the conventional process for energy and material consumption has been initiated.

341 (DOE/CS/40081-T4) In-plant demonstration of optimization of energy utilization in beck dyeing of carpet. Proposed Part III, Phase III extension of DOE contract. Georgia Inst. of Tech., Atlanta (USA). [nd]. 34p. DOE Contract AS05-76CS40081. Source: NTIS, PC A03/MF A01.

A proposal to demonstrate on a commercial scale an optimized procedure for beck dyeing of carpet to improve energy utilization is discussed. The proposal is for Phase III. A number of energy conserving procedural and equipment modification including lower dyeing temperature, lower liquor ratio, lower air exhaust flows, and recycle of hot spent dyebaths will be demonstrated in the plant dyeings. Pilot-scale experiments suggest that these modifications will reduce direct energy consumption in carpet dyeing by 400 Btu per pound of carpet processed. Adoption of the modified process by only 50% of the carpet industry would yield an annual reduction in energy consumption of 1×10^{12} Btu's (1.7×10^5 BOE). The pilot-scale experiments also indicate that a cost savings of approximately 2 cents per pound of carpet dyed can be achieved with the suggested modifications. The demonstrated technology will have application in other types of nylon and polyester fiber dyeing. The Salem Carpet Mills carpet dyeing facility at Chickamauga, Georgia, will be the site of the demonstration.

342 (DOE/CS/40081-T5) Development and demonstration of energy-conserving drying modifications to textile processes. Part II, Phase III extension of DOE contract. Brookstein, D.S. Georgia Inst. of Tech., Atlanta (USA). 30 Jan 1979. 8p. DOE Contract AS05-76CS40081. Source: NTIS, PC A02/MF A01.

Experiments with the Machnozzle are reported and they indicate that significant amounts of energy can be saved during drying in industrial processes. The Machnozzle is now viewed as a vacuum slot acting in reverse, that is, a device in which a relatively large pressure differential across the fabric can be obtained. The problem of steam condensation in the Machnozzle was discussed in the reporting period and a mathematical simulation of steam can dryer has been initiated to continue the development of an optimization program for steam can dryers in industrial use.

343 (DOE/CS/40086-T1) Preliminary of sugar beet cossettes to reduce energy in sugar beet processing. Final technical report, August 1, 1978-January 31, 1981. Randall, J.M. Department of Agriculture, Albany, CA (USA). Western Regional Research Center. 30 Jun 1981. 56p. DOE Contract AI01-78CS40086. Order Number DE81026001. Source: NTIS, PC A04/MF A01.

In the United States, the beet sugar industry is the most intensive user of energy, per unit value of product shipped. Approximately 2.6×10^6 Btu of energy are required per ton of beets processed. The increasing cost and scarcity of energy has made the industry very receptive to process changes which can reduce energy requirements for sugar production. A two-year project was undertaken to determine the feasibility of liming fresh sugar beet cossettes, prior to extraction, as a means of reducing energy consumption. Fresh Ca(OH)_2 was added to cossettes for 10 min prior to introduction into the diffuser (extractor). It was found that up to 3.5×10^5 Btu/ton of beets sliced could be saved in pulp drying and 0.45×10^5 Btu/ton could be saved in production of lime (13.5% and 1.7%, respectively, of current overall energy requirements of the beet-sugar process). Quality of raw juice from the diffuser was much better with limed cossettes

than with control cossettes. Experimental thin juice was slightly higher in lime salts and lower in quality than controls. Liming of cossettes by dipping in a slurry of 2.6% $\text{Ca}(\text{OH})_2$ gave better results than mixing of cossettes with dry $\text{Ca}(\text{OH})_2$ and would be much easier to implement in an existing plant.

344 (DOE/CS/40092-T1) **Optimization of energy usage in textile finishing operations. Part I. The simulation of batch dyehouse activities with a general purpose computer model.** Beard, J.N. Jr.; Rice, W.T. Jr. Clemson Univ., SC (USA). Dept. of Chemical Engineering. 1980. 210p. DOE Contract AS05-76CS40092. Source: NTIS, PC A10/MF A01.

A project to develop a mathematical model capable of simulating the activities in a typical batch dyeing process in the textile industry is described. The model could be used to study the effects of changes in dye-house operations, and to determine effective guidelines for optimal dyehouse performance. The computer model is of a hypothetical dyehouse. The appendices contain a listing of the computer program, sample computer inputs and outputs, and instructions for using the model. (MCW)

345 (DOE/CS/40098-T1) **Energy conservation research in the paper and allied products industry. Phase 1.** Clark, J.L.; Holcombe, W.D.; Hartley, E.M.; Carr, W.W. Georgia Inst. of Tech., Atlanta (USA). Engineering Experiment Station. Oct 1979. 135p. DOE Contract AS05-78CS40098. Source: NTIS, PC A07/MF A01.

The Engineering Experiment Station of the Georgia Institute of Technology has conducted a study of certain concepts for energy conservation in the paper manufacturing industry. The primary emphasis of the study was evaluation of a textile industry device called a Machnozzle as an aid to dewatering of the press section felts. Experimental results indicate that significant reduction in felt moisture may be obtained by installing and operating the Machnozzle just prior to the suction box. Analysis of the economic and energy impact is hampered by lack of a clear understanding of the relationship between felt moisture and paper sheet moisture. Further study in this area is recommended. Also addressed in this project is the concept of maintaining higher feedstock temperatures, particularly through retention of thermal energy from the pulping process. Various problems relating to high temperature processing are discussed.

346 (DOE/CS/40150-2) **High consistency forming process for paper making. Part 1. A research, development, and demonstration program plan for the US Papermaking Industry. Final report.** Thermo Electron Corp., Waltham, MA (USA). Apr 1980. 161p. DOE Contract AC02-78CS40150. (TE-4250-216-80). Source: NTIS, PC A08/MF A01.

The subject of research, development, and demonstration (RD and D) of energy conserving technologies applicable to papermaking operations downstream of the pulping process is addressed. An RD and D Program Plan is presented based on a survey of leading representatives of the papermaking industry, equipment manufacturers, consulting engineering firms, the American Paper Institute, and the Technical Association of the Pulp and Paper Industry. For perspective, the program plan is presented against the general background of the industry's current issues and concerns. The second part of the paper, Phase I, final report, deals with papermaking test facilities. The case for a centralized test facility is discussed. The results of a survey

of existing pilot paper machines are presented. The energy saving potential of high consistency forming is considered and related to existing evidence. Simple theoretical models for the press nip action and the drying process are developed to predict where high consistency forming will reduce energy consumption. A special dynamic former has been designed, fabricated, and commissioned to allow development of a laboratory high consistency headbox. The design and construction of a low speed headbox has been completed and the complete system operated. Special equipment and techniques for the measurement of the water and air permeability of sheet samples have been developed and are described.

347 (DOE/CS/40150-T1) **High consistency forming process for papermaking. Phase II. Final report.** Kranz, W.T.; Judd, M.; Rotherham, J. Thermo Electron Engineering Corp., Waltham, MA (USA); Thermo Electron Corp., Auburn, MA (USA). Lodging Div. Sep 1980. 98p. DOE Contract AC02-78CS40150. Order Number DE81026511. Source: NTIS, PC A05/MF A01.

The demonstration program for saving energy that can be obtained by forming paper and paperboard products at initial high fiber concentration is discussed. Under Phase II, a limited number of design modifications were made to the low speed high consistency headbox. These resulted in improved sheet formation for samples used in subsequent press studies. Comparisons of sheet physical and drainage properties were made between low and high consistency sheets. Equipment for these tests was designed and fabricated during Phase II, including a laboratory scale dynamic roll nip press with single felt. The high consistency sheet had significantly higher permeability and compressive modulus than the low consistency sheet. In simulated three nip press studies the high consistency sheet demonstrated a 1.5 to 2.5% higher solids content than the low consistency sheet under the same operating parameters. The effect of variables such as machine speed, sheet basis weight, nip loading and entering sheet consistency were investigated. Rules for scaling between laboratory and full size press nips have been established. The energy saving potential for the paper industry through the use of high consistency forming was estimated as 6 to 7% of current total consumption.

348 (DOE/CS/40208-T1) **Evaporation by mechanical vapor recompression. Technical progress report, September 1-December 31, 1979.** Iverson, C.H.; Coury, G.E. Beet Sugar Development Foundation, Fort Collins, CO (USA). 1979. 26p. DOE Contract AC03-79CS40208. Source: NTIS, PC A03/MF A01.

Progress to date in the development of a study of the application of the technologies of mechanical vapor recompression and falling film evaporators as applied to the beet sugar industry is reported. Progress is reported in the following areas: technical literature search and plant visitations of existing applications of VR FFE.

349 (DOE/CS/40211-T1) **Development of a cold corrugating process. Final report.** Sprague, C.H. Institute of Paper Chemistry, Appleton, WI (USA). May 1985. 638p. DOE Contract AC02-79CS40211. Order Number DE85017238. Source: NTIS, PC A99/MF A01; GPC Dep.

This report covers four project phases. An executive summary is included. In the second section, the basic process elements of forming and bonding are covered separately. The pilot trials work is covered in Section III, while Section IV is devoted to commercial prototype system development

and evaluation: specification and acquisition of the system components; checkout tests and the system modifications; and results obtained from the system.

350 (DOE/CS/40212-T1) **Energy conservation in false twist texturing. Final report.** Kang, T.J.; Kimrey, H.D.; Seyam, A.M.; Kaufman, F.; El-Shiekh, A. North Carolina State Univ., Raleigh (USA). School of Textiles. Apr 1981. 14p. DOE Contract AS05-79CS40212. Order Number DE81028114. Source: NTIS, PC A02/MF A01.

The feasibility of using heating techniques other than contact electric heating to heat filament yarns during the False Twist Texturing Process is investigated. Laser, microwave, and infrared radiation heating are investigated. A summary of a paper, A Study of Microwave Texturing of Polyester Yarns, is included in the publication. (MCW)

351 (DOE/CS/40213-T1) **Technical and economic feasibility of membrane technology. Fourth technical progress report, June 17-September 16, 1980.** Sandre, A. Beet Sugar Development Foundation, Fort Collins, CO (USA). Oct 1980. 46p. DOE Contract AC03-79CS40213. Source: NTIS, PC A03/MF A01.

Progress is reported on the investigation of the potential application of reverse osmosis, ultrafiltration and electrodialysis to the system of solids concentration in beet sugar process streams. During this period, emphasis was put on running reverse osmosis tests with a new prototype machine to select the most suitable membranes for the concentrating of sugar solutions. An economic analysis of using reverse osmosis in a factory producing 10^6 gal/day of thin juice is discussed. (DMC)

352 (DOE/CS/40258-T1-Vol.1) **Critical-fluid extraction of organics from water. Volume I. Engineering analysis. Final report, 1 October 1979-30 November 1983.** Moses, J.M.; de Filippi, R.P. Little (Arthur D.), Inc., Cambridge, MA (USA). Jun 1984. 92p. DOE Contract AC01-79CS40258. Order Number DE84012669. Source: NTIS, PC A05/MF A01; GPO Dep.

Critical-fluid extraction of several organic solutes from water was investigated analytically and experimentally to determine the energy conservation potential of the technology relative to distillation. This Volume gives the results of an engineering analysis. The process uses condensed or supercritical carbon dioxide as an extracting solvent to separate aqueous solutions of common organics such as ethanol, isopropanol and sec-butanol. Energy input to the systems is electric power to drive compressors. A detailed process analysis included evaluation and correlation of thermophysical properties and phase equilibria for the two- and three-component systems involved. The analysis showed that a plant fed with 10 weight percent ethanol feed would consume 0.65 kilowatt-hours (kwh) of power for compression energy per gallon of alcohol. This energy consumption would be 5300 Btu of steam-equivalent, or 6500 Btu of fossil-fuel-equivalent energy. The extraction product, however, would require additional energy to produce high-purity alcohol. Doubling the ethanol feed concentration to 20 weight percent would reduce the energy required to about 0.30 kwh per gallon. Halving the ethanol feed concentration to 5 weight percent would increase the energy required to about 1.35 kwh per gallon. For the same feed composition, isopropanol can be separated with 48% of the energy required for ethanol. The same separation of sec-butanol can be done with 25% of the ethanol energy requirement.

353 (DOE/CS/40259-1) **Energy conservation in distillation. Final report.** Mix, T.W.; Dweck, J.S.; Weinberg, M.; Armstrong, R.C. Merix Corp., Wellesley, MA (USA). Jul 1981. 299p. DOE Contract AC07-76CS40259. Order Number DE81028650. Source: NTIS, PC A13/MF A01.

An energy audit of major processes in the petroleum, chemical, and natural gas liquids industries and of key columns in each major process indicates that approximately 2 quads of energy were consumed for distillation in the US in 1976. The breakdown of the energy usage by industry is: petroleum refineries, 66%; chemical (including petrochemical) industry, 29%; natural gas liquids processing, 5%. Techniques and current practices for conserving distillation energy are reviewed, and guidelines indicating those process conditions which favor the use of each energy conserving technique are enumerated. Tray and control retrofits are treated in greater depth. Expressions for payout times for these two retrofit options are developed based both on energy savings and on increased throughput. Calculations for industrial columns suggest that both types of retrofits will frequently have short (<6 months) payout times based on either criterion. Extractive distillation is also discussed in detail and criteria enabling the estimation of the energy which may be conserved using this technique are developed. Good housekeeping practices and field techniques for checking the energy efficiency of industrial distillations are also discussed.

354 (DOE/CS/40264-T2) **Hyperfiltration and energy in the food industry. Final report, Phase I.** Carre, Inc., Seneca, SC (USA); National Food Processors Association, Berkeley, CA (USA). Oct 1981. 65p. DOE Contract AC03-79CS40264. Order Number DE82004419. Source: NTIS, PC A04/MF A01.

This report describes the initial research and development phase of a program to evaluate the use of high temperature hyperfiltration to reduce energy usage in the food industry. Studies were conducted at two food processing plants in California. The program utilized a mobile laboratory. Results of screening tests (approximately 4 hours duration) were used to select one process stream for intensive testing (approximately 2 weeks duration) at each plant. Screening test results indicate a flux of 0.6 to 0.8 m/d (15 to 20 GFD) for the concentration of hot break tomato juice from 5% NTSS (Natural Tomato Soluble Solids). The potential annual energy saving for the preconcentration of tomato juice by hyperfiltration is estimated to be equivalent to about 23 million liters (6 million gallons) of oil. The tests on hot caustic peeling solutions (approximately 10% Sodium Hydroxide) and hot (82C, 180F) container wash water indicate technical feasibility of reclaiming these solutions. Short term testing data on the hyperfiltration of several olive processing streams are also presented. The test results are used to prepare economic estimates. Short pay back periods for energy savings by use of hyperfiltration in the areas of pre-vaporator concentration, chemical (caustic) recovery, and hot wash water recycle are predicted.

355 (DOE/CS/40271-1) **Energy conservation in fruit dehydrators utilizing recirculation of exhaust air and heat-recovery heat exchangers. Final report.** Groh, J.E.; Thompson, T.L. Arizona Univ., Tucson (USA). Environmental Research Lab Dec 1981. 60p. DOE Contract AC02-79CS40271. Order Number DE82018985. Source: NTIS, PC A04/MF A01.

Portions of document are illegible.

Dehydration of fruit in the United States is often done by means of a tunnel dehydrator utilizing large quantities of fossil fuel. Existing dehydrators have been designed to operate with maximum product through-put and with little regard for energy efficiency. By incorporating dampers for air recirculation and thermal energy recovery equipment on the exhaust air, the energy required in dehydration was cut by over 40%, satisfying the original objectives of the program. A commercial dehydrator tunnel was modified by installing a heat recovery heat exchanger and an exhaust air recirculation damper. Another tunnel was equipped with the exhaust air recirculation damper only. A third tunnel was unmodified. These three tunnels of a 24 tunnel facility were equipped with individual natural gas meters to measure energy consumption. The energy consumption of the heat exchanger equipped tunnel normally amounted to approximately 40% of the unmodified tunnel during raisin production.

356 (DOE/CS/40287-T2) **Oxygen production by the Moltox process. Final report.** Erickson, D.C. Energy Concepts Co., Annapolis, MD (USA). Feb 1983. 114p. DOE Contract AC01-79CS40287. Order Number DE83012847. Source: NTIS, PC A06/MF A01.

The results of a research and development project on a chemical separation of oxygen from air are reported. The separation is accomplished by reacting oxygen in air with a molten mixture of alkali metal nitrates and nitrites in an absorber. The salt is then circulated in a closed loop to a desorber, where pure oxygen is released. The research conducted has included a thermodynamic analysis, salt chemistry and corrosion experiments, process analysis, economic projections, and construction and operation of a continuous pilot plant. The research has shown this oxygen production method to have a 40% lower energy requirement and a 5 to 20% cost advantage when compared with cryogenic plants.

357 (DOE/CS/40334-T2) **Application of foams to the processing of fabrics. Final report.** Bedenbaugh, R. United Merchants Research Center, Langley, SC (USA). Jun 1984. 47p. DOE Contract FC01-80CS40334. Order Number DE84013387. Source: NTIS, PC A03/MF A01; GPO Dep.

The overall accomplishments of this work were: commercialization of foam processing in textiles, especially foam finishing, was accelerated by about five years. Since 1979, about 3 billion yards of fabric have been finished by the U.M.M. or subsequently developed foam systems with a savings of about 1.5 to 2 trillion Btu. In 1984 about 15% of all domestic textile finishing was by a foam process. Foam processing of textiles is being practiced throughout the domestic and international textile industry. Foam dyeing is commercial in specialized areas of the textile industry such as carpet dyeing and the pigment dyeing of lightweight filament fabrics. Foam printing will increase with the development of rotary printing machines designed especially for foamed print colors. The use of foamed chemical systems for desizing, scouring and bleaching of fabrics, especially fabrics containing dyed yarns, is increasing. The development of equipment and chemical systems for foam sizing of fabrics was accelerated in 1983, and commercial equipment is expected to be available in 1984. The public disclosure of foam processing technology has led to the development of competitive foam systems as well as alternate low wet pick-up systems. An independent audit of outside (non-U.M. and M.) demonstration sites has unequivocally established the energy savings and economic advantages of foam processing.

358 (DOE/CS/40341-T1) **Evaluation of hydrolysis as an energy-saving alternative to the Tomlinson furnace. Task I. More efficient char utilization.** Saint Regis Paper Co., Cantonment, FL (USA). Technical Operations Div. 1981. 58p. DOE Contract AC05-80CS40341. Order Number DE83002579. Source: NTIS, PC A04/MF A01.

Eight technologies for utilizing hydrolysis fuels were considered as having potential for increasing the production of electrical power over the base case technology. The technologies were: gas turbine, diesel engine, char gasification, fluidized bed combustion, cyclone burner, internal combustion engine, organic Rankine cycle, and Stirling engine. Design and cost data from vendors were used to incorporate into the paper mill steam/power system the more promising technologies for utilizing hydrolysis fuels. The resulting mill steam/power systems were compared on the bases of net purchased or exported power, net energy input to the overall system, capital cost, the return on the incremental investment over the base case system, the stage of development of the technology, the reliability of the technology, and the qualification of the vendor or vendors. The study indicated that the properties of char did not provide significant overall advantages over coal for topping cycles. The study also showed that the fuels utilization efficiency of hydrolysis can be increased further by raising the percentage of flash gas produced.

359 (DOE/CS/40341-T2) **Evaluation of hydrolysis as an energy-saving alternative to the Tomlinson furnace. Task III. Chemical causes of increased pulp yield.** Saint Regis Paper Co., Pensacola, FL (USA). Technical Operations Div. 1977. 15p. DOE Contract AC05-80CS40341. Order Number DE83017878. Source: NTIS, PC A02/MF A01.

The yield-enhancing effect was found to be the result of the presence of small but significant levels of polysulfide and calcium ions. Polysulfide ions are generated during the causticization of the hydrolysis filtrate and is the result of a partial-air oxidation of Na_2S that occurs under conditions existing during the causticizing process. In the presence of residual organics, calcium ions are complexed to form soluble calcium-organo complexes which allow for a carryover of a significant amount of calcium into the final cooking liquor. The presence of both ions in the final cooking liquor allow for pulp yield increases through the formation of alkali-stable aldonic acid end-groups which protect carbohydrates from alkaline-degradation.

360 (DOE/CS/40341-T3) **Evaluation of hydrolysis as an energy-saving alternative to the Tomlinson furnace. Task II. Chemistry of hydrolysis.** Saint Regis Paper Co., Pensacola, FL (USA). Technical Operations Div. 1981. 50p. DOE Contract AC05-80CS40341. Order Number DE83017879. Source: NTIS, PC A03/MF A01.

Studies were conducted of reactions involving model compounds of black liquor and reaction products when reacting black liquor at extreme conditions for the purpose of understanding the chemistry occurring in hydrolysis. Reaction studies of model compounds included: lignin precipitated from black liquor, the sodium salt of saccharinic acid, sodium lactate, sodium glycolate, sodium oxalate, sodium acetate and sodium formate.

361 (DOE/CS/40341-T4) **Feasibility of black liquor gasification in combined cycle cogeneration. Final report, Phase I.** Kelleher, E.G. Saint Regis Paper Co., West Nyack, NY (USA). Technical Operations Div. 30 Jun 1983.

225p. DOE Contract AC05-80CS40341. Order Number DE84002936. Source: NTIS, PC A10/MF A01.

A small-scale test program of 65% solids black liquor gasification was conducted in the bench-scale molten salt gasifier. Nine tests were performed using both air and oxygen as the oxidant. The black liquor gasified readily and the product gas had a dry-basis heating value of 70 Btu/scf with air and about 250 Btu/scf with oxygen. These values were almost identical to values predicted on the basis of thermodynamic equilibrium in the gas phase, indicating that the system had achieved near-equilibrium. However, the reduction of the melt to sodium sulfide was generally low. An independent research program aimed at improving the performance of air-blown black liquor gasification was conducted. That work resulted in a modified gasifier system design which increased the off-gas heating value to 120 Btu/scf and the reduction of the melt to over 95%. This was an improvement that would potentially allow use of the scrubbed product gas as a feed to a combustion gas turbine without prior enrichment.

362 (DOE/CS/40341-T5) Gasification of kraft black liquor and use of the products in combined cycle cogeneration. Final report, Phase II. Kelleher, E.G. Champion International Corp., West Nyack, NY (USA). Technical Center. Jul 1985. 132p. DOE Contract AC05-80CS40341. Order Number DE86003647. Source: NTIS, PC A07/MF A01; GPO Dep.

This Phase II study of kraft black liquor gasification and use of the product gases in combined cycle cogeneration based on combustion gas turbines was motivated by the very promising results of the Phase I feasibility study. The Phase I study indicated that the alternative technology to the Tomlinson recovery furnace had the potential of improving the energy efficiency and safety of combusting black liquor, reducing the capital and operating costs, increasing the electric power output, and providing an economical system for incremental kraft capacity additions. During Phase II, additional bench-scale experiments were run, pilot-scale experiments were conducted, equipment systems were investigated, and performance and economics were reanalyzed. All of the objectives of the Phase II project were met. Recommendations are summarized.

363 (DOE/CS/40341-T6) Conceptual design of a black liquor gasification pilot plant. Kelleher, E.G. Champion International Corp., West Nyack, NY (USA). Aug 1987. 94p. DOE Contract AC05-80CS40341. Order Number DE88003621. Source: NTIS, PC A05/MF A01; GPO Dep.

In July 1985, Champion International completed a study of kraft black liquor gasification and use of the product gases in a combined cycle cogeneration system based on gas turbines. That study indicated that gasification had high potential as an alternative to recovery boiler technology and offered many advantages. This paper describes the design of the plant, the construction of the pilot plant, and finally presents data from operation of the plant.

364 (DOE/CS/40350-T1) In-plant demonstration of a Machnozzle as a fabric-predrying device. Final report. Carr, W.W.; Holcombe, W.D.; Robertson, S.D.; Carter, W.C. Georgia Inst. of Tech., Atlanta (USA). Oct 1981. 129p. DOE Contract AS05-80CS40350. Order Number DE82010892. Source: NTIS, PC A07/MF A01.

The objective of the project was to demonstrate on a commercial scale the Machnozzle as a predrying device for fabrics. The report documents the in-plant demonstration

and includes a review of the pilot-scale research; a description of the in-plant demonstration and methodology used; results of the Machnozzle tests energy recovery tests, and fabric quality assessment tests; and an economic analysis of the Machnozzle as a predrying device with and without energy recovery. (MCW)

365 (DOE/ID-10210) Membrane applications and research in food processing: An assessment. Mohr, C.M.; Leeper, S.A.; Engellau, D.E.; Charboneau, B.L. EG and G Idaho, Inc., Idaho Falls (USA). Aug 1988. 317p. DOE Contract AC07-76ID01570. Order Number DE88016250. Source: NTIS, PC A14/MF A01; GPO Dep.

This assessment is intended to aid in planning separations research and development projects aimed at reducing energy consumption in the food industry. The food processing industry uses approximately 1.5 quadrillion Btu per year, 2% of the US national annual energy consumption. Food processing involves a variety of liquid feed, product, and waste streams and makes extensive use of thermal operations such as drying, evaporation, pasteurization, and distillation. As such, it is a candidate for energy conservation through the use of membrane separations. The assessment is organized according to Standard Industry Classification (SIC) Code for the food industry. Individual subindustries considered are: (a) Meat Processing, Dairy Products, Preserved Fruit and Vegetables, Grain Milling, Bakery Products, Sugar and Confectionery products, Edible Fats and Oils, and Beverages. Topics covered include: (a) background information on food processing and membrane separations, (b) a review of current and developing membrane separations for the food industry, (c) energy consumption and processes used in individual subindustries, (d) separations in the subindustries that could be augmented or replaced by membrane processes, (e) industry practices and market conditions that could affect adoption of new technologies, and (f) prioritized recommendations for DOE-OIP supported research to further use of membrane separations in the food industry. 435 refs.

366 (DOE/ID/12232-1-Pt.1) Energy efficient membrane processes for the separation of organic liquids: Part 1: Final report, September 28, 1982-December 31, 1986. Cabasso, I.; Acharya, H.R.; Korngold, E.; Liu, Z.; Stern, S.A.; Li, W.; Makenzie, T.; Poda, E. State Univ. of New York, Syracuse (USA). Coll. of Environmental Science and Forestry. Oct 1987. 195p. DOE Contract AS07-82ID12232. Source: NTIS, PC A10/MF A01 - OSTI; GPO Dep.

The potential usefulness of two membrane processes, namely, pervaporation and perstraction, for separating azeotropic mixtures of aromatic and aliphatic hydrocarbons was studied theoretically and experimentally. A third membrane process, osmotic phase-separation, was investigated experimentally. The separation of an azeotropic mixture of benzene and cyclohexane was used as an example. Part II of this report will discuss membrane processes for the separation of alcohol/water mixtures. Mathematical models of pervaporation and perstraction were developed for computer simulations of the processes. The perstraction model presented herein is the first of its kind. Additionally, the energy requirements and capital investments costs for the separation of an azeotropic benzene/cyclohexane mixture were determined and compared with those for extractive distillation. 31 refs., 64 figs., 19 tabs.

367 (DOE/ID/12232-1-Pt.2) **Energy efficient membrane processes for the separation of organic liquids: Part 2: Final report, September 28, 1982-December 31, 1986.** Cabasso, I.; Acharya, H.R.; Korngold, E.; Liu, Z.; Stern, S.A.; Li, W.; Makenzie, T.; Poda, E. State Univ. of New York, Syracuse (USA). Coll. of Environmental Science and Forestry. Oct 1987. 177p. DOE Contract AS07-82ID12232. Order Number DE89002486. Source: NTIS, PC A09/MF A01 - OSTI; GPO Dep.

The present report demonstrates the use of membrane technology for dehydration processes concentrating on two examples: azeotropic separation of isopropanol-water, and separation of ethanol-water mixtures (starting at 84.5 wt. % ethanol where separation by distillation begins to be progressively more energy intensive). The principles of the membrane separation processes employed in such separations were discussed in Part I of the report. The advantage of the membrane processes is that they do not require the addition of a third component and separation is a continuous process. Pervaporation, perstraction, and air-sweep pervaporation were thoroughly studied for these separations. An urgent need for the identification of the appropriate membrane was realized. This study has revealed that ion-exchange membranes are suited for these separations. Results are discussed. 9 refs., 68 figs., 33 tabs.

368 (DOE/ID/12232-1-Pt.3) **Energy efficient membrane processes for the separation of organic liquids: Part 3 (Supplement report): Final report, September 28, 1982-December 31, 1986.** Cabasso, I.; Acharya, H.R.; Korngold, E.; Liu, Z.; Stern, S.A.; Li, W.; Makenzie, T.; Poda, E. State Univ. of New York, Syracuse (USA). Coll. of Environmental Science and Forestry. Oct 1987. 53p. DOE Contract AS07-82ID12232. Order Number DE89002487. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

In this supplemental report, two pilot plants are described. The first is air purge pervaporation (or air sweep pervaporation hollow fiber system) for the separation of azeotropic aqueous liquids. The second describes pilot plant construction and operation for the perstraction process. Several configurations for the air purge pervaporation process were studied and were shown to yield high purity products e.g., isopropanol from the azeotropic mixture with water was enriched to 99.9%. Parallel and U-module configuration were used and durability experiments up to 120 days were carried out successfully. The report describes the first successful low scale pilot plant unit and elements for perstraction process. The conclusion and outcome of this study are two fold. First, membrane systems in a pilot plant unit proved to be very efficient in upgrading nonpermeable components in a membrane system and especially when dealing with azeotropic mixtures. For example, more than 99% isopropanol can be produced from a feed liquid which is 88% i-PrOH (azeotropic mixture with water). The membrane system proved to be durable within the time limit of the experiments (120 days). Second, all parameters including the various configurations of the pilot plants (which are still being studied) are available for chemical, petroleum, and other US industries. 3 refs., 22 figs., 2 tabs.

369 (DOE/ID/12243-T1) **Replacement of chemical intensive water treatment processes with energy saving membrane. Final report.** Mickley, M.C.; Goering, S.W. Coury and Associates, Lakewood, CO (USA). Nov 1983. 73p. DOE Contract FC07-83ID12243. Order Number DE84011028. Source: NTIS, PC A04/MF A01, GPO Dep.

The project investigated the use of charged ultrafiltration membranes to treat hard water. More specifically, the work was undertaken to (1) make charged ultrafiltration membranes to demonstrate the technical feasibility of the chemical grafting approach; (2) evaluate the market potential for charged ultrafiltration membranes; and (3) evaluate the cost and energy savings for using charged ultrafiltration as compared to lime-based clarification and other treatment methods. The results suggest that chemical grafting is a relatively simple, reproducible and low-cost way to modify existing substrate materials to give them enhanced transport performance. Process studies lead to the identification of good market potential for membrane processes using charged ultrafiltration membranes. Capital and operating costs relative to lime-based clarification are favorable for low- and medium-sized treatment plants. Finally, substantial energy savings are apparent as compared to lime-based precipitation systems which incur substantial energy consumption in the lime production and transportation steps.

370 (DOE/ID/12293-1) **Research on an energy-efficient drying process. Final report.** Ray, R.J. Bend Research, Inc., OR (USA). 26 Feb 1986. 75p. DOE Contract AC07-82ID12293. Order Number DE86013369. Source: NTIS, PC A04/MF A01; GPO Dep.

Objective was to investigate the feasibility of using a membrane-based process for the recovery of energy from dryer-exhaust streams. The membrane allows the separation of a hot, moist, dryer-exhaust stream into a low-moisture air stream and a low-pressure stream of high-purity water vapor. Conventional vapor recompression can then be used to compress the water vapor to a usable quality, allowing the latent heat to be recovered using a condenser. The recovered heat can then be returned to the dryer or used elsewhere in the plant. In many cases, this scheme allows the recovery of eight to ten times as much energy as is required to operate the compressor. Laboratory experiments indicate that the process is feasible. The successful completion of a long-term field test at a Crown Zellerbach paper mill suggests that the membranes are robust enough to withstand operation on actual industrial dryer-exhaust streams. Design and economic optimization studies indicate that the process is only marginally economical.

371 (DOE/ID/12422-T1) **Membrane separation processes in the petrochemical industry. Phase I, September 29, 1982-March 31, 1984.** Li, N.N. Signal UOP, Inc., Des Plaines, IL (USA). Research Center. 15 Dec 1984. 99p. DOE Contract AC07-82ID12422. Order Number DE85017030. Source: NTIS, PC A05/MF A01; GPO Dep.

This report describes research work focused on the development of new membrane processes which show significant savings in energy when compared with existing separation technology. Two applications have been selected for study. The first is liquid hydrocarbon separations where ultrafiltration membranes are used to separate low-molecular-weight solvents from high-molecular-weight oils. The second application involves CO₂/CH₄ separation for natural gas treating, enhanced oil recovery, and landfill gas. For both applications, a review of the literature is presented along with new data on membrane permeation and expected energy savings associated with the use of membrane technology.

372 (DOE/ID/12425-1) **Energy-efficient membrane separations in the sweetener industry. Final report.** Ray, R.J. Bend Research, Inc., OR (USA). 14 Feb 1986.

70p. DOE Contract AC07-82ID12425. Order Number DE86013370. Source: NTIS, PC A04/MF A01; GPO Dep.

Objective was to investigate the use of membrane processes as energy-efficient alternatives to certain conventional separation processes now in use in the corn-sweetener industry. Three applications of membranes were studied during the program: the concentration of corn steep water by reverse osmosis; the concentration of dilute wastes, called "sweetwater," by a combination of reverse osmosis and countercurrent reverse osmosis; and the enrichment of corn syrup in fructose by a process involving selective complexation of fructose by membrane filtration. Laboratory experiments were conducted for all three applications, and the results were used to conduct technical and economic analyses of the process. Calculations indicate that the use of reverse osmosis in combination with conventional mechanical-vapor-recompression evaporation to concentrate steep water, offers savings of a factor of 2.5 in capital costs and a factor of 4.5 in operating costs over currently used evaporation alone. In the concentration of sweetwater by reverse osmosis and countercurrent reverse osmosis, capital costs would be about the same as those for evaporation, but operating costs would only be about one-half those of evaporation. For the fructose-enrichment scheme, preliminary results indicate that the savings in energy alone for the membrane process would be about \$0.01/lb of sweetener produced by the process, or about \$20 million annually, for the corn-sweetener industry.

373 (DOE/ID/12473-1) **Assessment of potential energy savings in fluid separation technologies: technology review and recommended research areas. Final report.** Bravo, J.L.; Fair, J.R.; Humphrey, J.L.; Martin, C.L.; Seibert, A.F.; Joshi, S. Texas Univ., Austin (USA). Center for Energy Studies. 31 Dec 1984. 277p. DOE Contract AS07-83ID12473. Order Number DE85013839. Source: NTIS, PC A13/MF A01; GPO Dep.

Five fluid mixtures separation technologies were identified with potential for achieving significant energy savings in the oil and gas, chemical and paper industries if implemented in lieu of current separation practices. State-of-the-art evaluations are presented for each separation technology. 71 figs., 44 tabs. (PSB)

374 (DOE/ID/12473-2) **Alternative separation processes for fluid mixtures.** Bravo, J.L. Texas Univ., Austin (USA). Center for Energy Studies. May 1986. 82p. DOE Contract AS07-83ID12473. Order Number DE86013371. Source: NTIS, PC A05/MF A01; GPO Dep.

This report is a collection of studies on the energy-saving potential of some separation technologies in the process industries. It is a compilation of preliminary information that was developed during the execution of another DOE-sponsored project. Three industrially important fluid mixtures were studied: ethanol-water, air, and ethylbenzene-styrene. Current technology for the separation of these mixtures involves distillation as the main step. The minimum energy requirements for various fluid separations are presented and applied to alternative separation schemes for the three processes under consideration. Results showed that, in the future, improving distillation and combining it with alternative separation processes will probably prove more successful than outright displacement of distillation. Results also showed that, among the alternatives studied, membrane and adsorption technologies show excellent potential for energy savings, but their application is limited by materials problems and lack of engineering design data.

375 (DOE/ID/12553-1) **Separation, fractionation, concentration and drying of food products: Technology progress report, October 1, 1984-March 3, 1987.** Rose, W.W.; Pedersen, L.D.; Merlo, C.A.; Brewbaker, P.L. National Food Processors Association, Dublin, CA (USA). Nov 1987. 119p. DOE Contract AC07-84ID12553. Order Number DE88006269. Source: NTIS, PC A06/MF A01; GPO Dep.

This report describes the first and second phases of a three phase project, the object of which is to develop energy efficient separation, concentration, and drying processes for food products, especially juice products, in order to reduce energy requirements and their associated costs for processing, preservation, and transportation. Presently in juice processing, much water is eliminated through evaporation. However, there are significant limits to the current evaporation technology. If, however, the juice could be separated, prior to evaporation, into liquid and solid fractions, and the liquid concentrated further, the containerization and transportation costs could be significantly reduced. Separation methods investigated in this project are: vacuum filtration, centrifugation, and crossflow microfiltration.

