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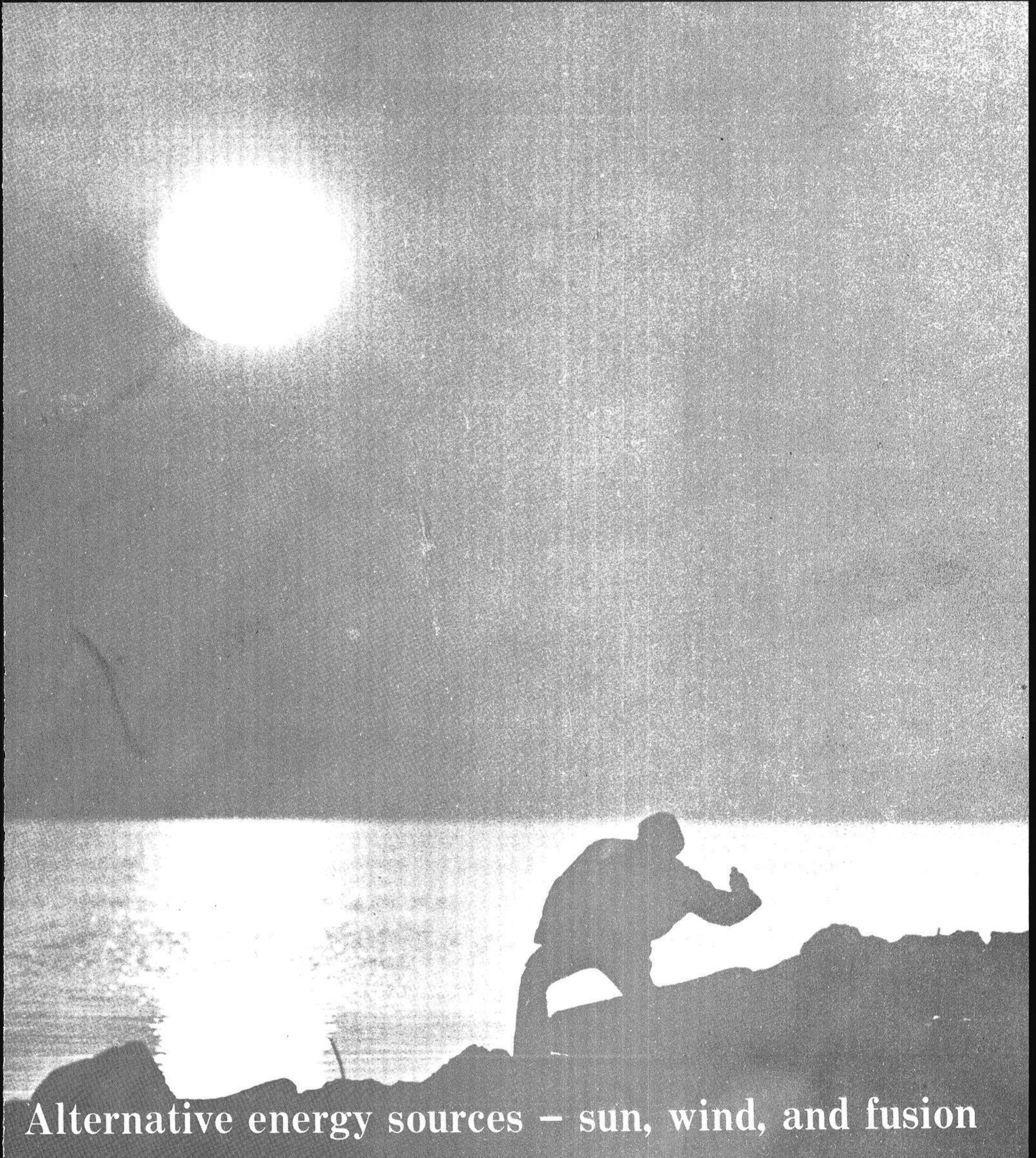

Alternative energy sources – sun, wind, and fusion

> *"Modern man worships at the temple of science, but science only tells him what is possible . . . not what is right."*
> Milton S. Eisenhower

wisconsin engineer

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Wind Generates Power

Man harnessed the wind to power his earliest ships at sea, and now hopes are raised that it will also provide modern power needs.

by Jeff Kratz
of the Engineer Staff

What makes a kite fly, powers a sailboat, plays a vital part in determining football strategy? What takes the sweat out of a hot summer day and freezes you to the bone six months later? What is the force that makes the windows pop out of the John Hancock building in Boston?

And what has the potential of supplying all the installed electrical capacity the United States will need in the year 2000 A.D., even if only one one-hundredth of one per cent of it can be harnessed to generate electricity?

No, not Superman. But like the comic book hero, the wind is a powerful force and has the capability of being a powerful friend to mankind.

Today, with our dependence upon fossil fuels and atomic reactors, it may seem strange to suggest that man's oldest source of power may again come back into prominence. But the potential is there, and unlike oil or coal, there is very little chance of ever suffering a wind shortage.

It has been estimated that the winds of the northern hemisphere contain about 10^{14} kilowatts of potential electrical power. A large part of this is included in the prevailing westerlies that move constantly across the United States.

It is now believed that this country will need 10^{9} kilowatts of installed electrical power by the turn of the century. Simple arithmetic suggests that if even a tiny part of one per cent of this potential can be captured, it will be able to supply all the country's requirements 26 years from now, when the demand will be many times what it is today.

Electrical engineers from all over the United States have been experimenting with plans to tap this source of power that blows past us every day.

"The individual components for creating a wind generator are already on hand," said Daniel Reitan, a professor in Electrical Engineering at the University of Wisconsin-Madison. "We can build the generators with today's technology. The only question is when are we going to start."

