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GUEST EDITOR'S INTRODUCTION

This issue of the *Johns Hopkins APL Technical Digest* has as its principal theme work in several civil program areas that have energy as a common theme: its generation, use, conservation, and impacts on the physical and social environment.

APL's primary mission is the application of science and technology to enhance the security of the United States. In particular, the Laboratory assists the U.S. Navy in the accomplishment of its national defense objectives. From its inception during World War II until the mid-1960's, APL was fully engaged in this primary mission. However, during the last 15 years APL has sought opportunities to apply some of the technology and skills developed in its defense research to the solution of urgent civil problems. The Department of Defense, the Navy, and the Trustees of the University have supported and encouraged this policy. Civil programs now constitute 15 to 20% of APL's work.

APL applies several criteria to its selection of civil programs: the problems must be nationally important and appropriate to the public service mission of The Johns Hopkins University; the work must not compete with industry; and the results must be publishable and confer no competitive advantage.

The civil programs fall rather naturally into three major categories: biomedical engineering (in collaboration with the Johns Hopkins Medical Institutions); applications of space science and technology; and programs in the areas of energy, environment, transportation, and public safety. The first two areas will provide themes for future *Digest* issues. This issue presents a representative sample of work in the third area.

In 1973, APL analyzed alternative energy technologies that could reduce the increasingly critical national dependence on imported petroleum. The importance of coal for both direct combustion and conversion to gas and liquid fuels and of nuclear power generation was recognized, but it was concluded that it would be best for established industries and laboratories to undertake these developments. It was decided to concentrate primarily on longer range goals: utilization of lower grade heat sources, renewable resources and conservation techniques, and research on promising concepts. The energy sources selected were geothermal heat, a potentially enormous but relatively low grade resource; ocean thermal energy, i.e., the solar energy stored in the heated surface waters of the oceans, another enormous and fully renewable resource; urban waste sources; and photovoltaic conversion. In energy conservation, the heating and cooling of buildings was recognized as an area of wasteful use of fossil fuels, with a large potential for improved energy storage, management, and utilization of solar and environmentally available heat.

Although large geothermal resources appear to be widely distributed in the United States, only 1% or less, all in the far west, are suitable for direct utilization to generate electricity. Throughout most of the continental United States, the relatively low temperature (below 250°F) or high mineral content of geothermal hot water require its indirect application through heat exchange or heat pumping to space heating and process industries that can advantageously and economically use low temperature heat. Hot dry rock, a large potential resource, requires the cycling of water down into the hot strata and back to the surface. In most areas, the quality, quantity, and practical exploitation potential of geothermal energy are still largely unknown. APL is carrying out for the Department of Energy a broad study of the resource potential and the engineering and economic aspects of geothermal energy exploitation throughout the eastern United States, including engineering feasibility, economic and market analyses, and socioeconomic and institutional factors. The lead article gives a broad background review of geothermal energy, followed by an article on more detailed engineering and economic considerations, using as an example the Crisfield, Maryland site for which considerable data are now available.

In 1973, APL recognized the potential of ocean thermal energy conversion (OTEC), which utilizes the temperature difference between the warm surface and cold deep waters of the tropical ocean. While this concept was not economically attractive in the era of abundant cheap fossil fuel, in-house studies indicated that OTEC could become economically competitive with rising costs of other energy sources through the application of state-of-the-art engineering and construction technology. APL has become a leader and pioneer in conceptualizing the process, cycle analysis, and mechanical design of OTEC plants; demonstrating experimentally the feasibility of economical heat exchanger designs; and presenting engineering and economic analyses that have helped to generate government and industry enthusiasm and support. In particular, APL has evolved the concept of the OTEC plantship that grazes the tropical oceans and produces onboard energy-intensive chemical products such as ammonia. OTEC plants that are moored off-shore and cable electricity directly on-shore are applicable only to a fairly small number of suitable U.S. sites such as Hawaii, Puerto Rico, and southern Florida, but their potential is limited. The grazing plantship can efficiently exploit the whole ocean in the areas of highest seasonal surface water temperatures (deep water temperatures are nearly constant) and deliver ammonia worldwide. Ammonia is an essential agricultural fertilizer and chemical raw material in steadily increasing worldwide use whose production now requires a substantial percentage of increasingly scarce natural gas. Perhaps more important in the long run, ammonia is an efficient and economic vehicle to transport and store hydrogen, which can be readily released on demand for electric generation via efficient fuel cells. The basic OTEC concept has been published in the technical literature and was previously reported in the *APL Technical Digest* **14**, No. 1. The current article updates the engineering and economic status of the OTEC plantship and compares it with other large electric power sources.