376 (DOE/ID/12553-2) **Separation, fractionation, concentration and drying of food products: Final report, March 4, 1987-March 31, 1988.** Merlo, C.A.; Rose, W.W.; Pedersen, L.D.; Brewbaker, P.L. National Food Processors Association, Dublin, CA (USA). Mar 1988. 84p. DOE Contract AC07-84ID12553. Order Number DE89004638. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

This project studied energy efficient processes for separation, fractionation, concentration, drying, and recombination of food products, in order to reduce energy requirements for processing, preservation, and transportation. The project had three phases. In the laboratory-scale phase, results of which are summarized in this report, tomato puree was separated by three methods: conventional vacuum filtration, centrifugation, and crossflow microfiltration to produce pulp and serum. Three methods of recombination were examined: homogenizing, stomacher blending, and static (in-line) mixing. Satisfactory recombined purees were obtained. In addition, after centrifugation, the pulp was rinsed producing rinsed-pulp, and the rinse water was added to the serum producing rinse/serum. The rinse/serum was concentrated by evaporation. This was recombined with the rinsed-pulp and water producing satisfactory puree. 11 refs., 18 figs., 18 tabs.

377 (DOE/ID/12553-3) **Separation, fractionation concentration and drying of food products: Addendum report, April 1, 1988-April 30, 1989.** Merlo, C.A.; Rose, W.W.; Pedersen, L.D. National Food Processors Association, Dublin, CA (USA). Aug 1989. 81p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-84ID12553. Order Number DE90001036. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

Tomato juice fractions and paste produced in an On-Site Study were subjected to a storage study. The fractions and paste were evaluated initially before storage, made into control and recombined purees, and the purees were evaluated. The purees were similar in viscosity, differed somewhat in color and syneresis. The paste and concentrated serum were stored 3 months at 40, 70, 90 F; the pulp was frozen. After storage, control and recombined purees were made; the purees made from 70 F stored paste or serum were thermally processed. These thermally processed purees were stored 3 months at 40, 70, 90 F. After storage, the recombined purees stored at 70 and 90 F showed a viscosity

loss within 0.1–0.3 cm of the viscosity loss of the control purees. 19 refs., 16 figs., 20 tabs.

378 (DOE/ID/12608–2-Vol.1) **Design and control of energy efficient drying processes with specific reference to foods: Volume 1, Literature review: Final report, September 23, 1985 to April 23, 1987.** Franzen, K.; Liang, H.; Litchfield, B.; Murakami, E.; Nichols, C.; Waananen, K.; Miles, G.; Okos, M. Purdue Univ., Lafayette, IN (USA). Apr 1987. 142p. DOE Contract FG07-85ID12608. Order Number DE88008725. Source: NTIS, PC A07/MF A01; GPO Dep.

A literature review has been completed and pertinent data from previous food drying studies, information on available and developing sensors for control and monitoring of dryers, production rates and values of various food products has been obtained. This information was used to select the food products to be studied. The areas reviewed in detail include (a) Fundamental Drying Studies, (b) Quality of Foods, (c) Viscoelastic Properties of Grains and Food, (d) Thermal Properties of Porous Foods, (e) Energy Efficient Dryer Designs and (f) Density Independent Moisture Measurement.

379 (DOE/ID/12608–2-Vol.2) **Design and control of energy efficient drying processes with specific reference to foods: Volume 2, Food property studies and recommendations: Final report, September 23, 1985–April 23, 1987.** Franzen, K.; Liang, H.; Litchfield, B.; Murakami, E.; Nichols, C.; Waananen, K.; Miles, G.; Okos, M. Purdue Univ., Lafayette, IN (USA). Apr 1987. 209p. DOE Contract FG07-85ID12608. Order Number DE88008734. Source: NTIS, PC A10/MF A01; GPO Dep.

Research on the drying of food, with particular emphasis on energy conservation, is presented. Topics discussed include: pasta drying, viscoelastic properties, food quality, thermal conductivity, microwave moisture measurements, and prediction of breakage in corn. (CBS)

380 (DOE/ID/12619–1) **Tubeless evaporation process development: Final report.** Schroeder Process Corp., Santa Ana, CA (USA). Dec 1987. 179p. DOE Contract AC07-86ID12619. Order Number DE88006289. Source: NTIS, PC A09/MF A01; GPO Dep.

A tubeless evaporation process which has the potential to combine the advantage of both evaporation and freezing processes, without their disadvantages is being developed. The TEP is capable of concentrating process solutions of such things as sugar, caustic soda, salt, sodium sulfate, black liquor from the pulp and paper industry, cooling tower blowdown, "spent" pickling liquor (sulfuric acid) from the steel industry, and nitric acid with potential energy savings of half to three-quarters of the energy required by conventional evaporators, with about half of the capital and maintenance cost. It has similar potential for the production of fresh water from seawater. The process uses working fluids (WF's) at their freezing point to effect direct contact heat exchange. The purpose of this project was to find additional and lower cost WF's in the laboratory, to obtain sizing information for the major equipment for an economic evaluation and a pilot plant design in a bench scale plant, and to perform the economic evaluation, and the pilot plant design and cost estimate. 6 refs., 37 figs., 7 tabs.

381 (DOE/ID/12621–2) **Electroacoustic dewatering of food and other suspensions: Phase 2.** Kim, B.C.; Zelinski, M.S.; Criner, C.L.; Senapati, N.; Muralidhara, H.S.; Jirjis, B.; Beard, R.E.; Cummings, C.; Chauhan, S.P. Battelle Columbus Div., OH (USA). 31 May 1989. 239p. Sponsored by USDOE, Washington, DC (United States). DOE Contract

AC07-85ID12621. Order Number DE90000742. Source: NTIS, PC A11/MF A01 - OSTI; GPO Dep.

The food processing industry is a large user of energy for evaporative drying due to limited effectiveness of conventional mechanical dewatering machines. Battelle's Electroacoustic Dewatering (EAD) process improves the performance of mechanical dewatering machines by superimposing electric and ultrasonic fields. A two phase development program to demonstrate the benefits of EAD was carried out in cooperation with the food processing industry, the National Food Processors Association (NFPA) and two equipment vendors. In Phase I, laboratory scale studies were carried out on a variety of food suspensions. The process was scaled up to small commercial scale in Phase II. The technical feasibility of EAD for a variety of food materials, without adversely affecting the food properties, was successfully demonstrated during this phase, which is the subject of this report. Two Process Research Units (PRUs) were designed and built through joint efforts between Battelle and two equipment vendors. A 0.5-meter wide belt press was tested on apple mash, corn fiber, and corn gluten at sites provided by two food processors. A high speed citrus juice finisher (a hybrid form of screw press and centrifuge) was tested on orange pulp. These tests were carried out jointly by Battelle, equipment vendors, NFPA, and food processors. The apple and citrus juice products were analyzed by food processors and NFPA. 26 figs., 30 tabs.

382 (DOE/ID/12626–2) **Ordered ceramic membranes: Annual progress report, March 1987–May 1988.** Anderson, M.A. (Wisconsin Univ., Madison, WI (USA)); Hill, C.G. Jr. Wisconsin Univ., Madison, WI (USA). Aug 1988. 67p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AS07-86ID12626. Order Number DE89009027. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

The properties of ceramic membranes prepared via the sol-gel process can be controlled by varying the suspension and interfacial chemistries of the precursor sols. The Year 1 Progress Report described the effects of changing several variables. This report presents results on the effect of sintering conditions on the properties of unsupported titania membranes. A description of the effect of phosphate addition on the preparation of alumina and titania membranes is also included, although this study is not yet complete. The preparation of silica membranes is also discussed. This second year of work has also included characterization of supported membranes, membranes which have been deposited on a support and then sintered to fix the membranes in place. These studies have involved measurements of the permeability of the supported membranes to various aqueous feed streams utilizing a laboratory scale test apparatus. PH and temperature effects on the flux of water through the membranes is described. Permselectivity measurements utilizing solutions of polyethylene glycol (PEG), bovine serum albumin, and cheesy whey, are also discussed. Because dissolution of membranes at extreme pH values can be a major problem in potential industrial applications, the stability of both unsupported and supported membranes at different pH values was determined. 9 refs., 22 figs.

383 (DOE/ID/12626–4) **Ordered ceramic membranes: Annual progress report, May 1988–May 1989.** Anderson, M.A.; Hill, C.G. Jr. Wisconsin Univ., Madison, WI (USA). Jun 1989. 37p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AS07-86ID12626. Order

Number DE89017426. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

As in the first two years of this project, research during the third year covered three major areas: preparation and characterization of supports for the membranes; preparation and characterization of the membranes themselves; and determination of the behavior of systems in which the membranes are attached to supports. The primary interest in supports was to develop formulations which would provide more reproducible permeabilities (flux of water through the support). Several different clay formulations have been shown to give quite reproducible permeabilities, with the actual permeability varying by nearly an order of magnitude among the different formulations. Supports with smoother surfaces were also fabricated, but rejection studies which compared membranes coated on these supports to membranes coated on rougher supports did not show any significant differences. Ceramic membranes have been prepared which are composed of three different materials: alumina, titania and silica.

384 (DOE/NBM-1003) **Energy efficient fertilizer production with the pipe-cross reactor: Executive briefing report, Technology transfer.** Pacific Northwest Lab., Richland, WA (USA). 1982. 38p. DOE Contract AC06-76RL01830. Order Number DE88015214. Source: NTIS, PC A03.

A new technology that consumes less energy, produces a superior product, provides increased operating flexibility, and improves a production efficiency is available to manufacturers of granular NPKS fertilizers. The pipe-cross reactor, developed by the Tennessee Valley Authority in a project sponsored by the US Department of Energy, can save \$1 to \$2 per ton in production costs as a result of energy savings for steam and drying. This annual energy savings ranges from \$50.00 to \$100.00 per year for each plant, depending on annual production and operating conditions. The estimated installed cost of the pipe-cross reactor for most plants is about \$70.00. A conservative estimate of the payback period is approximately 1 year. Additional benefits make the pipe-cross reactor even more appealing. The unit allows use of less expensive raw materials and easier-to-handle liquid raw materials, increases productivity, reduces pollution, reduces nitrogen losses, and produces a superior product. The pipe-cross reactor, which fits into the granular drum of a conventional ammoniation-granulation system, is a chamber where water, ammonia, and acids react forming a hot melt. The hot melt is sprayed onto a bed of solids in the granulator: pressure is reduced, and the moisture contained in the melt flashes off as steam. Pellets are formed in the same manner as in the conventional process, except that little or no steam is added and a drier product is produced greatly reducing or eliminating the need for drying. Plants operating with a conventional ammoniation-granulation system with or without the preneutralizer process can be retrofitted with a pipe-cross reactor. Twenty-two US fertilizer producers already have installed the units and have reported recovery of their investment.

385 (DOE/NBM-1082) **Membranes: Separation and drying processes: Technical briefing report, technology transfer.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Sep 1987. 16p. Order Number DE88017288. Source: NTIS, PC A03/MF A01; GPO Dep.

Membrane technology now being developed for separation and drying applications will save energy in industrial

processes, both by reducing the amount of energy used and by recovering energy that would normally be lost. A new membrane separation process that is projected for use in the corn sweetener industry could preconcentrate waste water streams, reducing the need for conventional evaporation. Net energy savings may be as much as 50%. A membrane system proposed for drying applications could be combined with vapor recompression to recover energy that is normally lost when water vapor in dryer exhaust streams is vented to the atmosphere. Preliminary tests indicate this membrane process may recover 30% of the energy contained in the latent heat of the water vapor. Under the sponsorship of the US Department of Energy's Office of Industrial Programs, Bend Research, Inc., of Bend, Oregon, investigated the technical and economic feasibility of these two membrane processes. 9 refs.

386 (DOE/NBM-2013353) **Closed-cycle textile dyeing: full-scale hyperfiltration demonstration (design).** La France Industries, SC (USA); Carre, Inc., Seneca, SC (USA). [nd]. 76p. Order Number DE82013353. Source: NTIS, PC A05/MF A01.

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Hyperfiltration (HF) is a membrane separation technique that has been used successfully in desalination of natural water. Because energy, process chemicals and water are discharged from industrial processes in large quantities, the application of various types of membranes to recover through recycle has been studied in a series of government sponsored research projects. The results of the research led to the current project of joining a full scale dynamic membrane HF system with an operating dye range into an integrated production unit. The dye range is a multi-purpose unit having a variety of effluents from preparation and dyeing of textile fabric. This report describes the design and construction of the hyperfiltration equipment; presents and evaluates data from one year of operation; gives costs for equipment, installation and operation, and credits for savings due to recycle; and describes the primary objectives of an 18 month project continuation.

387 (DOE/OR/21400-T352) **An economic and energy evaluation of the replacement of conventional technology with continuous chromatography in the production of high-fructose sugar.** Byers, C.H. (Oak Ridge National Lab., TN (USA)); Holmes, J.M. Oak Ridge National Lab., TN (USA). Oct 1988. 63p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC05-84OR21400. Order Number DE89010393. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

As a major portion of a program to assess the energy and economic advantages of using the concept of continuous chromatography as a replacement technology for the separation portion of a number of technologies, a representative the burgeoning biotechnology area was sought, where there is significant developmental activity, and one which represents a sufficiently large annual production to have a significant energy impact on a national scale. The production of high fructose sugars was selected as the candidate system which met these criteria. A trend in the sugar industry is the replacement of sucrose with fructose from corn. Fructose is considerably sweeter than sucrose per unit weight and thus lower in calories for equivalent sweetness. The process which begins with corn starch leads high-fructose corn syrup (HFCS), a mixture of fructose, glucose and higher-molecular-weight materials. HFCS is produced in a sequence of five principal operations. The three of direct

interest here are breakdown of the hydrolyzate polymer to individual glucose molecules using glucoamylase enzyme (saccharification), conversion of the glucose to a mixture of glucose and fructose, containing ~42% fructose, using immobilized glucose isomerase enzyme (isomerization); and separation unit. The primary function of the separation step is to concentrate the product to a 55% fructose, which accounts for about half the current output. Further there is a growing demand for 99+% fructose, from which crystalline material is made. This study focuses on the replacement of the separation unit, currently based on the SAREX process, with the continuous annular chromatograph (CAC), a recently-developed concept in multicomponent separations. 37 refs., 15 figs., 11 tabs.

388 (DOE/OR/21400-T357) **An economic and energy evaluation of the replacement of conventional technology with continuous chromatography in the dump leaching of copper ores.** Byers, C.H. (Oak Ridge National Lab., TN (USA)); Begovich, J.M.; Holmes, J.M. Oak Ridge National Lab., TN (USA); JMH Associates, Knoxville, TN (USA). Feb 1989. 239p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC05-84OR21400. Order Number DE89009038. Source: NTIS, PC A12/MF A01 - OSTI; GPO Dep.

The focus of this investigation is an economic and energy analysis of the implementation of CAC (continuous annular chromatography) to a large-scale industrial process. The technology selected is the dump leaching of copper and other metal values from low-grade copper ores. The portion of the presently used process to be placed in this case is the solvent extraction (SX) train in which the copper in solution is separated from the leach liquor from dump leaching. Instead of SX, we use the CAC for the separation and immediately obtain two advantages: (1) We can separate all of the metals such as iron, cobalt, and yttrium as well as copper in one operation, thus reducing the plant size and increasing the total metal values recovered; and (2) we exit with purer and more concentrated streams, thus improving the energy and economic picture. To scale the CAC, we have developed a model for the process which is implemented in ASPEN (Advanced System for Process Engineering). Modules for both the mass/energy balance part and the economics were implemented in ASPEN. ASPEN is a state-of-the-art process simulator which was originally written for the Department of Energy to be used in evaluating processes which are similar to the one we are considering. It allows one to perform the most complex material and energy balances automatically and to tie these in the same simulation to the economic evaluations of the process in question. Our implementation is an advanced version of the simulator, is distributed by JSD Associates.

389 (EGG-2282) **Membrane technology and applications: an assessment.** Leeper, S.A.; Stevenson, D.H.; Chiu, P.Y.C.; Priebe, S.J.; Sanchez, H.F.; Wikoff, P.M. EG and G Idaho, Inc., Idaho Falls (USA). Feb 1984. 135p. DOE Contract AC07-76ID01570. Order Number DE84009000. Source: NTIS, PC A07/MF A01; GPO Dep.

The literature on membrane technology and applications was reviewed and assessed. The report provides an overview of membrane technology, reviews potential applications of membrane technology in several industries, identifies technological deficiencies, and recommends areas for future research and development (R and D). Applications and R and D that will contribute to energy conservation and productivity improvements are emphasized. In the overview

of membrane technology, the basic concepts of membrane separations are discussed and the various membrane unit operations are described. Operations, membrane materials and equipment, and engineering aspects are also discussed. The industries considered in the review of membrane applications include mining, primary metal recovery, and fabricated metal products; food processing; textile and leather products; pulp and paper products; hydrocarbon (including synfuels) extraction and refining; the chemical process industries (inorganic chemicals processing, organic chemicals processing, pharmaceutical/biotechnology products); and medical and health care industry. In addition, applications in domestic, municipal, and commercial water treatment and energy conversion are reviewed. The assessment identifies promising applications for energy conservation and productivity improvement in various industries. Six generic process applications are identified: displacement of energy-intensive separations, recycle of sensible heat, recycle of materials, recovery of materials, chemical conversion, and energy conversion.

390 (EGG-EP-7635) **Research and development opportunities in the area of industrial drying.** Lawford, T.W.; Bradburn, H.F.; Evans, D.R.; Fullmer, K.S.; Naretto, C.J.; Reimann, G.A.; Semler, T.T.; Thompson, W.N. EG and G Idaho, Inc., Idaho Falls (USA). Feb 1988. 155p. DOE Contract AC07-76ID01570. Order Number DE88007714. Source: NTIS, PC A08/MF A01; GPO Dep.

This study has been conducted for the purpose of identifying research and development opportunities that, when implemented, would save energy in the area of industrial drying. Efforts were concentrated on eight industries, which use 85% of the total energy used for industrial drying. 7 figs., 5 tabs.

391 (EGG-M-89021) **Raman spectroscopy for on-line distillation process control.** Garrison, A.A. (Tennessee Univ., Knoxville, TN (USA), Measurement and Control Engineering Center); Muly, E.C.; Roberts, M.J.; Trimble, D.S.; Moore, C.F. EG and G Idaho, Inc., Idaho Falls, ID (USA). 26 Apr 1989. 9p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-76ID01570. (CONF-8910153-1: Annual meeting of the Instrument Society of America, Philadelphia, PA (USA), 22-27 Oct 1989). Order Number DE89016361. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

In order to effectively control distillation processes, it is necessary that the composition of the chemical mixtures within the column be measured directly or estimated from physical measurements. Direct on-line composition measurement has many advantages, but has been difficult in the past to implement with laboratory spectroscopic instrumentation. Raman spectroscopy is a highly selective method for composition determination which shows great promise for plant-wide on-line process measurements and control in these applications. The scientific and economic feasibility of using Raman spectroscopy has been demonstrated based on laboratory experiments utilizing a Fourier transform Raman spectrometer with a 1.06 micron near-infrared YAG laser. The use of near infrared excitation has been successful in minimizing fluorescence problems. A prototype instrument for on-line work is under development. Preliminary studies have employed fiber optics in laser excitation and Raman collection. This will allow the instrument to be placed in a control room. Optical multiplexers will be utilized to allow a single analyzer to determine concentrations at a number of points within the process. 4 figs.

392 (EGG-M-89322) **Membrane applications in the food industry: Survey and barriers.** Leeper, S.A.; Mohr, C.M.; Engalgau, D.E.; Charboneau, B.L. EG and G Idaho, Inc., Idaho Falls, ID (USA). 1989. 11p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC07-76ID01570. (CONF-8910272-1: 7. annual membrane technology/planning conference, Cambridge, MA (USA), 17-19 Oct 1989). Order Number DE90002042. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The Idaho National Engineering Laboratory (INEL), with the support and assistance of the US Department of Energy, Office of Industrial Programs (DOE-OIP), conducted a comprehensive assessment of membrane applications in the food industry. In the course of preparing the assessment, over 70 existing, developing, and potential membrane technology applications in the food industry were identified. In addition, barriers to expanded use of membrane technology in the food industry were identified for the purpose of defining future DOE-OIP research directions. In this paper, commercial, developing, and conceptual membrane applications in the food industry are briefly summarized and barriers to expanded use of membrane technology in the food industry are identified and discussed. 2 refs., 9 tabs.

393 (PNL-6552) **Separations innovative concepts: Project summary.** Lee, V.E. (ed.). Pacific Northwest Lab., Richland, WA (USA). May 1988. 114p. DOE Contract AC06-76RL01830. Order Number DE88009238. Source: NTIS, PC A06/MF A01; GPO Dep.

This project summary includes the results of 10 innovations that were funded under the US Department's Innovative Concept Programs. The concepts address innovations that can substantially reduce the energy used in industrial separations. Each paper describes the proposed concept, and discusses the concept's potential energy savings, market applications, technical feasibility, prior work and state of the art, and future development needs.

394 (PNL-SA-17216) **Proceedings of the International Energy Agency workshop on separation technologies.** Fassbender, L.L. (Pacific Northwest Lab., Richland, WA (USA)); Ashton, W.B.; Kinzey, B.R.; McDonald, S.C. Pacific Northwest Lab., Richland, WA (USA). Jul 1989. 89p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. (CONF-8801163-: International energy agency workshop on separation technologies, Coral Gables, FL (USA), 25-28 Jan 1988). Order Number DE89015172. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

An international separations workshop was held to review current international research and development (R and D) activities in separation technologies and to identify important R and D needs. Participants represented government, academia, and industry from Austria, Canada, the Netherlands, Sweden, the United Kingdom, the United States, and West Germany. Workshop activities included an identification of broad areas of R and D that are needed to advance the state of the art in separations science and technology, and some of the more focused, key research efforts needed. Participants, working in groups, developed more detailed R and D recommendations and identified example projects that address knowledge gaps in three major technology areas: (1) membranes, (2) drying, evaporation, distillation, dewatering, and freeze crystallization, and (3) solvent/supercritical fluid extraction. Also, as background for the technical discussions, members of each country represented at the workshop made formal presentations.

MATERIALS PROCESSING

Process Electrolysis

395 (CONS-5089-16) **Production of aluminum-silicon alloy and ferrosilicon and commercial purity aluminum by the direct reduction process. Final technical report, September 1, 1977-February 28, 1983.** Bruno, M.J. Aluminum Co. of America, Alcoa Center, PA. Feb 1983. 433p. DOE Contract AC01-77CS40079. Order Number DE83009361. Source: NTIS MF A01.

The objective of the program reported was to demonstrate technical feasibility of the Direct Reduction Process, including carbothermic reduction, alloy purification, and purification to commercial grade Al, in pilot plant units. Technical progress is reported in the areas of: burden preparation; reduction, including three alternative processes - blast furnace, blast-arc, and submerged arc; mathematical modeling of reduction systems; phase equilibria of variations on the Al-Si-O-C systems; alloy purification by fractional crystallization; recovery of commercial grade aluminum for Al-Si alloy by membrane electrolysis; and economic analysis of a commercial submerged arc process. For each of the reduction processes - blast furnace, blast-arc, and submerged arc - is given heat and mass balances, utilizing parts of the models developed, as well as descriptions of bench scale and pilot scale units and experimental results. (LEW)

396 (CONS-5089-16-App.) **Production of aluminum-silicon alloy and ferrosilicon and commercial purity aluminum by the direct reduction process. Final technical report, September 1, 1977-February 28, 1983.** Bruno, M.J. Aluminum Co. of America, Alcoa Center, PA. Feb 1983. 200p. DOE Contract AC01-77CS40079. Order Number DE83009362. Source: NTIS, PC A09/MF A01.

The objective of the program reported was to demonstrate technical feasibility of the Direct Reduction Process, including carbothermic reduction, alloy purification, and purification to commercial grade Al, in pilot plant units. Supportive calculations, drawings, analyses, etc. are given in the appendices. Additional data pertinent to the experimental work is indexed, including laboratory notebooks, internal reports, correspondence, design calculations, sketches, engineering drawings, subcontractor and consultant reports, and special reports from outside laboratories and companies. (LEW)

397 (DOE/CE/40545-9) **Raman spectroscopic study of molten salt electrolysis of light metals.** Yoon, S.Y. Massachusetts Inst. of Tech., Cambridge (USA). Dept. of Materials Science and Engineering. Jan 1985. 43p. DOE Contract FG07-82CE40545. Order Number DE85017480. Source: NTIS, PC A03/MF A01; GPO Dep.

Production of aluminum and magnesium by electrolysis of molten salts is studied with Raman spectroscopy. The I.G. process and aluminum chloride alkali chloride process were selected for the study. By measuring Raman spectra for the pure molten $MgCl_2$ it was confirmed that the experimental set-up is correct. Magnesium and aluminum were confirmed to exist in their electrolyte melts as tetrahedrally coordinated species. Raman spectra for $MgCl_2$ and $AlCl_3$ during electrolysis showed that it can be used as a reference for concentration change. Some result for the $AlCl_3$ electrolysis gave a clue to the problem of the occurrence of new species.

398 (DOE/CE/40545-20) **Diagnosis of sources of current inefficiency in industrial molten salt electrolysis cells by Raman spectroscopy: A topical report on chlorides: Topical report, June 1982-June 1987.** Sadoway, D.R. Massachusetts Inst. of Tech., Cambridge, MA (USA). Jun 1987. 191p. DOE Contract FG07-82CE40545. Order Number DE88005025. Source: NTIS, PC A09/MF A01; GPO Dep.

Contains thesis by Seok-Yeol Yoon: A spectroelectrochemical study of aluminum and magnesium electrolysis in molten chlorides.

Molten salt electrolysis, a very energy-intensive process, is used in the extraction of light metals. Aluminum production by the Hall process and magnesium production in the Dow and I.G. Farbenindustrie cells constitute the major commercial applications of metal electrowinning from molten-salt media at present. The energy input into the electrolysis cell is in the form of direct current, and the energy efficiencies in the magnesium or aluminum processes are only in the 30 to 40% range. Major energy reductions are achieved by reducing the cell voltage or by increasing the current efficiency. Goal of the research is to identify the sources of the current losses occurring in molten salt electrolysis. This research worked on the systems of I.G. Farben magnesium chloride and Alcoa smelting aluminum chloride processes. Raman spectra were measured and analyzed for each component or their mixtures of the electrolyte for magnesium and aluminum reduction in chloride melts. Raman measurements were also conducted on the melts of industrial composition for aluminum and magnesium electrolysis. In laboratory-scale cells which imitated industrial practice, Raman spectra were measured in situ during electrolysis in attempts to identify the streamers, coloration of electrolyte, and any subvalent species. They were known to occur only during electrolysis, and they have been reported to be possible current losses. Cyclic voltammetry was conducted to obtain information about the generation of subvalent species which were not detected by Raman measurement. These were thought to be kinetic entities present only during electrolysis. Results of Raman spectroscopy and electrochemistry of magnesium and aluminum reduction from molten chloride bath are presented. The results would be useful to establish the basis for the study of electrolysis of aluminum from molten fluoride media. 119 refs., 66 figs.

399 (DOE/CE/40545-25) **Diagnosis of sources of current inefficiency in industrial molten salt electrolysis cells by Raman spectroscopy.** Sadoway, D.R. Massachusetts Inst. of Tech., Cambridge (USA). Materials Processing Center. 29 Jul 1988. 57p. DOE Contract FG07-82CE40545. Order Number DE89004637. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

The purpose of this project was to employ Raman spectroscopy in the study of industrial molten salt electrolysis cells. The objective was to improve the understanding of the chemistry and electrochemistry of the relevant melt systems and, in turn, of energy loss mechanisms in the industrial processes. On this basis new ways to improve the energy efficiency of these industrial reactors might be identified. The research plan has several principal elements. First, there was the design and construction of laboratory scale representations of industrial molten salt electrolysis cells that would at the same time serve as spectrocells. Secondly, there was the mastery of the preparation of the molten salt electrolytes, what in industry is called the "front end." Thirdly, there was the adaptation of commercially available Raman instrumentation in order to facilitate the proposed

studies. It is the nature of the specimens that so dramatically distinguished this work from conventional Raman studies for which commercial instrumentation is designed: first, the laboratory scale electrolysis cells are large compared to typical spectrocells; and secondly, the cells operate at, what for Raman studies are, extremely high temperatures. 4 refs., 2 figs.

400 (DOE/ID-10208) **Techno-economic assessment of a carbothermic alumina reduction process.** EG and G Idaho, Inc., Idaho Falls (USA); Little (Arthur D.), Inc., Cambridge, MA (USA). Jul 1988. 90p. DOE Contract AC07-76ID01570. Order Number DE88015623. Source: NTIS, PC A05/MF A01; GPO Dep.

Arthur D. Little, Inc., undertook an assessment of a process for the carbothermic reduction of alumina based on prior work and a flowsheet developed by a technical committee for the US Department of Energy. This report documents the technoeconomic assessment which identified potentially viable subprocess steps and their economic viability based on past research findings. Economic comparisons show the carbothermic process has the potential for lower capital and operating costs than the conventional Hall cell. Potential energy savings would be substantial through the use of carbothermic reduction of alumina. However, several of the selected subprocesses have not been reduced to practice, and there exists an opportunity to further improve the process economics through research and development. 11 refs., 8 figs., 11 tabs.

401 (DOE/ID-10208-App.L) **Techno-economic assessment of a carbothermic alumina reduction process: Appendix L, Optimistic cost estimates for carbothermic reduction.** Little (Arthur D.), Inc., Cambridge, MA (USA). Jan 1989. 36p. DOE Contract AC07-76ID01570. Order Number DE89008052. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

A techno-economic assessment of a process for the carbothermic reduction of alumina based on prior work and a flowsheet developed by a technical committee for the US Department of Energy is described. Estimates indicated that one could expect operating costs for a new carbothermic plant at \$0.44-\$0.45/lb of aluminum vs. \$0.52 in a conventional plant using Hall cells based on conditions prevailing in mid-1988. This savings may not be sufficient to interest a new producer for new plant construction in the US considering the availability of aluminum from overseas facilities favorably situated to produce aluminum in the cost range of \$0.35-\$0.40/lb. The objective of this effort was to undertake optimistic estimates for capital investments and operating costs for the carbothermic reduction of alumina based on the flowsheet described in the body of this report. Estimates were to be of preliminary nature based on engineering judgment, discussions with industry personnel, and equipment suppliers. The results are presented here in Appendix L. The body of report is referenced continuously throughout the following text. Three Addenda are included at the end of Appendix L. 5 refs., 1 fig., 7 tabs.

402 (DOE/ID/12380-6) **Investigation of materials for inert electrodes in aluminum electrodeposition cells. Quarterly report, January-March 1984.** Massachusetts Inst. of Tech., Cambridge (USA). Jul 1984. 6p. DOE Contract FG07-83ID12380. Order Number DE84015036. Source: NTIS, PC A02/MF A01; GPO Dep.

Three compositions in the NiO-Fe₂O₃ system have been tested in the laser-heated floating zone apparatus. Acquired

literature has been used to generate the $\text{NiO-Fe}_2\text{O}_3$ phase diagram and begin a list of possible dopant additions to this system. Construction of the bench scale Hall cell has been completed. The reference electrode has been further developed. The TiB_2 synthesis program has concentrated on issues related to the volatilization of liquid reactants and on procedures necessary to do experiments safely.

403 (DOE/ID/12380-18) **Investigation of materials for inert electrodes in aluminum electrodeposition cells.** Haggerty, J.S.; Sadoway, D.R. Massachusetts Inst. of Tech., Cambridge, MA (USA). 14 Sep 1987. 250p. DOE Contract FG07-83ID12380. Order Number DE88003380. Source: NTIS, PC A11/MF A01; GPO Dep.

Work was divided into major efforts. The first was the growth and characterization of specimens; the second was Hall cell performance testing. Cathode and anode materials were the subject of investigation. Preparation of specimens included growth of single crystals and synthesis of ultra high purity powders. Special attention was paid to ferrites as they were considered to be the most promising anode materials. Ferrite anode corrosion rates were studied and the electrical conductivities of a set of copper-manganese ferrites were measured. Float Zone, Pendant Drop Cryolite Experiments were undertaken because unsatisfactory choices of candidate materials were being made on the basis of a flawed set of selection criteria applied to an incomplete and sometimes inaccurate data base. This experiment was then constructed to determine whether the apparatus used for float zone crystal growth could be adapted to make a variety of important based melts and their interactions with candidate inert anode materials. The third major topic was Non Consumable Anode (Data Base, Candidate Compositions), driven by our perception that the basis for prior selection of candidate materials was inadequate. Results are presented. 162 refs., 39 figs., 18 tabs.

404 (DOE/ID/12467-2) **Physical chemistry of carbothermic reduction of alumina.** Frank, R.A. Massachusetts Inst. of Tech., Cambridge (USA). Sep 1985. 181p. DOE Contract FG07-83ID12467. Order Number DE89004713. Source: NTIS, PC A09/MF A01 - OSTI; GPO Dep.

Production of aluminium, by means of carbothermic reduction of alumina, is discussed. By employing a solvent metal bath to absorb the alumina metal, carbothermic reduction of alumina was accomplished at temperatures 300°C lower than the temperatures reported in the literature. Reduction occurred without the formation of intermediate compounds and without the high volatilization of aluminum bearing species. Reduction of alumina immersed in a solvent bath appeared to be rate limited by chemical reaction control. The rates seemed to be a function of the activity of aluminum in the solvent metal bath. Reduction of alumina particles, above the surface of the bath, seemed to occur via vapor transport with carbon in the particles or in the crucible walls. Mass transport in the gas phase appeared to be rate limiting. The rates seemed to be a function of the distance separating the alumina and carbon sources. With both submerged alumina and alumina particles, increasing the surface area of the alumina increased the rate of reduction. 58 refs., 65 figs., 9 tabs.

405 (DOE/ID/12467-3) **Physical chemistry of carbothermic reduction of aluminum: Final report.** Elliott, J.F. Massachusetts Inst. of Tech., Cambridge, MA (USA). Dept. of Materials Science and Engineering. 16 Jun 1989.

180p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG07-83ID12467. Order Number DE89015201. Source: NTIS, PC A09/MF A01 - OSTI; GPO Dep.

A program of study of carbothermic reduction of aluminum was undertaken to investigate the underlying physical chemistry of reactions and processes. The primary goal of the research was to establish the physicochemical basis by the use of which it may be possible to develop schemes for the production of aluminum by direct carbothermic reduction, thus avoiding the use of electrochemical means such as is exemplified by the Hall-Heroult process. One task of the program was to propose one or more possible schemes, and a specific challenge in the investigation was to determine whether or not a process based on the counter-current shaft furnace could possibly be practical for the production of aluminum. In such a furnace, combustion of a carbonaceous fuel would provide heat required in the process, and carbon would also serve as the reducing agent as is the case for the production of crude iron in the iron blast furnace. 15 refs., 22 figs., 24 tabs.

406 (DOE/ID/12655-1) **Cerium oxide coated anodes for aluminum electrowinning: Topical report, October 1, 1986-June 30, 1987.** Walker, J.K. ELTECH Research Corp., Fairport Harbor, OH (USA). Dec 1987. 151p. DOE Contract AC07-86ID12655. Order Number DE88006572. Source: NTIS, PC A08/MF A01; GPO Dep.

Because of the cost of building and maintaining a carbon anode plant and the energy penalties associated with the use of carbon anodes in the production of aluminum, the use of inert anodes has long been proposed. Various cermet anodes have been investigated. In this paper, tests on a material, cerium oxyfluoride (CEROX), deposited in situ as an anode, are reported. (JDH)

407 (DOE/RL-88-25) **Cost effectiveness study for retrofitting American aluminum production plants with inert anode-cathode systems.** Galambas, J.W.; Eitel, G.L.; Payne, J.R. Stone and Webster Engineering Corp., Boston, MA (USA). Nov 1988. 119p. DOE Contract AC06-87RL11313. Order Number DE89002805. Source: NTIS, PC A06.

The present Hall-Heroult aluminum smelters utilize carbon anodes and cathodes to pass a current through an alumina/cryolite melt to produce elemental aluminum. Since about 1/2 kg of carbon is consumed for every kg of aluminum produced, the carbon anodes must be replaced about every eighteen days in the prebake cells. In addition the undulating surface to the molten aluminum, due to magnetic fields and escaping anode gas, requires that the anode-cathode distance (ACD) be greater than 4.0 cm. This large ACD causes the cell to be less energy efficient because the resistance heating in the electrolyte converts electrical energy to thermal energy without producing aluminum. The combination of a dimensionally stable anode with a drained and wetted cathode would permit reducing the ACD and produce a substantial increase in cell productivity at a lower specific electric energy consumption. The objective of this study is to determine the cost effectiveness of retrofitting American aluminum production plants with inert anode-cathode systems. 1 fig., 5 tabs.

408 (PNL-6593) **Immersion tests of TiB_2 -based materials for aluminum processing applications.** Schilling, C.H.; Graff, G.L. Pacific Northwest Lab., Richland, WA

(USA). Jul 1988. 51p. DOE Contract AC06-76RL01830. Order Number DE88017293. Source: NTIS, PC A04/MF A01; GPO Dep.

This report summarizes molten Al immersion tests conducted under the Stable Cathode Development task to evaluate the microstructural behavior of TiB_2 -based materials. Four types of TiB_2 -based materials were evaluated before and after nonpolarized exposure to molten Al at temperatures encountered in Hall-Heroult cells. Three of the materials, TiB_2 -graphite (TiB_2 -G) composites, TiB_2 -aluminum nitride (AlN) composites, and high-purity TiB_2 sintered from halide plasma reduction powders, were chosen because they are prime candidates for Al-wetted cathode applications, based on a literature review (Schilling, Hagen, and Hart 1987) and previous experimental research at PNL (Hart et al. 1987). Ceramic fiber mesh coated with chemical-vapor-infiltrated TiB_2 was also evaluated, based on the expected wear resistance of the high-purity TiB_2 coatings and the possibility of designing advanced cells with complex cathode shapes that are not possible attack mechanisms that are related to chemical reactions between molten Al and cathode constituents.

