POWER SOURCES

A conference report by ***John L. Moncrief***

THE Thirteenth Annual Power Sources Conference was held April 28–30, 1959, at the Shelbourne Hotel in Atlantic City. What was once a yearly review of progress made in the electrochemical field has been expanded over the past few years to cover all energy sources, power conversion systems, and power control devices which may find application in military programs. The sponsor of the conference, the Power Sources Division of the US Army Signal Research and Development Laboratory, Fort Monmouth, N. J., recognized that such an exchange of information is a practical necessity for specialists in the various fields.

Anticipation of an attendance of 700 to 800 people forced the committee to move from the traditional meeting place in Asbury Park to larger quarters in Atlantic City. This was a fortunate move since more than 1000 people registered this year. Of course, there is a possibility that the famous resort's facilities and reputation for extracurricular activities may have also been in part responsible for the record attendance.

Some 29 papers, delivered over the three-day period, were well received by large and attentive audiences as evidenced by the discussions from the floor following each presentation. The banquet on the evening of the first day was highlighted by a welcoming message from Brig. General A. F. Cassevant, Commanding General of Fort Monmouth.

On the more technical side, the keynote speaker, N. W. Snyder, head of nuclear and space power for the Advanced Research Projects Agency, established the theme for the conference with a general review of the existing and anticipated requirements, the state of the art, and the problems peculiar to power for space activities.

Dr. Snyder's premise for his review of requirements

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was the conviction that the exploration of the moon, Mars, and Venus will be both feasible and fruitful in the immediate future. Preliminary probes will be launched to acquire data for use in design and operation of later manned vehicles. It is probable that intermediate space stations will be necessary for planetary visits. Considering the power required for telemetry of data alone, we find that messages from Mars to the earth will require 25 000 times the power needed to send the same message from the moon. To operate a flying space station the astounding total of 20 megawatts of power will be necessary. Snyder predicted that nuclear reactors capable of producing this amount of power for several years will become available within 5 years. Depending upon the specific mission, power requirements exist for a variety of intermediate-range systems from 100 watts up. Regardless of type each system will face unique design problems because of its operating environment. Perhaps the most difficult of these problems is the maintenance of a proper heat balance in a gravitationless vacuum. Except for the radio-frequency power of the transmitters, all energy received or generated within the vehicle eventually becomes heat which must be dissipated by radiation. The quantity of heat disposed of by the radiator is proportional to T_R^4 which would lead one to believe that the energy conversion system should be designed to reject heat at a very high temperature so that the radiator weight would be low. Unfortunately available materials limit the initial temperature and the closer T_R approaches T_0 the larger the conversion device becomes for a given amount of power. Moving parts introduce mechanical perturbations which must be counteracted. New lubrication problems are faced because of the high vacuum. Circulation of coolants, particularly if the coolants enter the radiator in the vapor phase, will require the development of new methods to function in the gravitationless field. Protection against meteoric bombardment, cosmic radiation, and Van Allen radiation must be provided.

Dr. Snyder concluded that: (a) these problems are not unsurmountable, (b) no one power system has been developed to a point where it is clearly superior to all others, and (c) research and development should be increased in all areas of space power.

W. Crane of the Martin Company and E. Kittl of the US Army Signal Research and Development Laboratory, discussed the nuclear-thermo power system from the viewpoints of the selection of the radioactive isotopes and generator design parameters. The most promising isotopes for this type of system appear to be limited to cerium 144, promethium 147, polonium 210, strontium 90, curium 242, and plutonium 238 with cerium and curium showing the most promise with respect to gamma radiation, availability, cost of separation or production, and relatively low volume per curie. A serious problem is the potential hazard of handling otherwise attractive isotopes during the launching period. Ideally, the active material would have the form of a metal which will not burn or fracture if the vehicle fails to perform as expected.

C. M. Zener of Westinghouse described a three-stage thermoelectric generator in which telluride couples are arranged in cascade so that the heat rejected by one stage is accepted by the next. Impedance matching of the three stages is accomplished by proper selection, physical design, and connection of the individual elements. Dr. Zener expects to obtain a thermal efficiency approaching 35% with this system. This statement led to a spirited discussion from the floor since "efficiency" is defined in several ways. The engineer is inclined to consider the efficiency of such a system as the simple ratio of useful power output to energy input. On the other hand the physicist prefers to use thermal efficiency as a measure of the effectiveness of the element of a system he is investigating. This explanation cleared the air for V. C. Wilson of General Electric, who also prefers to work with this interpretation of efficiency in his investigation of thermionic converters. He has designed a vacuum tube diode with extremely close spacing between the cathode and anode. According to the Edison effect, electrons are emitted by the cathode when it is heated to a high temperature. The released electrons are captured by the anode since a positive potential is present because of the temperature difference. Thus a current will be generated when an external circuit is provided. Space charge is neutralized by the introduction of cesium vapor. While this work is of recent origin it promises eventual results of the same order of efficiency as the best thermoelectric devices. It should also be much smaller than the thermoelectric system. A great advantage would be gained for either system if the active elements could be in physical contact with a nuclear heat source. This calls for more research in materials which can live under these conditions.