Heating and cooling of buildings is one of the largest and among the least efficient energy consumers. The demand is severely unbalanced both diurnally and seasonally, making heavy use of natural gas and heating oil in the winter and electric power during the summer. The unbalanced load imposes capital and operating costs on the fuel and electric power suppliers. Some improvements are straightforward but not easy to implement on a very large scale, e.g., improved insulation and thermal management of individual buildings. The original or retrofit cost and the system operation and maintenance requirements are not trivial. Consideration of what present systems do — reject excess heat to the environment in summer, and generate heat to compensate for losses to the environment in the winter — makes obvious the desirability of storing summer heat for use in the winter and vice versa. In principle, this can be done on an individual building basis, but the size and cost of the energy storage system and its accompanying heat exchangers, compressors, pumps, etc., and the relative complexity of its operation, probably make it rather impractical except for very large buildings with professional supervision and maintenance.

A great improvement in overall efficiency, unit capital, and operating costs can be realized through economy of scale, i.e., community heat storage and management. This is the basic idea of the Community Annual Storage Energy System (CASES), in which a mixed community of single- and multiple-family residences, office and commercial buildings, schools, and other community activity centers are served by a central facility for heat energy storage and management. Summer cooling is provided by the melting of ice and the storage of warm water. This stored heat is released in winter by cooling and freezing the water. Additional economies may be achieved by load balancing among community buildings, e.g., some office buildings may be net heat producers even in winter, and taking advantage of favorable opportunities for environmental heat exchange, i.e., warm winter days and cool summer nights. CASES is applicable to urban and suburban communities throughout most of the United States, could largely replace the use of gas and oil for building heating, and could provide both diurnal and annual load leveling for electric utilities. The accompanying article describes the engineering features of the CASES system and displays the operating and economic analysis by computer simulation of a year of operation in a representative eastern mid-Atlantic community — Columbia, Maryland.

The use of momentum wheels for attitude control of satellites led to APL's interest in high-performance flywheels as a very attractive method of storing kinetic energy. This conclusion was reinforced by the study of flywheel energy storage and regeneration for automotive vehicles. The load-leveling characteristics of the flywheel — releasing its energy quickly to meet peak demands and regenerating it when the load drops — allow the prime mover to operate more nearly at optimum speed and power setting and to be sized for average rather than peak loads. Flywheels couple directly with rotating-shaft power sources or loads, e.g., internal combustion engines, gas or steam turbines, and electric generators or motors; are capable of an almost unlimited charge-discharge cycle life; are silent and relatively compact; and can be used in an extraordinarily wide range of vehicle and stationary applications. Most other energy storage systems require interconversion among kinetic, potential, thermal, electrical, or chemical energy with inevitable conversion losses. Some are limited in depth of discharge or charge-discharge cycle life; others cannot respond to a rapidly changing load.

Flywheels have been long known and used, e.g., to smooth the power output of impulsively powered cranked engines. However, the conventional steel wheel had significant drawbacks: a fairly low energy-to-weight ratio and a large required factor of safety because an overstress failure could be catastrophic. These limitations are overcome by applying the new technologies of high strength fibers and fiber-reinforced composite materials to yield flywheels with much higher strength-to-weight ratios, thereby attaining higher rotational speeds and specific energies with relatively small and light wheels. When these wheels are deliberately destroyed by overspeeding, they simply unravel into a tangle of broken fibers instead of coming apart in large destructive pieces. The gradual energy release is safely contained in the relatively light housing that is normally used to maintain a vacuum and reduce aerodynamic drag on the wheel.

