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Energy Studies reports on activities of the Center for Energy Studies and other energy-related news from The University of Texas at Austin. Subscription is free upon request (six issues a year).

The Center for Energy Studies is a multidisciplinary research center, the central liaison for energy research, education, and public service at The University of Texas at Austin. Dr. Herbert H. Woodson is director.

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Industry's Innovative Electric Technologies: Fast, Precise, Intense

(For industry, electricity is not cheap, nor will it probably ever be. An industrial firm at present must pay $15 to $16 per million Btu for electricity, $8 for an equivalent amount of oil, or about $4 for an equivalent amount of natural gas. Choosing expensive electricity over oil or gas would seem hardly to make sense. Yet why do many observers predict that over the coming decades industry will become more and more electrified?

A study by CES researcher Philip S. Schmidt sheds some light on these questions. Dr. Schmidt, a UT professor of mechanical engineering, has completed a year at the Electric Power Research Institute (EPRI) studying innovative uses of electricity in the manufacture of steel and other metals, automobiles, chemicals, petroleum, glass, paper, food, textiles and other products. His state-of-the-art survey, case studies, and findings are to be published in a forthcom-

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Energy Conservation Studies researcher Gary Reichelt demonstrates one of five microprocessor programs developed to perform quick, common industrial energy calculations: (1) Thermodynamic Properties of Steam, (2) General Curve Fitting of Data, (3) Heat Loss Estimation, (4) Pressure Loss and Pumping Power for Pipe Flow, and (5) Discounted Cash Flow Analysis. To order ($50 each), contact Energy Conservation Division, Center for Energy Studies, ENS 143, The University of Texas at Austin, Austin, Texas 78712.

ing EPRI report, *Electricity and Industrial Productivity: A Technical and Economic Perspective.*

The article below is adapted from that report and a paper by Dr. Schmidt to be published by Government Institutes, Inc., in the proceedings of the Tenth Energy Technology Conference, held in Washington, DC, February 28-March 2. The article is an introduction to electricity's useful properties and how they can be exploited by industry.)

Some Important Industrial Electrification Technologies

High-Temperature Materials Production

- Direct arc melting
- Induction melting
- Vacuum melting
- Plasma arc melting
- Direct resistance melting
- Electroslag remelting
- Plasma metals reduction
- Plasma chemical synthesis
- Electrolytic metals reduction

Medium- and Low-Temperature Materials Production

- Heat pumps and vapor compression
- Microwave heating and drying
- Infrared heating and drying
- Electrolytic separation
- Electrochemical synthesis
- Laser chemistry
- Variable-speed drives

High-Temperature Materials Fabrication

- Induction heating
- Laser heating and welding
- Electron-beam heating and welding
- Homopolar pulsed heating and welding
- Direct resistance heating and welding
- Electromagnetic and electrohydraulic forming
- High-temperature plasma surface treatment

Coating and Finishing

- Ultraviolet radiation curing
- Electron-beam curing
- Low-temperature plasma surface treatment
- Electroplating
- Electrophoretic painting

Electricity is an unusual form of energy in that virtually 100 percent of it can be converted to useful work. Three types of conversion exist: *electromotive,* an example of which is the electric motor; *electrothermal,* which includes all kinds of heating through electricity; and *electrolytic,* which is the process of using electricity to alter or separate molecules, as is done in electrolysis.

These three electrical phenomena can have profound technical and economic ramifications when exploited for industrial production. Electrical processes can provide unlimited input energy density, volumetric heat deposition, and precise controllability. In some cases, effects may combine synergistically to simplify production. From an economic standpoint, these advantages can result in reduced energy, capital, and labor costs, and improvements in the human and physical environment. A number of leading industrial electric processes are listed in the accompanying table.

Unlimited input energy density. In combustion processes, temperature cannot exceed the "adiabatic flame temperature," a practical limit of about 3000° F for typical industrial fuels burned in air. Electric heating has no inherent thermodynamic temperature limit. Temperatures of 10,000° F and higher are achieved routinely in arc-produced plasmas, and much higher temperatures are technically feasible. Generally in arc heating, material to be heated is placed between two electrodes and an arc of electricity is struck through the material, immediately heating it.

High-intensity heating with electric arcs finds important application in the steel industry in arc furnaces, where rapid melting is extremely important; melting rates three to five times faster than those of combustion-fired equipment can be achieved in modern arc furnaces. For this reason, arc furnaces are almost exclusively used now in scrap-based steel production. High heating intensity is also critical in plasma-based processes for chemicals and metals production.

