H_2O→TC3 = Hydrogen Fuel

by Jim McFarland

PHOTOGRAPHY BY THE AUTHOR

Ever since man began valuing some substances more than others, there has been continuous effort—scientific and not-so-scientific—expended toward the transmutation of the stuff nobody wants into the stuff everybody wants. In the Middle Ages it was lead into gold. With the dawn of the era of the automobile, it was water into gasoline. More recently it has been VW Beetles into Bugattis, Grand Prix Mercedes, and Bentleys. However, at least one of these dreams seems on the verge of becoming reality—the conversion of water into hydrogen fuel. It's not gasoline, but it is a viable source of highway horsepower and it can be generated from an onboard system. Jim McFarland, former publisher and editor of HOT ROD, *now with Edelbrock Equipment Company, has been following this project almost since its inception. His report follows.—Ed.*

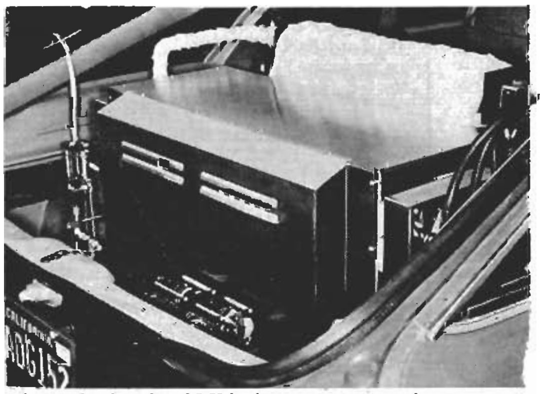
It has been proposed that hydrogen is the basic building block of all chemistry, and that if science could devise a means whereby hydrogen could be produced from water by practical means, society's reliance on petrochemical fuels would be substantially reduced— perhaps, in fact, eliminated. But there have been problems in the development of such processes. The processes most commonly discussed, coal gasification and electrolysis of water, have required more energy to produce the hydrogen than the energy available from the hydrogen produced, a case of more input than output resulting in a lack of cost effectiveness in hydrogen production. If it were possible to devise a "machine" whose output energy was greater than its input energy, a so-called "exothermic" process would result. The problem here was in the basic laws of thermodynamics, but that was before the development of the SLX process.

For years, this process has been under development by Omnia Research Corporation, a California-based organization. Through the intense efforts of this group, it appears a breakthrough of major proportions has been accomplished. So, with a view toward how this process could impact everyday modes of transportation, let's examine how ordinary water could be used as feedstock for the production of hydrogen fuel for internal combustion engines.

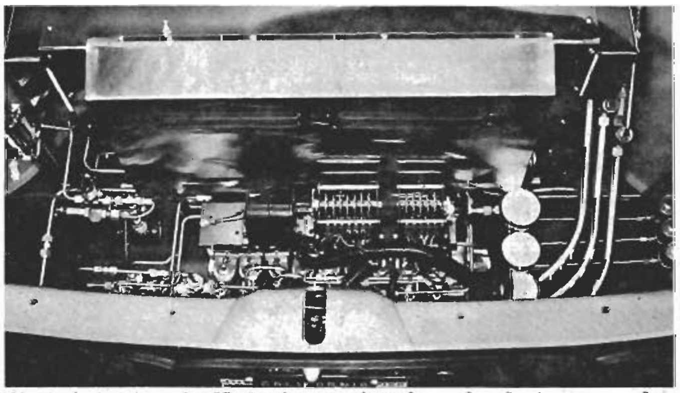
Water is composed of hydrogen and oxygen—there are two hydrogen atoms for every oxygen atom in each molecule, resulting in the common symbol H2O. The bonding of the atoms is based on a form of magnetic attraction. Given conditions that might alter this magnetic attraction, it is possible to separate the two. Keep in mind that there is nothing of radioactive interaction here. If an oxygen atom (while it is attracted to a hydrogen atom) is placed in an environment more favorable to attraction of another element or substance, the hydrogen atom is left free to find another "home." Simply stated, it's like magnets that are made to repel, not attract, each other, and seek other sources of attraction.