409 (PNL-6594) **Laboratory testing of TiB_2 -based cathodes for electrolytic production of aluminum.** Schilling, C.H. Pacific Northwest Lab., Richland, WA (USA). Jul 1988. 50p. DOE Contract AC06-76RL01830. Order Number DE88016180. Source: NTIS, PC A03/MF A01; GPO Dep.

Experimental research was performed to evaluate TiB_2 -based cathodes, which may be used for retrofitting existing commercial Hall-Heroult cells. Candidate cathode materials and retrofit designs were analyzed in laboratory-scale electrolysis tests and nonpolarized immersion tests in molten Al. The cathode materials and cathode attachment designs were selected based on a literature review (Schilling, Hagen, and Hart 1987) and previous experimental research at the Pacific Northwest Laboratory (Hart et al. 1987). 40 refs., 16 figs., 2 tabs.

410 (PNL-6746) **Inert electrodes program: Annual report, Fiscal year 1987.** Koski, O.H.; Marschman, S.C.; Schilling, C.H.; Windisch, C.F. Pacific Northwest Lab., Richland, WA (USA). Dec 1988. 120p. DOE Contract AC06-76RL01830. Order Number DE89005696. Source: NTIS, PC A06/MF A01 - OSTI; GPO Dep.

The Inert Electrodes Program is being conducted at the Pacific Northwest Laboratory (PNL) for the US Department of Energy (DOE), Office of Industrial Programs (OIP). The purpose of the program is to develop long-lasting, energy-efficient anodes, cathodes, and ancillary equipment for Hall-Heroult cells used by aluminum industry. The program is divided into three tasks with the following objectives: Inert Anode Development - to improve the energy efficiency of Hall-Heroult cells by development of inert anodes; Stable Cathode Studies - to develop methods for retrofitting Hall-Heroult cells with TiB_2 -based cathode materials; and Sensor Development - to devise sensors to control the chemistry of Hall-Heroult Cells using stable anodes and cathodes. This Inert Electrodes Program annual report highlights the major technical accomplishment of FY 1987. The accomplishments are presented in the following sections: Management, Materials Development and Testing, Materials Evaluation, Stable Cathode Studies, and Sensor Development. 50 refs., 47 figs.

411 (PNL-6805) **Laboratory-scale testing of non-consumable anode materials: Inert Electrodes Program.** Marschman, S.C. Pacific Northwest Lab., Richland, WA (USA). Mar 1989. 37p. DOE Contract AC06-76RL01830. Order Number DE89010283. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Development of inert anode materials for use in the electrolytic production of aluminum is one of the major goals of the Inert Electrodes Program sponsored by the US Department of Energy, Office of Industrial Programs, at Pacific Northwest Laboratory. The objectives of the Materials Development and Testing Task include the selection, fabrication, and evaluation of candidate non-consumable anode materials. Research performed in FY 1987 focused primarily on the development and evaluation of cermets that are based on the two-phase oxide system NiO - $NiFe_2O_4$ and contain a third, electrically conductive metal phase composed primarily of copper and nickel. The efforts of this task were focused on three areas: materials fabrication, small-scale materials testing, and laboratory-scale testing. This report summarizes the development and testing results of the laboratory-scale testing effort during FY 1987. The laboratory-scale electrolysis testing effort was instrumental in partially determining electrolysis cell operating parameters. Although not optimized, NiO - $NiFe_2O_4$ -Cu-based cermets were successfully operated for 20 h in cryolite-based electrolytes ranging in bath ratios from 1.1 to 1.35, in electrolytes that contained 1.5 wt % LiF, and at conditions slightly less than Al_2O_3 saturation. The operating conditions that lead to anode degradation have been partly identified, and rudimentary control methods have been developed to ensure proper operation of small electrolysis cells using nonconsumable anodes. 11 figs., 1 tab.

Metals Initiative

Refer also to citation(s) 2, 38, 48, 503, 539, 547, 548, 555, 558, 565, 574, 591, 592, 593, 604

412 (ANL-9006375) **Electromagnetic continuous casting project: Final report.** Battles, J.E.; Rote, D.M.; Misra, B.; Praeg, W.F.; Hull, J.R.; Turner, L.R.; Shah, V.L.; Lari, R.J.; Gopalsami, N.; Wiencek, T. Argonne National Lab., IL (USA). Oct 1988. 154p. DOE Contract W-31109-ENG-38. Order Number DE89006375. Source: NTIS, PC A08/MF A01 - OSTI; GPO Dep.

This report describes the work on development of an electromagnetic casting process for steel, which was carried out at Argonne National Laboratory between January 1985 and December 1987. This effort was concerned principally with analysis and design work on magnet technology, liquid metal feed system, coolant system, and sensors and process controllers. Experimentation primarily involved (1) electromagnetic studies to determine the conditions and controlling parameters for stable levitation and (2) feed-system studies to establish important parameters that control and influence fluid flow from the liquid metal source to the caster. 73 refs., 91 figs., 11 tabs.

413 (ANL/CNSV-8) **Energy and materials flows in the fabrication of iron and steel semifinished products.** Darby, J.B. Jr.; Arons, R.M. Argonne National Lab., IL (USA). Aug 1979. 73p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A04/MF A01.

Includes appendix.

The flow of energy and materials in the fabrication of iron and steel semifinished products from molten metal is discussed. The focus is on techniques to reduce the amount of energy required to produce the typical products of integrated steel plants and iron and steel foundries. In integrated steel plants, if only 50% of the steel being cast were continuously cast, industry-wide energy consumption would be reduced by 6 to 15%. Further major energy savings could be achieved by increased use of by-product gases and regenerators in the various reheat operations. Finally, systems optimization studies to maintain the even flow of materials at full capacity should yield further improvements in energy efficiency. In foundry operations, alternate heating methods in forging operations and the use of no-bake molding and core materials should result in substantial energy savings. Studies of specific operations will suggest housekeeping changes to minimize wasted energy. These changes might include fixing heat leaks, reducing floor space requirements, improving temperature regulation, lowering working temperatures in some steel-forming operations, redesigning products, and minimizing scrap generation. There is also a need for new, energy conserving technologies. A good example would be the development of nondestructive testing to determine the existence, location, and size of defects in ingots at elevated temperatures. A second example is the need to reduce, through system studies, the large amount of scrap typical of foundry operations. Finally, computer control of steel mill operations (materials flow, furnace residence times, excessive heating or overheating, and full capacity utilization of all facilities at all times) deserves further study.

414 (CONF-881129-1) **Design and MHD stability for horizontal electromagnetic continuous casting.** Hull, J.R.; Lari, R.J.; Praeg, W.F.; Turner, L.R.; Rote, D.M. Argonne National Lab., IL (USA). 1988. 38p. DOE Contract W-31109-ENG-38. From International symposium on casting near net shape products; Honolulu, HI, US; November 13, 1988. Order Number DE88011191. Source: NTIS, PC A03/MF A01; GPO Dep.

High-frequency electromagnetic (EM) fields are proposed for the continuous casting of thin sheets of metal in a horizontal orientation. Major EM components of the caster include a picture-frame magnet, conducting side guards for positioning and side containment, and an eddy current return path that requires an electrode near the inlet and pickup brushes or roller near the outlet of the caster. An inductance stabilization method provides global stability, and magnetic flux compression provides local stability. Stability analysis and EM heating constraints indicate that frequencies in the range of 25-100 kHz are desirable to levitate 6-mm-thick steel. For systems without active feedback, a conducting screen is required below the metal with a gap between the screen and the molten metal no more than twice the metal thickness. Experiments using 10-kHz EM fields to statically levitate sheets of molten tin indicate that dominant MHD instabilities correspond to theory. 23 refs., 3 figs.

415 (CONF-881129-2) **Coolant system considerations for electromagnetic continuous casting of steel.** Misra, B.; Battles, J.E.; Shah, V. Argonne National Lab., IL (USA). 1988. 14p. DOE Contract W-31109-ENG-38. From International symposium on casting near net shape products; Honolulu, HI, US; November 13, 1988. Order Number DE88012070. Source: NTIS, PC A03/MF A01; GPO Dep.

The success of electromagnetic continuous casting of sheet steel will depend, to a large extent, on the development of a coolant system. The problem of removing heat

from the electromagnetic caster is compounded by the induced eddy current heating and limits imposed on the maximum mass flow rate of the coolant to avoid instability of EM levitation. Extensive theoretical and numerical analyses have been conducted to define the coolant requirements, to identify possible solution to these problems, and to select reference operating conditions. The results of these analyses on the coolant system requirements in terms of casting speed, magnet length, coolant mass flow rate, and characteristics of electromagnetic levitation show that augmentation of heat transfer by a factor of 2 to 3 would be necessary for an economically viable casting system. A study of the literature shows that this requirement can be easily met by a variety of methods. The results from using nomograms to study the effect of design and operating parameters on the electromagnetic casting process are also presented. 21 refs., 6 figs., 3 tabs.

416 (CONF-881129-4) **Stabilization of a molten-metal/coolant-gas interface by electromagnetic fields.** Hull, J.R.; Wiencek, T. Argonne National Lab., IL (USA). 1988. 17p. DOE Contract W-31109-ENG-38. From International symposium on casting near net shape products; Honolulu, HI, US; November 13, 1988. Order Number DE89004269. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

One of the critical issues affecting the cooling of a liquid-metal free surface with a high-velocity gas is the threshold gas velocity for wave formation. In electromagnetic levitation casting, the presence of high-frequency magnetic fields affects the onset and character of waves formed on the interface. A series of experiments was conducted in which nitrogen gas flowed at uniform velocity in a rectangular channel over the surface of a shallow horizontal dish containing liquid tin. The threshold gas velocity was determined when 10-kHz magnetic fields were applied to the surface. The magnetic fields were oriented both parallel and perpendicular to the gas flow. The threshold velocity increased as magnetic field strength increased. Substantial suppression of wave formation was observed with the magnetic field perpendicular to the gas flow, which contradicts previous theoretical predictions. 10 refs., 7 figs.

417 (DOE/CE-0256-1) **Steel Initiative: Development of superplastic steel processing: First annual progress report, March 15, 1988-March 15, 1989.** Sherman, D.H. (Caterpillar, Inc., Peoria, IL (USA)); Leach, J.M.; Hayes, A.F.; Lemsky, J.A.; Thomas, J.D.; Geiger, G.H.; Goldberg, A.; Strum, M.J.; Sherby, O.D. USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC (USA). Office of Industrial Programs. Sep 1989. 16p. Sponsored by USDOE, Washington, DC (United States). Order Number DE90003277. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The influence of aluminum content and thermomechanical processing steps on developing fine microstructures in ultra-high carbon steels (UHCS) was examined. The presence of aluminum results in ultrafine pearlitic structures without proeutectoid carbide networks, and greatly retards the eutectoid transformation kinetics. This retardation facilitates processing, which involves various combinations of DET and DETWAD steps. By applying the transformation kinetics as a guide, uniform through-thickness microstructures and superplastic properties are readily obtainable in thick sections. Superplasticity studies revealed that superplastic behavior is enhanced by aluminum additions and by increasing the amount of warm deformation during DETWAD processing.

This trend is attributed to a decrease in ferrite grain size and an increase in the ferrite-grain-boundary angle, and hence, to an increase in the ease of grain-boundary sliding. Studies on the cold-rolling characteristics of a UHCS-Al alloy reveal that it can be cold-rolled to 50% in the fully pearlitic condition without annealing, and to over 60% in the fully spheroidized condition. Room-temperature tensile properties were obtained on DETWAD-processed material. Identical properties were obtained in the rolling and transverse directions, which is attributed to the ultrafine, isotropic microstructure. Two trial strand-casting runs were initiated. Modified Fe-C diagrams incorporating aluminum and/or silicon additions were constructed. Materials have been processed both at LLNL and at Ladish for evaluation of their die-filling capability.

418 (DOE/CE/15227-5) **Evaluation of the KIDC [Kress Indirect Dry Cooling] system for coke oven pushing and quench tower emission control.** Vajda, S. S and E Consultants, Inc., Pittsburgh, PA (USA). 23 Sep 1988. 47p. DOE Contract FG01-85CE15227. Order Number DE89000002. Source: NTIS, PC A03 - OSTI.

The KIDC system, as observed at Granite City Steel on June 21, 1988, eliminates both pushing and quenching emissions. The coke is pushed into a container that is slightly wider and longer than the oven. The container is sealed at the oven door jamb, a guillotine door on the container is opened at the oven for the push and is closed and sealed after the push. A slightly negative pressure is maintained in the container during the push to prevent any pollutants from exiting into the oven or escaping to the atmosphere. The pushing force is only slightly higher than the normal push. No volatile gas mixtures are in the container box since oxygen is effectively absent. Coke yield is improved. Coke quality is improved similarly to existing dry quench systems. Since the system is environmentally sealed, some coking can take place in the container, ovens could be pushed slightly earlier, improving the production of the battery. The production of the blast furnace could be expected to improve, when the improved quality KIDC coke is used. 13 refs.

419 (DOE/CE/15285-T1) **Trials at Clemson University, SC of method for continuous casting of non-ferrous strips: Final report, June 28-August 6, 1987.** Palmer, F.M. Palmer (Forrest M.), Hilton Head, SC (USA). 16 Sep 1987. 16p. DOE Contract FG01-86CE15285. Order Number DE89004154. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

This project was an attempt to prove a process using a metered flow of molten metal onto two counter-rotating drums, near their apexes, which when semi-solidified and carried over to the gap between the two drums would form a thin continuous strip. Such a strip could be fortified with filaments or whiskers to manufacture metal matrix composites at lowered cost. Preliminary work with lead had demonstrated that relatively simple equipment and procedures would produce strip on one drum with an adequate surface on the side contacting the drum. It was, therefore, expected that two drum casting could be used to produce strip with an adequate surface on both sides and that the process could be adapted for aluminum using the same equipment. The original plan had been to carry out the work in the foundry facility at Pennsylvania State University during 1986. However, various delays occurred, and when the sponsoring professor, Dr. Alan B. Draper, died, it was decided to move the project to Clemson University, SC, which had aluminum

melting facilities, and to carry out the work during the summer of 1987. 4 figs.

420 (DOE/CE/15323-T5) **Effects of auxiliary heat treatments on flame-cutting procedures.** Somers, B.R. (Lehigh Univ., Bethlehem, PA (USA)); Smith, H.; Varughese, R.; Pense, A.W. Lehigh Univ., Bethlehem, PA (USA). 14 Apr 1989. 31p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG01-87CE15323. (ATLSS-89-08). Order Number DE89011827. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

One inch and two inch thick flame-cut samples of A588 steel were prepared using three different cutting treatments including cutting with auxiliary pre and post heat, cutting with auxiliary post heat only, and cutting with no auxiliary. The auxiliary heat was applied to the cutting process using a proprietary fixture designed by Roussey Associates. Each of these cutting treatments was applied at both a fast and a slow cutting speed. Surface hardness tests showed that within the same composition and thickness the hardest flame cut surfaces occurred at the faster cutting speed when no auxiliary heat was applied. The softest surface occurred at slow cutting speeds when both pre and post heat flames were applied. Microhardness traverses show the tempering effects of the auxiliary heat. Bend tests displayed for the one inch samples with pre and post heat, at both cutting speeds, none or only very slight cracking. Numerous slight cracks, however, were found when no auxiliary heat treatment was used. While pre and post heat treatments reduced the cracking severity in the two inch plate, numerous slight cracks were still seen, even at slow cutting speeds. 6 refs., 13 figs., 5 tabs.

421 (DOE/CE/15384-T1) **Textured substrate method for the direct continuous casting of steel sheet: Technical progress report No. 1.** Gaspar, T. Ribbon Technology Corp., Gahanna, OH (USA). 21 Oct 1988. 5p. DOE Contract FG01-88CE15384. Order Number DE89003290. Source: NTIS, PC A02/MF A01; GPO Dep.

The overall objective of this research project will be to demonstrate the feasibility of casting rapidly solidified steel strip 2 mm (0.080 in.) thick or greater using a textured chill block as described in US Patent No. 4,705,095, issued on November 10, 1987, to Ribbon Technology Corporation. The effect of melt overflow process variables on strip dimensions and uniformity will be investigated. Process variables include, but are not limited to, the following: super heat of the melt; wetting of substrate material; tundish design; and casting speed. Type 304 stainless steel and AISI 1020 standard carbon steel will be investigated.

422 (DOE/CE/15384-T4) **Textured substrate method for the direct continuous casting of steel sheet: Technical progress report No.4.** Gaspar, T. (Ribbon Technology Corp., Gahanna, OH (USA)). Ribbon Technology Corp., Gahanna, OH (USA). 14 Jul 1989. 7p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FG01-88CE15384. Order Number DE89015481. Source: NTIS, PC A02/MF A01 - OSTI; GPO Dep.

The overall objective of this research project will be to demonstrate the feasibility of casting rapidly solidified steel strip 2 mm (0.080 in.) thick or greater using a textured chill block as described in US Patent No. 4,705,095, issued on November 10, 1987, to Ribbon Technology Corporation. The effect of melt overflow process variables on strip dimensions and uniformity will be investigated. Process variables include, but are not limited to, the following: super heat of the

melt; wetting of substrate material; tundish design; and casting speed. Type 304 stainless and AISI 1020 standard carbon steel will be investigated.

423 (DOE/CS/40132-T1) **Assessment of energy requirements in proven and new copper processes.** Pitt, C.H.; Wadsworth, M.E. Utah Univ., Salt Lake City (USA). Dept. of Metallurgy and Metallurgical Engineering. 31 Dec 1980. 376p. DOE Contract AS07-78CS40132. Source: NTIS, PC A17/MF A01.

Energy requirements are presented for 13 pyrometallurgical and 8 hydrometallurgical processes for the production of copper. Front end processing, mining, mineral processing, gas cleaning, and acid plant as well as mass balances are included. Conventional reverberatory smelting is used as a basis for comparison. Recommendations for needed process research in copper production are presented.

424 (DOE/CS/40242-3) **Instrument system for automated inspection of hot steel slabs. Implementation study. Final report, February-December 1984.** Tromborg, E.T.; Hunter, G.D.; Steen, R.D.; Wilsey, O.; Bonfiglio, A.J.; Prellwitz, S.B. Honeywell, Inc., Minneapolis, MN (USA). Technology Strategy Center; United States Steel Corp., Monroeville, PA. Research Lab. 1985. 106p. DOE Contract FC07-79CS40242. Order Number DE86007471. Source: NTIS, PC A06/MF A01; GPO Dep.

This study is directed at finding the best site for installing, testing, and demonstrating an Operational Hot Steel Slab Surface Inspection System. It is concluded that the steel industry is not able at this time to participate in the development and demonstration of this system. (DLC)

425 (DOE/CS/40361-T4) **Hierarchy control for energy savings in the steel industry. Annual report, July 1, 1980-June 30, 1981.** Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. 1981. 272p. DOE Contract AS07-80CS40361. Order Number DE81027861. Source: NTIS, PC A12/MF A01.

The report presents details of work completed during the past year, that in progress, and that planned for the immediate future under each of five tasks by each research team. It also details the working contacts maintained with the steel industry, particularly with those companies who sponsor the project. Chapter I presents background information and explains the present DOE project. The next three chapters present individual reports by researchers. These are: Task I, Process Mathematical Models; Task II, Integrated Production Planning and Control; Task III, Functional Requirements for a Hierarchical Computer Control System; and Task IV, Man-Machine Interfaces. Chapter V includes reports on workshops, meetings, etc. Particular progress was noted in the dynamic model of the blast furnace, in the scheduling study in batch annealing, and in the man-machine interface areas. (MCW)

426 (DOE CS 40361-T4(Vol.1)) **Temperature control of a continuous, push-type, five-zone, slab-reheating furnace for minimum-fuel usage. Volume I. Text and Appendix A.** Purdy, D.J.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1981. 281p. DOE Contract AS07-80CS40361. Order Number DE81027869. Source: NTIS, PC A13/MF A01.

Thesis.

Investigations are made of temperature control for a continuous, five zone, pusher type, reheat furnace used to heat slabs from the slabbing mill up to the rolling temperature needed for the hot strip mill. Minimum fuel rates needed to

achieve required outlet temperature as a function of production rate are determined. A scheme is presented for carrying out the transition from one steady state operating level to another with a near minimum of fuel usage. A method for using this transition scheme on a process control computer is also presented. A specific objective of this thesis is to suggest a control algorithm for temperature control that minimizes the amount of every consumption during production while that production is subject to various process variations and constraints. Chapter II describes the slab reheat furnace model used for the study. A list of model embellishments and detected errors are presented in addition to the steady state energy balance analysis of the model itself. Chapter III presents the three separate cases of furnace operation and their steady state configurations for eight operating points. Transitions from one of these operating points to another operating point is discussed in Chapter IV. This serves as a basis for the control strategies discussed in Chapter V. The last chapter summarizes the results and conclusions of the study and suggests recommendations for future work. Appendix A includes additional simulation results supplementary to those presented within the report text. Model documentation and computer program listings are presented in Appendix B, C, and D, presented in Volume II. (MCW)

427 (DOE/CS/40361-T4(Vol.2)) **Temperature control of a continuous, push-type, five-zone, slab-reheating furnace for minimum-fuel usage. Volume II. Program (Appendices B, C, D).** Purdy, D.J.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1981. 313p. DOE Contract AS07-80CS40361. Order Number DE81027269. Source: NTIS, PC A14/MF A01.

Thesis.

Appendices B, C, and D are presented of a report on investigations for a continuous, five zone, pusher type, slab reheat furnace. Appendix B presents computer documentation of the slab reheating furnace program (33 subroutines). Appendix C presents the slab reheating furnace computer program. Appendix D presents the shape factor program (introduction and program limitations). (MCW)

428 (DOE/CS/40361-T5) **Production scheduling of annealing furnaces. Report No. 119.** Gau, C.F.; Moodie, C.L. Purdue Research Foundation, Lafayette, IN (USA); Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1981. 66p. DOE Contract AS07-80CS40361. Order Number DE81027802. Source: NTIS, PC A04/MF A01.

The annealing of steel coils, where the object of the process is to remove the effects of previous cold working, is described. The procedure is described and involves stacking one coil on the other. To obtain a greater loading and thereby an increased annealing rate per furnace, a general computer procedure was established to provide the criteria for the optimal loading problem in terms of the stack height utilization and the energy efficiency of the annealing furnaces. The problem and the computerized procedure are described in detail. Results of computer runs made for specific examples are discussed. Conclusions are summarized. (MCW)

429 (DOE/CS/40361-T6(vol.2)) **Man-machine simulations in industrial systems. Volume II. Appendices. Report No. 118.** Davis, G.I.; Buck, J.R. Purdue Univ., Lafayette, IN (USA). Dec 1980. 271p. DOE Contract AS07-80CS40361. Order Number DE81027870. Source: NTIS, PC A12/MF A01.

Extensive appendices are presented to the thesis on the computer simulation approach to the design and analysis of industrial man made systems. A glossary, data, and background development for operator models are included in Appendices A, B, and C. Appendix D presents information on SAINT (System Analysis of Integrated Networks of Tasks) nodes and subroutines for operator models. This pseudo-language is a combination network modeling and simulation technique designed for the analysis of man-made systems. Appendix E documents the SAINT program for an ingot processing operation and Appendix F changes to basic programs for each experimental demonstration. (MCW)

430 (DOE/CS/40361-T8-Vol.1) **Mathematical modeling and control of the blast furnace process. Volume I. Chapters I-X.** Ufret, C.M.; Christiansen, E.L.; Spitzer, R.H.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Aug 1981. 304p. DOE Contract AS07-80CS40361. (PUR-122-Vol.1). Order Number DE85014919. Source: NTIS, PC A14/MF A01; GPO Dep.

Thesis. Submitted by C.M. Ufret.

This study develops a comprehensive optimization strategy for the blast furnace process, with production and economics as important objectives. (PSB)

431 (DOE/CS/40361-T8-Vol.2) **Mathematical modeling and control of the blast furnace process. Volume II. Chapters XI, XII and Appendices.** Ufret, C.M.; Christiansen, E.L.; Spitzer, R.H.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Aug 1981. 331p. DOE Contract AS07-80CS40361. (PUR-122-Vol.2). Order Number DE85014920. Source: NTIS, PC A15/MF A01; GPO Dep.

Thesis. Submitted by C.M. Ufret.

Possible alternatives for the development of the models needed to calculate the dependent variables as a function of the independent variables are discussed.

432 (DOE/CS/40361-T9) **Analysis of the scheduling problems in ingot handling.** Bullington, S.F.; Moodie, C.L. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Mar 1983. 124p. DOE Contract AS07-80CS40361. (PUR-135). Order Number DE85014921. Source: NTIS, PC A06/MF A01; GPO Dep.

Thesis. Submitted by S.F. Bullington.

The steel production processes from the steelmaking furnaces to the primary rolling mill are considered. A method for sequencing the heats to be refined in the steelmaking furnaces on a particular day is presented. Control procedures for use at the soaking pit area are also analyzed. A heuristic method is developed for sequencing heats to be refined in the steelmaking furnaces. The method is a simple, single-pass, "look-ahead" procedure which is based on the information provided by a dynamic ingot heating model. The heuristic considers the estimated future status of facilities, and the relative priority of different types of steel, in addition to optimal track time and soaking time information obtained from the ingot heating model. The optimal track times and soaking times obtained from the heating model are also used in the control of operations at the soaking pit area. The procedures are tested using a digital computer simulation model of a steel production facility. The "forward-looking" method is also compared to a "backward-looking" heuristic.

433 (DOE CS 40361-T10) **Integrated production planning and control system for steelmaking facilities with an energy conservation criterion.** Li, C.M.; Moodie

C.L. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Dec 1982. 181p. DOE Contract AS07-80CS40361. (PUR-132). Order Number DE85014922. Source: NTIS, PC A09/MF A01; GPO Dep.

Thesis. Submitted by C.M. Li.

Effects of plant scheduling on overall energy usage in an integrated steel plant were determined and techniques were designed to minimize the quantity of energy utilized. The design and development of an integrated production control strategy through which the energy usage are discussed as well as test methodology and preliminary investigation.

434 (DOE/CS/40361-T11-Vol.1) **Tasks and functional specifications of the steel plant hierarchical control system. Volume I. Chapters 1-15.** Williams, T.J. (ed.). Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Jun 1984. 270p. DOE Contract AS07-80CS40361. (PUR-98-Vol.1). Order Number DE85014914. Source: NTIS, PC A12/MF A01; GPO Dep.

Outlines of a basic control system are presented to illustrate the current concept of a widely distributed set of isolated functions carried out by small and relatively inexpensive computer systems. These systems will be highly redundant to preserve the integrity of the control system in the face of the possible failure of any one unit. Their work will be coordinated by a set of successively higher level, and probably larger, computers connected together and connected to the distributed remote control computers by an extensive plant communications system.

435 (DOE/CS/40361-T11-Vol.2) **Tasks and functional specifications of the steel plant hierarchical control system. Volume II. Chapters 16-21.** Williams, T.J. (ed.). Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Jun 1984. 333p. DOE Contract AS07-80CS40361. (PUR-98-Vol.2). Order Number DE85014915. Source: NTIS, PC A15/MF A01; GPO Dep.

Report No. 98.

This report summarizes the work carried out during the Purdue University projects, Systems Engineering of Computer Control Systems for Large Industrial Steel Complexes, and Hierarchy Control for Energy Savings in the Steel Industry to define the requirements and set the specifications for a hierarchical computer control system to provide the overall process control, production and energy use scheduling, and production and energy management for a typical steel production facility; that producing a flat-rolled, sheet steel product.

436 (DOE/CS/40361-T12) **Self-tuning controller for rolling mill processes. Interim progress report.** Papanagiotou, I.; Maliotis, G.; Koivo, A.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Jan 1984. 135p. DOE Contract AS07-80CS40361. (PUR-141). Order Number DE85014928. Source: NTIS, PC A07/MF A01; GPO Dep.

This report presents an adaptive self-tuning controller for the control of the rolling mill. This controller is designed on the basis of a time-series model (AR model) in which the parameters are estimated recursively on the basis of the available information (on-line). The controller gains are determined at each sampling instant so that the outputs follow the desired values as closely as possible. The self-tuning controller is thus in the form of a feedback controller whose gains are calculated continuously on-line. The basic time-series model which relates the inputs to the outputs of the system will be described first, then the controller algorithm.

Simulation studies on the resulting system are presented to demonstrate the applicability of the approach.

437 (DOE/CS/40361-T13) **Proposal for a generalized operator's console for the steel industry.** Reback, R.H.; Govindaraj, T.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1982. 76p. DOE Contract AS07-80CS40361. (PUR-128). Order Number DE85014929. Source: NTIS, PC A05/MF A01; GPO Dep.

The purpose of this proposal is to develop an operator's console which effectively utilizes human factors considerations, is capable of accomplishing process control tasks in any area of a steel plant, and has the potential to develop into an American Steel Industry Standard. Human factors considerations are essential to facilitate use of the operator's console and to enhance the probability of its being accepted by the steel industry. Obviously, for such an operator's console design to become such a standard, it must be capable of accomplishing most if not all of the process control tasks throughout the steel plant. Standardization is desirable to ease operator training requirements, to allow operator and supervisor mobility throughout the plant, and to reduce the total system cost through larger scale production by the computer systems manufacturer.

438 (DOE/CS/40361-T14-Vol.1) **Modelling, estimation and control of the soaking pit: an example of the development and application of some modern control techniques to industrial processes. Volume I. Chapters 1-8.** Lu, Y.Z.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Oct 1982. 281p. DOE Contract AS07-80CS40361. (PUR-134). Order Number DE85014916. Source: NTIS, PC A13/MF A01; GPO Dep.

This work integrates separate models of the earlier researchers of the separate stages of the ingot handling process into one integrated model able to handle all phases of the process. It also is the first application of the techniques of state space modelling, on-line estimation and advanced control as a total set of techniques to minimize the energy consumption of industrial processing.

439 (DOE/CS/40361-T14-Vol.2) **Modeling, estimation and control of the soaking pit: an example of the development and application of some modern control techniques to industrial processes. Volume II. Chapters 9-14 and Appendices.** Lu, Y.Z.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Oct 1982. 294p. DOE Contract AS07-80CS40361. (PUR-134-Vol.2). Order Number DE85014917. Source: NTIS, PC A13/MF A01; GPO Dep.

A major contribution of this work is its integration of the separate models of the earlier researchers of the separate stages of the ingot handling process into one integrated model able to handle all phases of the process. It also is the first application of the techniques of state space modelling, on-line estimation and advanced control as a total set of techniques to minimize the energy consumption of industrial processing.

440 (DOE/CS/40361-T17-Vol.1) **Dynamic mathematical model and simulation of the iron blast furnace. Volume I. Chapters I-VI.** Christiansen, E.L.; Ufret, C.M.; Spitzer, R.H.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Feb 1982. 378p. DOE Contract AS07-80CS40361. (PUR-126-Vol.1).

Order Number DE85014930. Source: NTIS, PC A17/MF A01; GPO Dep.

Thesis. Submitted by E.L. Christiansen.

The strategy of the dynamic model of the blast furnace process and the results of various tests on the model are presented. A brief process description is included as part of Chapter One. The basic elements shared by both steady state and dynamic mathematical models are explained in Chapter Two. Chapter Three presents a detailed account of the boundary conditions, initial conditions, model inputs and predictions, and the numerical solution technique employed in the dynamic simulation. The elements and processes are brought together in an explanation of the dynamic simulation strategy in Chapter 4, with results in Chapter Five. A summary of the dynamic model studies along with the conclusions and suggestions for future dynamic model work are given in Chapter Six. The Appendices contain derivations of the dynamic differential equations and listings of the data decks and computer programs. (PSB)

441 (DOE/CS/40361-T17-Vol.2) **Dynamic mathematical model and simulation of the iron blast furnace. Volume II. Chapters V-VI and Appendices A-B.** Christiansen, E.L.; Ufret, C.M.; Spitzer, R.H.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Feb 1982. 340p. DOE Contract AS07-80CS40361. (PUR-126-Vol.2). Order Number DE85015061. Source: NTIS, PC A15/MF A01; GPO Dep.

Thesis. Submitted by E.L. Christiansen.

The mathematical model dynamically simulates the iron blast furnace process was debugged and revised to provide a more complete account of its dynamic behavior from the initially programmed version. Verification tests were made on the improved dynamic model to check its ability to simulate the response of an actual furnace to step changes in the input streams. In addition, a first attempt at model validation was made by using eight days of time-dependent input data collected from an operating furnace and comparing the predicted to the reported values of the variables describing the output streams.

442 (DOE/CS/40361-T17-Vol.3) **Dynamic mathematical model and simulation of the iron blast furnace. Volume III. Appendices C-H.** Christiansen, E.L.; Ufret, C.M.; Spitzer, R.H.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Feb 1982. 490p. DOE Contract AS07-80CS40361. (PUR-126-Vol.3). Order Number DE85015062. Source: NTIS, PC A21/MF A01; GPO Dep.

Thesis. Submitted by E.L. Christiansen.

This volume includes the following appendices for documentation of the dynamic blast furnace model: Input Files to the Dynamic Simulation; Computer Program for the Dynamic Simulation; Computer Program of the Overall Mass Balance on the Final State of the Dynamic Model Verification Tests; Data Inputs and Results of the Mass Balance Program; Input Files and Computer Programs Necessary in Plotting the Dynamic Simulation Results; and Kinetic Expressions Used in the Shaft Region of the Blast Furnace Dynamic Model.

443 (DOE/CS/40361-T18) **Hierarchical control for energy savings in the steel industry. Fourth annual report, July 1, 1983-September 30, 1984. Final report, July 1, 1982-September 30, 1984.** Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. 1984. 397p. DOE Contract AS07-80CS40361. (PUR-146). Order Number DE85014927. Source: NTIS, PC A17/MF A01.

This report summarizes and references research on steel mill processes with the objective of developing a hierarchical computer control system to control processes and conserve energy in a steel mill producing flat rolled, strip, sheet steel. References are given for a large number of more detailed technical documents prepared by PLAIC on the modelling and control of various steel making processes, scheduling techniques, human factors considerations, and other topics related to the proposed hierarchical control system. Topics specifically covered in this report present the progress obtained in studies of overall production scheduling, of direct rolling and hot charging scheduling practices, of the theoretical development of hierarchical control concepts, of coordination practices in the hierarchy, of blast furnace dynamic models, and of coke oven dynamic models. Also included are measures taken to assure a technology transfer of project results to the steel industry.

444 (DOE/CS/40361-T19-Vol.1) **Temperature control of a continuous, push type, five zone, slab reheating furnace for minimum fuel usage. Volume I. Text and Appendix A.** Purdy, D.J.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1981. 279p. DOE Contract AS07-80CS40361. (PUR-91-Vol.1). Order Number DE85014923. Source: NTIS, PC A13/MF A01; GPO Dep.

Thesis. Submitted by D.J. Purdy.

This report treats the reheat furnace used to heat slabs from the slabbing mill up to the rolling temperature for the hot strip mill. It determines the minimum fuel rates needed to achieve required outlet temperatures as a function of production rate. It also presents a scheme carrying out the transition from one steady state operating level to another with a near minimum of fuel usage. A method for using this transition scheme on a process control computer is also presented here.

445 (DOE/CS/40361-T19-Vol.2) **Temperature control of a continuous, push type, five zone, slab reheating furnace for minimum fuel usage. Volume II. Program (Appendices B, C, D).** Purdy, D.J.; Williams, T.J. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1981. 312p. DOE Contract AS07-80CS40361. (PUR-91-Vol.2). Order Number DE85014924. Source: NTIS, PC A14/MF A01; GPO Dep.

Thesis. Submitted by D.J. Purdy.

Documentation is presented for slab reheating furnace program and for shape factor program.

446 (DOE/CS/40361-T20) **Production scheduling of annealing furnaces.** Venkatesh, N.; Moodie, C.L.; Ravindran, A. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Apr 1982. 93p. DOE Contract AS07-80CS40361. (PUR-127). Order Number DE85014926. Source: NTIS, PC A05/MF A01; GPO Dep.

Thesis. Submitted by N. Venkatesh.

The development of a computerized procedure for optimal scheduling of steel coils in a batch annealing furnace is reported. The batch annealing process is accomplished by placing the coils in a portable-cover furnace during the heating and cooling cycle. The number of coils that can be stacked on a base is limited by the height of the furnace. The objective is to generate the stacks so as to maximize the throughput which is measured in terms of tons processed per hour. Chapter 1 mentions the scope of the report and gives a brief description of the batch annealing

environment. Chapter 2 reviews the heuristic solution procedure developed by Gau. Chapter 3 gives the integer programming formulation and the results obtained. Chapter 4 describes the heuristic solution procedure to maximize the tons processed per hour. Chapter 5 contains the conclusions made from this study. The Appendices contain tables of the results, program listings and references.