Volumetric energy deposition. All of the electrothermal phenomena are volumetric; that is, they generate heat inside a material rather than on its surface, a significant advantage in many processes. To produce metal forgings, a rough shape (the billet) must be heated to softening temperature so that it can be hammered or pressed into the desired form. In a conventional fuel-fired forging furnace, heating imposed at the surface by radiation and convection is inherently slow, typically requiring several hours. With induction heating, in which electrical energy is deposited directly within the material, the process is reduced to several minutes or less. Thus it offers the potential for higher production rates with significantly reduced energy and material losses, even taking into consideration the lower efficiency of electrical generation and transmission.

Another example of volumetric heating is the drying of moist materials with microwave or radiofrequency radiation. In conventional drying, heat must diffuse into the material from the surface while moisture diffuses out, a slow process since most materials of interest are poor thermal conductors. If drying is accelerated too much by faster heating, overdrying of the surface can occur, causing cracks and degradation of the product. With microwave and radiofrequency heating, this problem is largely eliminated, and drying rates can be greatly increased, improving overall productivity, product yield, and product quality.

Precise controllability. Electricity is often referred to as an "orderly" form of energy, in contrast to thermal energy, which is random in nature. This orderliness means that electrical processes can be controlled much more precisely than thermal processes. Since electricity has no inertia, it can be instantly varied in response to process conditions—such as material temperature, moisture content, or chemical composition—and a desired state can be accurately maintained. Lasers and electron beams can be focused at the work surface to produce energy densities a million times more intense than an oxyacetylene torch. The focal points of these high-intensity energy sources can be rapidly scanned and moved with computer-controlled mirrors or magnetic fields to deposit energy exactly where it is needed. This focusing can be a tremendous advantage, for example, in heat-treating of parts precisely at points of maximum wear, thereby eliminating the need to heat and cool the entire piece. In electrolytic processes, energy is imparted directly to a substance to produce molecular separation or to induce chemical reactions selectively, the chemical equivalent of microsurgery.

Synergistic combinations of effects. In some processes, electrolytic, electrothermal, and electromotive effects combine in an advantageous way. In the Hall process for deriving aluminum from alumina, ohmic (resistance) heating helps keep the cryolite bath in the molten state, while electrolysis causes pure aluminum to separate out and collect at the cathode. In a coreless induction melting furnace, used for melting metal for casting, an electromagnetic coil surrounds the crucible. Electromagnetic induction from the coil heats and melts the charge and at the same time induces a strong electromotive stirring action, which enhances heat transfer to the solid material and greatly improves homogeneity of the melt. The latter effect is especially important in the production of high-alloy castings; it can be a major determining factor in the choice of induction melting over alternative methods.

Reduced fixed cost. High energy density and precise control typically result in an increased rate of production, which, in most cases, reduces fixed cost per unit of product. Labor, overhead, and interest on capital are spread over a larger production volume, and thus, even when the cost premium of electricity increases energy cost per unit, total production cost may, in fact, be less.

Reduced capital requirements. Electrical process equipment is typically economical in smaller unit sizes than combustion equipment, largely because fuel handling and environmental control occur at the power plant and not the factory. The economy of scale that is normally axiomatic of industrial facilities is much less significant in most electric-based production systems. In fact, electrical production technology can give rise to an "economy of reduced scale," in that smaller equipment requires less space and allows facilities to be decentralized and sited near raw material sources and product markets. These factors are particularly evident in electric-based steelmaking.

Reduced energy consumption. At first thought it would seem that primary energy consumption with electrical processes should always be higher than that with conventionally fueled systems, especially in light of the three-to-one conversion ratio of fuel to electricity at the power plant. The opposite is true in many cases, however. The ability of electricity to be precisely controlled and precisely directed where it is needed often reduces energy costs. In addition, the short heating times characteristic of most electrothermal processes can sharply reduce the parasitic losses inherent in relatively slow combustion equipment.

Flexibility of raw material base. High energy intensity and precise control of electricity permit more flexibility in raw materials than is possible with most conventional processes. Arc furnaces, for example, can utilize either scrap or direct-reduced iron with little or no process modification. Valuable materials, such as ferrochrome and ferrovanadium, can be produced in a plasma reactor from low-grade, domestically available ores, rather than from high-grade ores available only from foreign sources.