It has been suggested that hydrogen and oxygen atoms could be disassociated by the right process. If water were to be conditioned in terms of temperature and pres-

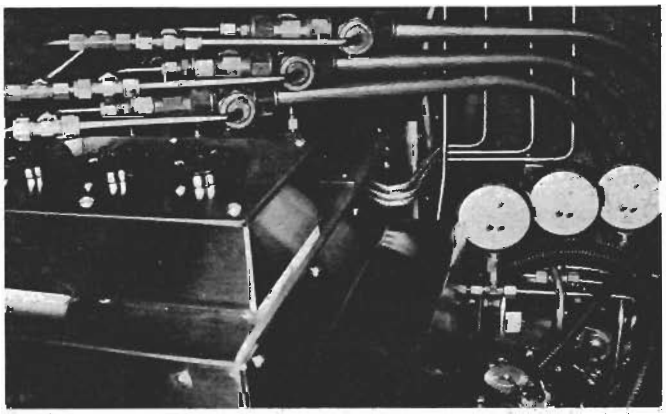
Omnia Research Corporation selected a front-drive Plymouth Horizon TC3 coupe as the mule for its SLX process prove-out. It's shown here on the Omnia chassis dynamometer rollers with the 3-chamber hydrogen generator taking up most of the back seat cargo area. Production unit could be smaller.



The triple-chamber SLX hydrogen generator plus all of the necessary valves and tubing isn't that much larger than the engine at the front of the car. The Horizon and its SLX processor were built strictly as a demonstration exercise to show feasibility of the idea.



Vertical view into the Horizon's cargo bay shows the phasing system for each of the three chambers in the SLX processor. Phasing is controlled by a series of mechanical cams on a rotating shaft. Cams control the 6-sec production cycles in each of the three chambers.



Each of the three chambers is fitted with a pressure/vacuum gauge that indicates by its reading which phase each chamber is running in during operation of the SLX generator. Readings change on gauge faces every 6 secs.

All it takes to get hydrogen fuel from water is a lot of hard work and defiance of the laws of thermodynamics

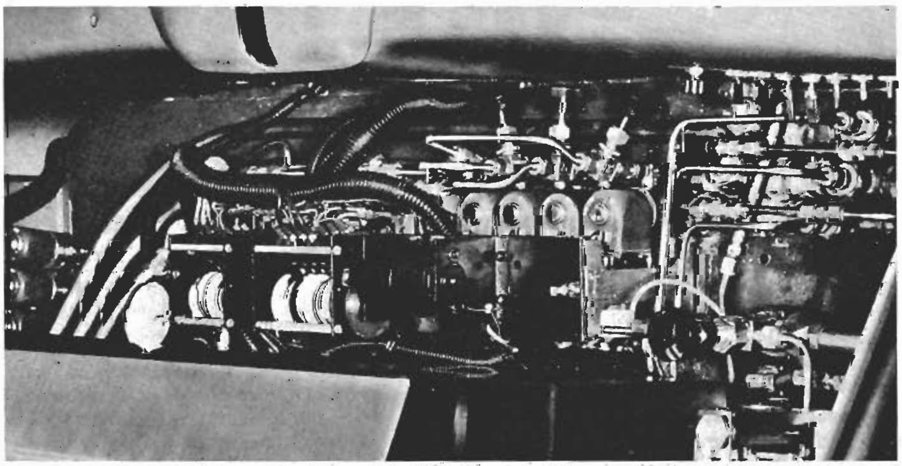
sure, and subjected to a particular chemical substance (a reactant), "contained" oxygen atoms and "released" hydrogen atoms might result. In fact, this is the basis of the new SLX process.

In an enclosed vessel, water is heated to a temperature of about 300° F. It is next introduced into a reactant chamber containing material that will interact with water. Under specific conditions of temperature and pressure, the reactant captures oxygen atoms and holds them while releasing atoms of hydrogen. The process could be called an exothermic oxidizing reaction: It causes reaction heat to be generated, since heat is the prime ingredient. Once free from the oxygen atoms, the hydrogen atoms are reunited by a photochemical process that releases reaction heat and results in hydrogen molecules. What we have are two reactions taking place simultaneously and interdependently within the same reaction chamber. These reactions both liberate and recombine hydrogen atoms to form H2. The potential enormity of such a discovery is staggering.