Prof. Reitan has been involved with the development of plans to design and construct small wind alternators for use in rural areas. He says a small 20 kilowatt generator would be sufficient for most users.

"The average family needs only about 700 kilowatt hours per month," he said. "A wind alternator and storage unit would easily be able to supply this."

Reitan has devised a formula to determine the kilowatt potential of placing the same alternator in different positions to take advantage of stronger average winds. His formula is $P_{kw} = Kv$, where P equals the potential kilowatts, K equals a constant, and v equals the velocity of the wind.

This equation suggests that at low wind velocities, the difference of even a few miles per hour can mean a very great difference in kilowatts generated. An example supplied by Reitan shows that the potential kilowatts with a ten m.p.h. wind equals 1000K, while with a 12 m.p.h. wind, the figure jumps to 1728K, a 73 per cent increase.

"The siting of the wind alternator is very important," said Reitan. "It must be placed in a location where it will be exposed to the highest velocity average winds."

Reitan says that the small wind generator he has been working on would be equipped with a storage unit that could hold five days of electricity. He contends that there is little or no chance of not having any wind for five days in a row.

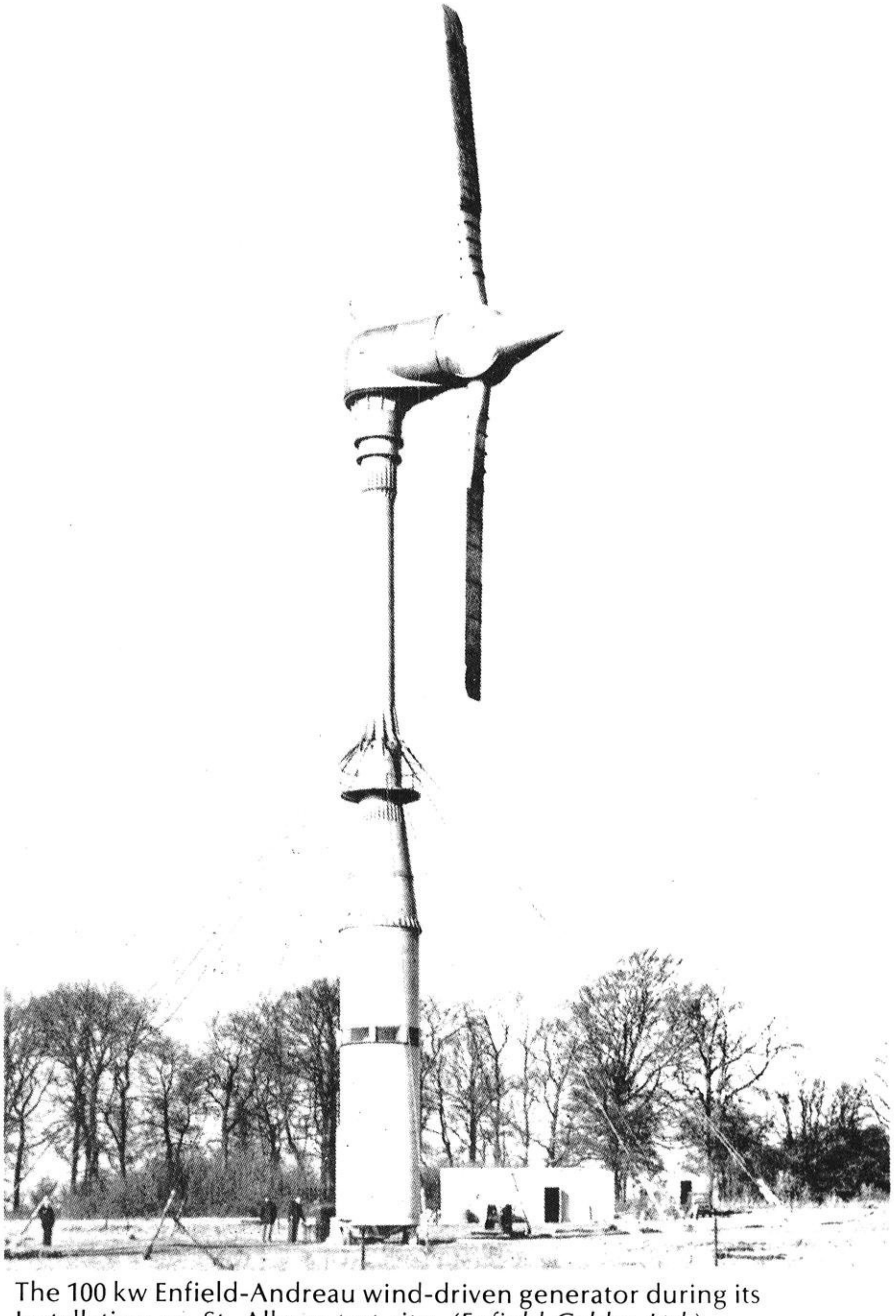
Unlike conventional windmills, a wind alternator would be turned by even the smallest breeze. Reitan explains this is because the windmill is used directly for mechanical energy, and needs a great deal of power to overcome inertia and begin pumping.

"Wind alternators are electrical, not mechanical," Reitan stressed. "They would not need nearly the same amount of force to turn as would a windmill which converts to mechanical energy."