Improved product quality and yield. In overall production economics, product quality and yield (i.e., the ratio of final product output to raw material input) are critically important. Electrical processes typically provide improvements in both areas. Induction heating of forging billets and microwave drying of moist products are striking examples.

Decoupling of production from fuel supply. A discussion of the relative merits of various methods would be incomplete without mention of the problems of energy supply. Combustion-based processes are highly dependent on the availability of specific fuel sources, since combustion equipment in general is not very adaptable to changes in fuel type. The shift to electric-based processes places the choice of fuel on the electric utility, where optimizing energy conversion is the primary concern. Thus over the long term, basic processes for the manufacture of products can remain essentially the same, while the utilities respond to the changing situation in primary fuel markets.

The complexity and diversity of industrial processes make it impossible to generalize about the extent of the benefits implied by the above discussion. Processes must be studied on a case-by-case basis to understand where the selection of energy source fits in and how it affects the process technically and economically.

UT-Austin Energy

Outlook Cautiously Optimistic, Fusion Engineering Director Tells Congressmen

The outlook for nuclear fusion engineering is "cautiously optimistic," Dr. Herbert H. Woodson, interim director of the UT Center for Fusion Engineering, told a congressional subcommittee March 15.

Before the Subcommittee on Energy Research and Production of the House Science and Technology Committee, Dr. Woodson summarized the findings of the Committee on Magnetic Fusion of the National Research Council.

Fusion faces "engineering challenges of enormous complexity," he said, but these "can be identified with a relatively high level of confidence." Many fusion reactor materials and systems cannot be developed until experiments in a realistic fusion environment can be made.

Utilities cannot be expected to invest their capital in fusion energy in the near future, Dr. Woodson said. However, valuable industrial participation can occur in the areas of defining requirements for fusion devices, managing projects, supplying components, exchanging personnel, and providing engineering services.

Dr. Woodson warned against making exclusive engineering choices too early, while the scientific base is still inadequate.

Compact Pulsed Homopolar Licensed to OIME, Inc., for Manufacture and Sale

A new technology born out of the fusion energy research program at The University of Texas at Austin has moved from campus laboratory to the commercial marketplace.

Known as the compact pulsed homopolar generator, the new technology is a method of supplying pulsed power at very high levels—hundreds of megawatts for a second or less, depending on the application.

President Peter T. Flawn of UT Austin and A. E. Prince, Jr., president of OIME, Inc., an Odessa engineering and manufacturing company, announced UT's agreement to license the manufacture and marketing of the homopolar generator to OIME. The agreement, which specifies that UT will retain ownership rights, was approved April 15 by the UT System Board of Regents.

OIME designs and custom fabricates precision oilfield and industrial equipment for use all over the world. It is a subsidiary of Parker Drilling Company of Tulsa, Oklahoma, one of the largest publicly held land-based drilling companies in the world.

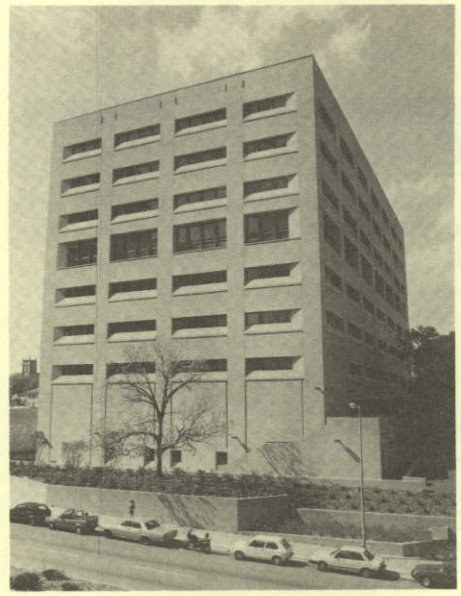
The compact pulsed homopolar generator was developed by engineers at UT Austin's Center for Electromechanics. It produces pulsed electrical discharges of very high current and has applications for processes requiring repetitive bursts of energy such as welding and heating of metal billets.

In addition to the oil and gas industry, the homopolar machine has applications in such divergent areas as the railroad, automobile, steel, electric power plant, and pipeline industries.

"The machine operates by rotating a flywheel in a magnetic field up to several thousand rpm, then decelerating the flywheel almost instantly. This converts the rotational kinetic energy to electrical pulses at very high power levels," said William F. Weldon, technical director of the Center for Electromechanics and one of the inventors of the UT machine.