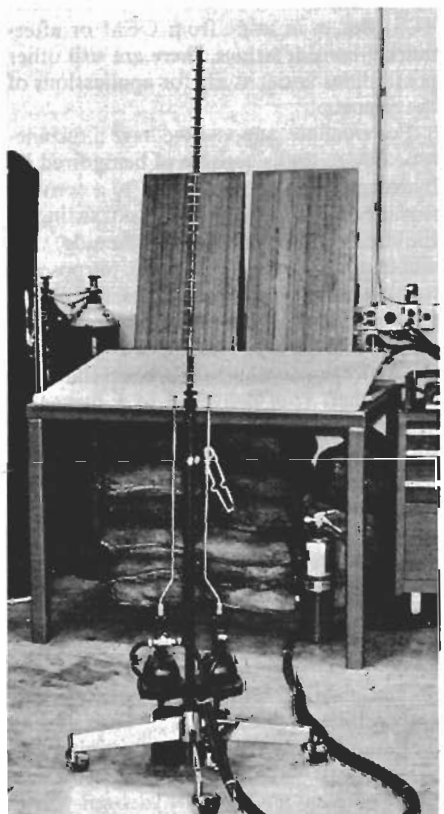
But let's focus now on the use of hydrogen as fuel for our daily transportation (although it is really only one minor aspect of its importance). In an internal combustion engine like the 1.7-liter engine installed in Omnia Research's Plymouth Horizon TC3 laboratory mule, hydrogen burns much more quickly and at higher temperatures than gasoline. An engine intended to run on hydrogen requires changes to combustion chamber design, ignition, timing, combustion surface texture, method of fuel delivery, spark plugs, and combustion-exposed materials (pistons, rings, and valve heads, for example). Spark plug characteristics relative to cold-start versus warm-engine driveability also must be changed. Sudden burning of fuel and resulting cylinder pressure rises can lead to damaged pistons, rings, walls, gaskets, and bearings. Uncontrolled, these conditions could be compared to the detonation of gasoline in ordinary engines.

But despite the differences in the rate of combustion between gasoline and hydrogen, there are specific benefits to be derived. Perhaps the most significant is that combustion of hydrogen largely produces water. Consequently, concerns for environmental pollution caused by petrochemicals are completely eliminated. Oxides of nitrogen, carbon monoxide, and unburned hydrocarbons are *not* major byproducts of hydrogen combustion. Open exhaust pipe tests performed in enclosed laboratories with the TC3 produce no traceable odors and show only water condensation at the tailpipe. In addition, there is substantial reduction in the amount of combustion residue formed in the combustion chambers of a hydrogen engine. So-called "heavy ends" of petrochemicals tend to produce residue in the exhaust systems of conventional engines. In fact, hydrogen acts as a "scrubber" and can reduce the amount of pollutants in industrial smokestacks. While this is more applicable to industrial use of hydrogen along with petrochemical fuels, we mention it here to show yet another benefit it could provide to conventional gasoline-fueled engines.

As a retrofit system, there are possibilities under study. However, from a practical standpoint, other engine modifications such as those previously mentioned would



The network of cams, lines, and valves outside the main assembly controls the routing of water, hydrogen, and surplus radicals that are released during the second, or purge, cycle of the complete process.



When the SLX system is in operation, this pilot-lit burner flares hydrogen during the purge cycle in a 16-in. flame as proof positive that the system produces fresh hydrogen from water every few seconds.

increase the amount of investment in a present-day production vehicle. Fuel savings would be substantial, and the payback period would be considerably shortened as compared to conventional fuel-saving retrofit devices.

Detroit, on the other hand, would be in a better position to react to such a change in basic vehicle fuel. Internal metallurgical changes could be made to an engine's interior without sweeping design alterations. The use of contemporary onboard fuel management systems could allow much greater precision in ignition timing and fuel-flow control. Costs of exhaust emission control equipment (catalytic converters, oxygen sensors, manifold absolute pressure sensors, feedback carburetors, and similar devices) would be eliminated, thereby lowering overall vehicle cost.

Omnia Research Corporation has already had authenticating energy balance tests performed by outside independent engineering consultants. These tests not only proved the validity of the SLX process as an exothermic (heat-*producing*) machine, but also verified that the present lab model could be up- or down-sized for a variety of uses (including that of onboard fuel production for highway vehicles). This you will note in the accompanying photographs of the Omnia hydrogen-fueled Horizon TC3. But even aside from OEM or aftermarket considerations, there are still other possibilities under study for applications of the process.