447 (DOE/CS/40361-T31-Vol.1) **Blast furnace dynamic model: reconstruction of the PLAIC blast furnace dynamic model. Volume I. Chapters 1-6 and appendices I-V. Report No. 149.** Blattner, J.L.; Mika, L.M.; Tanski, J.A.; Schiller, T.L. Purdue Univ., Lafayette, IN (USA). Purdue Lab. for Applied Industrial Control. Jan 1986. 516p. DOE Contract AS07-80CS40361. Order Number DE86008994. Source: NTIS, PC A22/MF A01; GPO Dep.

A new system for the dynamic simulation of the blast furnace has been constructed. The major advantages of the new simulation over the previous one are: The FORTRAN programs are extensively documented; improved execution speed; an interface system for the required operating data has been developed; and top pressure rather than blast pressure is a control variable. The improved execution speed has involved a speedup of approximately seven to one. The new simulation has been constructed to allow reasonable ease in changes or additions to reaction rates and other phenomenon, such as silicon transfer to the hot metal via silicon gas species. It should be possible to apply the simulation to a laboratory furnace. This volume covers the six chapters (conceptualization, reactions considered in simulation model, solution of state equations of working volume and hearth, system structure of the blast furnace simulations, sensitivity analysis of simulation) and the first 5 appendices (transport equations for smelter simulation, pressure drop equation, hearth simulation, computer code listings for material properties and charging). (DLC)

448 (DOE/ID-10176) **Techno-economic assessment of electric steelmaking through the year 2000.** Bosley, J.J.; Clark, J.P.; Dancy, T.E.; Fruehan, R.J.; McIntyre, E.H. Steelcon, Inc., Pittsburgh, PA (USA); Carnegie-Mellon Univ., Pittsburgh, PA (USA). Center for Metals Production. Jul 1987. 204p. DOE Contract AC07-76ID01570. Order Number DE88003227. Source: NTIS, PC A10/MF A01; GPO Dep.

This paper presents a critical review of the outlook for electric steelmaking including an assessment of existing and potential electric arc furnace (EAF) capacity. Suggested areas of development to minimize energy consumption and optimize output are also featured. 20 figs.; 62 tabs.

449 (DOE/ID/12443-2) **Technology development for thin strip metal casting, Phase 2: Final technical report.** Williams, R.S. Westinghouse Electric Corp., Pittsburgh, PA (USA). Research and Development Center. 7 Mar 1988. 177p. DOE Contract AC07-83ID12443. Order Number DE88013689. Source: NTIS, PC A09.

The Phase II program has been conducted by a team of engineers from Westinghouse Electric Corporation and Armco, Inc., with the objective of providing a suitably sized experimental planar flow casting machine, and using it to perform casting trials to address the above technical uncertainties for cast thicknesses and speeds representative of industrial production, and with sufficient duration to diminish thermal transient effects. A nominally 7 ft. diameter water-cooled copper wheel planar flow casting system has been designed, fabricated and installed in a dedicated 15,000 sq. ft. foundry facility at Armco Inc., Middletown, Ohio. This

system is capable of casting 3 in. wide strip and operating at surface speeds up to 25 ft/sec. Additionally, the facility also contains a 16 in. diameter water-cooled wheel with interchangeable casting substrates of different materials. This small wheel facility has been adapted to utilize the melt overflow process for casting of 3 in. wide strip. These casting facilities are supported by a 500 lb. induction melting furnace and necessary liquid steel handling equipment. Adequate techniques have been developed for transportation and filtering of liquid steel without undue temperature loss. Good control of the planar flow casting process was not achieved during this program, however given such control and the adoption of clean steel practices, the inference is that the process will be capable of producing strip which is readily cold-rollable in the as-cast condition. After cold rolling and annealing, such material should have useful mechanical properties. 8 refs., 112 figs., 10 tabs.

450 (DOE/ID/12444-T1) **Technology development of thin strip metal casting: feasibility study. Final report.** Flemings, M.C.; Grant, N.J. Massachusetts Inst. of Tech., Cambridge (USA). Jan 1984. 164p. DOE Contract AS07-83ID12444. Order Number DE86005068. Source: NTIS, PC A08/MF A01; GPO Dep.

The technical problems in producing thin steel strip in the 0.010 inch to 0.187 inch range by direct casting technology are very great and include the problems of (1) achieving adequate throughput, (2) metal feed design, and (3) achieving strip of acceptable surface finish free of cracking and other defects. This last point comprises the "crux problems" of development of a practical strip casting technology, and any new process must solve these problems. Our work in this program has two major thrusts. One was experimental and mathematical modelling investigations of a specific casting technology (wheel casting) with emphasis on innovative techniques for solving the crux problems mentioned above, the second was a literature review and modelling study of two other approaches to strip casting: semi-solid casting, and spray forming. Work was also performed on modelling two alternative approaches: semi-solid casting and spray-forming.

451 (DOE/ID/12545-1-Vol.1) **Thin section casting program: Volume 1, Executive summary and overview: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 45p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009030. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The objective of this project which started in September 1984 was to develop a new casting technology which could be both applied to the total range of hot- and cold-rolled sheet steels, and be successfully developed within a five-year project time scale. These requirements resulted in the choice of a thin-section-casting approach (casting around 1-inch-thick) over the alternative strip casting approach (casting around 0.1-inch-thick). The TSC approach was expected to result in significant capital cost, operating cost, and energy savings over current 10-inch-thick slab casting technology.

452 (DOE/ID/12545-1-Vol.2) **Thin section casting program: Volume 2, Horizontal TSC [thin-section casting] approach: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 484p. Sponsored

by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009031. Source: NTIS, PC A21/MF A01 - OSTI.

In horizontal thin-section casting (HTSC), 1-inch-thick steel sections are produced at speeds up to 600 ipm or about 60 tons per hour per foot of width (tphf). Liquid steel is fed from the ladle, and flows through a specially designed tundish, then flows through a refractory feeding tube, nozzle, with approximately the same external dimensions as the cast section, into a near-horizontal rectangular mold whose all four sides are traveling in the same direction and speed as the steel casting. This report is the second of a six volume set on thin section casting. This volume covers the research on horizontal TSC. 5 refs.

453 (DOE/ID/12545-1-Vol.2A) **section casting program: Volume 2-A, Appendix to volume 2: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 788p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009032. Source: NTIS, PC A99/MF A01 - OSTI.

This volume contains reports on the design, construction, and operation of the horizontal thin-section-casting dynamic simulator facility (H-DS) at the USS Technical Center's pilot facilities in Universal Pennsylvania (UPF). A dynamic simulator is a small-scale pilot facility that bridges the development gap between bench-scale work and a full-scale pilot facility. The main objectives of the H-DS program are (a) to provide a critical "proof-of-concept" of closed-pool (injection) feeding, and (b) an evaluation of a near-full-scale casting system for steel (1-inch-thick by 17-inch-wide product) using a twin-belt caster. As originally configured, this phase also included a vertical feeding dynamic simulator to be operated concurrently with the H-DS. Based on the DS results, large-scale pilot facilities were to be constructed using the most successful of two feeding approaches for final evaluation. This plan was later modified by only building an H-DS facility at UPF. A smaller version of the V-DS called the V-rig was built at Bethlehem. Expanded casting campaigns are to be conducted independently on each casting approach at UPF and Bethlehem's Research Laboratory. 14 refs.

454 (DOE/ID/12545-1-Vol.3) **Thin section casting program: Volume 3, Vertical TSC [thin-section casting] approach: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 301p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009033. Source: NTIS, PC A14/MF A01 - OSTI.

A prototype vertical twin belt caster was designed, constructed and tested at Bethlehem Steel Corporation's Homer Research Laboratory for the development of a thin section casting process. In the prototype caster the moving mold was aligned vertically and each of the two endless steel belts was tensioned around an upper and a lower large pulley by means of a third smaller pulley. The mold consisted of a long parallel lower section and a shorter V-shaped top section into which liquid steel was fed from a tundish via a submerged refractory nozzle. Mold length, defined as the distance from the meniscus in the V-mouth to the tangent point of the lower pulleys, was about eleven feet. The length of the V-mouth was 27 in. The belts were continuously supported between the upper and lower pulleys by a unique back-up system. Downstream support consisted of two pairs

of foot rolls and a vertical water-cooled steel structure that would permit a cast length of about nineteen feet. A chain driven bar was used to start a cast and support the slab. The aim was to cast 1 in. $\times$ 17 in. sections at 250 in./min. The details of the prototype vertical caster, except the end walls, are given. The water modeling studies conducted at USSteel to establish tundish nozzle port sizes, inclinations and depth of submergence below the meniscus for optimum flow pattern in the V-mouth are included. The design analyses of the copper end walls and the 10-ton liquid steel trials conducted with the refractory end walls are presented. The fourteen liquid steel trials conducted with the vertical caster and the concluding remarks on vertical feeding system development are discussed.

455 (DOE/ID/12545-1-Vol.4) **Thin section casting program: Volume 4, Static cast product bending, straightening, and rolling: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 63p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009034. Source: NTIS, PC A04/MF A01 - OSTI; GPO Dep.

Statically cast 1/2", 3/4", and 1" thick steel slabs were subjected to hot rolling in a laboratory reversing mill and to simulated coiling-uncoiling on a three-point bender-unbender. Tensile properties and microstructures of hot bands thinner than 0.15" produced from the statically cast slabs were found to be independent of initial slab thickness and similar to those from conventionally cast 8"-10" thick slabs. Cold rolled and batch annealed product from the statically cast slabs had mechanical properties equivalent to those of conventionally processed deep-drawing quality steel. Overall, the results of this task indicated that 1/2"-1" thick steel sections produced in a twin belt caster can be coiled and uncoiled in a hot coiler box downstream of the caster without generating any cracks in the product, and that the total range of hot and cold rolled sheet and strip products with qualities equivalent to those of conventionally produced can be obtained from the 1/2"-1" thick sections. This report is the fifth of a six volume set on thin section casting.

456 (DOE/ID/12545-1-Vol.5) **Thin section casting program: Volume 5, Westinghouse MHD Project: Final report.** USX Corp., Monroeville, PA (USA). USS Technical Center; Bethlehem Steel Corp., PA (USA). Homer Research Lab. Jan 1989. 303p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC07-84ID12545. Order Number DE89009035. Source: NTIS, PC A14/MF A01 - OSTI.

This final report includes the subcontract title "Magnetofluidynamically enhanced feeding system for thin section steel caster."

In September of 1984, the R&D Center entered into a 3-year contract to develop a magnetofluidynamically enhanced feeding system. This report describes the work conducted under this contract. A design for an MFD device to enhance the feeding system of a horizontal steel caster was conceived, analyzed, and successfully tested with a low melting point liquid metal. Difficulties with integrating the device into an existing demonstration caster led to a decision to forego MFD feeding enhancement. All work on the DOE contract was stopped in 1987 upon commercial demonstration of a vertical thin section steel caster. 27 refs., 89 figs., 20 tabs.

457 (EGG-M-88158) **Horizontal and vertical twin-belt casting of 1-inch-thin sections of sheet steel.** Moore, M.R.; Daniel, S.S.; Ozgu, M.R. EG and G Idaho, Inc., Idaho Falls (USA). 1988. 43p. DOE Contract AC07-76ID01570. (CONF-881161-1: AIME-TMS international symposium, Honolulu, HI, US, November 13, 1988). Order Number DE88015126. Source: NTIS, PC A03/MF A01; GPO Dep.

Innovative horizontal and vertical twin-belt casting systems were developed and tested in casting trials to provide alternative approaches to solving the crux technical problem of feeding liquid steel into the thin mold gap so as to achieve the excellent as-cast surface quality necessary to allow subsequent direct rolling of top-quality sheet. The horizontal approach involved an innovative feeding system to feed the 1-inch-thick caster entry, but the twin-belt Hazlett machine itself was largely conventional. In contrast, the opened-up entry of the vertical twin-belt machine allowed the use of conventional lathe tube and flux pouring systems, but the machine itself was complex and deformed the casting down to the 1-inch thickness. Extensive modeling work was done to support both approaches. 15 refs., 21 figs., 1 tab.

458 (EPRI-EM-5445) **Technoeconomic assessment of electric steelmaking through the year 2000: Final report.** Bosley, J.J. (ed.); Clark, J.P.; Dancy, T.E.; Fruehan, R.J.; McIntyre, E.H. Carnegie-Mellon Univ., Pittsburgh, PA (USA). Center for Metals Production; Steelcon, Inc., Pittsburgh, PA (USA). Oct 1987. 230p. Order Number DE88002254. Source: NTIS, PC A11/MF A01 - Research Reports Center, Box 50490, Palo Alto, CA 94303; GPO Dep.

The electric steelmaking industry may soon account for 40% of US steel production. This assessment of existing and potential electric arc furnace capacity includes R and D recommendations for minimizing energy consumption and optimizing output. 20 figs., 63 tabs.

459 (FEA-185-D) **Data base: the potential for energy conservation in nine selected industries. Volume 6. Steel. First edition. Conservation paper number 14.** Federal Energy Administration, Washington, DC (USA). 1975. 144p. Source: NTIS, PC A07/MF A01.

This study is concerned with the potential for energy conservation in U.S. industries. The purpose of the total study, contained in 3 separate volumes, is to provide basic data on energy consumption in industry and to identify opportunities for energy conservation. These opportunities can then be the subject of economic and policy studies to determine how best to realize them. Basic data for all 9 industries are summarized. Data for the steel industry, i.e., in-depth material balance and energy consumption data for raw steel production, is included in this volume. (LCL)

460 (IDO-1570-T21) **State-of-the-art review of computer control in the steel industry.** Kusik, C.L.; Mounier, M.R.; Kucinkas, G.J. Little (Arthur D.), Inc., Cambridge, MA (USA). Jun 1979. 99p. DOE Contract EY-76-C-07-1570. Source: NTIS, PC A05/MF A01.

To develop and demonstrate cost-effective, energy-conserving programs, the Federal Government has implemented a cost-shared program with the iron and steel industry which, if successful, would significantly reduce the nation's dependence on all forms of energy, particularly on petroleum-based fuels. An appropriate Federal role is one of supporting development programs showing good potential of being economic, but not being funded by the private sector for various reasons, including (1) the risk of failure being such that the private sector will not undertake the work, and

(2) benefits being so generally dispersed among different firms that no one private organization has sufficient incentive to fund the required research, development, and testing. This document provides the Department of Energy with a state-of-the-art assessment on computer control in the iron and steel industry and identifies program areas having energy-conservation potential by greater application of computer control. Program areas must be technically feasible, show a potential for energy conservation (especially scarce fuels), and be realistic in terms of ultimate application to a steel mill environment.

461 (IDO-10089) Use of coal injection and oxygen in a blast furnace to produce fuel gas. Final report, November 26, 1980. United States Steel Corp., Monroeville, PA. Research Lab. Dec 1980. 37p. DOE Contract AC07-76ID01570. Source: NTIS, PC A03/MF A01.

The feasibility of operating a blast furnace with coal injection and oxygen to produce fuel gas has been evaluated. Probable operating conditions were based on United States Steel Corporation's experience with coal injection on an experimental blast furnace. It was found that the cost of the gas produced would, as expected, be sensitive to the costs of coal, coke, and oxygen used and also to the capability of the process to burn coal instead of coke. To be economically viable, the medium Btu produced [270 Btu per standard cubic foot (Btu/scf)] from coal, coke, and oxygen at \$30 per ton (\$/T), \$100/T, and \$48.60/T, respectively, would have to have a selling price between \$6.74 per million Btu (\$/MMBtu) and \$7.38/MMBtu depending on the coal-to-coke ratio assumed to be achieved in the process. Because these selling prices are considerably higher than current costs for natural gas or fuel oil, it would appear that the operation of a blast furnace as a fuel gas producer would not be economically viable at this time.

462 (IDO-10095) Compilation of reports on direct reduction technology and economics. Final report. Davis, C.G.; McFarlin, J.F.; Pratt, H.R. EG and G Idaho, Inc., Idaho Falls (USA); United States Steel Corp., Monroeville, PA. Research Lab. Jun 1981. 192p. DOE Contract AC07-76ID01570. Order Number DE81026053. Source: NTIS, PC A09/MF A01.

A study was made of alternative direct-reduction (DR) processes for a steel plant sited at an east-coast or gulf-coast location for comparison with the blast furnace/basic oxygen process steelmaking at a like location. The processes surveyed include: (1) natural-gas-based DR processes, (2) commercial and second-generation coal-based DR processes, (3) coke-oven-gas DR processes, and (4) new technology. This report presents process descriptions, energy requirements, process economics for the DR process, and comparative economics for steelmaking by alternate routes.

463 (LA-UR-88-2128) Structure of grain boundaries in iron. Harrison, R.J.; Spaepen, F.; Voter, A.F.; Chen, Shao-Pin. Army Materials Research Agency, Watertown, MA (USA). Materials Technology Lab.; Harvard Univ., Cambridge, MA (USA). Div. of Applied Sciences; Los Alamos National Lab., NM (USA). 1988. 26p. DOE Contract W-7405-ENG-36. (CONF-8708268-1: 34. Sagamore army materials research, Lake George, NY, US, August 31, 1987). Order Number DE88014412. Source: NTIS, PC A03/MF A01; GPO Dep.

The present research has been carried out as part of the Steel Research Group's program to improve the properties

of ultra-high-strength steels. It is an investigation of the mechanism of cohesion at grain boundaries as a step toward the design of alloy steel with improved resistance against boundary decohesion under stress corrosion conditions. This research involves a theoretical study of grain boundaries in iron alloys, examining the mechanism of cohesion as affected by structure including imperfections, by the average alloy composition and by segregation at the boundaries. This paper summarizes what we have done to date in obtaining approximate grain boundary structures. We have tested the approximate interatomic potential for iron which we have obtained by using it to compute the interplanar spacings at the surface and then comparing the computed results with experimental observations. Results are discussed. 51 refs., 9 figs., 3 tabs.

464 (ORNL/TM-10747) A preliminary study on the use of magnetohydrodynamic forces to remove impurities from molten metals. Hobson, D.O. Oak Ridge National Lab., TN (USA). Jun 1988. 19p. DOE Contract AC05-84OR21400. Order Number DE88013508. Source: NTIS, FC A03/MF A01; GPO Dep.

Experimental and modeling work on the use of magnetohydrodynamic forces for separating particulate impurities from molten metals is described. Several experimental systems are described, which use ac or dc electromagnets and, thereby, either induced or direct currents to produce the required forces. Recommendations are made for further optimization of the separators. 8 refs., 5 figs., 2 tabs.

465 (PNL-6537) Direct measurement of solids: High temperature sensing: Experimental development and testing of high temperature pulsed EMATs [electromagnetic acoustic transducer]: Final report. Boyd, D.M.; Spanner, G.E.; Sperline, P.D. Pacific Northwest Lab., Richland, WA (USA). Apr 1988. 60p. DOE Contract AC06-76RL01830. Order Number DE88009859. Source: NTIS, PC A04/MF A01; GPO Dep.

A pulsed laser/pulsed EMAT (electromagnetic acoustic transducer) receiver system has been demonstrated for measuring the time of flight of acoustic signals in hot steel samples. Attenuation and signal-to-noise ratio are important parameters to be monitored. A continuous contact EMAT application was not achieved; thermal analysis found that contact times of 5 seconds with cooling times of 45 seconds are required at 1300°C. The equipment requires field hardening and improved packaging before system reliability can be assessed. 22 refs., 35 figs. (DLC)

466 (PNL-6737) In plant demonstration of high temperature EM pulser and pulsed EMAT receiver: Final report: Experimental development and testing of ultrasonic system for high temperature applications on hot steel. Boyd, D.M.; Sperline, P.D. Pacific Northwest Lab., Richland, WA (USA). Nov 1988. 40p. DOE Contract AC06-76RL01830. Order Number DE89003726. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

This report describes work performed under the Field Work Proposal on the "In-Plant Demonstration of a High-Temperature EM Pulser and pulsed EMAT Receiver" for the Department of Energy's Office of Industrial Programs. Cost sharing by the American Iron and Steel Institute (AISI) helped provide both technical guidance and equipment for the plant demonstration. This report covers the time period from January 1988 through September 1988.

467 (PNL-SA-16885) Pulsed EMAT [Electromagnetic Acoustic Transducer] acoustic measurements on

a horizontal continuous caster for internal temperature determination. Boyd, D.M. Pacific Northwest Lab., Richland, WA (USA). Oct 1989. 15p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. (CONF-891024-4: The Metallurgical Society fall meeting: materials week, Indianapolis, IN (USA), 1-5 Oct 1989). Order Number DE90002735. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Development of a Pulsed Electromagnetic Acoustic Transducer (EMAT) through transmission system for acoustic measurements on steel billets up to 1300 degrees C has been completed. Laboratory measurements of acoustic velocity were made, and used to determine the average internal temperature of hot stainless and carbon steel billets. Following the success of the laboratory system development, the laboratory EMAT system was subsequently tested successfully at the Baltimore Specialty Steel Co. on a horizontal continuous caster. Details of the sensor system development and the steel plant demonstration results will be presented. Future directions for the high temperature pulsed EMAT internal temperature concept will be discussed for potential material processing applications. 33 refs., 11 figs.

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Refer also to citation(s) 413, 497

468 (CAES-462-A-77) Cupola furnace: state-of-the-art. Draper, A.B.; Keith, R.E.; Sylvia, J.G. Pennsylvania State Univ., University Park (USA). Center for Air Environment Studies. May 1977. 166p. DOE Contract EY-76-S-02-2840. Source: NTIS, PC A08/MF A01.

The evolution of cupolas, i.e., furnaces used to melt cast irons, is reviewed. The design and operation of hot-blast, cold-blast, and novel cupolas, energy conservation and air pollution control aspects of cupola operation, and the mathematical modeling of cupolas are discussed. (LCL)

469 (CAES-504-78) Cupola furnace: machine-readable bibliographic data base. Keith, R.E. Pennsylvania State Univ., University Park (USA). Center for Air Environment Studies. 1978. 76p. DOE Contract EY-76-S-02-2840. Source: NTIS, PC A05/MF A01.

One of the tasks comprising ERDA Contract EY-76-S-02-2840, "Minimization of Cupola Energy and Air Pollution," has been the carrying out of a comprehensive survey of world literature relating to the cupola furnace for melting of cast iron. It was decided to computerize the literature references acquired in order to facilitate future searching of the bibliographic data base and to provide for its convenient extension and enlargement. This document describes the data base, how to search it, and how to add and edit references. Included are a number of instructions and cautionary notes for persons having responsibility for its management in the future.

470 (CAES-506-78) Three zone energy model of cupola operation. Renford, O.; Draper, A.B. Pennsylvania State Univ., University Park (USA). Jun 1978. 79p. DOE Contract EY-76-S-02-2840. Source: NTIS, PC A05/MF A01.

The design and operating details of a three-zone mathematical model of cupola operation in its present state of development are reported. Several examples are presented of what the model can do using field data collected from seven production foundries as input. The model can provide detailed information relative to the energy distribution within a cupola in terms of the charge materials and the blast rate.

Further developments now, being proposed, will make it possible to predict the energy distribution within a cupola in terms of blast temperature, oxygen enrichment and optimum allocation of the energy developed in the combustion zone when using the divided blast concept in conjunction with higher adiabatic flame temperatures. These later developments could result in major energy savings through improving the coke rate for a typical, conventional cupola using 6 : 1 iron to coke ratio to a new level of 10 : 1 to 12 : 1. There is a potential saving of \$150,000 per yr in metallurgical coke alone assuming the coke cost is \$120 per ton and there is a full usage of the technology developed. Even at one half the rate, the reduction in melting energy would be 2.3×10^{13} Btu per year if fully adopted and 1.1×10^{13} Btu per year if only 50 percent of the potential is achieved.

471 (COO-2840-11) Cupolas minimize the energy required to melt ferrous alloys. Draper, A.B. Pennsylvania State Univ., University Park (USA). Center for Air Environment Studies. May 1979. 12p. DOE Contract EY-76-S-02-2840. (CONF-790803-54: 14. intersociety energy conversion conference, Boston, MA, US, August 5, 1979; CAES-531-79). Source: NTIS, PC A02/MF A01.

Historically the cupola has been the most effective furnace for melting cast irons. Although its supremacy was challenged by electric melting furnaces in the 1960's, persisting energy scarcity and high cost have encouraged a resurgence of interest in cupola technology. Using the optimum design features of modern cupolas and the best melting practices, they can achieve melting efficiencies of 45% or more based on the energy value of the original coal. In contrast, electric melting only uses 21% of the energy in coal. Despite these facts, many foundrymen fear that there will be problems because of poor metallurgical control if they use cupolas. Yet experience has proven otherwise. In terms of energy conservation and economy it is better to use large cupolas as scrap melters in the steel industry. Yet there is still a deep rooted prejudice against the cupola plus basic oxygen furnace route to steel making.

472 (DOE/CS/40041-1) Slot Forge Furnace demonstration. Final report. Hague International, South Portland, ME (USA). Feb 1981. 14p. DOE Contract AC02-77CS40041. Source: NTIS, PC A02/MF A01.

A Hague International Slot Forge Furnace was tested and installed to demonstrate a high performance energy conserving slot forge furnace in an industrial environment. This furnace was used to heat 2-1/2" round x 31-1/8" long bars in preparation for an upsetting operation. Each piece was heated twice, in separate operations, and upset on both ends. The Hague International Model IV Slot Forge Furnace used in the program was designed with a nominal throughput capacity of 3000 lbs/h. Due to production requirements the demonstration furnace was operated in the range of 3800 lbs/h. A base case furnace adjacent to the Hague furnace operated simultaneously. Fuel consumption and steel throughput data for both furnaces were collected and analyzed. A heating rate of 746 Btu/lb for the Hague furnace and 1620 Btu/lb for the base case furnace was demonstrated. Data demonstrated the Hague furnace's ability to save 54% of the fuel consumed by the base case furnace.

473 (DOE/CS/40335-T1) Enhancement of energy savings through accelerated implementation of high-performance forge furnaces. Final technical report. Hague International, South Portland, ME (USA). Feb 1982.

138p. DOE Contract FC01-80CS40335. Order Number DE82010913. Source: NTIS, PC A07/MF A01.

Portions of document are illegible.

Hague International successfully demonstrated under both controlled and actual production conditions that a well designed slot forge furnace equipped with a ceramic recuperator could consume as much as 65% of the fuel normally consumed by a forging furnace. Thus the Department of Energy, entered into a cooperative agreement to accelerate the introduction of Hague International's high efficiency slot forge furnace into the forging industry. This report details the basis of the cooperative agreement and the history of the host sites covered by the agreement. Fifteen (15) host sites participated in the program.

474 (TID-27440) **Efficient operation of slot forging furnaces.** Berg, C.A. Department of Energy, Washington, DC (USA). 1977. 48p. DOE Contract EY-76-C-02-2877. Source: NTIS \$9.25.

This manual outlines field-proven procedures that were used in an operating forge shop to reduce the fuel consumption of slot forge furnaces by 20 to 35%. Reductions in fuel consumption were obtained by (1) application of temperature controls; (2) air/fuel ratio control; (3) damper control; (4) slot-loss reduction; (5) application of basic insulation principles; (6) burner selection and modification; (7) use of recuperator; (8) preheating work; and (9) proper operating procedures. Analyses of furnace designs are presented from both a theoretical and a practical standpoint. Present-worth calculations of future savings that can be used to justify the suggested improvement are analyzed. A practical operator's checklist is included as an appendix. It can easily be adopted or modified for use in most slot forging departments and by itself may be expected to result in significant operating savings.

Comminution

475 (DOE/CE/15292-T9) **The CARRI-CEL Impact Breaker (VSI crusher): Final technical report.** Carri-Cel Rock Breaker, Inc., Cleveland, TN (USA). 16 Dec 1988. 146p. DOE Contract FG01-86CE15292. Order Number DE89004757. Source: NTIS, PC A07 - OSTI.

The CARRI-CEL Impact Breaker (CIB) is a vertical shaft impact crusher used in the processing and reduction of stone as well as other minerals and friable items such as glass. It achieves this by propelling the material into a breakage area where the material "explodes" along its natural fault lines from the impact forces. The purpose of this grant and study was for further research and development of the CIB and the Flex Break Rock Cell while demonstrating to aggregate producers the energy saving capabilities as well as the crushing capabilities in various quarries and types of rock throughout the country. This would in turn promote the use of this new energy saving technology in an industry whose methods have changed little in the past 80 years and where energy conservation is rare. In the past, plants were designed by picking a crusher that would produce the desired product at the desired tons per hour (TPH) rate, then just adding as much horsepower as it took to achieve that goal.

476 (DOE/ID/12440-1-Vol.1-Vol.2) **Mathematical modeling of two-stage classification. Volume I. Project results; Volume II. Background information. Progress report.** Baltich, L.K. AMAX Extractive Research and Development Center, Golden, CO (USA). Jan 1985. 147p. DOE Contract FC07-83ID12440. Order Number DE85015423. Source: NTIS, PC A07/MF A01; GPO Dep.

The objectives of the Mathematical Modeling of Two-Stage Classification contract are to develop and verify computer simulation models of particle size classification technology that will enable users to design the optimum configuration and operating conditions of two-stage classifiers for energy conservation. Project work to date has included collecting and analyzing data from commercial and pilot-plant operations, development of a computer simulation program, and two-stage classification simulation and evaluation. Volume I of this report contains descriptions of the project work carried out and the results obtained from April, 1983 to October, 1984. An overview of the project plan is also included in the first volume. A summary of comminution, classification, and mathematical modeling background information is presented in Volume II.

477 (DOE/ID/12440-2) **Mathematical modeling of two-stage classification. Final report.** Baltich, L.K. AMAX Extractive Research and Development Center, Golden, CO (USA). Mar 1986. 154p. DOE Contract FC07-83ID12440. Order Number DE87000776. Source: NTIS, PC A08/MF A01; GPO Dep.

The objectives of the "Mathematical Modeling of Two-Stage Classification" contract were to develop and verify computer simulation models of particle size classification technology that will enable users to design the optimum configuration and operating conditions of two-stage classifiers for energy conservation. Project work included collecting and analyzing data from commercial and pilot-plant operations, development of a computer simulation program, two-stage classification simulation, and flowsheet evaluation. This report contains descriptions of the project work completed and the results obtained from April 1983 to December 1985. An overview of the project plan and the conclusions and recommendations resulting from the project are also included. The computer simulation program was developed on the VAX 11/785, VMS v.4.2 system, used by AMAX Extractive Research and Development Center and written and compiled in FORTRAN-77.

478 (DOE/ID/12440-3) **Mathematical modeling of two-stage classification technology transfer summary and user's guide.** Baltich, L.K. AMAX Extractive Research and Development Center, Golden, CO (USA). Aug 1987. 118p. DOE Contract FC07-83ID12440. Order Number DE88003849. Source: NTIS, PC A06/MF A01; GPO Dep.

CIRCUIT is a computer program developed for use in designing optimum two-stage classification configurations and operating conditions for energy conservation. It was developed in a cooperative effort between AMAX Research & Development Center and the US Department of Energy, Conservation Technologies Division. This document contains the final summary report for the technology phase of the project and the User's Guide for CIRCUIT. CIRCUIT is now available for use with IBM compatible personal computers.

479 (DOE/ID/12441-2) **The role of abrasion and corrosion in grinding media wear: Annual technical progress report.** Moore, J.J.; Iwasaki, I. Minnesota Univ., Minneapolis (USA). Dept. of Civil and Mineral Engineering. 12 Jun 1984. 122p. DOE Contract FC07-83ID12441. Order Number DE88007082. Source: NTIS, PC A06.

Aim of this research program is to establish the effect of mill size and batch or continuous operation on the role of corrosive and abrasive wear during mineral grinding operations. Grinding ball wear tests are being conducted on the laboratory, pilot plant and industrial scale. This report gives

the results of the first year's work of the two year research program and are discussed under the following headings: Wear Tests in an 8-inch Laboratory Mill (Using Three Different Ball Chemistries for Both Taconite and Molybdenite Ore); Wear Tests in a 36-inch Batch Mill (Using High Carbon Low Alloy Steel Balls with Taconite); Mechanisms of Erosive Wear in Taconite Grinding (Using Mild Steel Balls); The Effect of Slurry Rheology on Grinding Media Wear (Using Mild Steel Balls - Quartzite Combination); and Pilot Plant continuous Grinding Tests (Using High Carbon Low Alloy Steel Balls with Taconite Ore).

480 (DOE/ID/12441-T1-Vol.1) **Role of abrasion and corrosion in grinding media wear. Volume 1.** Moore, J.J.; Iwasaki, I. Minnesota Univ., Minneapolis (USA). Mineral Resources Research Center. [1986]. 143p. DOE Contract FC07-83ID12441. Order Number DE86009471. Source: NTIS, PC A07/MF A01; GPO Dep.

Purpose of this project was to investigate the effect of grinding conditions, e.g., pH, P_{O_2} , grinding media composition and, in particular, size of mill on the wear rates and wear mechanism for both a molybdenite ore and a magnetic iron ore. This allowed data to be obtained on the correlation of scale-up between small diameter laboratory mills and industrial mills and provided a relatively inexpensive test method to be developed for the selection of grinding media used with different ores. Secondly, the effect of the physico-chemical properties of the slurry on wear mechanism(s) and wear rates was evaluated using various slurry media and additives. Results of this work were aimed at providing information from which a more efficient selection of grinding media and conditions may be made which will reduce the total energy consumed in the grinding of minerals.

481 (DOE/ID/12441-T1-Vol.2) **Role of abrasion and corrosion in grinding media wear. Volume II.** Moore, J.J.; Iwasaki, I. Minnesota Univ., Minneapolis (USA). Mineral Resources Research Center. 1984. 189p. DOE Contract FC07-83ID12441. Order Number DE86009472. Source: NTIS, PC A09/MF A01; GPO Dep.

Thesis. Submitted by J.N. Orlich as "Effect of slurry rheology on the erosive wear of grinding media".

The effects of slurry rheological properties on the erosive wear of grinding media and grinding efficiency (percent minus 325 mesh) have been studied in a laboratory ball mill using minus 10 mesh quartzite. A laboratory procedure was also utilized to evaluate the tendency for the slurry to coat the grinding media. Media wear decreased continuously with increasing percent solids while grinding efficiency was maximized at 60% solids. Slurry percent solids were found to be the critical factor affecting media wear in high percent solids slurries while other factors such as viscosity were more important at lower percent solids. This was demonstrated by the use of a grinding aid in a 70% solids slurry which resulted in only a small increase in wear (44 to 45.6 mg/ball) despite a significant reduction in viscosity (2359 mPa S at 75 rpm). Slurry relative viscosity was found to control the thickness of the slurry coating the balls which was in turn related in a direct linear manner to media wear. In terms of percent minus 325 mesh, the effects of viscosity and ball coating were in agreement with those presented in the literature. Scanning electron microscopic evaluation of ball surfaces and visual inspection of the movement of the ball charge both tended to support the theory of grinding in ball mills through nipping more so than attrition.

482 (DOE/ID/12441-T1-Vol.3) **Role of abrasion and corrosion in grinding media wear. Volume III.** Eggert, J.F. Minnesota Univ., Minneapolis (USA). Mineral Resources Research Center. 1985. 112p. DOE Contract FC07-83ID12441. Order Number DE86009473. Source: NTIS, PC A06/MF A01; GPO Dep.

Thesis.

The relative contributions of abrasion and corrosion and the effect of scale-up on the wear rates of three different grind materials in molybdenite and taconite ore milling under three mill atmospheres was investigated. A standardized marked ball wear test was implemented to obtain reliable and reproducible results from the three mill sizes. The mechanisms responsible for wear were determined through SEM and EDX examinations.

ENERGY AUDITS

483 (DOE/CE/40699-T7) **Energy management assistance for small and medium-size manufacturers: An evaluation of EADCs' performance in manufacturing plants, 1986-1987.** Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Center for Energy Management and Industrial Technology. Dec 1987. 30p. DOE Contract FC01-84CE40699. Order Number DE88004588. Source: NTIS, PC A03/MF A01; GPO Dep.

Small and medium-size manufacturers served by the Energy Analysis and Diagnostic Center (EADC) program are interviewed periodically to reveal how well the EADCs carried out their responsibilities. These structured interviews enable the engineering staff who manage the program to learn how well the EADCs did their work in these plants and how effectively they reported the results. This report presents the results of interviews conducted during the 1986-87 program period at the plants of 175 manufacturers served by nine EADCs located between New England and Colorado.

484 (DOE/CE/40699-T8) **Energy conserved and costs saved by small and medium-size manufacturers: [Final and annual report], 1985-86 EADC [Energy Analysis and Diagnostic Center] program period.** Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Mar 1988. 41p. DOE Contract FC01-84CE40699. Order Number DE88008815. Source: NTIS, PC A03/MF A01; GPO Dep.

The Energy Analysis and Diagnostic Center (EADC) program continues to provide energy-conserving and cost-saving assistance in the plants of small and medium-size manufacturers. This report presents the results of energy audits in 300 such plants carried out by ten EADCs during the 1985-1986 program period. Also included are the results obtained during 1987 from manufacturers who implemented 1,267 of the EADCs' recommendations from the preceding year.

485 (DOE/CE/40699-T9) **Energy conserved and costs saved by small and medium-size manufacturers: 1985-1986 EADC [Energy Analysis and Diagnostic Center] program period.** Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Mar 1988. 41p. DOE Contract FC01-84CE40699. Order Number DE88008614. Source: NTIS, PC A03/MF A01; GPO Dep.