At UT Austin, homopolar generators were first explored as a source of inexpensive power for the confinement and heating of plasmas in fusion experiments. The invention is a "technology spin-off" of UT's fusion research program, Mr. Weldon noted.

Support for homopolar research at the university has come from the Texas Atomic Energy Research Foundation, the US Department of Energy, the National Science Foundation, the Federal Railway Administration, and most recently from the Defense Advanced Research Projects Agency and the US Army.



The Engineering Teaching Center 2 will open its doors in September.

New Engineering Building to House Solar, HVAC, and Other Energy Labs

When mechanical engineering students and faculty move into UT's new Engineering Teaching Center 2 in July and August, they will begin to use an array of solar, air-conditioning, and other energy-related laboratories.

The $25 million, nine-level building, located in the north part of the UT campus, is to become the new home of the Department of Mechanical Engineering and the Materials Science program, Dr. H. Grady Rylander, chairman, said.

One unusual feature of the building is an extensive monitoring system for the heating, ventilation, and air conditioning (HVAC). The whole building, in fact, is instrumented as an HVAC lab, which is monitored from the sixth floor, Dr. Rylander said.

The solar project lab is a penthouse structure on the roof of the Engineering Teaching Center. Photovoltaic panels, flat-plate and concentrating collectors, and a wind generator will be installed on the roof. Other energy-related laboratories include heat transfer, energy systems, combustion, engine test and emissions control, air conditioning, and energy computations.

The formal dedication for the Engineering Teaching Center will take place September 23.

CES Update

Office of Director

A study of **how heat transfer occurs in industrial furnaces** has been funded by the National Science Foundation and will be under way June 1.

The project is headed by Dr. John R. Howell, Solar Division researcher and professor of mechanical engineering. The goal is to develop a way to design industrial furnaces more precisely, especially in terms of their energy consumption.

This new method is an effort to achieve the computing ease and speed of the leading method, the Hottel zoning approach, but eliminate some of the drawbacks associated with it, such as the difficulty of adequately representing furnaces of complex geometries. The new furnace design method is based on the concept of exchange factors, and these are to be determined in a series of experiments, Dr. Howell said.

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Dr. Herbert H. Woodson, director of the Center for Energy Studies, has been named to head the **Energy Engineering Board** of the National Research Council.

The basic purpose of the board is to give advice from an engineering point of view to the federal government on national energy policies and technologies. The National Research Council is the principal operating agency of the National Academy of Sciences and the National Academy of Engineering.

Dr. Woodson said the board has been largely inactive for several years and will be resuming activities in June.

Another UT faculty member, Dr. Allen J. Bard, professor of chemistry, is also a board member.

Energy Conservation

Dr. Jerold Jones, head of the Energy Conservation Studies Division, has been appointed chairman of a committee to reevaluate **ASHRAE Standard 90,** the leading guideline in the United States for the energy-conserving aspects of building design.

ASHRAE is the American Society of Heating, Refrigeration, and Air Conditioning Engineers. Much of the analytical work is being carried out by Batelle's Pacific Northwest Laboratories and Lawrence Berkeley Laboratory at the University of California. The project is funded by the US Department of Energy.

Dr. Jones said both the energy and the economic aspects of building features and systems are being studied, particularly in terms of life-cycle costing.

Energy costs have risen, Dr. Jones said, but they remain fairly low compared to first cost—the cost of construction. Of a building's twenty-five-year lifetime costs, its energy costs can vary from as low as 5 percent to about 30 percent, depending on the design and function of the building. The higher that percentage, the more savings are possible through energy conservation, Dr. Jones said.

The technical evaluation committee is expected to present a draft report of its recommendations in May; when final, the report will go out for public review and comment.

Geothermal Studies

Three geopressured-geothermal wells in Texas and Louisiana have started **yielding small quantities of oil,** Dr. Myron Dorfman, head of the Geothermal Studies Division, announced recently.

"It's an enigma," he said. Geopressured formations contain hot brine and dissolved natural gas. The presence of oil in such formations is unexpected. The three wells are all located along the Gulf Coast: the Dow No. 1 Parcpardue in Louisiana, the Pleasant Bayou No. 2 in Brazoria County, Texas, and a well of opportunity, the Lear No. 1 Koelemay in Texas.