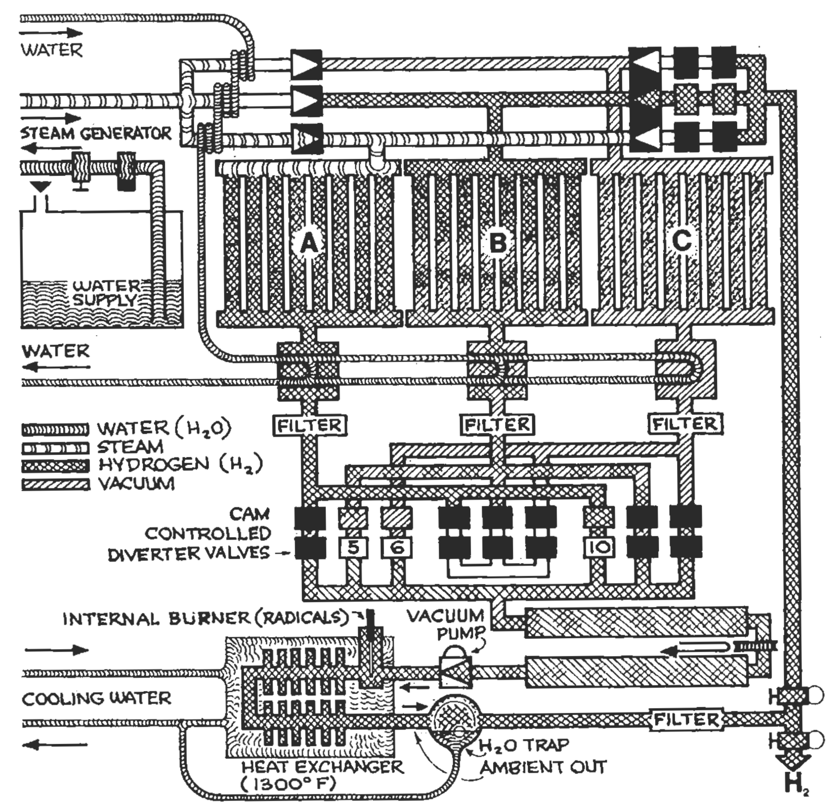
For example, suppose we have a turbine-type device that's capable of being fired by hydrogen. This could amount to a conventional turbosupercharger unit consisting of the combustion chamber (turbine side) that would burn hydrogen for the purpose of turning a shaft connected to a set of planetary gears driving an alternator (compressor side). What we would have at this point is a hydrogen combustion process that generates shaft rpm delivered to a means of producing electrical power. Directed to a system of storage batteries, such a mechanism could provide continuing electrical recharge, in effect creating an infinite-range electric car that uses water as the source of fuel. Omnia's Horizon is already in operation utilizing hydrogen as a fuel. The fact that it will start and run on hydrogen (acting against a road-load chassis dynamometer) is clear indication that a hydrogen-powered internal combustion engine vehicle is possible. The basis for its fuel supply is a device incorporating the SLX process.

Economical analysis of hydrogen versus gasoline in an internal combustion engine has already proven the cost-effective potential of H2 over gasoline. But, as readers of *Motor Trend* know, there are some aspects to be considered in the overall scheme of alternative fuels. Perhaps the most critical is hydrogen availability, which brings us back to the fundamentals of the SLX process. Incredibly, it offers the availability of an exothermic process where hydrogen is produced from deionized water. Since there is heat produced during the combined thermochemical and photochemical processes, liberation of heat in excess of that required to start and continue hydrogen production allows system efficiency in excess of 100%. Data gathered by a Chicago-based consulting firm showed a range of system efficiency from a low of 143% to a high of more than 200%. It is this feature of the SLX process which has caused considerable stir within the scientific and academic communities.

The significance of this feature as applied to a vehicle is mind-boggling. For with this capability, it is possible to use a portion of the produced hydrogen to raise incoming water temperature to the level required prior to reaction chamber entry. Such excess would reduce the amount of hydrogen required for primary fuel consumption by the vehicle, and would further extend its driving range.

The possibilities of hydrogen as fuel have long been known, and if the demonstrated capability of the SLX process becomes of widespread use to the automotive industry, automotive fuel availability and concerns for environmental impact by combustion engines may soon change radically. Further, when you consider that the ability to separate hydrogen and oxygen atoms allows for the synthesis of other fuels such as ethanol and methanol, we may be dealing with a process for which we do not have a current definition. For by the rearrangement by photochemical means of surplus hydrogen and oxygen atoms left over from the initial disassociation process, many types of other O-H molecules (such as hydrogen peroxide) can be constructed. While continuing experiments are dealing with such secondary recovery techniques, the initial impact of the SLX process is yet to be felt. But it will be soon, for it offers the opportunity for science to work with a brand-new chemical "erector set" to build what is needed to keep society moving. MT

The SLX Process



Schematic diagram of the three reactant chambers and the system routing of water, hydrogen, and free radicals resulting from the purge cycle. The three cycles consist of introduction of heated water and production of hydrogen, purge cycle to exhaust free oxygen and surplus hydrogen, and a vacuum cycle that prepares the reactant chamber for the next charge of heated water. A system of filters and heat exchangers is used to process and condition the hydrogen produced.