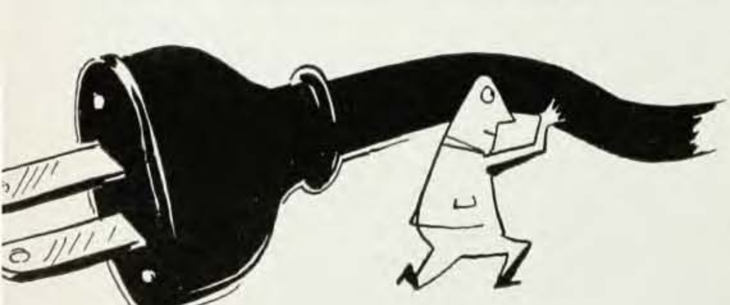
To complete the thermal energy picture, R. J. Denington of Thompson Products outlined the controlling parameters of a dynamic heat engine based upon the mercury vapor cycle. Operating at 1200°F, the specific weight of the complete system would be 10 pounds per kw output for ratings of 200 kw and more. Operating with mercury at higher temperatures, or with rubidium at 1800°F, would reduce the weight to about

7 pounds per kw. The higher temperature would also permit the use of a lighter radiator. The gyroscopic influence of the high-speed turbine rotor upon the attitude of the vehicle creates a special problem.

Solar energy, while low in specific density, is constant and inexhaustible. Photons may be converted directly to electricity or the thermal energy may be used to power heat engines. M. Telkes of Curtiss-Wright, who has devoted many years to the subject, reported on her work in collecting and concentrating solar energy. The development of new materials for windows and coatings has made it possible to obtain concentration ratios in excess of 10 000 with efficiencies approaching the theoretical limit of 60 to 70%. The development of power storage systems, to permit continuous operation for solar-powered vehicles when they pass through the shadow of the earth, is another field where much work remains to be done.

W. Cherry of the US Army Signal Research and Development Laboratory was quite optimistic about the future of solid-state solar converters. He feels that silicon cells with an efficiency of 15% will be mass produced in the near future. He also predicted the production of cells several square feet in area (as contrasted with the present 2 cm^2) by evaporating or spraying "*p*" and "*n*" films on an insulating substrate. These large cells will be electrically and mechanically coupled to form folded "rugs" which may be easily packaged in the nose cone and expanded after orbit is achieved.

Secondary batteries supply control power for many of the major missiles. In these applications instant readiness and complete reliability are vital. In earlier systems, using alkaline nickel-cadmium batteries, it was not possible to determine the state of charge since the specific gravity of the electrolyte does not change as it does in lead-acid batteries. The voltage regulation is so good that the loaded voltmeter test is useless. A. W. Speyers, Vitro Laboratories, described an alkaline battery tester in which a very sensitive detection system measures and compares the incremental voltage changes during a very short, well-controlled charge-discharge cycle. The device will also detect weak cells. Later missiles employ automatically activated zinc-silver oxide batteries which are designed to undergo years of storage in the unactivated state without maintenance and without loss of capability. Since this type of battery cannot be tested, reliability can only be based upon a high degree of engineering confidence. N. Wilburn, US Army Signal Research and Development Laboratory, gave the final report on an extensive test program to prove that production batteries will have the required reliability. Some 500 batteries were selected and stored under a variety of severe ambient conditions over periods up to two years prior to activation and discharge through a standard load. In each case the battery met maximum requirements.



Fuel cell batteries provided subject matter for an entire session. Papers by A. Hunger of the US Army Signal Research and Development Laboratory, M. Feldman and L. Niedrach of General Electric, G. Evans of National Carbon, M. Eisenberg of Lockheed Aircraft, and R. Werner of the Mine Safety Appliance Research Corp., demonstrated the scope and magnitude of activity in this field and the promising future for this new electrochemical system. The regenerative system, wherein the end product H_2O is dissociated by photolysis, electrolysis, or pyrolysis, separated, and reintroduced to complete the cycle, is most attractive for future long-term space power applications.

The "once-through" hydrogen-oxygen system has great promise for short-term high-output applications where the allowable fuel tankage will determine the battery's life.

Mr. Hovendon of the Signal Research and Development Laboratory reported that the Leclanche cell is still the primary source of power for the Army's tactical electronic equipment. Although this system has been in world-wide use for nearly 100 years, its unit capacity has been doubled in the last ten years largely through Signal Corps supported research. What was once nearly as perishable as fresh eggs can now be stored for several years. In his reporting, he predicted that improvement in cells now in development may make these achievements look modest by comparison. Progress is also being made in another area which is troublesome to all electrochemical systems—low-temperature operation.

While only some of the highlights of the conference have been presented here it is easy to see how broad the field has become and yet how closely related the problems are. The audience was composed of specialists in practically every phase of physics, chemistry, and engineering. Your scribe feels sure that each one of them was challenged by one or more of the problem areas developed during the presentations and went home impressed with the magnitude of the program and with the optimistic outlook expressed by each speaker.

A. F. Daniel and D. Linden were chairman and co-chairman, respectively. One big criticism these hard-working gentlemen had to face up with was that since Signal Corps research years ago led to the establishment of the US Weather Bureau, why couldn't better weather have been arranged so the delegates could have had the opportunity to conduct scientific observations regarding the effects of solar radiation on the attractive promenaders of the Atlantic City beachfront.