The Energy Analysis and Diagnostic Center (EADC) program continues to provide energy-conserving and cost-saving assistance in the plants of small and medium-size manufacturers. This report presents the results of energy

audits in 300 such plants carried out by ten EADCs during the 1985-86 program period. Also included are the results obtained during 1987 from manufacturers who implemented 1267 of the EADCs' recommendations from the preceding year.

486 (DOE/CE/40699-T10) **Energy conserved and costs saved by small and medium-size manufacturers: 1986-1987 EADC program period.** Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Industrial Technology and Energy Management Div. Mar 1989. 40p. DOE Contract FC01-84CE40699. Order Number DE89011374. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The Energy Analysis and Diagnostic Center (EADC) program provides energy-conserving and cost-saving assistance to small and medium-size manufacturers in 36 states. Engineering faculty from 13 universities, assisted by graduate and undergraduate students, analyze energy usage and manufacturing operations in each plant and then prepare an individualized report that recommends specific actions and estimates their costs and their benefits. Manufacturing plants are eligible if they meet the size criteria and are not more than 150 miles from an EADC. The US Department of Energy, Office of Industrial Programs, sponsors the EADC program, which is managed by University City Science Center, through its Industrial Technology and Energy Management (ITEM) Division. This and similar reports are prepared from data which ITEM staff members extract as they review every energy audit report prepared by the EADCs. Eventually these data also include the results of manufacturers' implementation of EADCs' recommendations, together with costs and savings. 14 tabs.

487 (DOE/CE/40806-T1) **Energy management assistance for small and medium-size manufacturers: Manufacturers' evaluations of EADCs' services, 1987-1988.** Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Industrial Technology and Energy Management Div. Jan 1989. 34p. DOE Contract FC01-87CE40806. Order Number DE89006753. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Small and medium-size manufacturers continue to express strong confidence in and satisfaction with the energy-conserving and cost-saving services provided by the Energy Analysis and Diagnostic Centers. That conclusion is based upon in-depth interviews with 243 of the 388 manufacturers (63%) served during 1987-1988 by an EADC. These interviews were conducted at the manufacturing plants by engineers from the Industrial Technology and Energy Management (ITEM) division of University City Science Center, which manages the EADC program under agreement with the Office of Industrial Programs, US Department of Energy. University engineering faculty and a mix of graduate and undergraduate students who make up the staff of each EADC perform energy audits under subcontract to the Science Center at manufacturing plants which are located within about 150 miles of the university. This report presents the chief results obtained during two series of interviews with 63% of the manufacturers in 36 states served by 13 EADCs during 1987-1988. These include the principal benefits derived by the manufacturers, the extent to which EADCs' recommendations are being understood and implemented, and the manufacturers' perceptions about the ways EADCs carry out their dual mission of industrial service and educational enrichment. The 243 manufacturers interviewed represent 19 different industries (2-digit SIC codes), and they collectively employed over 39,700 persons and sold

more than \$4.7 billion worth of products and services during the past year. 4 figs., 5 tabs.

488 (DOE/CE/40806-T2) **Energy management assistance for small and medium-size manufacturers: Manufacturers' evaluations of EADCs' services, 1988-1989.** Reeder, K.M.; Kirsch, F.W. University City Science Center, Philadelphia, PA (USA). Oct 1989. 34p. Sponsored by USDOE, Washington, DC (United States). DOE Contract FC01-87CE40806. Order Number DE90003440. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Small and medium-size manufacturers continue to express strong confidence in and satisfaction with the energy-conserving and cost-saving services provided by the Energy Analysis and Diagnostic Centers. That conclusion is based upon in-depth interviews with 227 of the 340 manufacturers (67%) served during 1988-89 by an EADC. These interviews were conducted at the manufacturing plants by engineers from the Industrial Technology and Energy Management (ITEM) division of University City Science Center, which manages the EADC program under agreement with the Office of Industrial Programs, US Department of Energy. University engineering faculty and a mix of graduate and undergraduate students who make up the staff of each EADC perform energy audits under subcontract to the Science Center at manufacturing plants which are located within about 150 miles of the university. This report presents the chief results obtained during two series of interviews with 67% of the manufacturers in 36 states served by 13 EADCs during 1988-89. These include the principal benefits derived by the manufacturers, the extent to which EADCs' recommendations are being understood and implemented, and the manufacturers' perceptions about the ways EADCs carry out their dual mission of industrial service and educational enrichment.

489 (DOE/CS/40048-2) **Demonstration of the potential for energy conservation in several food-processing plants. Final report, December 15, 1977-December 31, 1980.** Okos, M.R.; Marks, J.S.; Baker, T. Purdue Univ., Lafayette, IN (USA). Dept. of Agricultural Economics. 15 Oct 1981. 486p. DOE Contract AS02-77CS40048. Order Number DE82005298. Source: NTIS, PC A21/MF A01.

Portions of this report are illegible.

A detailed energy audit was performed on an operating fluid milk plant with a 1979 production of 12.33 million gallons. Approximately 52% of the fuel energy was lost to inefficient boiler operation. About 40% of the electrical demand is from refrigeration compressors. A detailed evaluation was made of various energy saving options. The process heat requirements can be economically decreased to 8.4 billion Btu from the present 26.4 billion Btu's. Similarly it was found that 1.15 million kWh of electricity could be saved based on the 1979 consumption load. Using various heat recovery options, it was found, while maintaining the normal investment criterion, the boiler fuel requirement could be decreased to less than 1 billion Btu's per year.

490 (DOE/CS/40048-3) **Demonstration of the potential for energy conservation in a creamery. Final report.** Clark, S.; Okos, M. Purdue Univ., Lafayette, IN (USA). Dept. of Agricultural Engineering. 1 Oct 1981. 468p. DOE Contract AS02-77CS40048. Order Number DE82010505. Source: NTIS, PC A20/MF A01.

An intensive analysis was made of the energy consumption opportunities of an operating dairy plant. The layout of

the food plant is given. Data on the monthly and yearly pattern of fuel use are presented. The procedure for conducting an energy audit to obtain utility flow parameters is described. Descriptions and balances of the utilities (water, steam, refrigeration, electricity, and gas) are included. Descriptions of processes and products are given. A program, written to calculate mass and energy balances on the spray dryer using data gathered in the plant, is utilized. Energy saving methods employed and alternatives discussed in detail are evaporators; the spray dryer, and boilers. Regeneration and other methods of heat recovery are discussed. Information included in appendices includes: definitions; product rankings and yearly production; mass and energy balance calculations; computer programs; time lines of equipment use; description and current operation of equipment. (MCW)

491 (DOE/CS/40199-T5) **CENTEC project quarterly report.** Centec Corp., Fort Lauderdale, FL (USA). Jul 1980. 4p. DOE Contract AC03-79CS40199. Order Number DE81027024. Source: NTIS, PC A02/MF A01.

Energy surveys were made at 21 food processing plants. Combustion efficiency data on the boilers are briefly mentioned. (MCW)

492 (DOE/CS/40402-T2-Vol.2) **Case histories of recently implemented technologies for citrus-processing energy-efficiency improvement. Volume II. Final report.** Centec Corp., Reston, VA (USA). Dec 1982. 32p. DOE Contract AC01-80CS40402. Order Number DE83006268. Source: NTIS, PC A03/MF A01.

For each of six citrus industry sites where energy efficiency improvement technologies have been implemented, a case history is presented which describes the implemented technology, its investment cost, and the energy and cost savings. The technologies are: double pressing in feed mill operation; evaporator microprocessor controller; feed mill vent stack controller; addition of a waste heat evaporator to a feed mill; enhanced lime reaction for improved pressing and dewatering in a feed mill, and added effect to a temperature-accelerated short-time evaporator. (LEW)

493 (PNL-4319) **Case history studies of energy conservation improvements in the dairy industry.** Pacific Northwest Lab., Richland, WA (USA). Jun 1982. 94p. DOE Contract AC06-76RL01830. Order Number DE82018828. Source: NTIS, PC A05/MF A01.

Presented are ten case histories about energy-efficient technologies implemented by the dairy industry. For each case is presented: the name and location of the company, and its product line; energy consumption and costs at the plant before and after implementation of energy-conserving technology; the factors that prompted the investment; and product quality as a result of the new equipment. The measures presented are: refrigeration compressor replacement, turbulators in boiler tubes, stack exchange on boilers, reverse osmosis, six-effect evaporator, multi-effect evaporator with thermal vapor recompressor, spray dryer heat recovery, efficient compressor operations, mechanical vapor recompression evaporator, preheated spray dryer air with recoverable waste heat. (LEW)

494 (PNL-4320) **Case history studies of energy conservation improvements in the meat industry.** Pacific Northwest Lab., Richland, WA (USA). Jun 1982. 85p. DOE Contract AC06-76RL01830. Order Number DE82018830. Source: NTIS, PC A05/MF A01.

Presented are case histories for ten energy-efficient technologies implemented by the meat industry. For each case

is presented: the name and location of the plant, name of plant employee contact with address and telephone number, energy consumption and costs at the plant before and after implementation of energy-conserving technology, description of the investment decision process, and changes in production or product quality as a result of the new equipment. The measures presented are: continuous rendering, high-pressure return on the boiler, heat recovery from condensate return and flash steam, continuous whole blood processing, preheating of process water with recovered refrigeration waste heat, continuous rendering of poultry scraps, electrical stimulation of beef, preheating and storing process water with recovered refrigeration waste heat, microcomputer control system, and housekeeping improvements. (LEW)

495 (PNL-4362) **Ten case-history studies of energy-efficiency improvements in pulp and paper mills. Final report.** Battelle Pacific Northwest Lab., Richland, WA (USA); Centec Corp., Reston, VA (USA). 1981. 99p. DOE Contract AC06-76RL01830. Order Number DE82018829. Source: NTIS, PC A05/MF A01.

The ten technologies chosen for case history development are: sonic sootblowing in boilers, boiler operation on oil-water emulsified fuel, energy efficient motors, computerized control of excess air for boilers, boiler control and load allocation, driving of waste-activated sludge by multiple effect evaporation, pre-drying of hog fuel, lime kiln computerization, heat wheel for process heat recovery, and organic Rankine bottoming cycle for thermomechanical pulping heat recovery. For each case study, there is given: the company name, employee contact, plant summary, a description of the energy consuming process and of the energy-saving action, an assessment of energy savings, and the decision process leading to the adoption of the measure. A data summary for discounted cash flow analysis is tabulated for each case. (LEW)

496 (PNL-4363) **Energy conservation in the textile industry: 10 case histories.** Pacific Northwest Lab., Richland, WA (USA); Georgia Inst. of Tech., Atlanta (USA). Engineering Experiment Station. [nd]. 95p. DOE Contract AC06-76RL01830. Order Number DE82018831. Source: NTIS, PC A05/MF A01.

Presented are ten case studies of energy conserving technologies that have been implemented by the textile industry. For each case is given: the name and location of the plant and an employee contact, description of products, energy consumption and costs in years before and after the energy conserving technology was implemented, energy savings since the energy conserving technology was implemented, description of investment decision-making process, and description of any institutional and environmental considerations. Measures included are: tandem preparation line, dyebath reuse, bump-and-run (dyebath temperature drifts for the last 85% of the hold time), foam finishing, wastewater heat recovery, wastewater chlorination and reuse, oven exhaust air counterflow, boiler economizer, wood-fired boiler, and solar industrial process heat. Several other energy conserving technologies that were not studied are briefly summarized. (LEW)

497 (PNL-4636) **Energy audit of three energy-conserving devices in a steel-industry demonstration program. Task I. Hague forge furnaces. Final report.** Lownie H.W., Holden, F.C. Battelle Columbus Labs., OH (USA). Jun 1982. 169p. DOE Contract AC06-76RL01830.

Order Number DE83007254. Source: NTIS, PC A08/MF A01.

A program to demonstrate to industry the benefits of installing particular types of energy-conserving devices and equipment was carried out. One of these types of equipment and the results obtained under production conditions in commercial plants are described. The equipment under consideration includes improved forge furnaces and associated heat-recovery components. They are used to heat steel to about 2300 F prior to hot forging. The energy-conserving devices include improved insulation, automatic air-fuel ratio control, and a ceramic recuperator that recovers heat from hot combustion gases and delivers preheated air to high-temperature recirculating burners. Twelve Hague furnaces and retrofit packages were purchased and installed by eleven host forge shops that agree to furnish performance data for the purpose of demonstrating the energy and economic savings that can be achieved in comparison with existing equipment. Fuel savings were reported by comparing the specific energy consumption (Btu's per pound of steel heated) for each Hague furnace with that of a comparison furnace. Economic comparisons were made using payback period based on annual after-tax cash flow. Payback periods for the Hague equipment varied from less than two years to five years or more. In several cases, payback times were high only because the units were operated at a small fraction of their available capacity.

498 (PNL-4733) **Energy audit of three energy-conserving devices in a steel-industry demonstration program. Task II. Garrett-Airesearch high-effectiveness recuperator. Final report.** Lownie, H.W.; Holden, F.C. Battelle Columbus Labs., OH (USA). 9 Mar 1983. 42p. DOE Contract AC06-76RL01830. Order Number DE83013394. Source: NTIS, PC A03/MF A01.

The Office of Industrial Programs of the Department of Energy has undertaken a program to demonstrate to industry the benefits of installing various energy-conserving systems. Preliminary results are presented from one of those systems, a high-effectiveness metallic recuperator designed and manufactured by AiResearch Manufacturing Company of California, a division of the Garrett Corporation of Torrance, California. This high-effectiveness recuperator recovers waste heat from the exhaust gases of an industrial furnace and returns preheated combustion air to the furnace thereby increasing thermal efficiency and improving fuel economy. Installations have been completed or are in progress for 5 of the 20 host sites originally planned. Preliminary operating data are available for three sites, and these indicate that improvements in fuel economy are achieved at about the levels predicted. These ranged from about 17 to 37 percent of the unrecuperated furnace fuel consumption rates. Procedures are presented for calculating payback times using a cumulative after-tax cash flow method which includes tax investment credits, estimates of general and fuel-price inflation, and maintenance costs. For the sites where sufficient information was available to make such calculations, payback times were in 1-2 year range.

499 (PNL-4770) **Economic and energy audit of textile foam processing.** Machacek, R. Little (Arthur D.), Inc., Cambridge, MA (USA). Jun 1983. 91p. DOE Contract AC06-76RL01830. Order Number DE83015020. Source: NTIS, PC A05/MF A01.

Conventional wet processing of textiles - dyeing, or application of such surface finishes as soil and water repellents, antistatic agents, fire retardants, permanent press agents,

and starch - consumes about 0.19 quadrillion Btu's of energy per year, the equivalent of 30 million barrels of oil. Because wet processing involves immersion of the fabric in a water bath, most of the energy used is in the form of heat for drying. In the newer foam finishing approach, the chemicals for surface finishes are dispersed in a mixture of water and air. The chemicals are concentrated in a relatively small amount of water, and air is injected to form a thick, stable foam. Because little water is involved, drying time and temperature may be drastically reduced. Authur D. Little, Inc., conducted an economic and energy audit of foam processing that considered the technical feasibility, reliability, energy savings, and economic incentives for using foam finishing. We monitored four plants that finish textiles (carpets, broad-woven fabrics, and tubular knits). The plants were selected by the developer of the foaming process (United Merchants and Manufacturers, Inc.) to represent a wide range of textile finishing applications.

TECHNOLOGY TRANSFER

500 (DOE/CE-0038) **The industrial sector technology use model: Project summary.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Dec 1982. 18p. Order Number DE88015213. Source: NTIS, PC A03/MF A01; GPO Dep.

A two-year cooperative project between private industry and government to develop a credible tool for analyzing and understanding the impacts of public policy and business decisions on industrial energy use has just been completed. The resulting analytical model, a computer program called the Industrial Sector Technology Use Model (ISTUM), is expected to be broadly useful to public policy analysis, and for business planning by equipment manufacturers, energy suppliers and trade associations. The basic premise in ISTUM is that technology choices are made to minimize the total cost of production. In order to develop the capability of simulating these choices, extensive and detailed data concerning industrial sector production technologies, capabilities, and energy requirements were collected. A highly disaggregated representation of both industry specific processes and generally applicable energy services.

501 (DOE/CE-0157) **Annual report to the Congress and the President on industrial energy efficiency improvement, 1984.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Jun 1986. 76p. Order Number DE86013423. Source: NTIS, PC A05/MF A01; GPO Dep.

This annual report to the Congress and President is divided into three major sections: (1) a presentation of data on energy consumption and efficiency improvement across the entire industrial sector; (2) a presentation of data and discussion on methods used to conserve energy for manufacturing industries grouped within each two-digit SIC category; and (3) a brief discussion on industry progress in recovered materials utilization.

502 (DOE/CE-0173) **The DOE Industrial Energy Conservation Program: Overview of ceramic research.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Dec 1986. 51p. Order Number DE87003613. Source: NTIS, PC A04/MF A01; GPO Dep.

In general, ceramics projects accounted for over 10% of the \$41 million in DOE-IP allocated funding, and involved almost 13% of the 94 FY 1986 funded projects. The bulk of these efforts was found to include three discrete, coordinated subprograms whose main objective was to promote the use of ceramics technology in specific industrial applications: advanced heat exchangers; inert electrodes; and membranes.

503 (DOE/CE-0176) The DOE industrial energy conservation program: Research and development in the iron and steel industry. USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Feb 1987. 26p. Order Number DE87006192. Source: NTIS, PC A03/MF A01; GPO Dep.

In an effort to maintain a strong and productive industrial base and to reduce reliance on imported energy sources, the US Department of Energy, Office of Industrial Programs, conducts industrial energy conservation research and development activities. To date, the Office of Industrial Programs has supported over two hundred research and development projects covering a wide spectrum of industrial applications. This brochure presents a summary of the Office of Industrial Programs' research and development activities to date for the steel industry. It was prepared to serve as a tool to aid in the transfer of the results of these activities to those interested in Federal Industrial energy conservation activities.

504 (DOE/CE-0178) The DOE Industrial Energy Conservation Program: Program summary. USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Dec 1986. 32p. Order Number DE87007153. Source: NTIS, PC A03/MF A01; GPO Dep.

With its industrial partners, the Industrial Program has successfully developed over 20 new technologies now in commercial use. These technologies saved an estimated 38.9 trillion Btu in 1986, worth \$156 million per year at an average energy price of \$4 per million Btu. These completed technologies are only the leading edge of over 100 active R & D projects. More adaptable, fuel-flexible cogeneration technologies developed by the Program are an important contribution to industry's resilience to future energy shocks. New, higher-temperature waste heat recovery equipment and incrementally improved process technologies developed by the Program will help to moderate growth in the amount of industrial fuel use. Major process innovations are being pursued by the Program and private industry.

505 (DOE/CE-0184) Annual report to the Congress And the President on industrial energy efficiency improvement, 1985. USDOE Assistant Secretary for Conservation And Renewable Energy, Washington, DC. Office of Industrial Programs. May 1987. 81p. Order Number DE87011085. Source: NTIS, PC A05/MF A01; GPO Dep.

This report is divided into three sections: A presentation of data on energy consumption And efficiency Across the entire industrial sector, A presentation of data And discussion on methods used to conserve energy for manufacturing industries grouped within each two-digit SIC category. And A brief discussion on industry progress in recovered materials utilization.

506 (DOE/CE-0243) The DOE industrial energy conservation program: Research and development in materials development and applications. USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Dec 1988.

29p. Order Number DE89005981. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Materials are critical to the many industrial processes, and improvements in various materials has increased the energy efficiency of many processes. This brochure describes the Office of Industrial Program's research and development activities in the advancement of materials technology. The purpose of this brochure is to provide interested parties with information on federal industrial energy conservation activities related to materials. The brochure is comprised of the following sections: Materials Development, summarizes the state of materials development and major areas of materials-related research and development by IP; Potential Energy Savings, identifies the potential for energy conservation through advances in materials; Office of Industrial Program's Material Research and Development, describes specific, selected materials-related R and D projects conducted by IP; and R and D Data Base, lists contractor, principal investigator, and location of materials-related R and D efforts sponsored by IP. 11 figs.

507 (DOE/CH/10093-31) Programs in energy conservation: Industrial programs. Solar Energy Research Inst., Golden, CO (USA). Dec 1988. 17p. Sponsored by US-DOE, Washington, DC (United States). DOE Contract AC02-83CH10093. Order Number DE89000803. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

In an era of uncertain energy costs, oil import-driven trade deficits, and intense international competition in industrial markets, leadership in the development and use of energy-conservative technologies is vital to the well-being of US industry. The Industrial Energy Conservation Program, managed by the Office of Industrial Programs (OIP) of the US Department of Energy (DOE), supports research and development (R and D) to improve the energy efficiency of industrial processes and to develop technologies that use multiple types of fuels. In pursuing these primary objectives, the program also advances US technological leadership and enhances US industry's competitive position. The program communicates information on emerging technologies widely and promptly throughout industry. The challenge addressed by the program is broad. Industry's share of national energy consumption currently amounts to 36%. This energy is used in a wide variety of combustion applications, chemical reaction and electrolytic processors, and direct motor-drive applications. Many of these processes have energy efficiencies far below theoretical limits and substantially lower than the efficiencies of competing processes in other countries. An improvement of only 1% in the rate of industrial energy use would save about 0.3 quad (one quad is a thousand trillion Btu) per year, worth about \$1 billion.

508 (DOE/CS/2123-T1) Computer technology can enhance industrial energy efficiency. Centec Consultants, Inc., Fort Lauderdale, FL (USA). 1979. 36p. DOE Contract AC01-76CS40104. Source: NTIS, PC A03/MF A01.

Rapid escalation in energy costs since 1973 has increased operating costs and, in turn, caused a sharp rise in the prices of both consumer and industrial products. Reoptimizing manufacturing processes to account for higher energy costs is a formidable task and will strain the technical manpower of industrial communities. Analysis of a process will identify several technological or operating options that might decrease operating costs by improving energy efficiency and feedstock use. Each option must be carefully evaluated to achieve the maximum return on invested capital and manpower costs. Developments in

computer technology have created tools with potential for energy conservation in the process industries comparable in some cases to the use of more energy-efficient process equipment. Some of the new developments are discussed. This report was written to familiarize the process industry manager with computer applications that have potential for minimizing energy consumption and to present an overview of the current level of computer technology and terminology as it applies to the process industry.

509 (DOE/CS/2123-T2) **Computer technology: its potential for industrial energy conservation. A technology applications manual.** Centec Consultants, Inc., Fort Lauderdale, FL (USA); Centec Consultants, Inc., Reston, VA. 1979. 64p. DOE Contract EX-76-C-01-2123. Source: NTIS \$9.50.

Today, computer technology is within the reach of practically any industrial corporation regardless of product size. This manual highlights a few of the many applications of computers in the process industry and provides the technical reader with a basic understanding of computer technology, terminology, and the interactions among the various elements of a process computer system. The manual has been organized to separate process applications and economics from computer technology. Chapter 1 introduces the present status of process computer technology and describes the four major applications - monitoring, analysis, control, and optimization. The basic components of a process computer system also are defined. Energy-saving applications in the four major categories defined in Chapter 1 are discussed in Chapter 2. The economics of process computer systems is the topic of Chapter 3, where the historical trend of process computer system costs is presented. Evaluating a process for the possible implementation of a computer system requires a basic understanding of computer technology as well as familiarity with the potential applications; Chapter 4 provides enough technical information for an evaluation. Computer and associated peripheral costs and the logical sequence of steps in the development of a microprocessor-based process control system are covered in Chapter 5.

510 (DOE/CS/40402-T4) **DOE Industrial Energy Conservation Program.** Department of Energy, Washington, DC (USA). Office of Industrial Programs. 1984. 32p. DOE Contract AC01-80CS40402. Order Number DE84012880. Source: NTIS, PC A03/MF A01; GPO Dep.

The background, function, technical achievements, and plans of the Industrial Energy Conservation Program are described. Technical achievements are presented in the areas of waste energy reduction, cogeneration, and industrial process efficiency. A list of research and development contractors is included. (MHR)

511 (DOE/IEC-88/1) **Industrial Energy Conservation: A current awareness bulletin.** Williams, L.E. (ed.). USDOE Office of Scientific and Technical Information, Oak Ridge, TN. Jan 1988. 34p. Order Number DE88008287. Source: NTIS, PC A03/MF A01; GPO Dep.

Industrial Energy Conservation (IEC) announces on a monthly basis the current worldwide information on all aspects of energy conservation in industry, including alternate energy sources; improved materials, equipment, and processes; waste heat recovery; and industrial waste management. This publication contains the abstracts of DOE reports, journal articles, conference papers, patents, theses, and monographs added to the Energy Data Base (EDB) during the past month. Also included are US information

obtained through acquisition programs or interagency agreements and international information obtained through the International Energy Agency's Energy Technology Data Exchange or government-to-government agreements.

512 (DOE/NBM-7012450) **Research and development in sensor technology: The DOE industrial energy conservation program.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC. Office of Industrial Programs. Apr 1987. 23p. Order Number DE87012450. Source: NTIS, PC A02; GPO Dep.

Sensor technology is an important component of modern day process technologies. It lends itself to further research and development with the potential for increased energy efficiency and productivity. Sensors are used by industry in practically every aspect of the production process. The utilization of automatic control systems and the anticipation of increased future applications of computers in production processes have highlighted the importance of research in this area. Recognizing this need, IP has funded a series of targeted projects to develop process-specific sensors as well as sensors for generic applications. This brochure describes, in summary form, the Office of Industrial Programs' research and development (R & D) efforts in the advancement of sensor technology.

513 (DOE/NBM-8002773) **Research and development separation technology: The DOE Industrial Energy Conservation Program.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC (USA). Office of Industrial Programs. Jul 1987. 33p. Order Number DE88002773. Source: NTIS, PC A03/MF A01; GPO Dep.

This brochure summarizes the Office of Industrial Programs' R&D efforts in the advancement of separation technology. The purpose of this brochure is to provide interested parties with information on federal industrial energy conservation activities in separation technology. The brochure is comprised of the following sections: Separation Technology, summarizes the current state of separation technology and its uses. Potential Energy Savings, discusses the potential for industrial energy conservation through the implementation of advanced separation processes. Office of Industrial Programs' R&D Efforts in Separation Technology Development, describes the separation R&D projects conducted by IP. R&D Data Base, lists contractor, principal investigator, and location of each separation-related R&D effort sponsored by IP.

514 (DOE/NBM-8005775) **Research and development in the textile industry.** USDOE Assistant Secretary for Conservation and Renewable Energy, Washington, DC (USA). Office of Industrial Programs. Jun 1987. 19p. Order Number DE88005775. Source: NTIS, PC A03/MF A01; GPO Dep.

Included in the portfolio of IP's projects are the R & D activities for several advanced technologies targeted at the textile industry, one of the top ten energy intensive industries in the country. These R & D projects have primarily been aimed at improving the energy efficiency and productivity of textile production processes. Many projects in this area have been successfully completed, and some have resulted in the development and implementation of new technologies (e.g., foam processing) for various process steps. Other projects have produced technical results that have later been utilized by the industry in other capacities (e.g., hyperfiltration). Several projects at various stages of

development are currently underway. This brochure describes the Office of Industrial Programs' R & D activities relevant to the textile industry. The brochure is comprised of the following: Industry Update, Energy Consumption in the Textile Industry, Energy Consumption in the Textile Industry, Potential Energy Savings in the Textile Industry, Office of Industrial Programs, R & D Efforts, and R & D Data Base.

515 (DOE/OSTI-3409) **The Office of Industrial Programs technical reports: A bibliography.** Blackburn, P.S. (comp.). USDOE Office of Scientific and Technical Information, Oak Ridge, TN (USA). Oct 1988. 80p. Order Number DE88006687. Source: NTIS, PC A05/MF A01 - OSTI; GPO Dep.

This bibliography is the first annotated publication containing information on all scientific and technical reports sponsored by the DOE Industrial Energy Conservation Program during the years 1974-1987. The abstracts are grouped by program subdivision as shown in the Contents. Cross categorization is provided when the report covers more than one topic. Within each group, arrangement is alphabetized by report number in reverse chronological order. Interim progress reports have been excluded when there is a final report on the project.

516 (DOE/OSTI-11633) **Office of industrial programs research in progress.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. Oct 1988. 32p. Order Number DE88016467. Source: NTIS, PC A03/MF A01; GPO Dep.

The US 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 US 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.

517 (EGG-M-26687) **Research in industrial combustion systems: Current and future R and D.** Rebello, W.J.; Keller, J.C. EG and G Idaho, Inc., Idaho Falls, ID (USA); PAR Enterprises, Inc., Fairfax, VA (USA). 1987. 9p. DOE Contract AC07-76ID01570. (CONF-8709166-5; 9. annual industrial energy technology conference, College Station, TX, US, September 16, 1987). Order Number DE88006789. Source: NTIS, PC A02/MF A01; GPO Dep.

This paper briefly describes the current R and D activity in industrial combustion systems. The areas covered are novel

burner systems, oxygen enriched systems, combustion controls and sensors and unique industrial process modifications. Some of the future research needs in industrial combustion systems have been identified. These include improved techniques of heat transfer to the load, improved sensors, plasmas to process materials and flash or pneumatic reactors for the metals, non-metals and petrochemical industries. 26 refs.

518 (NBS-Handbook-115) **Energy conservation program guide for industry and commerce (EPIC).** Gatts, R.R.; Massey, R.G.; Robertson, J.C. National Bureau of Standards, Washington, DC (USA). Inst. for Applied Technology. Sep 1974. 207p. Source: NTIS, PC A10/MF A01.

An abstract for this document appears in EAPA 1:20. An abstract to NBS-Handbook-115 (Suppl. 1), dated Dec. 1975 appears in: ERA 1:23563. 175 references.

519 (NBS-Handbook-115(Suppl.1)) **Energy Conservation Program Guide for Industry and Commerce (EPIC).** Massey, R.G. (ed.). National Bureau of Standards, Washington, DC (USA). Office of Energy Conservation. Dec 1975. 84p. Source: GPO \$2.25.

The first supplement to the National Bureau of Standards Handbook 115 "Energy Conservation Program for Industry and Commerce (EPIC)," provides more ideas and suggestions to aid in energy conservation efforts by industrial companies, educational systems, hospitals, and government agencies. The supplement includes a revised explanation of how to implement an energy conservation program, an expanded checklist of energy conservation opportunities, additional case studies, and additions and revisions to other sections of the handbook.

520 (NBS-Handbook-120) **Energy management guide for light industry and commerce.** Kelnhofer, W.J.; Wood, L.A. National Bureau of Standards, Washington, DC (USA). Dec 1976. 28p. Source: GPO \$0.70.

The Energy Management Guide for Light Industry and Commerce is a training tool to assist small industrial and commercial organizations in an energy conservation program. It is part of a planned series of guides and training aids to assist industry in making the most efficient use of the energy supply. While much of the information in the Light Industry Guide has been published in NBS Handbook 115(Energy Conservation Program Guide for Industry and Commerce), the material has been edited and re-written in shortened form for use by the large number of small organizations with a limited supply of technical manpower. The energy conservation case studies (Cost Saving Opportunities) have been written with this target audience in mind.

521 (NBS-Handbook-121) **Waste heat management guidebook.** Kreider, K.G.; McNeil, M.B. (eds. National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. 179p. Source: GPO \$2.75.

Seven papers on sources of waste heat in industrial processes and the technical and economic aspects of heat recovery are presented. A separate abstract was prepared for each chapter; one chapter, Economics of Waste Heat Recovery, by R. Ruegg of NBS, is included in Energy Abstracts for Policy Analysis (EAPA). (LCL)

522 (NBS-Handbook-121, pp. 5-8) **Sources and uses of waste heat.** Rohrer, W.M. Jr. (Univ. of Pittsburgh); Kreider, K.G. National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC

(USA). Feb 1977. In *Waste heat management guidebook*. 5-8p.

Sources and uses of waste heat from industrial processes are discussed by defining waste heat, presenting tabulated data on the temperature of the heated effluents from specific industrial equipment, enumerating uses of waste heat in heat exchange processes and by suggesting ways to organize and implement a waste heat management program. (LCL)

523 (NBS-Handbook-121, pp. 9-23) **Determination of waste heat requirements.** Rohrer, W.M. Jr. (Univ. of Pittsburgh); Geiger, G.E. National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 9-23p.

The theoretical bases for estimating the quantity and quality of heat available in a waste stream and the transfer of waste heat for use in another material or process are discussed. (LCL)

524 (NBS-Handbook-121, pp. 53-140) **Case studies of successful systems for industrial waste heat recovery.** Leidy, B. (Univ. of Pittsburgh). National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 53-140p.

Summaries are presented of several successful industrial installations of waste heat recovery systems. These case studies are selected to represent: major commercial options in waste heat recovery equipment, e.g., radiation recuperator, economizer, heat wheel; various industrial applications of heat recovery equipment. Examples are glass-making, forge furnace, paint and varnish processing; and various geographical locations throughout the US. The case studies are presented without naming the industrial firm where the system was successfully operated. In each case, a check has been made of the data used or recorded by the firm to establish the benefits resulting from the application of the waste heat recovery system.

525 (NBS-Handbook-121, pp. 25-51) **Economics of waste heat recovery.** Ruegg, R. (National Bureau of Standards, Washington, DC). National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 25-51p.

Concepts and analytical techniques are presented which can guide the industrial plant manager in evaluating the economic efficiency of investments in waste heat utilization. The use of alternative methods of evaluating and comparing energy-saving investments is explained. The methods which are treated range from very simple, first-level techniques such as determination of the payback period, to more comprehensive techniques such as benefit-cost analysis, life-cycle cost analysis, and the internal rate-of-return method. The discussion covers the treatment of taxes, inflation, and uncertainty in data estimates and assumptions. The kinds of financial data needed to perform the economic analyses are identified, and the appropriateness of the different evaluation methods for analyzing various kinds of investment decisions is explained.

526 (NBS-Handbook-121, pp. 141-154) **Commercial options in waste heat recovery equipment.** Rohrer, W.M. Jr. (Univ. of Pittsburgh). National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 141-154p.

Common types of waste heat recovery equipment used in industrial plants are discussed in some detail. The operation and performance characteristics of the following types of industrial heat exchangers are described: gas-to-gas units including radiation and convection recuperators, heat wheels, heat pipe, heat exchangers, gas or liquid-to-liquid regenerators, waste heat boilers, and heat pumps. (LCL)

527 (NBS-Handbook-121, pp. 185-200) **Engineering data for waste heat recovery.** National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 185-200p.

Data and graphs are compiled which are used in the various case studies and which are valuable in analyzing large classes of waste heat problems. These graphs include: natural gas combustion chart; heat content of the major components of flue gases; heat capacity of the major components of flue gases; theoretical dew points of flue gases from industrial fuels; fuel savings available using combustion air preheating; heat recovered by recuperation as a function of flow rate and air preheat temperature; and fuel saving nomographs for air preheaters. Tables contain information on: heat transfer coefficients for steel pipes and plates; steam table extracts; apparent specific heats of steels; physical properties of fuel oil at 60°; typical properties of petroleum fuels; properties of gases; and conversion table to SI units.

528 (NBS-Handbook-121, pp. 155-184) **Instrumentation.** National Bureau of Standards, Washington, DC (USA); Federal Energy Administration, Washington, DC (USA). Feb 1977. In *Waste heat management guidebook*. 155-184p.

In order to make optimum use of waste heat, the engineer or manager needs to select techniques for measuring the essential parameters of the system with which he is dealing. Available technology for such measurements, is reviewed with discussions of four vital areas: thermometry, flow and pressure measurement, infrared thermography, and flue gas analysis.

529 (NBS-Handbook-124) **Energy management for furnaces, kilns, and ovens.** Wood, L.A.; Ward, J.F.; Kreider, K.G. National Bureau of Standards, Washington, DC (USA). Office of Energy Conservation. Jan 1978. 46p. Source: NTIS, PC A03/MF A01.

This handbook, part of the EPIC Energy Management Series, is directed to the user of direct fired heating equipment in light industry. Other publications in this series outline steps to plan and establish an energy conservation program in a business or industry. This handbook is a guide to making decisions as to just what actions are appropriate and effective for energy savings in equipment such as furnaces, kilns, and ovens. The major technique described is the heat balance. Examples of heat balances are used to identify energy losses on a batch furnace, a continuous paint dryer oven, and a slot forging furnace. Typical energy conservation opportunities in combustion control, insulation, etc. are discussed. Simplified methods of calculation and measurement are given. Benefit/cost analysis and the time required to recoup investment are described as means of evaluating energy-saving investments.

530 (PNL-4499) **Survey and analysis of federally developed technology.** Reed, J.E.; Conrad, J.L. Energetics, Inc., Columbia, MD (USA). Feb 1983. 110p. DOE Contract AC06-76RL01830. Order Number DE83008124. Source: NTIS, PC A06/MF A01.

The methodology and results of a test effort to determine whether there exist unexpected opportunities for the direct transfer of technologies from federal laboratories to industry are presented. Specifically, the latest results of six federal laboratories with potential application in the pulp and paper industry, particularly those results applicable to improving energy productivity, were evaluated, cataloged, and distributed to industry representatives to gauge their reaction. The principal methodological steps in this effort were the development of a taxonomy of the pulp and paper industry, identification of industry needs and laboratory capabilities, laboratory visits, review of technology findings with industry, and evaluation and compilation of industry responses.

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531 (ANL/CNSV-3) Energy and materials flows in the fabrication of aluminum products. Arons, R.M.; Wolsky, A.M. Argonne National Lab., IL (USA). Aug 1978. 69p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A04/MF A01.