ENERGY ALTERNATIVES

Congratulations on your editorial, "Energy Alternatives—Research and Development" (November 1979 issue) in regard to a need for a much greater funding commitment toward the development of photovoltaic solar cell technology. Indeed, the good news is that major breakthroughs are being made in solar cell technology. The bad news is that even solar cells may have a waste-disposal problem. According to one D.O.E. (*D*epartment *O*f *E*nergy) official, "the compounds used in 'doping' photovoltaic cells, such as cadmium, arsenic, gallium, and indium may pose health risks if not handled properly."

As a suggestion, we should renew our national commitment to further space exploration, and "space industrialization" in particular, to help solve down-to-earth energy problems. There are several reasons for that:

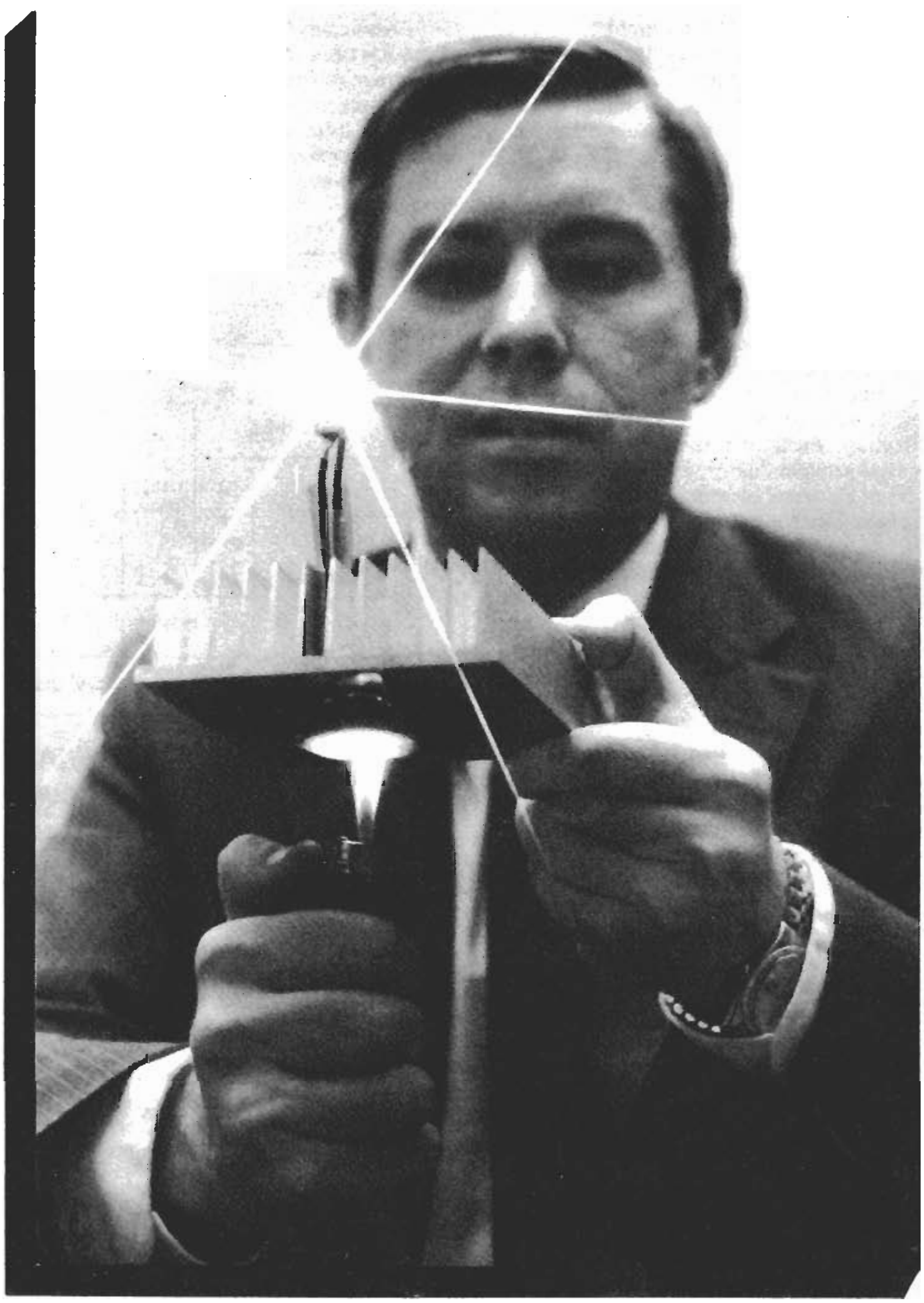
1. Outer-space offers a large supply of clean energy with the "solar power satellite" alternative.
2. Outer-space offers a low-gravity environment for new and unique industrial processes.
3. Space engineering may continue to pay off high dividends in terms of appropriate "spinoff" products—such as *consumer items* that help home owners directly reduce their energy bills (as with the NASA "power-chopper" device).
4. The vastness of outer-space would provide a safe place for the disposal of industrial wastes.
5. Most important: Space exploration offers Americans the hope of a new frontier, essential to human growth and economic development.