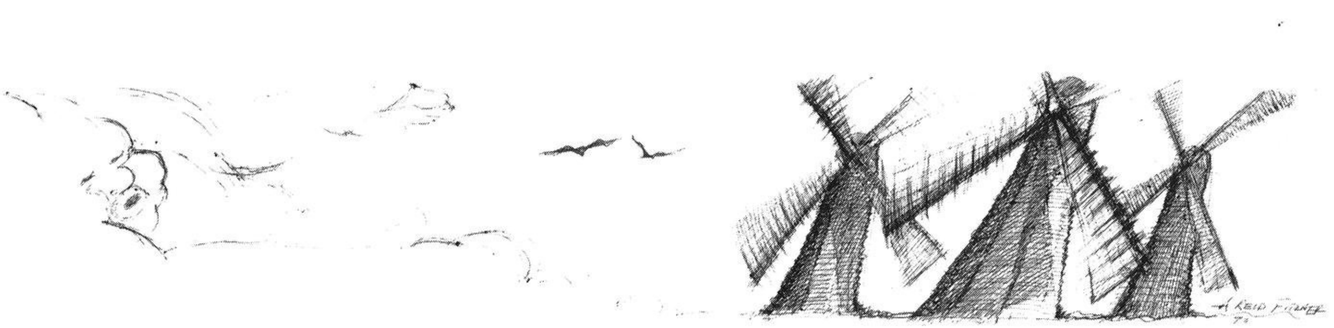
Reitan's plans call for the conversion of the wind power into alternating current, then to direct current by means of a bridge rectifier. Reitan contends that most of the electrical appliances used in the home would then be powered by DC.

"Most things around the average home run better on DC," he explained. "Alternating current would only be needed for items with induction motors, like television sets and refrigerators."

Reitan forsees the day when power companies could be hooked up with these small rural generators. He says that most of the time the power company could siphon off what the homeowner does not need to help its own energy requirements, while the home owner could call on power from the company when he needed



The 100 kw Enfield-Andreau wind-driven generator during its Installation on St. Albans test site. *(Enfield Cables Ltd.)*



it. A meter would keep track of the net flow both ways for billing purposes.

Wind energy has many advantages over the energy produced by fossil fuels. It is non-polluting, as changing wind power into electricity creates no particulates, gases, or radio-activity. It particularly does not waste heat, a complaint long associated with nuclear reactors.

Tapping the power of the wind requires no drilling, mining, refining, long transportation, importing or regulating. There are no explosive dangers, and the whole system is generally free of many of the ecological and sociological objections that many other energy sources often attract.

However, while the wind, like water, is everywhere, it is not a free source of energy. Reitan estimates that it would cost approximately $700 per kilowatt hour to totally install a 20 kw wind alternator, and the price of a storage unit would probably double this figure.

"At the present time it costs about 2.34 cents per kilowatt hour to get your electricity from Madison Gas and Electric," said Reitan. "The cost for a wind generator and storage unit would be about three times this."

Reitan predicts that the costs may become more competitive in the future, as fossil fuels become scarcer and as the wind power technology becomes improved and modified.

In an attempt to improve this technology, Reitan wants to construct some test generators to get a better understanding about what will and will not work when trying to convert wind into electricity. However, he paints a bleak picture when talking about getting funds for his experiments.

"The new federal energy program is still nearly a year away," he said. "The money is there, but it will take the bureaucracy about that long in order to sort everything out within itself."

Private contributions may be just as hard to obtain, for Reitan says "everybody wants to start at the top. The private funding agencies want you to construct a giant one megawatt generator, or something roughly equivalent. Nobody is willing to admit that you have to start small and work your way up to those big projects, learning as you go."

"Giant floating generators could be anchored off shore in the oceans to harness the unobstructed winds."

Power companies are also reluctant to invest money in wind power because it is not competitive cost-wise at the present time. These companies are for the most part owned by stockholders, explains Reitan, and therefore cannot spend money that will not immediately return a profit.

More and more people are becoming aware of the potential of wind power, and this has led to a recent rash of publicity. The Wisconsin State Assembly has even gotten into the act, holding hearings and discussing the possibilities of state funding in the area. Reitan welcomes the interest, but wants to start testing.

"I have my plans and I would like to get going now," he said. "I am only asking for about $30,000 or so. This is not much when compared to some amounts spent in the energy field."

While Reitan is concerned for the present time with small generators, he also realizes the tremendous potential wind power has if used on a wide scale. Banks of generators could be set up to serve metropolitan areas, and giant floating generators could be anchored off shore in the oceans or Great Lakes to take advantage of unobstructed winds that flow over these flat surfaces.

The generators themselves would look nothing like the multi-blade windmills that still dot the rural countryside. Consisting of fewer than six blades, these generators would resemble airplane propeller engines.

The blades themselves would be shaped so that they self-feather, that is, they adjust their shape to the wind and govern themselves so they keep under a certain number of rpms. The blades would be connected by wire struts to protect them from wavering, the whole system would be gust protected by a catch mechanism, and there would be a gale lockout device so that the blades would stop and turn sideways into the wind if the velocity was too great.

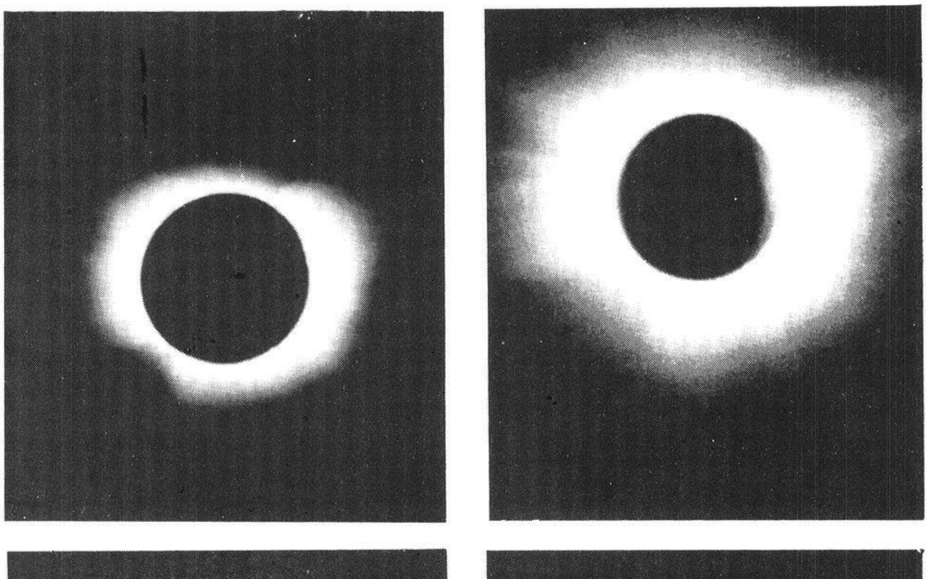
The base would be able to rotate so that the blades would always face the proper way, which on most wind generators would be the opposite way from an airplane propellor. The alternator would be upwind from the blade instead of "behind" it.