For the past decade, APL has been developing and testing design and fabrication concepts, evaluating materials, and analyzing numerous applications for high strength, low cost "super-flywheels." For example, APL recently demonstrated for the Department of Energy the feasibility of a cost-effective "plug-in" flywheel system for household use that provides peaking power requirements and is regenerated by the household electric power during the off-peak, low-rate nighttime hours. The accompanying article reports on the status and prospects for large-scale application of flywheel technology.

In collaboration with The Johns Hopkins University Department of Geography and Environmental Engineering and the Chesapeake Bay Institute, APL has, since 1971, evaluated for the State of Maryland the environmental and socioeconomic impacts of all proposed energy generating facilities, both fossil and nuclear (previously described in the *APL Technical Digest* **13**, No. 3). This work has led to the development of energy facility siting computer models that have been applied regionally and nationally for the Departments of Energy and Interior and the Electric Power Research Institute. The present article describes a single environmental impact assessment — the effect of salt drift and fallout from a power plant natural-draft cooling tower using brackish water. It illustrates the many technical and institutional considerations, the complexity, and the care required to perform properly an environmental impact assessment. The experience gained and methodology developed over nearly a decade make Maryland a national leader and a model for other states in environmental impact assessment. During last year's Three Mile Island accident, the Johns Hopkins team was able to advise the Governor daily of the probable impact on Maryland of a radioactive release from the crippled plant.

A destructive form of energy release occurs in unwanted fires. In the United States they cause over 7000 deaths, several times as many traumatic injuries, and several billion dollars of direct economic damage each year — one of the worst records among industrialized nations. Yet amazingly little was known about either the physical or the socioeconomic factors involved in the occurrence of fires, the causes and extent of casualties and damage, or more effective means for fire prevention and control.

In support of rocket and ramjet missile propulsion development, APL has long conducted fundamental and applied research in the field of combustion. In 1970 the Research Applied to National Needs (RANN) program of the National Science Foundation asked APL to become one of its centers for research on the problems of unwanted civil fires, the first significant federal effort in this area.

In conjunction with the School of Hygiene and Public Health of The Johns Hopkins University and with Maryland state and local fire and health agencies, APL undertook four areas of work: fire casualty studies, combustion research, systems analysis and development, and information and education. (The overall program was previously described in the *APL Technical Digest* **14**, No. 2 .) One of the most important contributions has been the quantitative study of fire fatalities in the context of the circumstances of the fires and the physical, economic, and social characteristics of the victims. This pioneering study has, for the first time, produced a body of reliable quantitative data on the causes of fire deaths and their relationship to toxic conditions at the site and the demography, health, and habits of the victims, e.g., cigarette smoking, alcohol consumption, etc. These data provide important insights for fire fighting, emergency medical treatment, efficacy of preventive measures (e.g., smoke detectors), and better public information and education. The accompanying article summarizes the methodology and findings of the fire casualty studies.

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Other energy-related initiatives not reported in detail in this issue are active at APL. Some of the Milton S. Eisenhower Research Center work described in the previous issue (*Johns Hopkins APL Technical Digest* **1**, No. 1) bears on the direct utilization of solar energy. For example, Department of Energy-sponsored and in-house research on vacuum-deposited thin-film semiconductors, directed by Dr. Charles Feldman, may help to meet the urgent need for lower cost photovoltaic cells, while basic research on photo effects at semiconductor-electrolyte interfaces under the direction of Dr. T. O. Poehler may help to provide the basis for photochemical cells that can decompose water to produce hydrogen and oxygen. Nonintrusive intrumentation techniques developed by APL to study combustion in propulsion engines should also be useful in research to improve coal combustion efficiency, for example, in pressurized fluidized beds and coal-fired gas turbines or combined cycles.