With a strong commitment toward space industrialization, we may someday see photovoltaic solar cells being produced very inexpensively for use on earth and in outer-space.

PAUL JUSTUS,
Mission, KS

OTEG Devices

Generating electricity from a heat source? Not exactly a new idea, unless you're doing it by heating a semiconductor with a flick of your lighter. Kevin Ransom gives us some insight into the development of solid-state thermoelectric devices.



SUPPOSE — just suppose — you had an inexpensive machine able to convert heat to electricity, all without moving parts. Imagine the applications...

Thermoelectrics, the conversion of heat into electricity without moving parts, was discovered more than 100 years ago. But for many years, it didn't enjoy large-scale commercial application. During the 1950's and 60's, even though there was a resurgence of interest in using thermoelectric energy conversion, lower-cost energy sources were still plentiful, limiting the use of thermoelectrics to space satellites and special applications.

But times have changed. Now, in an energy-conscious world, thermoelectrics has emerged as a viable method of converting heat — sometimes waste heat, into useable electrical power.

Recently, Ovonic ThermoElectric Co., of Troy, Michigan, began production and marketing of Ovonic ThermoElectric Generators (OTEG's), a patented product the company feels puts it one up on other such thermoelectric devices introduced thus far. The reason: the OTEG's use semiconductors made from an 'Ovonic'' material, a material that has been chemically modified and given properites that the company claims make it more versatile, and therefore superior, to the materials traditionally used as electric semi-conductors. In the case of the OTEG, that special property is its highly efficient conversion of up to 250°C of applied heat into electricity. The company claims other thermoelectric devices operate at much lower efficiency when working at such high temperatures.

Ovonic ThermoElectric is a union of Energy Conversion Device, Inc. (ECD) and American National Resources Company (ANR), an oil and gas exploration, extraction and transportation firm that recently branched out into the arena of new energy technology. The two companies became partners in 1981, but ECD has been in the energy conversion business since 1961, when scientist and inventor Stanford Ovshinsky founded the company in Detroit. Ovshinsky's premise was that certain materials could be modified in a way that altered their molecular structure. He believed that introducing molecular disorder to a meterial, made it more versatile than a material whose naturally-occurring molecular structure was more orderly.

Ovshinsky discovered that these chemically-modified substances could be used in the commercial development of inexpensive semi-conductor devices, solar cells and storage batteries.

In 1977, ECD consultant Sir Neville Mott, lent credibility to Ovshinsky's theories by winning the Nobel Prize in physics for his own studies of semiconductors made from modified, disordered substances.

The OTEG is Ovonic ThermoElectric's principal product. It is a patented solid-state device that is typically one to two inches square and contains 50 to 100 tiny (about 50/1000 of an inch) elements — made from an Ovonic substance — arranged in a grid and covered on both sides by aluminum oxide. The aluminum oxide acts as both an electrical insulator and a conductor of heat.

How OTEG's Work

The OTEG's make use of a physical phenomenon called the Seebeck effect, in which heat applied to one side of a semiconductor creates a temperature differential that causes free electrons to run toward the colder region.

Inside of an OTEG, the Ovonic semiconductors are arranged in pairs. (See drawing). Each pair is comprised of an N-type semiconductor, in which the carriers of electrical current are the negatively charged electrons; and a P-type semiconductor, in which the charge carriers are positive. The pairs are connected by conductive copper straps.

For the OTEG to convert heat to electricity, sufficient heat is applied to one side of the OTEG to create a temperature differential of about 200 degrees (Celsius) — the optimum range between the heated side and the non-heated side. The charge carriers (positive in the P-type, negative in the N-type) at the hot side of the elements become more energetic than those at the cold end. These more energetic carriers then move toward the cold end. The cold end of the P-type element is now loaded with positive carriers, making it positively charged. Meanwhile, the cold end of the N-type is now dominated by the negative-charged electrons; hence, it is negatively-charged.