Wind power is a source of energy that can be tapped today. The technology is present, and Prof. Reitan and others are completing their plans. How long this country and the rest of the world continues to be dependent upon a slowly declining fossil fuel supply would be directly related to the progress that is made in using the sources of power that are all around us.

A Sunny Proposition
or
A Light Source of Energy

by Rick Giesler

of the Engineer Staff



SPOKANE, Wash., — VIEWS OF SOLAR ECLIPSE — These are four views of the solar corona which becomes visible after the moon passes in front of the sun in the eclipse, totally blotting out the sun's light. The lower right is the "diamond ring" effect seen just as the total eclipse ends and the light from the sun streams between mountains and valleys on the moon. (AP WIREPHOTO)

Increasing concern for environmental quality has brought attention to the use of solar energy as a replacement of conventional energy sources and as an additional energy source to meet new needs.

Sunlight strikes the earth and its atmosphere with about 32,000 times the total amount of all energy which is now used. The intensity of solar radiation averaged over the year on a surface outside the earth's atmosphere is 1.39 killowatts per meter squared. The sun radiates nearly as a black body at 5800-6000 degrees Kelvin.

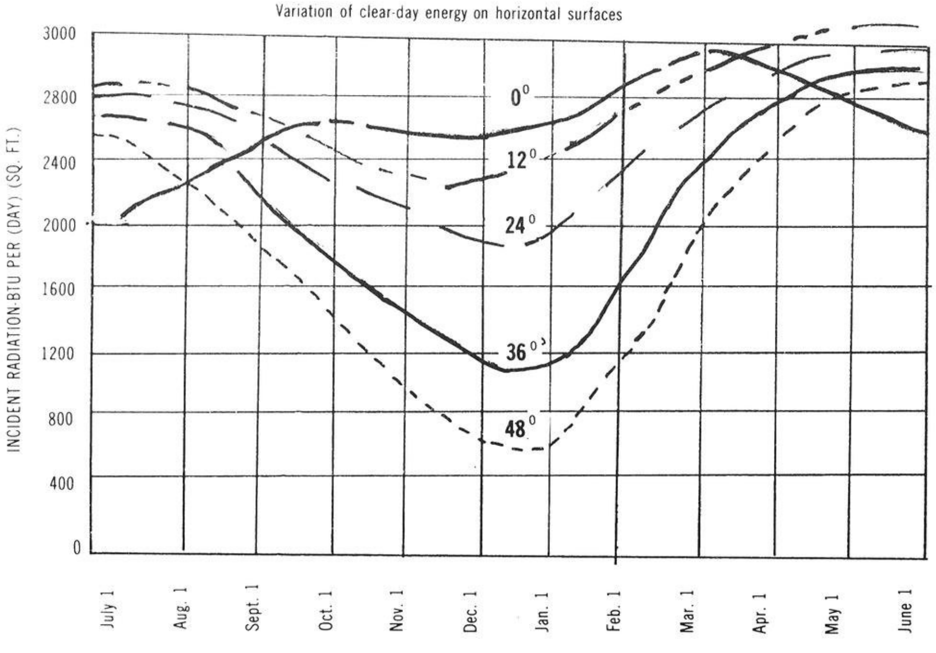
Energy available at the earth's surface depends on the weather. As solar radiation penetrates earth's atmosphere, it is absorbed or scattered by clouds, air molecules, water vapor, ozone, carbon dioxide and suspended particles. Both the direct and diffused solar radiation available at the surface of the earth are functions of these variables. Due primarily to the variability of cloudiness, the availability of solar radiation can only be described statistically on a long-term basis.

About one half of the sun light reaching the earth's surface is visible, and the other half is infrared. One or two per cent is ultraviolet. The orientation of the earth plays an important role in the amount of solar radiation received. Surfaces oriented on a diagonal plane may receive more than those surfaces that are horizontally oriented, depending on the position of the earth at that time. Figure 1 shows clear day radiation on a horizontal plane at various times of the year for various latitudes.

Technological Consideration

Solar radiation is most readily converted to heat, and has been considered for such application as space heating, air conditioning, power generation, evaporative processes and domestic water heating. These thermal energy uses loom in the United States energy economy. Comfort heating, for example, consumes about one fifth of the energy used in the U.S. In order to use the energy from the sun, it must first be collected in some fashion.

Two types of "collectors" used to intercept solar radiation and convert it to some useful form are



the flat plate collector and the focusing collector, shown in Figure 2.

The large flat plate receivers are made of sheet metal, usually iron, copper, or aluminum, to give good heat conduction. The surfaces are blackened with dull paint. The plate absorbing the radiation, rises in temperature and transfers the heat to a fluid, usually air or water, flowing on the back side of the collector. Flat plate collectors can utilize both beam and diffused radiation, do not need to be oriented towards the sun, and can deliver energy at temperatures ranging up to about 100 degrees centigrade.