Several theories have been put forth to explain the presence of oil, Dr. Dorfman said: (1) retrograde condensation with pressure draw-down, (2) diffusion of heavy hydrocarbons along migratory paths, (3) trapping of heavy hydrocarbons along silty-shaley bedding planes within sandstone bodies, and (4) expulsion of heavy hydrocarbons, in addition to water and gas, from illite. The geothermal researchers are sampling and testing the oil to determine its source.

Nuclear Studies

Two Nuclear Studies Division researchers are developing a way to gather **accurate data on beryllium** and its ability to multiply neutrons to enhance the breeding of fuel inside the blanket of a hybrid fusion-fission reactor of the future.

Beryllium, the second lightest of the metals, is an excellent material for enhancing the efficiency of fusion reactors. One of the main functions of a fusion reactor is to produce heat for electric power generation, but another is the ability to breed nuclear fuel.

Breeding occurs when neutrons emitted by the fusion reaction of the core strike materials in the surrounding wall (called a blanket). Neutrons striking the material lithium create tritium, one of the substances needed to fuel the fusion reactor—but not quite enough tritium is created to make the reactor self-sustaining.

However, if neutrons strike beryllium, most of the time the beryllium will split into two helium atoms and give off two neutrons—thus doubling the neutron rate, and increasing the tritium rate. In fact, this higher neutron rate allows another material, thorium, to be put in the blanket. Neutrons striking thorium create uranium-233, a fuel for conventional reactors.

One present problem with beryllium is that researchers are uncer-

(Continued on next page)

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tain about its neutron multiplication potential. Experiments in the past have varied 25 percent from values predicted by current data.

To provide better data, Drs. Wiley Davidson, CES research associate, and Nolan Hertel, assistant professor of mechanical engineering, have developed a way to measure the multiplication of a neutron source placed in a hollow beryllium sphere. They will take data with several neutron detectors called Bonner balls (with and without the beryllium sphere), then weight the combined responses by mathematical formula and derive counts.

Dr. Davidson said this method will allow simplified, benchmark experiments to be carried out for a number of different neutron sources to obtain reliable data on beryllium's ability to multiply neutrons.

Separations Research Program

A prospectus for the CES Separations Research Program was released April 11, and single copies are available free to those interested in the program.

The new program, to start up in January 1984, will focus on fundamental research of separations processes of interest to industry, according to Dr. James R. Fair, program head, and Dr. Jimmy L. Humphrey, program manager. Industrial firms will be invited to join as charter sponsors. Sponsors will be asked to contribute funding to the program, and in turn will receive the research results generated by the program.

The research will address separations processes of the chemical, petroleum refining, gas processing, biological, food, textile, and pharmaceutical industries.

To learn more about the program and obtain a copy of the prospectus, contact Dr. Jimmy L. Humphrey (512/471-4946), Center for Energy Studies, ENS 143, The University of Texas at Austin, Austin, Texas 78712.

Solar Studies

A hybrid air-conditioning system that can be solar powered, the invention of two university researchers, has been awarded a US patent.

The device is a hybrid double-absorption cooling system, said Dr. John R. Howell, Solar Studies Division researcher and professor of mechanical engineering. He and former graduate student C. S. Patrick Peng invented the design in 1981. Mr. Peng is now with Amoco Production Research in Tulsa. The patent is held by The University of Texas System.

The double-absorption cooling system allows low-grade heat sources such as solar, waste heat, or geothermal to be used to cool air. It would be most applicable on a commercial or industrial scale, Dr. Howell said. Like other inventions patented by the university, the double-absorption cooling system may be licensed to private firms for manufacture and sale. Building a prototype is the next step in the process, Dr. Howell said.

The system has an absorption cycle and a desiccant cycle. The two cycles share the same working fluid (lithium chloride, for example), using it as both the absorber and the desiccant (drying agent), thus lowering the cost of the machine.

In the absorption cycle, water vapor is evaporated out of a water-lithium chloride mixture, then condensed and cooled by reducing pressure. Because these steps occur at lower-than-atmospheric pressure, the water boils and condenses at much lower temperatures than normal.

The cooled water is used in turn to cool air by contact in a heat exchanger. In the desiccant cycle, the lithium chloride is directly exposed to the same air to extract water from it. The air, now cooled and dehumidified, leaves the unit. Laden with water, the lithium chloride returns to the absorption cycle and is combined with the remaining dry lithium chloride to begin the absorption cycle anew.