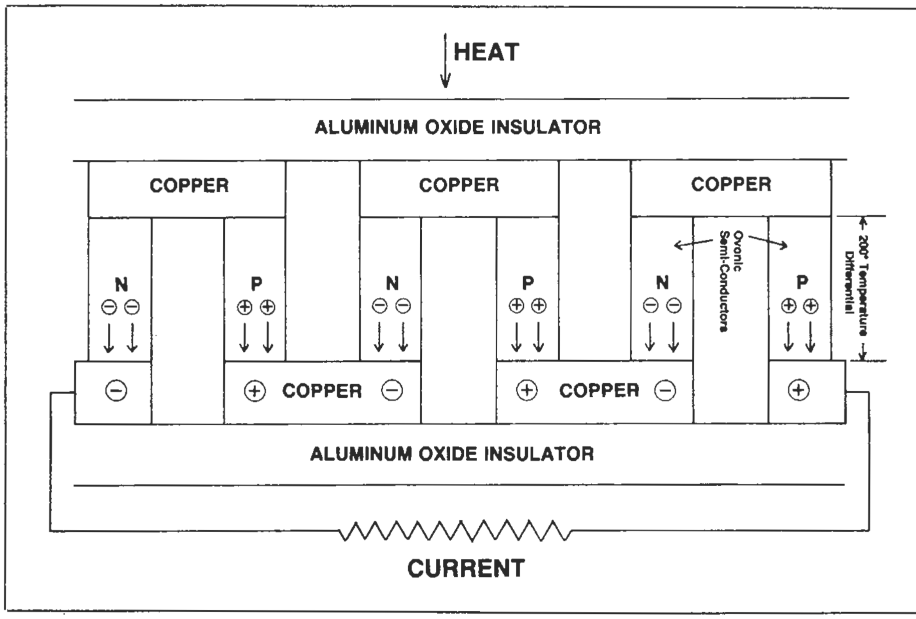
The two elements are also electrically connected at the charged cold ends — allowing electric current to flow between them, making electrical energy available for useful work.

With the 200-degree temperature differential, each pair of elements will produce roughly .08 volts. Higher voltage is attained by using 25 to 50 pairs of elements, connected in series.

OTEG Applications

Ovonic ThermoElectric is currently producing remote power generators which use several OTEG's to provide power in areas not serviced by electric companies. There are four different verisons, ranging in power output from 6 V, 100 milliamps to 24 V, 10 amps, depending on how much power is needed. They can be used as an electrical power source for oil and gas flow measurement devices, weather monitoring stations, navigational lights and radio repeaters. Additionally, a remote power generator can be used to put a positive charge into a gas or oil pipeline to protect it from corrosion caused by electrical ground current.

Ovonic has found that the biggest demand has been from companies that manufacture electronic measurement devices used to record and control oil and gas flow at wellsite and at pipeline locations, where ownership of the gas changes from a pipeline company to a gas distribution company.



An illustration of the Ovonic ThermoElectric Generator showing the N–P pairs.

Traditionally, such information has been recorded mechanically by a device called a chart recorder which records hydrocarbon flow with a jagged line on a circular paper graph. Data from these recorders, often subject to varying interpretations, have led to controversies between gas producers and gas buyers. The use of such devices also requires that technicians travel to the site, often remote, to retrieve the graph and install a new one — time-consuming and expensive, particularly if the locale is an offshore platform.

Well owners are finding that the electronic recording of such information is quicker and far more accurate. One manufacturer of electornic gas measurement devices — Nu-Tech Industries, of Oklahoma City — cites an outside test in which its measurement device recorded gas flow with a one-tenth of one per cent margin of error. Chart recorders, on the other hand, made errors of 100 per cent and higher in the same test. Nu-Tech presently has 25 of its "Nu-Flo" devices in operation in Texas and Oklahoma, with plans to expand into Louisiana.

The use of such computerized devices at remote locations requires an independent energy source. That's where the OTEG comes in. Several OTEG's are lined up on both sides of a burner face that uses a platinum catalyst to burn a small amount of gas drawn from the well. The OTEG converts that heat into electricity, which in turn powers the computer that electronically records and transmits (via Nu-Tech's radio network) the gas flow information to a central radio receiver station.

When used as a power source for navigational lights, radio repeaters or weather monitoring stations, the remote generators rely on cylinders full of propane or compressed natrual gas for primary energy. The canisters are replaced about once a month.