With focusing collectors, it is easy to obtain much higher temperatures, but they usually cost more. Focusing collectors, which use some kind of optical system to raise the energy flux density to higher levels, may have the advantage of less expensive surfaces and lower thermal losses from the absorbing surface. However, orientation systems are required and material problems are many. No focusing collectors for practical energy delivery systems have yet been used.

Recent Developments

Most of the work that has been done to date on solar energy has concerned individual applications in contrast to "energy systems."

Water heating for domestic hot water supply has become a common use of solar energy. Solar water heaters have been able to compete with more conventional heaters, which may have good radiation, but expensive conventional energy costs. Domestic solar water heaters are small units with water storage tanks and auxiliary electric heaters attached to make hot water available during periods of no radiation. There are a variety of solar water heaters but all work on the same principal. The water is heated by solar collector then stored for future use. Boiling water usually requires a focusing collector.

Solar distillation for desalting of water has seen considerable development, and a number of small community scale installations are now in operation. Light rays are transmitted through the cover and heat the water in the basin which evaporates. The vapor subsequently condenses on the lower surface of the transparent cover, from where it flows by gravity to collection troughs and stored, all desalted. Operations of these stills has been studied in some detail. Community scale units have been constructed in southern Spain, Australia, islands in the Aegean, and a new still is being developed for the Makran coast of Pakistan.

Consideration of the economics of solar distillation indicate that in good climates it's the least expensive method of desalting up to 50,000 gallons daily. In larger capacities, fuel-fired desalting processes appear now to be more economical. The cost of solar distilled water appears to be in the range of $2 to $3 per thousand gallons, about 59 to 75 cents per cubic meter.

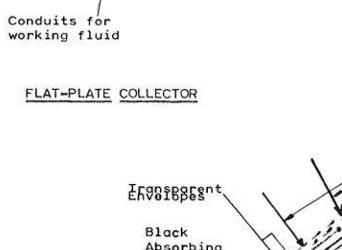
Comfort heating of houses is an application with possible significance to the United States energy economy, as a significant fraction of U.S. fuel requirements are for comfort heating. In the past fifteen years, there have been several experimental houses built and operated in the United States. Several of these are still in operation.

The temperature required for heating houses is low, so it is unnecessary to use expensive focusing and movable solar collectors. All solar space heating is done with flat plate collectors mounted horizontally on a flat roof, tilted toward the equator on a roof placed vertically along the side of a building facing the equator. The heat received from the sun is transferred from the collector to the heat-storage unit or house by a stream of circulating water or air.

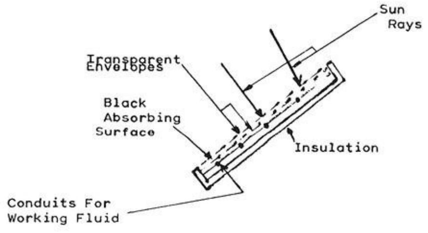
The experimental systems developed to date have been based on solar air heaters with hot water storage. Typically, the collector area has been one-half or two thirds of the floor area of the house, with the systems designed to carry similar fractions of the

COLLECTORS

FOCUSING COLLECTOR



FLAT-PLATE COLLECTOR



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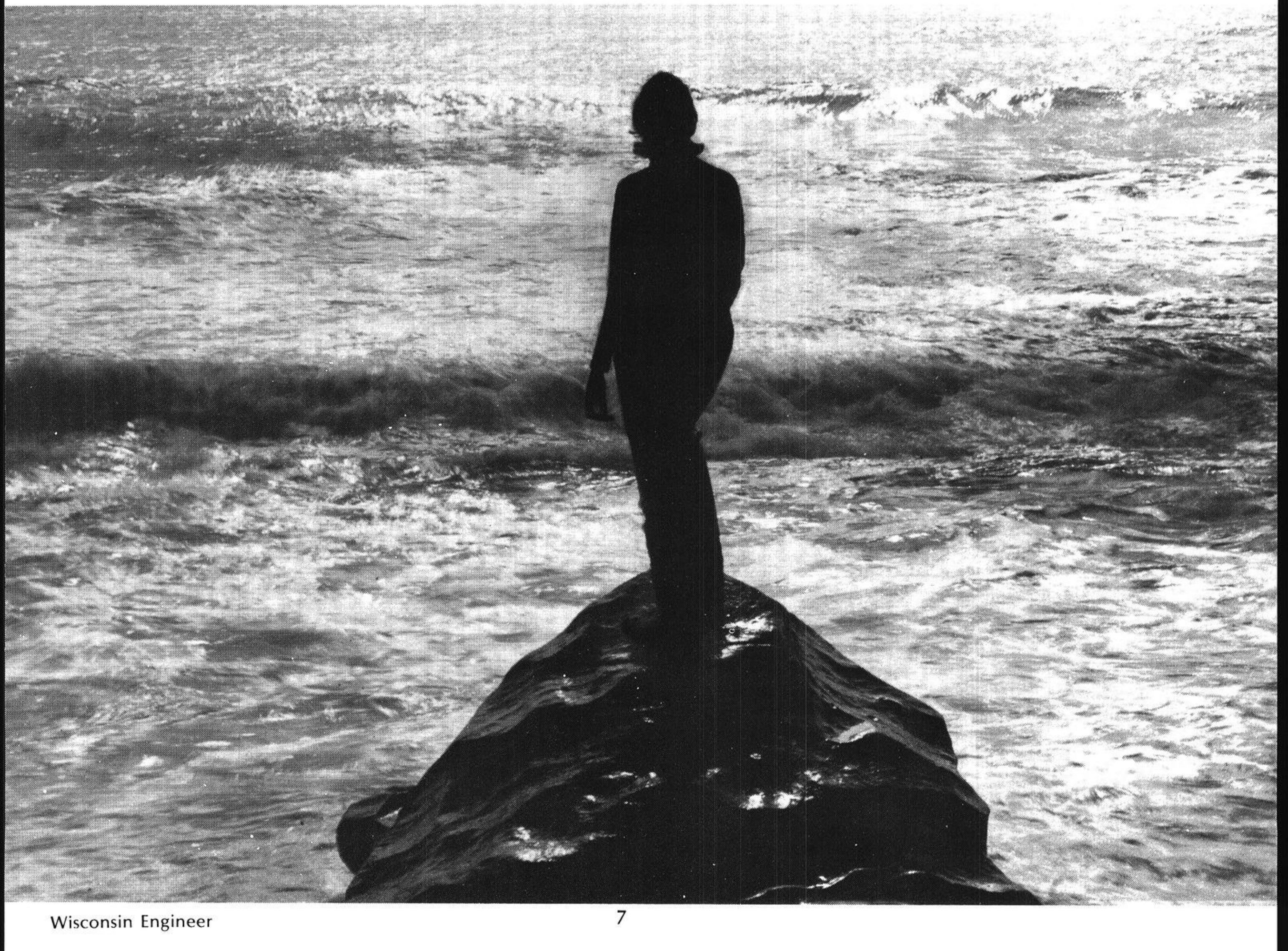