In 1977, 1.5% of all purchased fuels and electricity used by US industry was consumed in the holding, casting, melting, and production of mill products by the aluminum industry. An in-depth understanding of how that energy is used is necessary for the formulation of plans to reduce energy consumption. Similarly, assessment of the relative value of innovative energy efficient processing techniques depends upon a better understanding of current practice. This report describes the aluminum fabrication process in great detail and cites energy use and efficiency for each process step. It is concluded that the most effective approaches to energy conservation would be use of methods for waste heat reduction and recovery, reduction of scrap generation during processing, use of induction heating for both melting and heat treating, and use of alternative processing techniques that eliminate energy intensive intermediate steps.

532 (ANL/CNSV-10) Energy and materials flows in petroleum refining. Gaines, L.L.; Wolsky, A.M. Argonne National Lab., IL (USA). Feb 1981. 159p. DOE Contract W-31-109-ENG-38. Order Number DE81024484. Source: NTIS, PC A08/MF A01.

The total energy consumed by petroleum refining is approximately 3 quads, making refining the largest industrial use of energy. United States refineries processed 13.5×10^6 bbl/d of crude oil in 1980, about 39% of which was imported. Refinery processes, which separate and transform crude into desired end products, consume - mostly for separation - about 10% of the energy content of the crude, taking 23% of this energy for crude distillation, 31% for cracking and fractionation, 11% for reforming and fractionation, and 6% for alkylation and fractionation. The last three of these processes are primarily designed to increase yield of gasoline, which makes up 42% of refined product volume. Lubricating products constitute only 1% of product volume, but their manufacture, being energy intensive, consumes 8% of total refinery energy. Lubricating oils are unusual among refinery products in that they can be recycled, as can asphalt, and some chemicals and polymers derived from petroleum. Several straightforward process modifications could reduce

refinery energy consumption as much as 20%. Further reductions in energy use would require development of new processes, such as alternatives to distillation. Shale oil, coal, and biomass are possible substitutes for petroleum in the long term.

533 (ANL/CNSV-11) Energy and materials flows in the copper industry. Gaines, L.L. Argonne National Lab., IL (USA). Dec 1980. 104p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A06/MF A01.

The copper industry comprises both the primary copper industry, which produces 99.9%-pure copper from copper ore, and the secondary copper industry, which salvages and recycles copper-containing scrap metal to extract pure copper or copper alloys. The United States uses about 2 million tons of copper annually, 60% of it for electrical applications. Demand is expected to increase less than 4% annually for the next 20 years. The primary copper industry is concentrated in the Southwest; Arizona produced 66% of the 1979 total ore output. Primary production uses about 170×10^{12} Btu total energy annually (about 100×10^6 Btu/ton pure copper produced from ore). Mining and milling use about 60% of the total consumption, because low-grade ore (0.6% copper) is now being mined. Most copper is extracted by smelting sulfide ores, with concomitant production of sulfur dioxide. Clean air regulations will require smelters to reduce sulfur emissions, necessitating smelting process modifications that could also save 20×10^{12} Btu (10×10^6 Btu/ton of copper) in smelting energy. Energy use in secondary copper production averages 20×10^6 Btu/ton of copper. If all copper products were recycled, instead of the 30% now salvaged, the energy conservation potential would be about one-half the total energy consumption of the primary copper industry.

534 (ANL/CNSV-15) Energy and materials flows in the production of liquid and gaseous oxygen. Shen, S.; Wolsky, A.M. Argonne National Lab., IL (USA). Aug 1980. 37p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A03/MF A01.

Liquid and gaseous oxygen is produced in an energy-intensive air separation process that also generates nitrogen. More than 65% of the cost of oxygen is attributable to energy costs. Energy use and materials flows are analyzed for various air separation methods. Effective approaches to energy and material conservation in air separation plants include efficient removal of contaminants (carbon dioxide and water), centralization of air products user-industries so that large air separation plants are cost-effective and the energy use in transportation is minimized, and increased production of nitrogen. Air separation plants can produce more than three times more nitrogen than oxygen, but present markets demand, at most, only 1.5 times more. Full utilization of liquid and gaseous nitrogen should be encouraged, so that the wasted separation energy is minimized. There are potential markets for nitrogen in, for example, cryogenic separation of metallic and plastic wastes, cryogenic particle size reduction, and production of ammonia for fertilizer.

535 (ANL/CNSV-16) Energy and materials flows in the production of pulp and paper. Hersh, H.N. Argonne National Lab., IL (USA). May 1981. 193p. DOE Contract W-31-109-ENG-38. Order Number DE82000890. Source: NTIS, PC A09/MF A01.

A broad overview is presented of the US pulp and paper industry, emphasizing its manufacturing processes and energy requirements at the unit process level. Also discussed

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are its patterns of energy use, the means it has for coping with energy supply problems, the potential of its forest holdings to supply fuels and chemical feedstocks, recycling, public policy, and actions that could be taken to reduce future fossil fuel demand. The aggregate purchased energy required to make paper from pulpwood is estimated to be $15 \pm 5 \times 10^6$ Btu/ton of composite product in 1980, which possibly could be reduced to 7 to 10×10^6 Btu/ton by 1990. The purchased-energy requirement for unbleached kraft pulp is 3 to 3.5×10^6 Btu/ton, which can approach zero in a properly designed mill. The most energy-consuming unit process is paper drying (5 to 9×10^6 Btu/ton). The industry provides 50% of its fuel requirements from its own resources and is the nation's largest cogenerator of steam and electricity. Thus, the industry is better able to reduce its use of fossil fuels than are other energy-intensive industries.

536 (ANL/CNSV-17) Energy and materials flows in the cement industry. Sapp, J.E. Argonne National Lab., IL (USA). Jun 1981. 230p. DOE Contract W-31-109-ENG-38. Order Number DE82001609. Source: NTIS, PC A11/MF A01.

The cement industry is a large user of energy. In 1976, for example, the cement industry consumed 0.7% of the nation's direct energy, using 50 million tons of coal, 5.5 million barrels of fuel oil, 88,107 million cubic feet of natural gas, and 10,558 million kilowatt hours of electricity. Earlier, in 1971 when the cement industry was sixth in total energy use for heat and power among SIC four-digit industries, cement production consumed the most coal in that SIC group. From 1947 through 1976, the period covered by this study, cement industry energy consumption increased by 58%. However, process improvements during that period reduced the direct energy needed to produce a metric ton of cement 23% for dry processors and 17% for wet processors. There are constraints but further energy reductions are possible for individual producers through continued equipment modernization.

537 (ANL/CNSV-30) Disaggregating input-output models. Wolsky, A.M. Argonne National Lab., IL (USA). Feb 1982. 31p. DOE Contract W-31-109-ENG-38. Order Number DE82021268. Source: NTIS, PC A03/MF A01.

A general solution is given to the problem: with little computation, construct a more disaggregated input-output model from an available model, using information about some activities that were aggregated when the available model was built. The solution is exact and explicit. Concomitant approximate solutions, with error bounds, are also given. When only partial information is available, the exact solution guides its user to inexpensive and precise sensitivity analysis. Detailed consideration is accorded to the solution of the most frequently occurring problem - the disaggregation of one sector into two.

538 (ANL/CNSV-33) Industrial-waste exchange: a mechanism for saving energy and money. Gaines, L.L. Argonne National Lab., IL (USA). Jul 1982. 49p. DOE Contract W-31-109-ENG-38. Order Number DE83004423. Source: NTIS, PC A03/MF A01.

Industrial-waste exchanges have been established to assist, in the transfer of waste materials to companies that can use them, as is or treated, to displace virgin raw materials as process inputs. A waste exchange may provide information that expedites the transfer, or it may actually take possession of the material. Benefits of industrial-waste exchange

include avoided disposal costs and reduced energy and dollar costs for raw materials. Uses can be found for most wastes listed in waste-exchange catalogs, including spent acid, waste solvents, and used lubricating oils; substantial savings of energy and dollars are often possible through recycling of these potentially valuable materials. Lack of economical separation technology, the small quantities available at some sites, restrictive or uncertain regulation, and lack of knowledge of a material's uses are all barriers to successful operation of industrial-waste exchanges, but these barriers can be overcome by appropriate action.

539 (ANL/CNSV-41) Energy and materials flows in the iron and steel industry. Sparrow, F.T. Purdue Univ., Indianapolis, IN (USA). Jun 1983. 115p. DOE Contract W-31-109-ENG-38. Order Number DE83017530. Source: NTIS, PC A06/MF A01.

Past energy-consumption trends and future energy-conservation opportunities are investigated for the nation's iron and steel industry. It is estimated that, in 1980, the industry directly consumed approximately 2.46×10^{15} Btu of energy (roughly 3% of total US energy consumption) to produce 111 million tons of raw steel and to ship 84 million tons of steel products. Direct plus indirect consumption is estimated to be about 3.1×10^{15} Btu. Of the set of conservation technologies identified, most are judged to be ready for commercialization if and when the industry's capital formation and profitability problems are solved and the gradual predicted increase in energy prices reduces the payback periods to acceptable levels.

540 (ANL/CNSV-TM-57) Barriers to the adoption of energy-conserving technologies in the textile industry. Evans, A.R.; Zussman, S.K. Argonne National Lab., IL (USA). Sep 1979. 105p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A06/MF A01.

An overview of the textile industry and a discussion of energy-conserving technologies currently available at the pilot-demonstration stage are presented. Existing and potential barriers to the adoption of these technologies in the textile industry identified are: economic; technical acceptance; conflict between commitments of capital for compliance with environmental and health regulations and for investment in energy conservation measures; and a lack of information and technical expertise. Possible measures to eliminate barriers to the implementation of energy-conserving technologies are discussed. (MCW)

541 (ANL/CNSV-TM-58) Energy and materials use in the production and recycling of consumer-goods packaging. Gaines, L.L. Argonne National Lab., IL (USA). Feb 1981. 32p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A03/MF A01.

A comparison is made of the energy consumed annually in the United States to produce paper, glass, steel, aluminum, and plastic for consumer-goods packaging and types of energy used for production are examined. Energy saved through recycling and combustion for energy recovery also is considered. A maximum of 1.5 quad could be saved if this packaging material were recycled, and about 0.6 quad could be recovered if it were burned as part of municipal solid waste. Paper and plastic compete in several markets, including bags and milk containers: in almost all cases, the plastic container requires less energy to produce and recycle. However, the major energy input to paper manufacture is wood, rather than oil and natural gas. Glass bottles require less energy to produce than aluminum or steel cans.

On the other hand, aluminum cans take less energy to recycle than bottles, and recycled aluminum cans are the least energy intensive of the single-serving beverage containers, except for refillable glass bottles that are reused several times. For family-sized beverage bottles, a plastic bottle uses less energy to make and to recycle than a glass bottle. In addition, plastic bottles are combustible. However, glass bottles could be made with no oil or natural gas input, and they can be reused.

542 (BMI OWTD-1) Documentation of the finite element code VISCOT/UX for thermomechanical analyses: Version 0.01. Lindner, E.N.; St. John, C. Battelle Memorial Inst., Willowbrook, IL (USA). Office of Waste Technology Development; Agapito (J.F.T.) and Associates, Inc., Rolling Hills Estates, CA (USA). Oct 1988. 151p. DOE Contract AC02-83CH10139. Order Number DE89004719. Source: NTIS (US Sales Only). PC E10-MF A01 - OSTI, GPO Dep.

Includes 10 sheets of 48x reduction microfiche.

VISCOT/UX is a general purpose finite element code capable of nonlinear, transient, thermoelastic or thermoviscoplastic analyses in either two-dimensional or axisymmetric geometries. Plastic deformations can be evaluated using a variety of models, based on Tresca, von Mises, Mohr-Coulomb, or Drucker-Prager yield criteria using an isotropic strain-hardening model. Thermal response can be incorporated in analyses with the input of the temperature field. The time-dependent response of materials can be simulated using an exponential creep law, which is thermoviscoelastic. The present version of the code has been specifically designed to be used in a microcomputer environment. To facilitate the code's portability, the code is written in standard FORTRAN77 as implemented under a UNIX operating system. It also employs the Frontal method (i.e., a direct elimination process) as a solution strategy, which minimizes core storage requirements and permits large problem solutions in this microcomputer environment. Under the present application, VISCOT/UX is to provide a tool for scoping analyses of underground excavations and experiments in conditions where the rock mass can be considered to be a relatively continuous body, and the response of various materials or zones is essentially isotropic. 22 refs., 50 figs., 15 tabs.

543 (BMI OWTD-2) User's guide to the programs PREVIS/UX and POSTVI/UX, Processor Programs for the Code VISCOT/UX: Version 0.01. Lindner, E.N.; St. John, C. Battelle Memorial Inst., Willowbrook, IL (USA). Office of Waste Technology Development; Agapito (J.F.T.) and Associates, Inc., Rolling Hills Estates, CA (USA). Oct 1988. 114p. DOE Contract AC02-83CH10139. Order Number DE89004720. Source: NTIS (US Sales Only). PC E03 MF A01 - OSTI, GPO Dep.

Includes 4 sheets of 48x reduction microfiche.

PREVIS/UX and POSTVI/UX are user-interactive codes for processing data files of VISCOT/UX, a two-dimensional, mechanical, finite element program. PREVIS/UX generates the input file for the program, including mesh generation and definition of boundary conditions and material properties. POSTVI/UX plots and contours the output of the analyses; it is capable of producing plots of a variety of parameters including displacements, factor-of-safety and stress strain invariants. Plots can be produced on a CRT screen, a printer, or a plotter. Both codes employ a menu format together with various graphics displays that guide the use in the operations of the code. This report is a user's guide to these programs. It includes an explanation of the user options for

each code and provides an overview of code structure as well as an example session with each code. The library modules and their functions are also described, together with notes on required device files. A listing of each code is included, as implemented on a Hewlett Packard Model 320 microcomputer with accompanying mouse, 6-pen plotter, and raster-based impact printer. Under the present application, PREVIS/UX and POSTVI/UX are to facilitate the use of the compute code VISCOT/UX in scoping analyses of underground excavations and experiments. These codes can however be modified to process the data of most two-dimensional mechanical finite element programs. 6 refs., 40 figs., 18 tabs.

544 (CONF-770234-) Energy conservation in the pulp and paper industry. Final report. Advanced Energy and Technology Associates, Dover, NH (USA). May 1977. 104p. DOE Contract W-31-109-ENG-38. 31-109-38-3766. From Energy conservation in the pulp and paper industry; Durham, NH, US: February 23, 1977. Source: NTIS. PC A06/MF A01.

Almost 40 specific research and development ideas were formulated by the 67 participants at this workshop. Projects were assessed with the following criteria in mind: potential energy savings, cost, risk, Federal role, time frame, and priority. Data are tabulated on the projects followed by six topics discussed by panel members: waste and recycling, energy management in the mill, papermaking, pulping and bleaching, power generation in the mill, and coating and conversion. Three summary speeches are included. (MCW)

545 (CONF-880540-1) Network architecture for OPS5. Butler, P.L.; Allen, J.D.; Bouldin, D.W. Oak Ridge National Lab., TN (USA). 1988. 14p. DOE Contract AC05-84OR21400. From 15. annual international symposium on computer architecture; No City Given, HI, US: May 30, 1988. Order Number DE88002802. Source: NTIS. PC A03 MF A01; GPO Dep.

The design and implementation of a non-Rete based architecture which captures some of the inherent parallelism in the OPS5 expert system language are discussed. A central feature of the architecture is a network bus over which a single host processor broadcasts messages to a set of parallel rule processors. This transmit-only bus is implemented by a memory-mapped scheme which permits the rule processors to be decoded in parallel. All OPS5 rule matching processes and most of those associated with conflict resolution are executed by the parallel rule processors. The host performs the tasks associated with the firing of a selected rule. Performance data are presented for the prototype system which comprises a host processor and 64 parallel rule processors, each embodying a Motorola MC68000 microprocessor and 512 bytes of unshared memory. 6 refs., 4 figs.

546 (CONF-881123-3) Multiphase hydrodynamic modeling and analysis of non-Newtonian coal/water slurry rheology. Wang, C.S.; Lyczkowski, R.W.; Berry, G.F. Argonne National Lab., IL (USA). Mar 1988. 8p. DOE Contract W-31109-ENG-38. From 3. international symposium on liquid-solid flows (WAM); Chicago, IL, US: November 28, 1988. Order Number DE89000584. Source: NTIS. PC A02 MF A01; GPO Dep.

A multiphase non-Newtonian hydrodynamic model has been developed to predict the spatial and temporal distributions of pressure, relative motion between solids and liquid, solids concentration, and slurry shear rate and viscosity. This model includes separate continuity and momentum

OTHER
Other

equations for each phase and extends the well accepted power-law, non-Newtonian constitutive relationship for shear stress calculations. The model has been partially validated by comparison with single-phase power-law non-Newtonian flow theory and the literature data. The present model has also been used to analyze the pure water, No. 2 diesel fuel and coal/water slurry data measured by using high pressure and high shear rate capillary tube systems. Excellent agreement has been obtained between the calculated and measured values on mixture shear rates and viscosity, mass flow rates, and pressure. 19 refs., 5 figs., 4 tabs.

547 (COO-2831-1) **Recommendations for future government-sponsored energy conservation research and development in the paper and steel industries.** Nydick, S.E.; Dunley, J.B. Thermo Electron Engineering Corp., Waltham, MA (USA). Aug 1976. 168p. DOE Contract EY-76-C-02-2831. Source: NTIS, PC A08/MF A01.

Based upon a previous study for the National Science Foundation, "A Study of Improved Fuel Effectiveness in the Iron and Steel and Paper and Pulp Industries," research and development, pilot-plant testing, demonstration testing, and information-dissemination programs for fuel-conserving process options for these two industries are suggested, which warrant support by the U.S. Energy Research and Development Administration by virtue of their potential attractiveness to industry and cost/benefit to the nation.

548 (COO-4930-1) **Potential for energy conservation in the metal forming industries. Progress report, July 1, 1978-August 15, 1979.** Avitzur, B.; Beidleman, C.R.; Smackey, B.M. Lehigh Univ., Bethlehem, PA (USA). Aug 1979. 178p. DOE Contract EM-78-S-02-4930. Source: NTIS, PC A09/MF A01.

Reduced energy consumption and improved product attributes are realizable benefits that are achievable through the adoption of optimal metal forming techniques. With the meteoric rise in energy costs, certain segments of the metal forming industries have accelerated their efforts in switching from energy intensive manufacturing techniques, e.g., casting, to metal forming, and, furthermore, from hot forming and machined components to cold forming, notably the automotive industry. The first year results of a two year study that will identify and document potential energy and cost savings associated with the adoption of low energy consumption techniques are presented. When compared with techniques requiring energy for hot forming, heat treatments, and excess or scrap material, the utilization of alternative metal forming processes offer considerable promise for energy savings. Descriptions of savings achieved by a combination of analytical methods and imaginative new processes are provided in the form of specific industrial case studies. The elimination of defects through the use of an analytical criteria for the prevention of the central burst is presented. Such available criteria for central burst serve as a justification for the desirability to develop criteria for the prevention of fishskin and other defects. Other savings which may be possible through the development of new technologies are included in an Appendix entitled: Recent Developments in Wire Making. One specific new process, Continuous Hydrostatic Extrusion, has been developed at Western Electric and is described in detail.

549 (DOE/CE/15245-T1) **Efficiency study of oil cooling of a screw compressor.** Tree, D.R.; McKellar, M.G. Purdue Univ., Lafayette, IN (USA). Ray W. Herrick

Labs. Apr 1989. 35p. DOE Contract FG01-87CE15245. Order Number DE89011417. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

One of the major goals of all compressor manufacturers is to build as efficient a compressor as possible. Over the last several years improvements to the design of screw compressors has made them efficiently competitive with other types of compressors, especially at large loads. The primary purpose of this research is to investigate four different methods of cooling a 250 horsepower compressor and determine their effects on the efficiency of the compressor. Two conventional methods, liquid injection and thermosyphon cooling, and two new methods, V-PLUS and Fresco oil injection, are investigated. The screw compressor used in the tests was a VRS-500 screw compressor made by the Vilter Manufacturing Corporation. 6 figs.

550 (DOE/CE/15254-T5) **[THERM-A-VALVE insulated valve coverings]: Final technical progress report.** Ball, R.D.; Smith, M.D. Ball (Randell D.), DeQuincy, LA (USA). 1987. 27p. DOE Contract FG01-86CE15254. Order Number DE89007148. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

THERM-A-VALVE is an insulation product designed to solve a major energy problem in the oil and gas exploration industry. Due to a variety of temperature, humidity, and pressure drop situations associated with the production of oil and gas, "shut-downs" occur halting production. The THERM-A-VALVE units were created to eliminate this "shut-down." THERM-A-VALVES are insulated valve coverings made of high density polyethylene which utilizes space-age quality insulation rendering the insulation protection with the highest R-Value attainable per inch of covering.

551 (DOE/CE-15297-T1) **Assistance in MSD Research and Development: Part 1, Small scale research, development and testing: Final report.** Worsey, P.N.; Canon, C. Incubator Technologies, Inc., Rolla, MO (USA); Missouri Univ., Rolla (USA). Rock Mechanics and Explosives Research Center. Mar 1988. 38p. DOE Contract FG01-86CE15297. Order Number DE88014586. Source: NTIS, PC A03; GPO Dep.

The development and testing of a simple mechanical stemming aid is described. The aid comprises a solid unit placed in the stemming above the explosive column and is designed to improve blasting efficiency and reduce drilling and blasting costs. It is designed to work with back filled drill cuttings or any other suitable stemming material. To date it has consisted of the testing of the aid in small diameter (1.5 and 1.625 inch) holes in Jefferson City Dolomite for both bench and crater blasting configurations. Full scale field trials are being conducted nearby in similar rock in an aggregate quarry. The data acquisition equipment used in Phase 1 included both a Spin Physics SP2000 high speed video motion analysis system and acoustic and seismic monitoring units. Measurements for each test included peak air over pressure, ground surface ppv, stemming displacement and velocity and face movement and extent. The results illustrate that the concept is sound and that its successful application to production blasting at full scale will be a function of manufacturing cost, the development of suitable insertion techniques for large diameter boreholes and the selection of a suitable low cost material for the aid. 17 refs., 20 figs.

552 (DOE/CE/15319-T8) **[High energy semiconductor switch]: Final report for the period February 24, 1987**

to February 24, 1989. Risberg, R.L. Risberg Power Electronics, Inc., New Berlin, WI (USA). 24 Feb 1989. 11p. DOE Contract FG01-87CE15319. Order Number DE89007399. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

The objective was a controller for electric motors. By operating standard Nema B induction motors at variable speed a great deal of energy is saved. This is especially true in pumping and air conditioning applications. To allow wider use of variable speed AC drives, and to provide improved performance, a better semiconductor switch was sought. This was termed the "High Energy Semiconductor Switch."

553 (DOE/CE/40625-T1) **Intelligent process control systems for materials heat treatment.** National Research Council, Washington, DC (USA). Commission on Engineering and Technical Systems. 1989. 41p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC01-84CE40625. (NMAB-457). Order Number DE90003663. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

This report on the application of intelligent process control systems for materials heat treatment is the result of the deliberations of the NMAB Industrial Energy Conservation Committee and is based largely on the results of a workshop held by the committee on January 10-11, 1989. The committee concluded that intelligent process control systems are important to the future of the heat treating industry and they can conserve energy while enhancing industry competitiveness. Specific recommendations for R and D that should be funded by government are included in the report because, in the committee's judgment, the structure of the industry and the limited sales volume restrict its incentives to undertake the work by itself. The committee also concluded that intelligent process control system developments can have a much greater impact in other industries than just in heat treating as the applications expand. 8 refs.

554 (DOE/CS-0147) **Classification and evaluation of electric motors and pumps.** Argonne National Lab., IL (USA); Little (Arthur D.), Inc., Cambridge, MA (USA). Feb 1980. 251p. DOE Contract W-31-109-ENG-38. Source: NTIS, PC A12/MF A01.

This study was mandated under Title IV, Part 3 of the National Energy Conservation Policy Act (NECPA). This classification and evaluation of electric motors and pumps represents a comprehensive study of their use in the industrial, transportation, commercial, agricultural, and municipal sectors of the US economy. The range of electric motors included all ac and dc integral and fractional hp units equalling or exceeding 1/6 hp. However, units of less than 1/6 hp and those in use in other than the previously defined sectors were summarily treated to ensure completeness. Pump equipment covered included the wide range of fluid-handling equipment powered by all energy forms. The range of sizes analyzed correlated with those for motors, roughly 1/6 to 20,000 shaft hp. An analysis task called for developing scenarios for the policy options stated in NECPA, based on labeling and standards, evaluating barriers to their implementation, and then evaluating probable results. 72 references, 65 figures, 78 tables.

555 (DOE CS 40015-T3) **Assessment of selected conservation measures for high-temperature process industries.** Kusik, C.L.; Parameswaran, K.; Nadkarni, R.; O'Neill, J.K.; Malhotra, S.; Hyde, R.; Kinneberg, D.; Fox, L.; Rossetti, M. Little (Arthur D.), Inc., Cambridge, MA (USA).

Jan 1981. 173p. DOE Contract AC03-78CS40015. Source: NTIS, PC A08/MF A01.

Energy conservation projects involving high-temperature processes in various stages of development are assessed to quantify their energy conservation potential; to determine their present status of development; to identify their research and development needs and estimate the associated costs; and to determine the most effective role for the Federal government in developing these technologies. The program analyzed 25 energy conserving processes in the iron and steel, aluminium, copper, magnesium, cement, and glassmaking industries. A preliminary list of other potential energy conservation projects in these industries is also presented in the appendix. (MCW)

556 (DOE/CS/40151-1-Vol.2) **Industrial energy productivity project: the pulp and paper industry. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 197p. DOE Contract AC01-79CS40151. Order Number DE83006911. Source: NTIS, PC A09/MF A01.

This volume contains a description of the analysis performed on the pulp and paper industry, and the major conclusions reached on the basis of ISTUM-2 results. A description of the industry, its structure, energy consumption patterns and major issues facing its future are presented. The major inputs to this analysis are described - macroeconomic inputs relating to product growth rates and fuel prices, and industry-specific inputs covering product mix changes, raw material analysis and major process mix projections. The representation of the paper industry is discussed; this includes material flows within the industry and description of the various processes and technologies considered. The structure and procedure of the paper industry material flow model which links final product requirements to process loads and utilization in the major processes of the industry are covered. The results are presented with discussions of the trends in energy use, technology penetration, and energy efficiency potentials in the industry under given scenarios. The appendix includes technology specifications for all the processes analyzed and discussed.

557 (DOE/CS/40151-1-Vol.3) **Industrial energy productivity project. Petroleum refining industry. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 214p. DOE Contract AC01-79CS40151. Order Number DE83006768. Source: NTIS, PC A10 MF A01.

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A description of the analysis performed on the Petroleum Refining industry in this study and the major conclusions reached on the basis of the ISTUM-2 results are presented. A description of the industry, its structure, energy consumption patterns and major issues facing it in the future is given. The major inputs to this analysis are described - macroeconomic inputs relating to product growth rates and fuel prices and industry-specific inputs covering product mix changes and raw material analysis. The representation of the petroleum refining industry is discussed; this includes material flows within the industry and description of the various processes and technologies included. The structure and procedure of the petroleum industry material flow model which links final product requirements to various process loads and utilization in the major processes of the industry are covered. Finally, the results are presented with discussions of the trends in energy use. Technology penetration

rates, and energy efficiency potentials within the industry under given scenarios. The appendix comprises technology specifications for all the processes analyzed and included.

558 (DOE/CS/40151-1-Vol.4) **Industrial energy productivity project. Iron and steel industry. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 267p. DOE Contract AC01-79CS40151. Order Number DE83006769. Source: NTIS, PC A12/MF A01.

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This volume documents the analysis performed on the iron and steel industry and the major conclusions reached on the basis of ISTUM-2 outputs. A brief description of the industry and its structure, energy consumption patterns and major issues facing the industry are presented. Macro inputs are described; these consist of macroeconomic inputs relating to product growth rates and fuel prices, and technology inputs covering product mix changes, raw materials analyses, and process analyses. The representation of the industry is discussed; this includes material flows within the steel industry and descriptions of the various processes and technologies considered in the analysis. Features of the steel industry flow model are given. Finally, results are presented with discussions of the trends in energy use, technology penetration, and conservation in the industry under the different scenarios analyzed. The technology specifications for all the steel industry process, carrier, and conservation technologies are included.

559 (DOE/CS/40151-1-Vol.6) **Industrial energy productivity project: other industries. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 284p. DOE Contract AC01-79CS40151. Order Number DE83006770. Source: NTIS, PC A13/MF A01.

This volume documents the analysis of all the other industries comprising the manufacturing sector excluding the pulp and paper, chemicals, petroleum, and iron and steel industries. Brief profiles of the industries are included and their energy consumption patterns. Macro inputs are given. The representation of processes and technologies within these industries are discussed. Sample results of the study analysis are presented with discussions of trends in energy use, technology penetration and conservation in the industry under different scenarios. The appendix contains the technology specifications for all the process, carrier and conservation level technologies.

560 (DOE/CS/40151-1-Vol.7) **Industrial energy productivity project. Generic energy services. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 216p. DOE Contract AC01-79CS40151. Order Number DE83006771. Source: NTIS, PC A10/MF A01.

Generic energy services are services where energy is utilized to perform the same type of function in all industries. Such service include: steam and power generation, machine drive, waste heat recovery, lighting and space heating, ventilation, and air conditioning. Since technologies involved in providing these services are common to most industries, they are analyzed here once, then applied to different industries with modifications implemented as required. In the case of steam generation, both boilers and cogenerators are analyzed and competed. Since the factors governing this competition differ between industries to a point that affects

the outcomes, the competition is performed within four industry groups. Technology characteristics and competition issues for boiler and cogeneration technologies providing the steam and power generation service are covered. Machine drive, or shaft power, services are defined and competition issues discussed. Characterization of add-on conservation technologies, i.e., units that can be added on existing or new equipment to recover or utilize heat that is recuperators, heat wheels, waste heat boilers, vapor recompression systems, process and combustion controllers, etc. Such generic services as lighting and industrial space heating, ventilation, and air conditioning are covered with less detail.

561 (DOE/CS/40151-1-Vol.8) **Overall study methodology. Industrial Energy Productivity Project. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 373p. DOE Contract AC01-79CS40151. Order Number DE83006772. Source: NTIS, PC A17/MF A01.

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Documentation of the seven main components of this study is presented in a sequence that parallels the steps of the model logic. The sequence starts with discussions of the approach used to develop two macroeconomic-level primary inputs for the study: projections of industrial output growth rates by industry type and geographic region, and average delivered energy prices by fuel type and region. An illustration is presented of how industry-wide growth projections are translated into process-specific material flow for the four intensively-studied industries (pulp and paper, petroleum refining, iron and steel, and chemicals) using material flow models. The Core of the ISTUM-2 technology competition methodology is presented at some length for process, carrier, and conservation technologies. The output of this competition is technology nominal market shares. The details are included of the mechanics of tracking the penetration of processes and technologies into the industrial sector production stocks through time by updating for each projection year stocks existing from the previous year minus retirements and plus new additions to meet growth in product demand. Energy management activities, i.e., house-keeping measures to reduce energy consumption, are defined, measured, and incorporated into the model's output. A description is included of the sources and methodology used to develop the data bases for energy consumption, production capacity, and actual production for each process represented that existed in the base year, 1976. Technology characterization data sources, definitions, and development methodology are described together with caveats and limitations of these data bases. (MHR)

562 (DOE/CS/40151-1-Vol.9) **Computer code documentation for the Industrial Sector Technology Use Model (ISTUM-2). Industrial Energy Productivity Project. Final report.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). Feb 1983. 440p. DOE Contract AC01-79CS40151. Order Number DE83006773. Source: NTIS, PC A19/MF A01.

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This updated version of the Industrial Sector Technology Use Model (ISTUM-2) has several major purposes: to evaluate the commercial viability of energy and conservation technologies; to determine the impact of macroeconomic forecasts such as fuel price and industrial growth projections on energy use patterns; and to assess the impact of federal

energy policies on both commercial viability of technologies and energy use. The structure and mechanics of the computer code which implements ISTUM-2's methodology are the focus of this overview. ISTUM-2 is written in the APL programming language. The general organizing body for any computer programming done in APL is known as a workspace. Workspaces contain any number of APL programs, called functions, which combine to perform large tasks. Included here are a user's guide, program binder, and appendices containing the workspaces. (MHR)

563 (DOE/CS/40166-T1) **Asphalt saturation of roofing felt on the felt machine. Final report. Progress report, January 1980-July 1981.** Woodring, W.J.; Davis, D.A.; Smith, W. GAF Corp., South Bound Brook, NJ (USA). 1981. 34p. DOE Contract AC01-78CS40166. Order Number DE82011115. Source: NTIS, PC A03/MF A01.

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The asphalt roofing industry manufactures approximately 10 million tons of product annually. This requires an estimated 40 trillion Btu's in process heat and 4 million tons of asphalt having a fuel value of 140 trillion Btu's. Pilot equipment was installed on a commercial felt machine to determine whether saturation on the felt machine was feasible and whether energy savings would result. A process was demonstrated by which adequate saturation levels can be achieved. Energy savings are estimated at 6.3 trillion Btu's per year on an industry-wide basis. An economic study with consideration of the rapid industry conversion from organic felt to the less energy-intensive glass mat-based roofing precluded further process scale-up and plans for commercialization.

564 (DOE/CS/40178-01(Vol.1)) **Relevance of the second law of thermodynamics to energy conservation.** General Energy Associates, Cherry Hill, NJ (USA). Jan 1980. 37p. DOE Contract AT01-79CS40178. Source: NTIS, PC A03/MF A01.

An analysis is presented of the potential relevance of the use of analytical tools based on the Second Law of thermodynamics to existing federal programs for energy conservation in the industrial, transportation, buildings, and utility sectors in the US. (LCL)

565 (DOE/CS/40300-T2) **IEA Energy conservation in the iron and steel industry.** Tunnah, B.G. Gordian Associates, Inc., New York (USA). Jan 1981. 100p. DOE Contract AC01-79CS40300. Source: NTIS, PC A05/MF A01.

The NATO Committee on the Challenges of Modern Society research program, under the auspices of the IEA, had the objectives of collecting data on material requirements and energy-consumption patterns in selected energy-intensive industries in the US and Western Europe, of identifying technologies and operating practices with the potential for energy conservation in those industries, and of recommending research projects that could lead to improved energy efficiency. The steel industry was selected for analysis and ideas for an international cooperative program were developed. Representatives from various countries conducted meetings and the form of an implementing agreement for a research and development program was finalized in December, 1980. The program includes three technical areas: hot-surface inspection, heat recovery, and coal gasification. Hot-surface inspection methods to be demonstrated are: optical, induction, electromagnetic ultrasonic, electromagnetic ultrasonic surface testing methods, and eddy current method for hot surface inspection and an infrared

system (possibly). Three heat-recovery projects are: ceramic heat wheel development; demonstration of granular bed/heat pipe system for heat recovery; and demonstration of tubular ceramic recuperators. Processes in coal gasification are: converter process, gas treatment, and iron treatment. Each project is described in detail. (MCW)

566 (DOE/CS/40361-T16) **Decision making and control hierarchies for production systems.** Davis, W.J. Illinois Univ., Urbana (USA). Dept. of General Engineering. Aug 1984. 268p. DOE Contract AS07-80CS40361. (PUR-145). Order Number DE85014925. Source: NTIS, PC A12/MF A01; GPO Dep.

Chapter one reviews project aims toward decision making tools for manufacturing industry. Chapter 2 defines decision making and control roles with interactions between subprocesses and the overall process with its environment also discussed. Chapter 3 deals with the management information system in addition to the above. Chapter 4 addresses the various hierarchical approaches. Chapter 5 concentrates on functional aspects while Chapters 6 and 7 look at consequences and efficiency for existing and future technologies. (PSB)

567 (DOE/EI/06548-01) **The MEMM [Midterm Energy Market Model] Industrial Boiler Fuel Submodel: Model documentation report.** Logistics Management Inst., Washington, DC (USA). 30 Jun 1980. 26p. DOE Contract AC01-78EI06548. Order Number DE89002715. Source: NTIS, PC A03/MF A01; GPO Dep.

EIA's Industrial Boiler Fuel Model was first incorporated as a submodel of the Midterm Energy Market Model (MEMM) in the summer of 1979. Incorporation of this submodel allows MEMM to reflect more accurately patterns of industrial energy demand and permits the analysis of the effects of coal conversion regulations, gas curtailments, and industrial fuel taxes. This technical memorandum documents the MEMM Industrial Boiler Fuel Submodel. It describes the submodel's assumptions, structure, data, and interface with MEMM. It also describes the particular assumptions and model structure that were used for the MEMM 78.1 runs. This technical memorandum is addressed primarily to energy analysts and operations research analysts interested in MEMM. It is not intended for use as a guide to running MEMM and does not discuss the computer implementation of MEMM or any of its components. 6 figs., 5 tabs.

568 (DOE/ET/13124-T1) **Energy analysis of 108 industrial processes.** Drexel Univ., Philadelphia, PA (USA). Oct 1980. 322p. DOE Contract AS07-76ET13124. Order Number DE82001003. Source: NTIS, PC A15/MF A01.