Future OTEG Applications

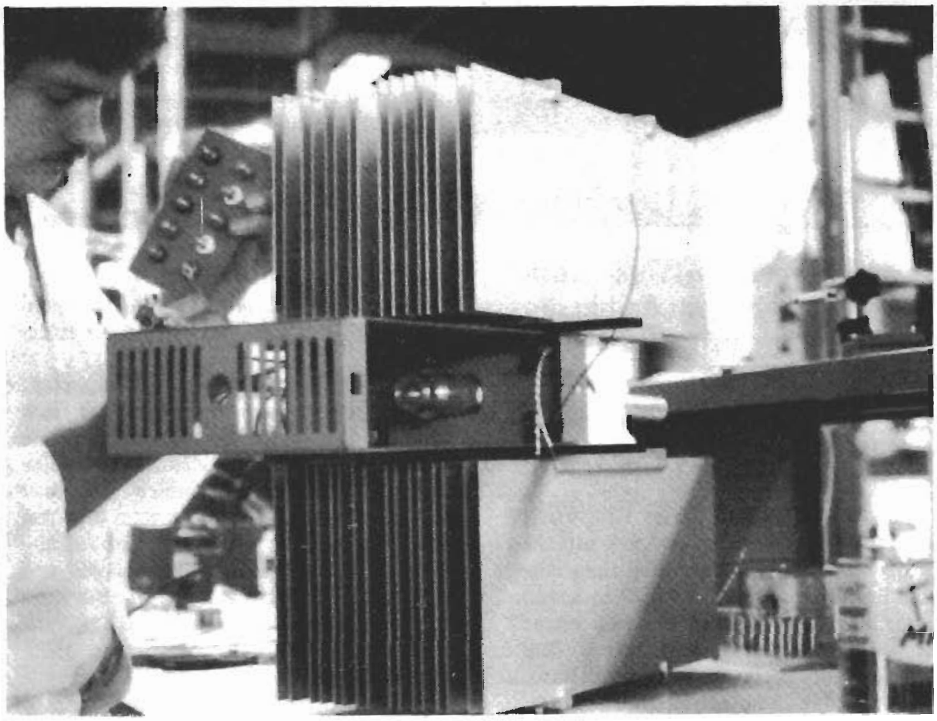
In addition, the OTEG's can convert heat from a wood stove into enough electricity to power a blower, radio, reading lamp or small water pump.

Although it is only in the prototype phase, Ovonic ThermoElectric has also developed a unit that employs a number of OTEGs to convert heat from a truck's exhaust into electrical current that would power the vehicle's electrical system, thereby elinating the need for an alternator. The company predicts a practical application of such a device within three or four years.

The technology that has produced these two devices is on that Stan Ovshinsky likes to compare with DuPont's successes with plastics in the 1950's.

"DuPont was making incredible strides back then," recalls Ovshinsky, "You could walk up to one of their chemists with a list of desired properties — such as colour, flexibility, scratch resistence, etc. — and he'd come back to you with a material that met all your specifications. They were joining molecules together in ways that didn't exist in nature.

"That's what we're doing here, except we're working with alloys of inorganic materials instead of organic materials. We can create a new noncrystalline substance, alter its composition with certain additives and dopants, and give it electronic properties suitable for a variety of applications. We think this is an important step in the electronics industry." **ET**



Ovonic technician, Ken Richardson, checks the power ouput of the Ovonic remote power generator, which uses several OTEGs in its conversion of heat to electricity at remote locations.

ETI NEXT MONTH

Another Look at Test Equipment

We follow up this summer's look at test equipment with another: a continuing compendium of what's out there and how to get the best from it.

Signal Generator Project

A useful signal generator for the testbench; based on the XR2206 function chip, it provides sine, triangle, and square waves.

ZX81 Tape Controller Project

Switch the cassette deck on and off via software; a relay prevents interaction between input and output lines.

A NEW FORCE?

A very important concept was brought out in the June 1976 article about Golka and "12-Million Volts." The idea of "re-creating the past to solve future needs" caught my attention.

Over 150 years ago, Oersted discovered a tiny force that causes a permanent magnet to turn at right angles to a current-carrying conductor. He didn't know it but he could have substituted an iron wire for the compass needle although he would not have been able to determine North from South. In all this time we have not been able to produce a permanent magnet that has a magnetic field similar to the one around a current-carrying conductor.

Anytime we find a new force, no matter how tiny, big things begin to happen. Modify Oersted's experiment. Obtain a straight iron-wire 12-inches long that has the same diameter as a current-carrying conductor and suspend it $^1/_{16}$-inch below and in parallel with the current-carrying conductor with three loops of thread. No matter which way the current flows in the current-carrying conductor, the iron wire is always lifted. How can we describe and use this new force?

We know if current flows in the same direction in two parallel conductors, they attract each other. Reverse the current in one conductor and they repel each other. There is no current in the iron wire yet it is always attracted. Why?

JOHN W. ECKLIN
Alexandria, VA