total annual heating loads. The system carries the total heating loads in spring and fall and a fraction of the heating loads during severe winter weather, with the balance provided by a conventional system. Typical U.S. winters are such that carrying 100 percent of the heating loads by solar energy storage systems would be impractical.

Conversion of solar energy to electrical energy is a more challenging and difficult proposition. Under space programs, technologically successful systems for conversion to electrical energy have been developed for space vehicles. Photovoltaic cells are one of them.

Photovoltaic cells, or barrier-layer cells, involve a P-N junction in a semiconductor between a positive layer, which contains movable positive charges or "holes" and an N-layer which contains movable negative electrons. When light of sufficient energy enters the crystal, electrons are released and they flow to an electrode, where they combine with the positive holes. A barrier at the P-N junction prevents the instant recombination of electrons and positive holes, causing the electrons to go through the wire, generating useful electricity. No material is consumed, and the operation of the cell can continue indefinitely.

These examples of the uses of solar energy are just a few of the many now under experiment. Although they all offer feasibility, there still are problems associated with the use of solar energy.

Efficient production of thermal energy available for practical use is a difficult problem. Much solar energy never reaches the earth's surface because of cloud cover. Since the energy is diffused, large area solar collectors are needed.

> ***"Total solar energy reaching the earth is greater than the world's energy needs."***

The efficiency of solar energy collection is highest at low temperatures, but energy collected at low levels is not usuable for many of our energy needs. For example, the maximum electrical conversion of the photovoltaic cell takes place at about 7,000 angstroms, which is close to the wavelength of maximum intensity in solar radiation. Because of variability solar energy must be stored for many uses, causing storage losses and additional costs of construction and maintenance of storage systems.

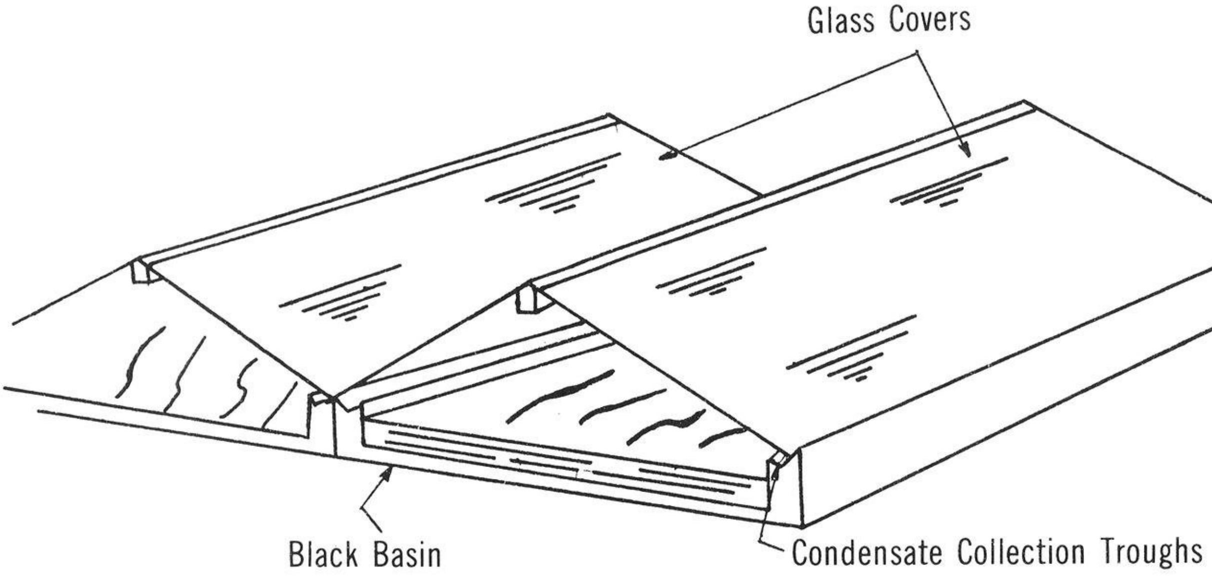
The great handicap in the development of comfort heating in isolated areas is the absence of electric power. All the solar-heated units as of now use some electricity for circulating either air or water.

The most serious problem in the use of solar energy today is cost. The cost of energy from conventional sources are widely variable, depending on the form of energy and location.