The data base of 108 industrial processes provides a preliminary assessment of the quantity and quality of waste energy which may be economically practical to recover in the industrial sector. The 108 processes covered are given five-digit Standard Industrial Classification (SIC) designations. They represent 13 of the 20 two-digit SIC's (20-39) in the industrial manufacturing sector. The methodology for constructing the data base is described. Section 2 contains energy and mass balances for the 108 industrial processes. In each case the process diagram is presented followed by a table in which the process unit operations are listed and each major process stream is characterized by temperature, energy and mass flow. (MCW)

569 (DOE/ET/13124-T2) **Energy analysis of 108 industrial processes.** Brown, H.L.; Hamel, B.B.; Hedman, B.A.; Koluch, M.; Gajanana, B.C.; Troy, P. Drexel Univ.,

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Other

Philadelphia, PA (USA). Dept. of Mechanical Engineering and Mechanics. 1985. 322p. DOE Contract AC02-76ET13124. Order Number DE86005389. Source: NTIS, PC A14/MF A01; GPO Dep.

The data base of 108 industrial processes is an outgrowth of an effort initiated in 1976 by Drexel University under contract to the Energy Research and Development Administration. Its purpose was to provide a preliminary assessment of the quantity and quality of waste energy which may be economically practical to recover in the industrial sector. As part of the initial effort, a two-digit industrial data base was developed to characterize and correlate industrial energy utilization and waste energy sources. Identification of major waste streams of this level permitted a preliminary analysis of waste energy recovery potential to be undertaken. The result of this effort is an industrial data base consisting of energy utilization data for 60 four-digit SIC industries. Selected on the basis of energy consumption as given in the 1976 Annual Survey of Manufacturers, these four-digit industries represent over 70% of the United States industrial manufacturing energy consumption. This is based on energy consumed as purchased fuels. The data base includes industries from 13 of the 20 two-digit SIC's (20 to 39) in the industrial manufacturing sector.

570 (DOE/ID-10204) **Combustion research opportunities for industrial applications: Final report.** Chace, A.S.; Hazard, H.R.; Levy, A.; Thekdi, A.C.; Ungar, E.W. Taratec Corp., Columbus, OH (USA). 31 Mar 1988. 137p. DOE Contract AC07-76ID01570. Order Number DE88014104. Source: NTIS, PC A07/MF A01; GPO Dep.

The purpose of this study was to identify critical combustion technology research and development opportunities which can provide energy savings and other process improvements in major domestic industrial sectors. This report is intentionally focused upon what industry needs, not on what industry is currently doing. This report deals with the combustion system, including heat generation, regulation of stoichiometry, heat transfer to the load, heat loss from processes, combustion control and diagnostic equipment. This report addresses five industrial sectors which are the major users of energy, namely: (1) primary metals; (2) stone, clay and glass; (3) petroleum and chemical; (4) pulp and paper and (5) food and kindred products. Steam generation, because it is a key factor in all industries, is also addressed. 15 refs., 7 figs., 5 tabs.

571 (DOE/ID-10204-2) **Combustion research opportunities for industrial applications: Phase II.** Chace, A.S. (Taratec Corp., Columbus, OH (USA)); Hazard, H.R.; Levy, A.; Thekdi, A.C.; Ungar, E.W. USDOE Idaho Operations Office, Idaho Falls, ID (USA); Taratec Corp., Columbus, OH (USA). 31 May 1989. 131p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC07-76ID01570. Order Number DE89014157. Source: NTIS, PC A07/MF A01 - OSTI; GPO Dep.

This report completes a two-phase project to identify critical combustion technology research and development opportunities which can provide substantial energy savings and other process improvements in major industrial sectors. The major energy intensive industries considered during this project are primary Metals, Chemical, Petroleum and Coal Products, Stone, Clay and Glass, Paper, and Food. The reader will find a discussion of project concepts including an analysis of the needs and justification for each project. Projects recommended for development are documented in a manner which will facilitate rapid initiation of projects by

DOE management or others responsible for improving combustion systems. Although an analysis of each project is contained in this report, a detailed development plan coordinating future development activities needs to be established in any follow-on effort. During the second phase of this project, the Phase I research opportunities were further defined and evaluated. Two project areas, namely improved heat flux and reduction in heat losses, are recommended for development which incorporate research opportunities with high potential for success. 3 refs., 5 figs.

572 (DOE/ID/12495-T31) **Electrochemical evaporator for concentrating caustic: A process development unit (PDU) study: Monthly status report, August 1, 1988-August 30, 1988.** Physical Sciences, Inc., Andover, MA (USA). 1988. 29p. DOE Contract FC07-84ID12495. (PSI-1034). Order Number DE89003808. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

This paper is concerned with a reactor analysis study of the PDU (Process Development Unit) of the ECC (Electrochemical Caustic Concentrator). The objective of developing the model for the PDU is to help understand the role of the various transport processes and their relative effects on the performance of the ECC. A parametric study on the caustic concentration distribution in the cathode and anode compartments and the corresponding cell voltages were computed. The parameters investigated include: (1) electrode polarization, (2) membrane transport properties, (3) membrane conductivity, (4) electrolyte flow rates, (5) electrolyte temperature, (6) gas flow rates, (7) gas temperature, (8) gas humidity, and (9) current density. 9 refs., 12 figs., 1 tab.

573 (DOE/MA-0320(Vol.1)) **Guideline for development of unclassified computer security awareness and training programs.** Oak Ridge National Lab., TN (USA). Feb 1988. 153p. Order Number DE89002479. Source: NTIS, PC A08/MF A01; GPO Dep.

This guide presents fundamental concepts, topics, and materials on many aspects of unclassified computer security that should be included in site level unclassified computer security awareness and training (CSAT) programs. These programs are intended for Department of Energy (DOE) and DOE contractor personnel involved in the management, operation, or use of unclassified Federal computer systems, including microcomputers and word processors. The purpose of this guide is not to specify mandatory requirements, but to provide information that can be selectively used in varying combinations for developing an effective training program that is best suited to a particular organization and audience.

574 (DOE/RL/01830-T55) **The US steel industry: An energy perspective.** Azimi, S.A.; Lowitt, H.E. Energetics, Inc., Columbia, MD (USA). Jan 1988. 157p. DOE Contract AC06-76RL01830. Order Number DE88005313. Source: NTIS, PC A08/MF A01; GPO Dep.

This report investigates the state of the US steel industry in terms of energy consumption and conservation. The specific objectives were: to update and verify energy and materials consumption data at the various process levels in 1983; to determine the potential energy savings attainable with current (1983), state-of-the-art, and future production practices and technologies (2000); and to identify new areas of research and development opportunity that will enable these potential future savings to be achieved. The results of this study concluded that in year 2000, there is a potential to save between 40% and 46% of the energy used in current

production practices, dependent on the projected technology mix. R & D needs and opportunities were identified for the industry. Potential R & D candidates for DOE involvement with the private sector were assessed and selected from the identified list.

575 (DOE/RL/01830-T56) **The US textile industry: An energy perspective.** Badin, J.S.; Lowitt, H.E. Energetics, Inc., Columbia, MD (USA). Jan 1988. 254p. DOE Contract AC06-76RL01830. Order Number DE88005312. Source: NTIS, PC A12/MF A01; GPO Dep.

This report investigates the state of the US textile industry in terms of energy consumption and conservation. Specific objectives were: To update and verify energy and materials consumption data at the various process levels in 1984; to determine the potential energy savings attainable with current (1984), state-of-the-art, and future production practices and technologies (2010); and to identify new areas of research and development opportunity that will enable these potential future savings to be achieved. Results of this study concluded that in the year 2010, there is a potential to save between 34% and 53% of the energy used in current production practices, dependent on the projected technology mix. R&D needs and opportunities were identified for the industry in three categories: process modification, basic research, and improved housekeeping practices that reduce energy consumption. Potential R&D candidates for DOE involvement with the private sector were assessed and selected from the identified list.

576 (DOE/RL/01830-T57) **The US pulp and paper industry: An energy perspective.** Elaahi, A.; Lowitt, H.E. Energetics, Inc., Columbia, MD (USA). Apr 1988. 240p. DOE Contract AC06-76RL01830. Order Number DE88008615. Source: NTIS, PC A11.

This report investigates the state of the US pulp and paper industry in terms of energy consumption and conservation. Objectives were: to update and verify energy consumption and production data for the various process steps in 1985; to determine the potential energy savings attainable by replacing current practices with state-of-the-art and advanced (2010) production practices and technologies; and to identify areas of research and development opportunity that will enable these potential future savings to be achieved. Results concluded that for the year 2010 production level, there is a potential to save between 34 and 53% of the energy use by replacing current technology practices with state-of-the-art and advanced technologies. R and D needs and opportunities were identified for the industry. Potential R and D candidates for DOE involvement were selected from the identified list, primarily based on their energy savings potential and the opinion of industry experts.

577 (DOE/RL/01830-T58) **The US cement industry: An energy perspective.** Venkateswaran, S.R.; Lowitt, H.E. Energetics, Inc., Columbia, MD (USA). May 1988. 236p. DOE Contract AC06-76RL01830. Order Number DE88011501. Source: NTIS, PC A11/MF A01; GPO Dep.

This report investigates the state of the US cement industry in terms of energy consumption and conservation. Objectives were to: update and verify energy consumption and productions data for the various process steps as of 1985; determine the potential energy savings attainable by replacing current practices with state-of-the-art and with advanced (2010) production practices and technologies; and identify areas of research and development opportunity that will enable these potential future savings to be achieved.

Results concluded that for a projected year 2010 production level, there is a potential to save between 31 and 55% of the projected energy use by replacing current technology practices with state-of-the-art and advanced technologies. R&D needs and opportunities were identified for the industry. Potential R&D candidates for DOE involvement were selected from the identified list based primarily on their energy savings potential and the opinion of industry experts.

578 (DOE/RL/01830-T60) **The US glass industry: An energy perspective.** Babcock, E.; Elaahi, A.; Lowitt, H.E. Energetics, Inc., Columbia, MD (USA). Sep 1988. 222p. DOE Contract AC06-76RL01830. Order Number DE88016850. Source: NTIS, PC A10/MF A01; GPO Dep.

This report investigates the state of the US glass industry in terms of energy consumption and conservation. The specific objectives were: to update and verify energy consumption and production data for the various process steps in 1985; to determine the potential energy savings attainable by replacing current practices with state-of-the-art and advanced (year 2010) production practices and technologies; and to identify areas of research and development opportunity that will enable these potential future savings to be achieved. The results of this study concluded that for the year 2010 production level, there is potential to save between 21 and 44 percent of the projected energy use by replacing current technology practices with state-of-the-art and advanced technologies. R&D needs and opportunities were identified for the industry. Potential R&D candidates for DOE involvement were selected from the identified list, primarily based on their energy savings potential and the opinions of industry experts. 100 refs.

579 (DOE/TIC-11118) **Pilot study to select candidates for energy. Conservation research for the chemical industry. Final report.** Burch, J.E.; Otis, J.L.; Hale, R.W. Battelle Columbus Labs., OH (USA). 15 Nov 1979. 116p. DOE Contract W-7405-ENG-92-113. Source: NTIS, PC A06/MF A01.

Every chemical process consists of one or more unit operations that effect physical changes in the raw materials, intermediates, or products. Many of these unit operations are used, singly or in combination, with unit processes to effect chemical changes. The same or different combinations of unit operations may be used to effect similar chemical changes in different chemical processes. This project was designed to study the functions and energy consumption of the various unit operations involved in several chemical processes and to identify areas where research could lead to energy-conservation options of broad utility to the chemical industry. Four energy-intensive chemical processes which produce ammonia and carbon dioxide, chlorine and caustic soda, carbon black, and ethylbenzene and styrene were selected for this study. Information was obtained from the literature on the structure of the industry sectors and the production technologies, and was used to determine material balances, process streams, temperatures, pressures, and energy requirements for the various unit operations. An energy matrix was prepared for each process, showing the function provided by and the energy involved in each unit operation or process. A variety of chemical engineers and chemists analyzed the energy matrices, flow charts, and other information for each process and made suggestions as to areas wherein research might be expected to produce energy-saving results.

580 (EGG-M-11187) **Ultrasonic characterization of non-uniform porosity distributions in SiC ceramic.** Telschow, K.; Walter, J.; Kunerth, D. EG and G Idaho, Inc., Idaho Falls, ID (USA). 1987. 15p. DOE Contract AC07-76ID01570. (CONF-870691-10: 14. annual review of progress in quantitative non-destructive evaluation, Williamsburg, VA, US, June 22, 1987). Order Number DE88004814. Source: NTIS, PC A03/MF A01; GPO Dep.

During fabrication of monolithic ceramic silicon carbide very localized regions of high porosity can be produced. This porosity often consists of a very large density of small pores. Even at wavelengths considerably larger than the pore size, significant effects can be observed in the propagation of ultrasonic waves through these materials. These effects include attenuation, scattering and changes in wave velocity and anomalous wave amplitude modulation due to the non-uniformity of the porosity distribution. This paper describes the characterization of such a porosity distribution in SiC utilizing these ultrasonic techniques and their correlation with x-ray and optical microscopy measurements. Significant effects were observed due to the nonuniformity of the porosity which resulted in enhancement of signal amplitudes greatly exceeding attenuation effects due to scattering. This unexpected result proved to be most sensitive to the boundaries of the porosity distribution and provided one of the best techniques for delineating its extent. 8 refs., 6 figs.

581 (FEA/D-76-381) **Energy efficiency and electric motors: a technical, economic, and policy analysis of efficiency standards in commercial and industrial electric motors and equipment.** Hunt, R.E.; Seabury, F.; Valence, P.F. Little (Arthur D.), Inc., Cambridge, MA (USA). Aug 1976. 201p. Source: NTIS, MF \$7.75.

This final report identifies areas of greatest energy conservation potential in electric motor use in the industrial and commercial sectors of the economy; assesses and projects the technological potential and economic trends that might influence the use of more efficient electric motors; and outlines possible Government strategies encouraging such use. It reports that the 1- to 125-hp polyphase motors were the predominant energy consumers, accounting for about 26 percent of the total electric power generated in the U.S. Estimates of their potential for increased efficiency, coupled with possible replacement rates of lower- to higher-efficiency motors, indicated potential savings by 1990 of 35 billion kWh/year or 60 million barrels of oil.

582 (LA-UR-88-3794) **An embedded atom potential for bcc iron.** Harrison, R.J.; Voter, A.F.; Shao-Ping Che. Los Alamos National Lab., NM (USA). 1988. 6p. DOE Contract W-7405-ENG-36. (CONF-880901-11: Metallurgical Society fall meeting and American Society for Metals materials week, Chicago, IL, US, September 24, 1988). Order Number DE89003577. Source: NTIS, PC A02 - OSTI.

We have used the embedded atom method (EAM) to construct inter atomic potentials for use with bcc iron. Our original motivation for this work was to model the grain boundaries in iron. The version of the EAM we have used is where the total energy is given as the sum of two body terms summed over pairs of atoms i, j , together with an embedding term given by the sum of embedding functions whose arguments are the total electronic charge density at the sites i . A Morse potential with the three parameters v_1 , v_2 and v_3 , is used to represent the two-body terms. The total electronic charge densities at each individual site which are the arguments of the embedding functions, are obtained from the linear superposition of atomic 4s Slater function

charge densities of form. The fifth parameter v_5 is taken as the cutoff distance for the atomic charge densities and for $\phi(r_{ij})$, which are adjusted for smoothness at cutoff. The embedding function itself is determined by the fit of the cohesive energy of bcc iron as a function of interatomic distance to the "universal" cohesive energy function described by Rose et al. 15 refs., 1 tab.

583 (NATO/CCMS-58) **Plastics industry: rational use of energy program pilot study.** Gordian Associates, Inc., New York (USA). 1977. 36p. DOE Contract EX-76-C-10-3869. Source: NTIS \$9.00.

This report presents the results of a study of energy consumption in the production of polyvinyl chloride in Italy, The Netherlands, the United Kingdom, and the United States. Comparative data on energy consumption have been assembled, and a series of recommendations for R and D work related to the efficient use of energy in the chemical industry has been developed. Previous studies have been reported on cement and steel. The major objectives of the Data Base Project are to collect data on industrial energy consumption for specific industries in different countries, to identify and analyze significant differences in energy consumption, to document technology transfer ideas, and to develop recommendations for research and development of energy-efficient technology in major industrial sectors. The comparative energy-consumption data assembled during this study include the energy requirements for all process steps needed to transform raw materials into PVC. This includes production of crude oil (or natural gas), naphtha (or ethane), and ethylene; mining of rock salt; production of chlorine; synthesis of vinyl chloride monomer (VCM); and polymerization of VCM to PVC. A range of 67 to 83 GJ/metric ton of PVC (including feedstock energy) was found for the participating nations, with the United Kingdom and The Netherlands lowest and the United States highest.

584 (NATO/CCMS-75) **Industrial International Data Base: energy analysis methodology. Rational use of energy program pilot study. Final report.** Chicago Univ., IL (USA). 1978. 55p. DOE Contract EX-76-C-10-3869. Source: NTIS \$9.50.

The Industrial International Data Base Project represents an effort to provide information for the responsible development of energy resources and the allocation of energy research and development funds in industry. This report covers the methodology study, which is a part of the Industrial International Data Base Project. Section 2 describes the Data Base Project and its organizational history. The recommendations of the Methodology Experts' Group are reported in Sec. 3, along with brief justifications. Section 4, which provides the general outline and discussion of the recommended method of analyzing total energy use, is directed at industrial managers, government officials, and potential energy analysts who are unfamiliar with the techniques and inherent difficulties of such assessments. Section 5 contains detailed examinations of more technical aspects of the analyses. Finally, the Appendixes contain exhibits that compare total sectoral energy use in selected countries, a list of documents published under the auspices of the Data Base Project, and a list of attendees at the experts' meetings. (MCW)

585 (NP-21907) **Potential for energy conservation in nine selected industries: the data base.** Gordian Associates, Inc., New York (USA). Jun 1974. 505p. Source: Gordian Associates Inc., New York, NY.

Basic data on energy consumption in nine industries in the U.S. is presented and energy conservation opportunities are identified. The industries include petroleum refining; copper; aluminum; steel; paper; plastics; cement; synthetic rubber; and glass. (LCL)

586 (ORNL/TM-10415) **Efficient alternatives for electric drives.** Comnes, G.A.; Barnes, R.W. Oak Ridge National Lab., TN (USA). Nov 1987. 71p. DOE Contract AC05-84OR21400. Order Number DE88003733. Source: NTIS, PC A04/MF A01; GPO Dep.

This analysis of industrial electric motors describes the current motor stock, its energy use and operating characteristics, and innovations that could change current use patterns. It provides calculations characterizing the economic attractiveness of several existing and potential options. One attractive option given particular attention is the adjustable-speed drive which can replace throttles or valves for many pumping operations. A major conclusion is that, throughout industry, options that are both energy-saving and economically attractive appear to penetrate markets more slowly than would be socially optimal. The final section examines characteristics of industry that may contribute to slow market penetration. 29 refs., 14 figs., 14 tabs.

587 (ORO-5262-5) **Refinery energy profile. Final report.** Maier, R.W.; Olivent, W.P.; Brandt, D.L.; Golden, T.G. Gulf Research and Development Co., Pittsburgh, PA (USA). Jan 1979. 303p. DOE Contract AC05-77CS40093. Order Number DE83006018. Source: NTIS, PC A14/MF A01.

Energy profiles are needed to identify areas with the greatest potential for achieving future energy savings. These profiles are essentially detailed energy balances of refineries showing all inputs and losses for the total refinery and for each of the individual processing units. By also showing the losses from each individual heater, exchanger, etc., the items with the greatest potential for saving energy are pinpointed. This report summarizes the work carried out by Gulf Research and Development Company at Gulf's Alliance refinery. This effort has developed a technique for preparing energy profiles at any refinery. In addition to the report, the work has resulted in the preparation of a User's Guide as a separate document outlining the procedures to follow in preparing energy profiles at any refinery. Although the objective of the contract was to develop the technique, some of the numerical results of the study at Alliance are of interest. Analysis of the Alliance profiles showed that about 75% of the energy leaving the refinery was lost from two areas; heater stacks (25%) and air and water cooled heat exchangers (50%). Further analysis led to estimates of the amount of energy potentially recoverable from these two areas. The energy profile for the Alliance refinery is summarized in Figures S-1, S-2, S-3, and S-4.

588 (PB-243612) **Potential for energy conservation in nine selected industries. The data base. Volume 1. Selected plastics.** Gordian Associates, Inc., New York (USA). Jun 1974. 149p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

Energy consumption data are discussed for the production sequences that result in the output of the following thermoplastic resins: low density polyethylene, high density polyethylene, polystyrene, and polyvinyl chloride. Other production information included are: natural gas liquids, availability of hydrocarbon raw materials, shifts in sources of raw materials, and potential for material substitution.

589 (PB-243613) **Potential for energy conservation in nine selected industries. The data base. Volume 2. Petroleum refining.** Gordian Associates, Inc., New York (USA). Jun 1974. 390p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$10.25.

A report is given of: methods of separation of crude oil into its constituent parts and conversion of intermediate materials into more valuable products to meet market demands; energy consumption and yield data; description of a typical refinery system in terms of material and energy balances; historical trends in processing technology; and various potentials for energy conservation in the refining process.

590 (PB-243614) **Potential for energy conservation in nine selected industries. The data base. Volume 3. Cement.** Gordian Associates, Inc., New York (USA). Jun 1974. 127p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

Processing sequences used to manufacture portland cement are described, and the energy consumption per short ton of cement produced are given. Production is divided into the following activities: raw materials acquisition, preparation of raw materials, clinker production, and grinding and mixing of product cement. Other items discussed include energy for size reduction and kiln energy use.

591 (PB-243615) **Potential for energy conservation in nine selected industries. The data base. Volume 4. Copper.** Gordian Associates, Inc., New York (USA). Jun 1974. 124p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.25.

A report is given on the processes used and the energy consumed in the production of refined primary copper. The traditional methods of copper production, mining and ore preparation, smelting, and refining, are described. Data related to material and energy consumption and ancillary process (such as limestone mining) are also covered, as is discussion of a number of new developments in the copper production process. Included are developments in the following areas: smelting techniques, copper refining, hydrometallurgical processes, and secondary copper.

592 (PB-243616) **Potential for energy conservation in nine selected industries. The data base. Volume 5. Aluminum.** Gordian Associates, Inc., New York (USA). Jun 1974. 128p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

A report is given on the materials balances and energy consumption data for the production sequence resulting in the output of primary aluminum ingots. The ingot are formed by casting the molten aluminum obtained from smelting are suitable for subsequent fabrication of products. Production of primary aluminum ingots is described, including mining of bauxite, refining bauxite into alumina, and smelting alumina into aluminum. Other data cover production of soda ash, lime, petroleum coke, cryolite and fluorspar, and caustic; energy requirements and consumption and the effect of raw materials imports.

593 (PB-243617) **Potential for energy conservation in nine selected industries. The data base. Volume 6. Steel.** Gordian Associates, Inc., New York (USA). Jun 1974. 144p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

Energy consumption data for the production sequence that results in the output of raw steel are given, including ingots, steel castings and strand or pressure cast blooms, billets, slabs, and other product forms. Material descriptions

OTHER
Other

include mining of ore, smelting iron ore into pig iron, coke production, semifinishing of steel, oxygen production, and production of fluxes. Other items included are depletion of high grade U.S. ores, decreasing ration of coke to pig iron, shifts in steel furnace technology, and new technology trends.

594 (PB-243618) **Potential for energy conservation in nine selected industries. The data base. Volume 7. Glass.** Gordian Associates, Inc., New York (USA). Jun 1974. 131p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

Energy consumption data for the production sequence leading to the output of glass containers are discussed. Process descriptions include mining of sand, limestone, rock salt and feldspar; and production of soda ash and glass containers. Other items discussed include electric energy, furnace efficiency, and material substitution.

595 (PB-243619) **Potential for energy conservation in nine selected industries. The data base. Volume 8. Selected paper products.** Gordian Associates, Inc., New York (USA). Jun 1974. 161p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$6.25.

A report is given on energy consumption for four major paper and paperboard products: newsprint, writing paper (chemical); corrugated containers; and folding boxboard. Descriptions include harvesting of roundwood and chip acquisition, wood preparation, pulping, pulp bleaching, paper and paperboard production, converting, ancillary materials, and energy consumption for overall production sequences.

596 (PB-243620) **Potential for energy conservation in nine selected industries. The data base. Volume 9. Styrene butadiene rubber.** Gordian Associates, Inc., New York (USA). Jun 1974. 137p. DOE Contract DI-14-01-0001-1842. Source: NTIS \$5.75.

Energy consumption data for the production sequence that results in the output of virgin styrene butadiene rubber (SBR) are discussed. SBR is defined as any copolymer of butadiene and styrene containing over 50% butadiene by weight. Virgin SBR used as a basis for the study is the product existing before addition of fillers, oils, carbon black, or other materials needed to impart particular characteristics to the rubber for specific end uses. Production description included in the report include the following: Styrene, butadiene, SBR, ethylbenzene by superfractionation, benzene by catalytic reforming, and benzene from coke oven light oil and dripolene.

597 (PB-245159) **Energy conservation potential in the cement industry. Conservation paper No. 26.** Portland Cement Association, Skokie, IL (USA). Jun 1975. 344p. (FEA/D-75/400). Source: NTIS \$9.50.

The potential for energy conservation in the cement industry is assessed. Chapter 1 covers projected energy requirements and examines the long-run growth patterns that will influence cement markets in Europe, Japan, and the U.S. Chapter 2 contains schematic process and flow diagrams and deals with the major steps required to produce a finished portland or modified portland cement from natural mineral deposits or industrial by-products. The discussion is divided into three steps: raw material preparation; pyroprocessing; and finish grinding and end uses. Chapter 3 deals with raw material preparation for manufacture of portland cement. Chapter 4 concentrates on pyroprocessing, production and energy consumption by process. Chapter 5 discusses finish grinding and treats divergent properties of

raw materials with respect to grinding. Chapter 7 discusses alkali reactivity and by-product gypsum. Chapter 8 deals with energy-saving technology that is, through use of preheaters, precalciners or major kiln modification or replacement. (207 references) (GRA)

598 (PB-262576) **Assessment of the potential for energy conservation through improved industrial boiler efficiency. Volume I. Final report.** KVB, Inc., Tustin, CA (USA). Jan 1977. 276p. DOE Contract FEA-C-04-50085-00. Source: NTIS, PC A13/MF A01.

This is a technical study of boiler efficiency in the use of gas, oil, and coal. It discusses cost-effective equipment additions and improvements, including heat-recovery devices and combustion controls, which controls, which could lead to greater efficiencies. Maximum attainable efficiencies using current technologies without consideration for cost are also reported.

599 (PB-262577) **Industrial boiler users' manual. Volume II. Final report.** KVB, Inc., Tustin, CA (USA). Jan 1977. 111p. DOE Contract FEA-C-04-50085-00. Source: NTIS, PC A06/MF A01.

See also Volume I, PB-262576.

This is an introductory manual for industrial boiler users on currently available methods and equipment for efficiency improvements. Designed for use by plant engineers, boiler-house supervisors, and equipment purchasing personnel, this manual discusses efficiency-improving maintenance practices and operational changes, currently available auxiliary equipment, and procedures for making cost/benefit evaluations of operations and equipment.

600 (PNL-SA-14740) **INDUST: An industrial data base.** Wilfert, G.L.; Moore, N.L. Pacific Northwest Lab., Richland, WA (USA). Jul 1987. 9p. DOE Contract AC06-76RL01830. (CONF-8709166-4: 9. annual industrial energy technology conference, College Station, TX, US, September 16, 1987). Order Number DE88003416. Source: NTIS, PC A02/MF A01; GPO Dep.

INDUST is a data base of energy flow information for the thirteen most energy-intensive industrial groups within the manufacturing sector. Within each industry group, INDUST contains data on plants, processes, equipment, and technology. The energy-use data in INDUST is continually being updated with the latest data from the Energy Information Administration (EIA). The EIA reports fuel consumption according to six categories: electricity, fuel oil, natural gas, coal and coke, and other fuels. INDUST can be used for many types of analyses. This paper discusses INDUST's structure and capabilities and one example analysis that helps the industrial sector forecast its electricity demands. 2 refs., 3 figs., 2 tabs.

601 (PNL-SA-17193) **Applications of new technologies using a systems approach.** Watts, R.L. (Pacific Northwest Lab., Richland, WA (USA)). Pacific Northwest Lab., Richland, WA (USA). Aug 1989. 11p. Sponsored by USDOE, Washington, DC (United States). DOE Contract AC06-76RL01830. (CONF-890814-4: American Institute of Chemical Engineer's summer national meeting, Philadelphia, PA (USA), 20-23 Aug 1989). Order Number DE89016826. Source: NTIS, PC A03/MF A01 - OSTI; GPO Dep.

Results have far exceeded the expectations of those who initiated planning eight years ago for the US Department of Energy's (DOE's) Innovative Concepts Program (ICP). The ICP was formally launched in 1983 by DOE's Office of Energy Utilization Research when it funded the first of several

experiments to develop and demonstrate methods for identifying and providing for the preliminary development of fragile new ideas for saving energy. The mission of this program is to increase the inventory of new concepts available for funding by other DOE programs and by private industry. In carrying out this mission, the ICP complements other programs designed to accelerate the process of applying new technology in industry. The ICP uses a systems approach to provide opportunity, means, and motive to potential innovators to help overcome the institutional, cultural, and motivational factors that cause a high mortality rate among new concepts. The ICP connects those who understand production and distribution and consumption problems with those who have potentially unique technology to apply to their solution. Innovators synthesize the results of their preliminary evaluations in a format found to be helpful to those who are in a position to make decisions about providing subsequent funding to further develop the concept. The innovator presents his results at a technology fair organized by the program to introduce the innovator to potential sponsors. The results also are presented in project summary reports and technical briefs. Three "experiments" have been completed to date, with 32 innovators receiving about \$15,000 each from the ICP. Thirteen of the 32 innovators participating in the three completed experiments have received follow-on funding totaling more than \$3,000,000. A fourth experiment is in process. 5 figs., 3 tabs.

602 (SAN-1225-T010-1) **Investment risk evaluation techniques: use in energy-intensive industries and implications for ERDA's Industrial Conservation Program.** Energy and Environmental Analysis, Inc., Arlington, VA (USA). 13 Jul 1977. 121p. DOE Contract EY-76-C-03-1225-010. Source: NTIS, PC A06/MF A01.

The trade-off between risk and rate-of-return in investment evaluations is crucial in assessing the commercial potential of future energy-conservation technologies. The focus of the Industrial Conservation Program at ERDA is to reduce the perceived risks of a given technology to the extent that the private sector will adopt the technology within the normal course of its business operations. These perceived risks may emanate from technical, institutional, or commercial uncertainties, or in many cases they may result merely from a company's or industry's lack of previous experience with a particular technology. Regardless of the source of the risk surrounding a project, the uncertainty it poses to the private sector will serve to inhibit decisions to invest. This study evaluates the treatment of risk in capital investments in certain energy-intensive industries which are the primary targets of ERDA's Industrial Conservation Program. These risks evaluation considerations were placed within a context that includes capital budgeting practices and procedures, organizational considerations, and basic rate-of-return evaluation procedures in the targeted energy-intensive industries (petroleum, chemicals, paper, textiles, cement, food processing, aluminum, steel, glass, and agriculture).

603 (SAN-1692-1) **Research, development, and demonstration for energy conservation: preliminary identification of opportunities in iron and steelmaking.** Little (Arthur D.), Inc., Cambridge, MA (USA). Jan 1978. 140p. DOE Contract EC-77-C-03-1692. Source: NTIS, PC A07/MF A01.

The Federal Government has initiated, expanded, and is accelerating a cost-shaped program with the iron and steel industry to develop innovative, cost-effective programs for new energy-saving technologies. The purpose of this

document is to identify opportunities for research and development in the iron and steel industry, giving due consideration to the many barriers that impede the implementation of new technology. These technology sectors also reflect the following three fundamental criteria that DOE has formulated to guide the selection of projects for consideration in this program: the project must have the potential to save energy; the project must be considered cost-effective when fully developed; when fully developed, the project must be considered reliable and have no negative effect on capacity. Concepts considered for commercial development have been selected because of their significant potential for conserving energy and/or critical fuel forms and on the assumption that they would involve: preparation of proposals by or in conjunction with companies associated with the steel industry, to ensure the practicality of the concept in a steelmaking environment; cost sharing with companies associated with the steel industry; and demonstration of technology that would provide an option for the iron and steel industry to be less dependent on natural gas and distillate fuels. In addition, the program is aimed at stabilizing employment and increasing U.S. strategic security.

604 (SAN-1692-T1) **Industrial recovered-materials-utilization targets for the metals and metal-products industry.** Little (Arthur D.), Inc., Cambridge, MA (USA). Mar 1980. 314p. DOE Contract EM-78-C-03-1692. Source: NTIS, PC A14/MF A01.

The National Energy Conservation Policy Act of 1978 directs DOE to set targets for increased utilization of energy-saving recovered materials for certain industries. These targets are to be established at levels representing the maximum feasible increase in utilization of recovered materials that can be achieved progressively by January 1, 1987 and is consistent with technical and economic factors. A benefit to be derived from the increased use of recoverable materials is in energy savings, as state in the Act. Therefore, emphasis on different industries in the metals sector has been related to their energy consumption. The ferrous industry (iron and steel, ferrous foundries and ferrous alloys), as defined here, accounts for approximately 3%, and all others for the remaining 3%. Energy consumed in the lead and zinc segments is less than 1% each. Emphasis is placed on the ferrous scrap users, followed by the aluminum and copper industries. A bibliography with 209 citations is included.

605 (SAN-1694-T1) **Industrial recovered-materials-utilization targets for the textile-mill-products industry.** Booz, Allen and Hamilton, Inc., Bethesda, MD (USA). 1979. 292p. DOE Contract EM-78-C-03-1694. Source: NTIS, PC A13/MF A01.

The Congress, in the National Energy Conservation and Policy Act of 1978 (NECPA), directed the Department of Energy to establish materials recovery targets for the metals and metal products, paper and allied products, rubber, and textile-mill-products industries. The targets were developed to provide incentives for using energy-saving recovered materials and to provide a yardstick for measuring progress and improvement in this endeavor. The NECPA indicates that the targets should represent the maximum technically and economically feasible increase in the use of energy-saving recovered materials that each industry can achieve progressively by January 1, 1987. Materials affected by recovered-materials targets include and are limited to aluminum, copper, lead, zinc, iron, steel, paper and associated products, textile-mill products, and rubber. Using information gathered from the textile-mill-products industry and from

OTHER Other

other textile-related sources, DOE has developed recovered materials targets for that industry. This report presents those targets and their basis and justification. Following an overview of the textile industry, the chapters are: Textile-Mill-Products Industry Operations; Economic Analysis of the Textile-Mill-Products Industry; Governmental and Regulatory Influence on the US Textile Industry; Current Mill Use of Recovered Materials in the Textile-Mill-Products Industry; Limitations on the Use of Recovered Materials in the US Textile-Mill-Products Industry; Materials-Recovery Targets; and Government and Industry Actions That Could Increase the Use of Recovered Materials.

606 (SAN-1701-T1) **Industrial recovered-materials-utilization targets for the rubber industry. Final report.** Hittman Associates, Inc., Columbia, MD (USA). 1979. 275p. DOE Contract EC-77-C-03-1701. Source: NTIS, PC A12/MF A01.

Targets for utilization of energy-saving recovered materials within the rubber-products industry are presented along with the documentation supporting these proposed targets. The recovered material used in this industry is termed recovered rubber (RR), and includes reclaimed (devulcanized) scrap rubber, and waste rubber products that have been re-treaded (tires) or slit into useful items. Reclaimed and ground scrap rubber are used either as a replacement for virgin rubber or as a filler material in the manufacturing of new products. While reclaimed rubber is much more widely used than ground scrap, often they are interchangeable. There is a trade-off of physical characteristics which much be considered in choosing between use of reclaimed rubber and ground scrap; however, the over-riding consideration is usually economic. As ground scrap becomes more economically attractive due to recent advances in grinding technologies, it will command a larger share of the market for recovered rubber. The rubber industry has been subdivided according to the Standard Industrial Classification system (SIC) four-digit code level. Targets have been developed for each subdivision that has potential for utilizing RR.

607 (SAN-1704-T1) **Industrial recovered materials utilization targets for the paper and allied products industry.** Resource Planning Associates, Inc., Cambridge, MA (USA). [nd]. 177p. DOE Contract EC-77-C-03-1704. Source: NTIS, PC A09/MF A01.

An analysis is presented in support of the targets for industrial recovered-materials utilization in the paper and allied products industry. The industry and recovered materials, respectively, are defined. The methodology for setting the 1987 targets for use of recovered materials is outlined. The technically feasible and economically practical use of recovered materials in manufacturing each of 10 grades of paper and paperboard is projected. These projections in view of projected supplies of recovered materials and the effects of government actions on projected supply and use of recovered materials are evaluated. The targets for use of recovered materials in each of the 10 paper and paperboard grades and in the industry as a whole are set. Finally, the effect of recovered-materials use on energy consumption in paper and paperboard manufacturing under four scenarios is examined and the principal issues that a subsequent analysis would need to resolve are identified.

608 (SAN-1731-T1) **Comparative study of the energy characteristics of powered hand tools. Part I. Executive briefing. Final report.** Varigas Research, Inc.,

Timonium, MD (USA). 1979. 42p. DOE Contract EY-77-C-03-1731. Source: NTIS, PC A03/MF A01.