In the area of environmental safety, basic knowledge of the acoustic properties of gases and high precision measurement techniques has been applied since 1975 by Dr. J. G. Parker to the development of improved acoustic methods for detection of natural gas pipeline leaks, under the sponsorship of the Gas Research Institute. Research on buried gas pipeline corrosion problems has recently been initiated.

An exciting new APL project is the use of urban solid-waste landfills to produce methane gas. The anaerobic bacteria, which are present in the soil, decompose buried organic wastes to produce methane and carbon dioxide. This has heretofore been a significant environmental nuisance and a real hazard when structures were built on old landfills that still emitted potentially explosive quantities of methane. APL is developing the technology to optimize methane production and recovery from urban landfills, converting them into an energy asset. Controlled use of natural decay processes in the earth may prove to be the most economical way to recover energy values from urban waste. Although relatively new, the landfill methane project, led by Dr. R. C. Eberhart, has already gained international recognition.

As an adjunct to the geothermal program, APL has recently completed a study for the Department of Energy of the technical, economic, and institutional issues involved in the exploitation of the significant low-head hydropower potential available in the northeastern United States.

Improved urban rapid transit systems could effect major savings in gasoline consumption as well as improved urban air quality by reducing the use of private automobiles. Unfortunately, the United States lags many other industrialized countries in this area. Since 1967 APL has worked with the Department of Transportation in the systems analysis and engineering evaluation of transportation systems. This continuing effort, currently directed by Mr. R. A. Makofski, considers the socioeconomic, environmental, and institutional impacts of transportation alternatives as well as their engineering design features. APL has also studied smaller and more energy efficient automotive vehicles for urban use.

APL has also applied energy conservation techniques to its own operating complex with great success. Fuel oil consumption was cut in half and electric power reduced about 25% by improved energy management, heat pumping, and recovery of waste heat from the computer system. Several newer buildings have no central heating plants, and most of the hot water is now provided by waste heat recovery. APL is applying its experience to assist the State of Maryland in reviewing the energy efficiency of state buildings.

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While this introduction was being written, Dr. John B. Garrison (a contributor to the current issue) loaned me a copy of *Fortune* magazine containing an article entitled "9,000 Billion Horsepower of Solar Energy" that reviews alternative options to rapidly dwindling petroleum resources. It states that known petroleum reserves will be virtually exhausted in about 15 years and examines the alternatives that appear to have sufficient technical merit to warrant serious consideration:

Synthetic fuels from coal	Wind
Oil shale and tar sands	Tides and currents
Alcohol from biomass	Solar thermal
Hydropower	Photoelectric
Geothermal	Atomic energy
Ocean thermal	

The article states that, while much development is still needed, geothermal power is already in use, gasohol (10% ethanol) is being produced and marketed in the United States, coal-based synthetic fuels based on the Bergius and Fischer-Tropsch processes are in production, shale oil production experiments are in progress, a recent ocean thermal experiment has produced power, and the Massachusetts Institute of Technology is setting up solar energy research under a large new grant. The article concludes that alternative energy sources seem technically assured, although probably expensive compared to historical oil prices, but timely development is essential.

Perhaps the only unusual feature of that article is its date — November 1938! Where have we been for 40 years? The answer also lies in that date. September 1938 — the infamous month of Munich and the inevitable slide within one year into World War II — was also the date of another significant event little noticed amid the turmoil of Europe. An oil tanker sailed from the Persian Gulf carrying the first commercial shipment from the newly opened fields in Arabia. Unknown to *Fortune's* anonymous and prescient author, petroleum reserves were about to be expanded by an order of magnitude. So — after the war — we all, like Rip van Winkle, went back to sleep for 30 years while petroleum resources were used up with unprecedented profligacy. Today we look at the 1938 *Fortune* list and note that, with the single exception of atomic energy, we are not much farther along now than then. Indeed, relative to consumption, the production of liquid and gaseous fuels from coal and biomass has actually regressed, and even the promise of atomic energy has not yet been adequately exploited. With fewer years left to squander and little hope of new Arabias, let us take a lesson from 1938 and get on with the tasks of developing alternative energy sources and utilizing them efficiently.