In order to make a significant contribution to an energy economy, the cost of solar energy must be competitive. In comfort heating with solar energy, a square foot of a well designed flat plate collector in a climate might produce a useful gain of 250,000 BTU's per heating season. If this collector were to cost two dollars per year for interest and amortization, the cost of delivered energy would be $1.60 per million BTU. Added to this cost would be the cost of energy storage, fluid pumping systems and maintenance.

Solar heating is not economical, primarily because of the low availability of collectors at a low price. Collector development and engineering will determine whether economic feasibility will be achieved.

The cost per kilowatt of installed **peak** photovoltaic cell capacity is about $50,000. The cost per kilowatt of installed **continuous** generating capacity in charged fuel-fired conventional plants is of the order of $1.50.



SCHEMATIC OF A BASIN TYPE SOLAR STILL

Estimated Costs of Solar Energy for Several Applications

Location	Type and Capacity	Cost	Notices and References
SPACE HEATING			
1. Central U.S.	10^5B.t.u./hr. oil burner	\$1.50/$10^6 10^6$B.t.u.	Fuel oil at 15¢/gal., fuel cost only.
2. Western U.S.	10^5B.t.u./hr. LPG system	\$2.00/10^6B.t.u.	Propane at 17¢/gal., fuel cost only.
3. Denver	Natural gas	\$0.75/10^6B.t.u.	Fuel cost only.
SPACE COOLING			
1. South U.S.	2-5 tons absorption	5-3¢/ton-hr.	Electric power at 2-4¢/k.w.h.C.O.P.=2.5,20% 10%/yr. load factor, equipment cost included at
2. South U.S.	2-5 tons compression	2.5-6¢/ton-hr. 5.5-9¢ton-hr.	Fuel cost only. at \$0.75 to \$2.00/10^6B.t.u. Same, with equipment cost included as in No. 1.
3. Cairo, Egypt	2-5 tons compression	12¢/ton-hr.	Electric power at 7.5¢k.w.h. fixed cost. 40% load factor.
4. Dakar, West Africa	2-5 tons compression	25¢/ton-hr.	Electric Power at 17¢/k.w.h. 10%/yr. fixed cost, 40% load factor.
POWER			
1. U.S.A.	Industrial large capacity	1¢/k.w.h.	Power generated at large central thermal power stations or hydroelectric stations.
2. U.S.A.	Small central power plant	3¢/k.w.h.	Power from a 10,000 k.w. central power station.
3. Rural U.S.	Auxiliary generator	4-8¢/k.w.h.	Power from small gasoline generator plants of 2-3 k.w. capacity.
4. Cairo, Egypt		7.5¢/k.w.h.	Residential lighting rate (7).
5. Dakar, West Africa		17¢/k.w.h.	Residential rate (3).
6. Rural India	Animal power	15-30¢/k.w.h.	Power for lifting irrigation water (8), estimated in terms of electrical equivalent.

Economic feasibility of solar application is dependent on good performance of the system, good climate, very long life and low annual cost. Solar applications are by nature capital intensive, and the availability of investment capital may also become a limiting factor.

Environmental Consideration of Solar Energy

The cost of energy from conventional sources may increase as environmental concerns mount, improving the competitive position of solar energy.

While some conventional systems may be ruled out on grounds of environmental damage or low availability, solar energy systems can meet a significant fraction of United States' energy needs, including home heating.

There are three detrimental effects in the use of solar energy.

- There may be adverse aesthetic considerations in the use of large areas of solar collectors. They do affect and put limitations on architecture if solar energy is to be controlled and used for heating.
- There could be local microclimate changes due to changes in albedo on installations of large areas of solar devices, or by the removal of vegetation.

The manufacturing processes involved in producing solar devices might have undesirable side effects.

Current Research

Solar energy research has received little effort. There is some activity in cadmium sulfide thin film photovoltaic processes and some efforts by the aerospace industry to apply space technology to special terrestrial applications. The main efforts in thermal processes are going on in Australia and the USSR, where needs and practicality are greatest.

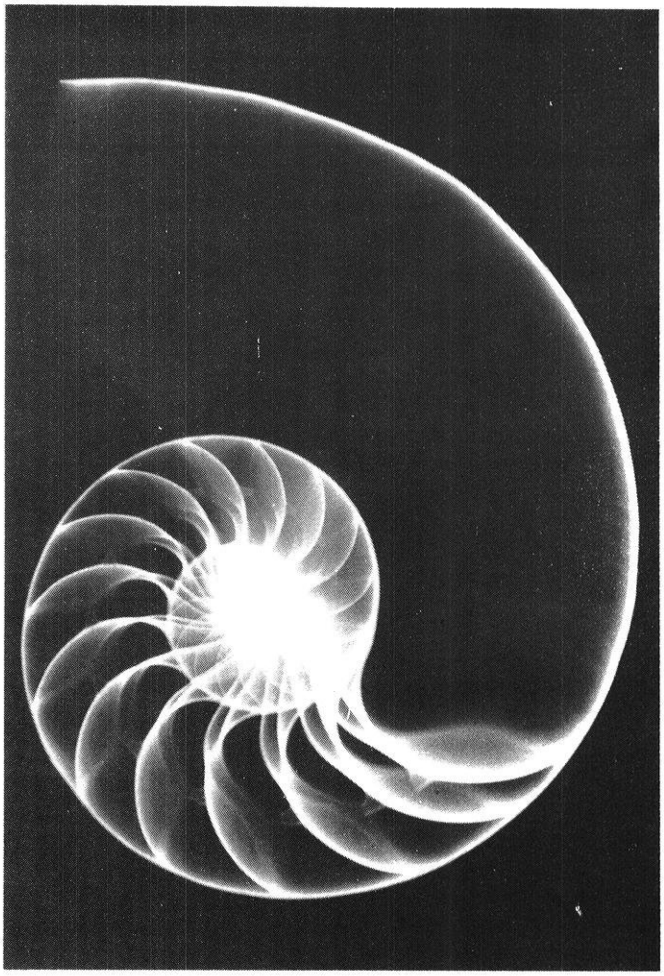
The total solar energy reaching the earth is much greater than the energy requirements of all the world's population and it could be used to replace the energy now being supplied by fossil fuels and electricity. But it will not be used at present except in a few special cases because the cost of collection and the investment required for solar devices are high.