The results of a theoretical analysis and a field test program to determine the relative energy efficiencies of different types of powered hand tools are presented. First analyzed and then tested were grinders, drills and nutrunners powered by hydraulic fluid, compressed air 60 Hz single phase electricity, three phase 180 Hz electricity, three phase 360 Hz electricity and, in the case of flexible shaft tools, three phase 60 Hz power. The work included the determination of the energy use of the total system including air compressors and frequency converters where appropriate. Distribution system losses also were considered. The result of the work is that the pneumatic tools, which have become the most popular tools in industry, use between five and fifteen times more energy than the various electrically powered tools to do the same work.

609 (SAN-1731-T2) **Comparative study of the energy characteristics of powered hand tools. Part II. Investigation reports. Final report.** Varigas Research, Inc., Timonium, MD (USA). 1979. 253p. DOE Contract EY-77-C-03-1731. Source: NTIS, PC A12/MF A01.

Results are presented of a theoretical analysis and a field test program to determine the relative energy efficiencies of different types of powered hand tools. First analyzed and then tested were grinders, drills and nutrunners powered by hydraulic fluid, compressed air 60 Hz single phase electricity, three phase 180 Hz electricity, three phase 360 Hz electricity and, in the case of flexible shaft tools, three phase 60 Hz power. The work included the determination of the energy use of the total system including air compressors and frequency converters where appropriate. Distribution system losses also were considered. The result of the work is that the pneumatic tools, which have become the most popular tools in industry, use between five and fifteen times more energy than the various electrically powered tools, to do the same work. Part I of the report is intended to provide an overview of the activity and a summary of the results. Part II, Investigation Reports, is the detailed exposition of the work and results. A related report, entitled Multifrequency Factory Operations, examines the potential energy savings which accrue when higher frequency electric power is used for lighting as well as tooling.

610 (SAND-87-2728C) **A new approach to machine-based perception of monocular images.** Osbourn, G.C. Sandia National Labs., Albuquerque, NM (USA). 1988. 31p. DOE Contract AC04-76DP00789. (CONF-880637-1: IEEE Computer Society conference on computer vision and pattern recognition, Ann Arbor, MI, US, June 5, 1988). Order Number DE88002418. Source: NTIS, PC A03/MF A01; GPO Dep.

A new approach to machine-based visual perception of monocular images is presented and demonstrated. The approach employs a recursive procedure to generate a series of "reconstructed" versions of the raw video image. The procedure is designed to imitate certain perceptual organization functions of the human visual system. Recognition of object categories is attempted at each step by comparing the newly generated regions to stored object categories. These generated regions may have relatively few edges or region pixels in common with any of the regions in the raw video image. Category retrieval is carried out using a software-based content-addressing scheme which provides access to complete object representations in memory using

incomplete portions of the representation. The category representation scheme is sufficiently general to allow a variety of poorly correlated images of specific category examples to be represented and recognized by a single general category representation. These properties are illustrated using a group of distorted, defective and idealized images of ASCII A's and handguns. 7 refs., 10 figs.

611 (SAND-87-2839C) **Automated generation of uniform Group Technology part codes from solid model data.** Ames, A.L. Sandia National Labs., Albuquerque, NM (USA). 1987. 13p. DOE Contract AC04-76DP00789. (CONF-880719-1: ASME international computers in engineering conference and exhibition, San Francisco, CA, US, July 31, 1988). Order Number DE88002508. Source: NTIS, PC A02/MF A01 - 02/MF A01: GPO Dep.

Group Technology is a manufacturing theory based on the identification of similar parts and the subsequent grouping of these parts to enhance the manufacturing process. Part classification and coding systems group parts into families based on design and manufacturing attributes. Traditionally, humans code parts by examining a blueprint of the part to find important features as defined in a set of part classification rules. This process can be difficult and time consuming due to the complexity of the classification system. Coding specifications can require considerable interpretation, making consistency a problem for organizations employing many (human) part coders. A solution to these problems is to automate the part coding process in software, using a CAD database as input. It is straightforward to translate the part classification rules into a rule based expert system. A more difficult task is the recognition of part coding features from a CAD database. Previous research in feature recognition has concentrated on material removal features (depressions such as holes, pockets and slots). Part classification requires the ability to recognize such features, plus other features such as hole patterns, symmetries and overall part shape. This paper extends feature recognition to include part classification and coding features and describes an expert system for automated part classification and coding being developed. This system accepts boundary-representation solid model data and generates a part code. Specific feature recognition problems (such as intersecting features) and the methods developed to solve these problems are presented.

Food Processing/Agriculture

Refer also to citation(s) 55, 56, 59, 60, 106, 185, 219, 221, 250, 251, 283, 317, 318, 327, 330, 335, 343, 354, 355, 365, 372, 375, 376, 377, 378, 379, 381, 387, 392, 489, 490, 492, 493, 494

612 (DOE BP 18944-T2) **Energy conservation study on Darigold fluid milk plant, Issaquah, Washington.** Seton, Johnson, and Odell, Inc., Portland, OR (USA). 15 Jan 1985. 103p. DOE Contract AC79-84BP18944. Order Number DE89005586. Source: NTIS, PC A06 - OSTI.

This report presents the findings of an energy study done at Darigold dairy products plant in Issaquah, Washington. The study includes all electrical energy using systems at the plant, but does not address specific modifications to process equipment or the gas boilers. The Issaquah Darigold plant receives milk and cream, which are stored in large, insulated silos. These raw products are then processed into butter, cottage cheese, buttermilk, yogurt, sour cream, and powdered milk. This plant produces the majority of the butter used in the state of Washington. The Issaquah plant

purchases electricity from Puget Sound Power and Light Company. The plant is on Schedule 31, primary metering. The plant provides transformers to step down the voltage to 480, 240, and 120 volts as needed. Based on utility bills for the period from July 1983 through July 1984, the Issaquah Darigold plant consumed 7,134,300 kWh at a total cost of \$218,703.78 and 1,600.633 therms at a total cost of \$889,687.48. Energy use for this period is shown in Figures 1.1 to 1.5. Demand charges account for approximately 23% of the total electrical bill for this period, while reactive charges account for less than 0.5%. The electrical usage for the plant was divided into process energy uses, as summarized in Figure 1.2. This breakdown is based on a 311-day processing schedule, with Sunday clean-up and holidays composing the 54 days of downtime.

613 (DOE/BP-8010989) **Energy conservation study on Simplot potato processing plant, Heyburn, Idaho.** Seton, Johnson, and Odell, Inc., Portland, OR (USA). 1 Mar 1985. 89p. Order Number DE88010989. Source: NTIS, PC A05.

This report presents the findings of an energy study done at the Simplot potato processing plant in Heyburn, Idaho. The study includes all electrical energy using systems at the plant but does not address specific modifications to process equipment. The plant receives raw potatoes and produces a mixture of pre-fried and frozen potato products including french fries and pre-formed patties, a dehydrated frozen product, starch, and processes and ships raw potatoes. The plant also contains a box line that makes cardboard cartons for all Simplot plants. The plant contains all necessary equipment and processes to produce a finished product and has long-term cold storage. 13 figs., 16 tabs.

614 (DOE/BP-8010990) **Energy conservation study on Lamb-Weston potato processing plant, Hermiston, Oregon.** Seton, Johnson, and Odell, Inc., Portland, OR (USA). 21 Mar 1985. 209p. Order Number DE88010990. Source: NTIS, PC A10.

This report presents the findings of an energy study done at the Lamb-Weston potato processing plant in Hermiston, Oregon. The study includes all electrical energy using systems at the plant but does not address specific modifications to process equipment. The Hermiston plant receives raw potatoes and produces a mixture of pre-fried and frozen potato products, including french fries, breakfast products, and a dinner product. The plant contains all necessary equipment and processes to produce a finished product but does not have on-site, long-term cold storage. The Hermiston plant purchases electricity from the Umatilla Rural Electrical Association (REA) on two main services: a 12.7 KV, three phase service for the electric boiler, and a three phase, 480 volt service that provides electricity for all other functions in the main plant (the wheelturning load).

615 (DOE/BP-8010993) **Energy conservation study on Agripac Processing Plant, Salem, Oregon.** Seton, Johnson, and Odell, Inc., Portland, OR (USA). 15 Jan 1985. 169p. Order Number DE88010993. Source: NTIS, PC A08/MF A01.

An energy study on electrical energy using systems was performed at Agripac plant No. 1 in Salem, Oregon, in the late summer and fall of 1984. The plant processes mainly green beans, corn and squash. The respective products are inspected, prepared and graded, after which they are either canned or frozen in freeze tunnels or cold storage cells. The canned products are sent through pressure cookers. In the

case of green beans and corn, some of the product is frozen in freeze tunnels and dumped into tote bins for the repack operation, while some is packaged in cartons and quick frozen in blast freeze cells. For squash, all the product processed is put into cartons and frozen in the cells. Energy conservation measures were calculated using a simple pay-back analysis. Conservation measures have been evaluated interactively to avoid overestimating savings, assuming that measures that are cost effective will be implemented as a package. In some cases, mutually exclusive conservation measures have been considered for a single application. These have been presented as an either/or measure. Details of the options are included in the text and the calculation sheets.

616 (DOE/CS/40087-T1) **Handbook for energy conservation in food canning plants.** Rao, M.A.; Downing, D.L. Cornell Univ., Geneva, NY (USA). Inst. of Food Science. Oct 1979. 189p. DOE Contract AS01-78CS40087. Order Number DE81028819. Source: NTIS, PC A09/MF A01.

Guidelines are presented so that personnel in food canneries can conserve energy. Information dealing with conservation applicable to food canneries is brought together in this handbook. Energy consumed in the production, harvesting, and the processing of foods are discussed in Sections I and II. The main components of an energy conservation program are discussed in Section IV. A list of energy conservation opportunities suitable for food canneries is given in Section V. Good housekeeping practices in the areas of lighting, heating, water and electricity use, steam use, boiler and power plant operations, and by preventing leaks from steam lines, steam traps, combustible gas and compressed air lines are discussed in Section VI. Section VII deals with the definition of boiler efficiency, sources of energy losses in boilers, minimum instrumentation requirements of a boiler, boiler combustion control systems, and good boiler maintenance practices. It also contains discussion on improving boiler efficiency by modification of boiler operating practices and the use of auxiliary equipment. Substantial energy savings that can be achieved by insulation and heat recovery are discussed in Section VIII. The potential for the use of heat pumps to recover heat is also covered. Section IX describes recent developments in improving the efficiency of blanchers and sterilizers. The use of solar energy, indirect energy sources, and financial evaluation procedures of investments are also discussed. (MCW)

617 (DOE/CS/40191-T2) **Handbook for energy management of atmospheric cookers.** Pedersen, L.; Rose, W.; Nicholson, J. National Food Processors Association. Berkeley, CA (USA). [nd]. 57p. DOE Contract AC07-78CS40191. Order Number DE84005500. Source: NTIS, PC A04/MF A01; GPO Dep.

The scope of this book is to show the potential energy savings through lowering of cooker temperature and through various redesigns, such as vapor recycle, water recycle, steam locks, insulation, etc. and in a comprehensive form provide a procedure for the Food Processor to determine the individual savings potential and to select the most efficient mode of operation. There have been selected and discussed various tests which hopefully together with the more general theoretical background will aid the Food Processor in obtaining a more efficient atmospheric cooker operation.

618 (DOE/CS/40199-T4) **Evaluation of energy-conservation technologies for the citrus-processing**

industry. Centec Consultants, Inc., Reston, VA. Jan 1980. 22p. DOE Contract AC03-79CS40199. Order Number DE82003555. Source: NTIS, PC A02/MF A01.

The following manual chapters are outlined and described: overview, boilers, juice evaporators, feed mills, refrigeration, additional energy savings potentials, emerging technologies, optimization of integrated plant energy systems, and economics. (MHR)

619 (DOE/CS/40380-T1) **Energy integrated dairy farm system in New York: Final report.** Walker, L.P.; Ludington, D.C.; Merrill, W.G.; Pellerin, R.A.; Reid, W.S.; Space, R.; Space, R. II; White, S.A.; Heisler, M.G.; Farmer, G.S. Cornell Univ., Ithaca, NY (USA). Sep 1985. 92p. DOE Contract FC07-80CS40380. Order Number DE87003864. Source: NTIS, PC A05/MF A01; GPO Dep.

This technical manual was developed from the experiences and results gained from Cornell University's Energy Integrated Dairy System Project (EIDS). Goal of the project was to reduce fossil fuels and fossil fuel-based inputs into an income producing dairy farm by substituting energy efficient processes and practices for energy-intensive ones, and using solar-based energy sources - wind, active solar, and biomass.

620 (DOE/CS/40382-T1) **Energy integrated cotton farm system in Arizona. Final report.** Energy Management Corp., Los Alamitos, CA (USA). Aug 1985. 111p. DOE Contract FC07-81CS40382. Order Number DE86012312. Source: NTIS, PC A06/MF A01; GPO Dep.

A partnership was formed with two Arizona farmers, W.B. Odom and J.L. Golightly, to apply practical energy conservation measures to their contiguous cotton farms. The Odom-Golightly farm complex (3500 acres) about 60 miles west of Phoenix, was selected as one of the Energy Integrated Farm System (EIFS) projects. Both the Irrigation Management System and the Biomass Combustion System were determined to be technically and economically feasible and were implemented on the farms under Phase II of the EIFS project. The other concepts were not found to be economically viable in the Phase I study. The projected savings were estimated to be 2,500,000 kWh/year with the Irrigation Management System and 74,000 gallons of propane per year with the Biomass Combustion System producing heat for drying the cotton. The project demonstrated that better irrigation management can be achieved through a continuous feedback loop providing actual soil moisture conditions to the farmer or irrigator. With the proper application of electronic data acquisition and control technology (soil moisture monitors) a system such as the one demonstrated on the Odom-Golightly farms is economically feasible. In many cases, an Irrigation Management System may potentially have paybacks as short as two years. Similarly cotton gins, particularly those handling short staple cotton exclusively, can cost-effectively use biomass (gin trash) combustors for heating the air used to dry the cotton, with a payback period from less than 4 years to 6 years.

621 (DOE/CS/40402-T2-Vol.1) **Assessment of citrus-processing energy-efficiency improvement. Volume 1. Final report.** Centec Corp., Reston, VA (USA). Dec 1982. 30p. DOE Contract AC01-80CS40402. Order Number DE83006327. Source: NTIS, PC A03/MF A01.

The citrus industry was surveyed in order to assess the impact of two programs toward the goal of implementing energy conserving options and the development of new

technologies. Six technologies were identified that have recently been implemented in the citrus industry, and a case history is summarized for each. Advanced technologies have been identified that could be applied in citrus processing plants and that would result in significant energy and operating cost savings. The industry sources indicated a need to prove these concepts in a research and development project such as a pilot plant before they will be implemented. (LEW)

622 (DOE/ID/12187-T1) **Kentucky Agricultural Energy Corporation 21-million gallon per year fuel-ethanol plant: Final report.** Kentucky Agricultural Energy Corp., Franklin, KY (USA). Nov 1987. 327p. DOE Contract FC07-81ID12187. Order Number DE88005199. Source: NTIS, PC A15/MF A01; GPO Dep.

This report describes the design, construction, start-up, and operation of the 21-million gallon per year ethanol facility built by KAEC in Franklin, Kentucky. Built from the ground up, the plant construction began at the 180-acre plant site on November 3, 1980. The first alcohol was produced on December 20, 1982. The plant is a dry milling fermentation facility. The plant also manufactures as co-products distillers dried grain with solubles (DDGS) at approximately 70,000 tons per year, and carbon dioxide at approximately 70,000 tons per year. The plant consumes 8 million bushels per year of yellow shelled corn. The actual operating data in this report are based on the four-month operating period of July, August, September, and October 1986. During this production period the plant averaged 103%, 88%, 105%, and 105% of design capacity for each month, respectively. This report will compare the design operation and economics with actual performance.

623 (DOE/ID/12493-T1) **Del Valle Hog Farm energy integrated farm system: Phase 3, Demonstration: Final report.** Berdoll, D. Del Valle Hog Farm, TX (USA). Aug 1985. 117p. DOE Contract AC07-84ID12493. Order Number DE87003117. Source: NTIS, PC A06/MF A01; GPO Dep.

The Energy Integrated Farm System located at the Del Valle Hog Farm has as its objectives the determination and demonstration of the technical and economical feasibility of methane production derived from the anaerobic digestion of swine manure and the reliability of this process as an alternate energy source for the production of fuel alcohol, electricity, and concentrated space heating. Manure from the 150 sow farrow-to-finish swine operation is used as the feedstock for the 4000 ft³ anaerobic digestion system. The approximately 6000 ft³ of methane-rich biogas produced daily is stored under pressure for ultimate usage throughout the integrated farm system. Large quantities of biogas are utilized directly for space heating of the farrow and nursery buildings. Additionally biogas is combusted in a motor generator for the production of electrical energy. The excess quantity of biogas produces the thermal energy necessary in the fuel alcohol facility for converting the starches in the feedstock grain sorghum into fermentable sugars and for concentrating the product alcohol through the distillation process. The fuel alcohol produced fuels for farm vehicles. A valuable by-product of the anaerobic digestion process, the digested inert and odorless sludge, is utilized as a fertilizer substitute and soil amendment on both coastal Bermuda grass and milo grain sorghum. Economic analyses performed on the various components of the integrated farm system illustrate fuel costs comparable with that of replacement fuels in 1984 dollars improving throughout the useful life of the particular energy component. 15 refs., 52 figs., 17 tabs.

624 (DOE/TIC-11375) **Energy conservation and cost benefits in the meat and poultry processing industry.** Department of Energy, Washington, DC (USA). Office of Industrial Programs. 1983. 24p. DOE Contract AC06-76RL01830. Order Number DE83012737. Source: NTIS, PC A02/MF A01.

Many processes can benefit from the use of heat exchangers for recovery of waste heat, efficient electric motors, and insulation. Modifications such as combustion air control for boilers and efficient compressors for refrigeration systems are also beneficial and widely applicable. Processes unique to the industry can also be modified to save energy. These modifications typically are capital intensive and often have adjunct product income in addition to energy savings that make them economically attractive. Examples of industry-specific technologies include hog skinning, continuous coagulation and drying of whole blood, and electrical stimulation and hot boning of beef.

625 (DOE/TIC-11376) **Energy conservation and cost benefits in the meat and poultry processing industry. Technology transfer; a technology applications manual.** Centec Corp., Fort Lauderdale, FL (USA); Centec Corp., Reston, VA (USA). 1982. 98p. DOE Contract AC06-76RL01830. Order Number DE82002046. Source: NTIS, PC A05/MF A01.

Auditing energy consumption and pinpointing areas where energy-conservation activities and investments can provide the most favorable economic return are covered. The wide-application energy-conservation techniques applicable in most industries, including the meat and poultry processing industries, are emphasized. Wide-application (often called generic) techniques include waste heat recovery, improvement of electric motor efficiency, added insulation, refrigeration improvements, and increases in boiler efficiencies. Specific examples of the application of these techniques in meat packing and poultry processing plants are cited. Specific processing changes that have already resulted in significant energy cost savings at some meat packing or poultry processing plants are examined. A summary checklist for energy conservation and brief case studies from industry are provided. Information is presented on energy price trends and discusses the analysis of capital investment alternatives.

626 (DOE/TIC-11378) **Energy conservation and cost benefits in the dairy processing industry.** Centec Corp., Reston, VA (USA). 1982. 118p. Order Number DE82014877. Source: NTIS, PC A06/MF A01.

Guidance is given on measuring energy consumption in the plant and pinpointing areas where energy-conservation activities can return the most favorable economics. General energy-conservation techniques applicable to most or all segments of the dairy processing industry, including the fluid milk segment, are emphasized. These general techniques include waste heat recovery, improvements in electric motor efficiency, added insulation, refrigeration improvements, upgrading of evaporators, and increases in boiler efficiency. Specific examples are given in which these techniques are applied to dairy processing plants. The potential for energy savings by cogeneration of process steam and electricity in the dairy industry is also discussed. Process changes primarily applicable to specific milk products which have resulted in significant energy cost savings at some facilities or which promise significant contributions in the future are

examined. A summary checklist of plant housekeeping measures for energy conservation and guidelines for economic evaluation of conservation alternatives are provided. (MHR)

627 (DOE/TIC/EG-84/601) **Energy integrated farm system: Del Valle Hog Farm.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 1p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

The Del Valle Hog Farm, a Texas hog farm with grain crops, is designed to conserve energy through methane generation, alcohol production, and efficient use of electrical energy. The integrated energy concepts to be demonstrated are: methane generation from swine manure to produce electricity and heat for alcohol fermentation and distillation and to produce hot water for heating the digester reactors and the hog feeding pens; and alcohol production from milo and distillation of 170 proof alcohol by use of methane and generated electricity. Specific energy technologies to be implemented are: anaerobic digester; gas compressors to store methane for peak demands; engine generator powered by methane; waste-heat exchanger on engine generator to produce hot water; continuous-process alcohol facility to produce 24 gal/day; and crop management.

628 (DOE/TIC/EG-84/602) **Energy integrated farm system: Millbrook Farm and Cornell University.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 1p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

Millbrook Farm, a New York State dairy farm with corn and alfalfa crops, is designed to conserve energy through energy integrated concepts including methane digestion, cogeneration, energy conservation crop practices, and a computer management system. The integrated energy concepts to be demonstrated are: methane generation from cow manure; cogeneration of thermal and electric energy from methane combustion. New York State Electric & Gas Company will accept excess electric power into its grid; energy conservation in crop production through conservation tillage and substitution of manure for nitrogen fertilizers; energy conservation through waste-heat recovery in milk cooling and in recycling of wastewater; and application of microprocessor control systems to control and monitor energy in the methane digester, the cogeneration equipment, and the waste-heat exchangers.

629 (DOE/TIC/EG-84/603) **Energy integrated farm system: Odom-Golightly Farms and Energy Management Corporation.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 1p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

The Odom-Golightly Farms, Arizona cotton and alfalfa farms, are designed to conserve energy through energy integrated concepts including an irrigation management system, and cotton trash combustion. The integrated energy concepts to be demonstrated are: energy conservation in crop irrigation through the implementation of an irrigation management system; energy conservation by using the existing by-products from the cotton-ginning process as a fuel source to generate heat to dry the cotton; and application of microprocessor control systems to control and monitor energy requirements.

630 (DOE/TIC/EG-84/604) **Energy integrated farm system: University of Nebraska Field Laboratory Farm.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 2p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

The University of Nebraska Field Laboratory Farm, a swine facility with grain and soybean crops, is designed to conserve energy through energy integrated concepts including alcohol production, grain dryers, greenhouses, methane digestion, energy conservation crop practices, and a computer management system. The integrated energy concepts to be demonstrated are: methane production from swine wastes in an anaerobic methane generator; production of alcohol from sweet sorghum; computerized farm energy management and conservation system; use of solar energy and methane gas in grain drying, water heating, and space heating for swine production shelters; use of waste heat and CO₂ from the ethanol plant in the greenhouse system; energy conservation in crop production through conservation tillage, conservation of fertilizer, and irrigation scheduling; and energy conservation by optimized construction of swine units and control of ventilation and temperature.

631 (DOE/TIC/EG-84/605) **Energy integrated farm system: Ubarri-Blanes Farm and University of Puerto Rico.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 2p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

Ubarri-Blanes Farm, a Puerto Rican dairy farm, is designed to conserve energy through energy integrated concepts including irrigation and wastewater management, solar energy utilization, methane digestion, efficient use of electrical energy, and experimental grasses. The integrated energy concepts to be demonstrated are: production of electrical energy from methane resulting from the anaerobic fermentation of dairy cow waste; production of feed and fertilizer by anaerobic fermentation of cattle waste; and wastewater management on the farm.

632 (DOE/TIC/EG-84/606) **Energy integrated farm system: North Dakota State University Agricultural Experiment Station.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 2p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

North Dakota State University Agricultural Experiment Station, a dairy farm with wheat, barley, sugar beet, and soybean crops, is designed to conserve energy through energy integrated concepts including wind break and solar energy for heating buildings, methane digestion, and energy conservation crop practices. The integrated energy concepts to be demonstrated are: generation of methane from manure; use of a milk-to-water heat exchanger and rock-bed heat storage in dairy operations; use of a solar collector energy system for space heat in the dairy barn (calf warming); efficient solid-liquid separation in manure collection system; use of digester effluent as bedding and fertilizer; and energy conservation by improved agriculture practices, such as conservation tillage, pest management, and soil testing for efficient use of fertilizer.

633 (DOE/TIC/EG-84/607) **Energy integrated farm system: Mathis Farm and Georgia Institute of Technology.** USDOE Office of Scientific and Technical Information, Oak Ridge, TN. 1984. 2p. Source: OSTI, PO Box 62, Oak Ridge, TN 37831.

Mathis Farm, a dairy farm with corn and soybean crops, is designed to conserve energy through energy integrated concepts including energy-efficient farming practices, methane digestion, irrigation and wastewater management, and efficient use of electrical energy. The integrated energy concepts to be demonstrated are: anaerobic digestion of cattle

manure to produce methane for an engine generator to provide electricity for the farm, with waste-heat recovery to produce hot water; use of digester sludge materials as bedding and fertilizer; farm energy audit and subsequent implementation of energy conservation practices; waste management on the farm; and energy conservation crop practices.

634 (EGG-M-33487) **The Department of Energy's Energy Integrated Farm System program.** Breckenridge, R.P.; Corrigan, M.K.; Thompson, W.N.; Price, D.R.; Bramwell, D.L. EG and G Idaho, Inc., Idaho Falls, ID (USA); USDOE, Washington, DC (USA); Florida Univ., Gainesville, FL (USA). 1988. 30p. DOE Contract AC07-76ID01570. (CONF-880215-2: 12. energy from biomass and wastes. New Orleans, LA, US, February 15, 1988). Order Number DE88006791. Source: NTIS, PC A03/MF A01; GPO Dep.

The Department of Energy (DOE) recently completed a program investigating the feasibility of integrating diverse energy production and energy conservation practices to reduce agriculture's dependence on fossil fuels. The Energy Integrated Farm System (EIFS) program was established in 1980 in response to the hardship imposed on US farmers by high fuel costs and unreliable fuel supplies. Seven farms located in various geographical regions of the US and Puerto Rico participated in the program. Each of these farms developed an energy integrated farm system project that used a unique combination of energy production and energy conservation methods to supply energy to the farm and reduce the farm's dependence on energy produced from nonrenewable sources such as coal and oil. Methods used at these projects included conservation tillage, solar heating, waste heat recovery, methane production from the anaerobic digestion of animal manure, electricity production from biogas, alcohol fuel production, fluidized-bed combustion of crop wastes, and computer-aided conservation irrigation. This paper gives a summarized report of the work done at the seven projects. It presents highlights and results, provides an overview of successes and problems and lists recommendations. 12 figs., 3 tabs.

Cement Research

Refer also to citation(s) 18, 151, 154, 536, 577, 590, 597

635 (DOE/CS-0039-1) **Interim technical report on the performance of blended cements in concrete viewed in relation to the potential offered by these cements for reducing energy consumption in cement manufacture.** Department of Energy, Washington, DC (USA). Oct 1978. 340p. Source: NTIS, PC A15/MF A01.

The production of portland cement, the key ingredient of concrete, is an energy-intensive process. The potential for realizing significant reductions in energy requirements is high, but a long time period will be required to realize this potential owing to high capital investments required to replace existing plants with more efficient systems. The use of blended cement appears to be one viable supplement to other energy conservation schemes related to the production of portland cement. Blended cements are hydraulic cements composed of mixtures of conventional portland cement with additions that are either themselves capable of hydraulic setting (certain metallurgical slags) or are pozzolanic (such as fly ash), industrial wastes or by-products (slags and fly ash), and spent oil shale or certain mine tailings. These materials are blended or interground with the portland cement clinker in an operation with relatively low

energy requirements. The potential energy savings offered by blended cement can be realized only if existing barriers to their manufacture and use are identified and acted upon. Work has been directed at an evaluation and modification of test procedures and specifications for blended cements and Battelle's Columbus Laboratories is concerned with properties and performance of blended cement concretes. The first phase of the program (Task No. 1) is a critical analysis of the situation regarding the engineering properties and performance record of blended cement concretes. In Task No. 2, research concerned with the engineering properties of blended cement concretes will be conducted. The final phase will draw on the analysis carried out in the previous tasks to prepare a document that will aid public policy makers in developing a strategy to overcome the barriers which currently hinder the use of blended cements in concrete construction in the U.S. (MCW)

636 (DOE/CS/40061-7) **Use of precalciner to remove alkali from raw materials in the cement industry. Final report, July 1978-July 1980.** Gartner, E.M. Portland Cement Association, Skokie, IL (USA). Jul 1980. 185p. DOE Contract AC02-78CS40061. Source: NTIS, PC A09/MF A01.

The objective of this work was to develop an efficient means of removing alkali metal compounds (alkalies) from high-alkali aluminosilicate raw materials of the type commonly used as part of cement raw mixes in order to increase the energy efficiency of cement manufacture. The intention of this project was to determine whether the high-alkali raw materials could be pyroprocessed separately to remove the alkalies before they entered the rotary kiln, where they would be mixed with the other raw feed components. If this could be achieved, considerable savings could be made in the energy required to remove alkalies, compared to conventional methods in which the cement raw mix must be treated as a whole. Two different methods of alkali removal were examined, namely, vaporization of alkalies at relatively low temperatures; and alkali-rich melt separation at relatively high temperatures. The results showed that the removal of alkalies by pyroprocessing of high-alkali raw feed components separate from the other cement raw mix components is not likely to be a practical alternative to the best available conventional precalciner technology. (LCL)

637 (DOE/CS/40250-T2(Draft)) **Development of low-energy methods for production of lime. Draft final report.** Mallow, W.A.; Dziuk, J.J.; Daugherty, K.E.; Safa, A. Southwest Research Inst., San Antonio, TX (USA). 31 Mar 1981. 65p. DOE Contract AC03-79CS40250. Order Number DE82011876. Source: NTIS, PC A04/MF A01.

Possible methods of reducing the fuel and energy requirements in the production of lime were identified. Four basic concepts were explored in pursuit of a viable method to improve the energy efficiency of lime manufacture: (1) enzymatic catalysis; (2) conversion by Lewis acids in protolytic solvents; (3) attrition grinding/frictional calcination; and (4) catalyzed calcination. The concept which proved most encouraging and which appears to be readily adaptable to current practice emerged with the discovery of the Fused Salt catalysts, which can be introduced with pulverized limestone in a furnace process similar to those commercially used today.

638 (DOE/CS/40339-T1) **Insulation performance data and assessment procedures for steam kiln energy conservation investments.** Zaccor, J.V. Scientific Service.

Inc., Redwood City, CA (USA). Sep 1980. 181p. DOE Contract AC03-80CS40339. Source: NTIS, PC A09/MF A01.

For a demonstration project, the costs and benefits of insulating concrete block curing kilns to isolate the kiln thermal mass from the curing cycle are determined. Data were developed on service life of FOAMGLAS insulation, the effect of Johnson burners on the insulation and mounting, performance of an alternative insulation (a rapidly installed, spray-on polyurethane foam), and a simple incentive to promote implementation of industrial energy conservation concepts. Data are tabulated and compared for the FOAMGLAS and CPR 480 polyurethane insulations. Specific studies of insulation that was installed on inside surfaces of kilns to lock the kiln-mass out of the curing cycle are given for Blocklite plant in California, the Ameron pipe plant in California, and the Superlite plant in Phoenix, Arizona. (MCW)

639 (FEA/D-76/091) **Proceedings of the FEA-PCA seminar on energy management in the cement industry.** Federal Energy Administration, Washington, DC (USA); Portland Cement Association, Skokie, IL (USA). 1975. 320p. (CONF-7510185-; FEA-PCA seminar on energy management in the cement industry, Philadelphia, PA, US, October 21, 1975; CONF-751086-; CONF-7511144-). Source: GPO \$3.75.

The 20 papers presented at the seminar covered all areas of energy management and conservation in the cement industry for short- and long-term considerations. They are: Energy Conservation Protection for America's Future by Roger W. Sant; Government-Industry Energy Conservation Programs by James K. Pont; Industry's Role in Meeting the Energy Challenge by R. D. MacLean; Impact of Higher Energy Cost on U.S. Cement Industry by Frank Stevens; review of FEA-PCA Energy Study by G. K. McCord; Coal Systems by Ib Jensen and George Koonsman; Energy Audit Procedures by A. W. Mees; Short-Term Energy-Saving Considerations for Kiln Systems and Controls by Carl Goller; Finish Grinding Systems by Earl J. Henry; Finish Grinding by Lars Hvitved; Short-Term Programs for Reduction of Energy in Cement Raw Feed Handling by Julian Lewis; Refractories-Life, Insulation, Coatings by Wesley Lueking; Energy Consideration in Clinker Cooling by Dr. Jay Warshawsky; Kiln Selection by K. T. Andersen; Roller Mills-Why and When by Dr. Gerd A. Schroth; Grate Preheater Kiln Systems by Dr. Gerd A. Schroth; Automation and Energy Reduction by Ralph H. Striker; Potential Promise, Prospects, and Pitfalls in Energy Conservation by the U.S. Cement Industry by Hoke M. Garrett; Personnel and Energy Conservation—a Re-education by P. W. Gutmann; and Financial Considerations in Energy Conservation by C. W. Howlett. (MCW)

640 (HCP/CS-1549) **Opportunities for energy conservation in finished concrete products. Final report.** Zaccor, J.V.; Jewett, J. Scientific Service, Inc., Redwood City, CA (USA). Sep 1978. 105p. DOE Contract EC-77-S-03-1549. Source: NTIS, PC A06/MF A01.

Based on an industrial audit and process analysis, two energy conservation opportunities were identified as applicable to the finished concrete products industry. One of these involved substituting a naturally cementitious material, pozzolan, for a portion of the cement, and the other involved the application of an appropriate insulation to achieve thermal isolation of material needlessly cycled with the product. Analyses of curing processes and small-scale laboratory tests were conducted to find appropriate blends of pozzolan, cement, and curing temperatures to achieve energy savings

while maintaining satisfactory early strength in concrete test cylinders. A parametric study of curing energy versus these mixtures and temperatures was made to arrive at an optimum energy saving "batch design" to try in the field. This proved to be a combination in which 30% of the cement was replaced by pozzolan. Applied to the 10% cement content concrete products manufactured each year, this measure could save 1.0 million tons of cement used annually (1980) at an energy cost of .86 million barrels of oil equivalent to produce. On-site surveys of several commercial block plants provided input for calculational assessments that indicated 40% to 70% of curing energy might be saved by insulation. This study showed that there are simple measures which can save money and energy in the concrete block industry; the demonstrated applications are directly pertinent to over 5,000 nearly identical processing units (kilns) in the concrete block industry; both measures are economically viable—for the insulation measure, returns on investment were 22% and 40%, calculated from the measured saving at two plants and the expected service life; and if applied nationwide, the energy saving would be about 1.5 million barrels of oil equivalent in the concrete block industry alone. (LCL)

641 (NATO/CCMS-46) **Industrial international data base: the cement industry.** Gordian Associates, Inc., New York (USA). 1976. 64p. DOE Contract E(49-1)-3863. Source: NTIS, MF \$4.50.

This report presents the results of a study of energy consumption in the manufacture of portland cement in the Federal Republic of Germany, Italy, the United Kingdom, and the United States; it is one of several energy-related projects initiated under the auspices of the NATO Committee on the Challenges of Modern Society (CCMS). Detailed research and development projects were developed following analysis of the basic data. The comparative energy-consumption data assembled during this study are presented in a series of exhibits in Appendix C to this report. Data on industry structure, market structure, cement production (by quantity and by type of cement), energy-resource consumption, kiln specific energy consumption, cement specifications, and key environmental standards are reported. A range of kiln fuel consumption from 820 to 1490 kcal/kg of cement was found for the participating nations, with the Federal Republic of Germany lowest and the United States highest. The cement study described in this report forms part of the Industrial International Data Base Project, itself a subproject of the NATO/CCMS Rational Use of Energy Program. Other industries being studied are steel and selected plastics and there is also a separate study group reviewing all aspects of energy-accounting methodology. The major objectives of the Data Base Project are to collect data on industrial energy consumption for specific industries in different countries, to identify and analyze significant differences in energy consumption, to document technology-transfer ideas, and to develop recommendations for research and development of energy-efficient technology in major industrial sectors.

642 (NBS-SP-542) **Possible contributions of cement and concrete technology to energy conservation.** Frohnsdorff, G.; Brown, P.W.; Clifton, J.R. (eds. National Engineering Lab. (NBS), Washington, DC (USA). May 1979. 79p. DOE Contract AT01-77CS40119. Order Number DE84005445. Source: NTIS, PC A05/MF A01; GPO Dep.

The purpose of the workshop was to identify and record ideas on possible contributions of cement and concrete technology to energy conservation in the near term and by

the year 2000. This included consideration of current technology as well as areas in which technological advances might be realized. The workshop was divided into working groups on cement composition, cement production, blending materials, concrete production, efficient use of concrete, and institutional factors. The essential results from the six working groups were statements of Energy-Saving Opportunities, Research Needs, and Unresolved Issues. The statements, which are the major part of this report, are presented without critical analysis.

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