However, fossil fuels—coal, gas, and oil— are irreplaceable and they are being consumed at an increasingly rapid rate. Eventually they will become more expensive, relative to other goods and services. Research and development, and eventually mass production of solar equipment, will lower the cost of the conversion of solar energy to a point where it can compete economically with fossil fuels. This competition will come gradually, first in selected areas where fuel is scare and sunshine abundant. Solar energy is not suitable for use in cold, cloudy regions or in large cities, where the acres of sunshine per person are not nearly enough to supply the needs. In a few areas, the use of solar energy can be considered immediately, and in other areas, only a slight advancement in solar energy technology is needed to make it feasible in the near future.

Much basic research has been done in heating, cooling, electricity and distillation. The sudden demand for solar-operated devices for the exploration of outer space came as a surprise, and it will be interesting to see what further surprises lie ahead in the coming years. It seems likely that the next few years will see the utilization of solar energy in many parts of the world.


Let's get together!

Fusion –



Working for Tomorrow's Energy Needs

by Mark Holler
of the Engineer Staff

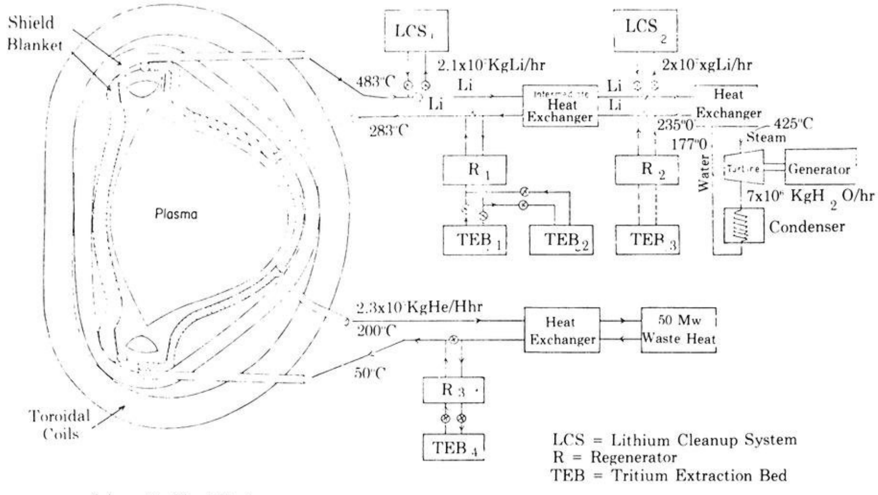
Practical fusion energy is the goal, but a multitude of problems still block the way. Working toward this goal, a team of researchers at the University of Wisconsin began in the fall of 1971 to prepare a paper study called UWMAK I. This study considers the difficulties in designing and building a full scale fusion reactor.

The project director is Prof. Gerald L. Kulcinski. Other nuclear engineers working on the project are Prof. Gilbert A. Emmert, whose information and help were invaluable in writing this article, Prof. Robert W. Conn, Prof. John M. Donhowe, Prof. Charles W. Maynard, Prof. William F. Vogelsang and Prof. Roger W. Boom. From the fields of chemical engineering and engineering mechanics are Prof. Warren E. Stewart and Warren C. Young. Filling out the rest of the research team are 14 graduate students.

For a nuclear fusion reaction to occur certain conditions must be met. The fusion fuel must be contained and isolated from its surroundings while it is heated to its ignition point of about 100 million degrees Kevin. Under these conditions, the fuel mixture is in the plasma state, a completely ionized gas. The confinement must be maintained long enough for the energy release to exceed the energy required for heating. Making the energy useful also requires consideration.

The general design chosen for the project was the Tokomak, which is considered the best contender by the Atomic Energy Commission. The Tokomak chamber is a toroid surrounded by superconducting windings which set up the confining magnetic field. The major radius of the toroid is 13 meters and the minor radius, the radius of the chamber, is 5 meters. The toroid is used because the field lines can be made continuous within the chamber, never passing outside. This is advantageous because the charged particles of plasma are inhibited only from moving normal to the magnetic field. The metal chosen for fabricating the toroid and its cooling jacket was stainless steel because of its good structural qualities and because the effects of radiation on it are known. Molybdenum, vanadium, niobium, or other refractory metals might have been used but, much less technology exists for working with them. The stainless steel wall life under the calculated rate of neutron bombardment is estimated to be about two years. After this time, the walls become extremely brittle and the first 30 or 40 centimeters must be replaced.

Some of the possible fusion reactions and a graph of the probability of these reactions oc-



Schematic Plant Design
Wisconsin Toroidal Fusion Reactor —UWMAK-1

curing as a function of ion energies is given in figure 3. The vertical axis will give the number of reactions per cubic centimeter per second when multiplied by the product of the deuterium and tritium densities. The energies that must be attained for these reactions to have a favorable cross section is somewhere from 7 to 15 kev, which corresponds to 100 million degrees Kelvin. Once a reaction reaches this temperature it will maintain itself at a rate depending on the density of the plasma.

The reaction chosen for UWMAK I was the deuterium-tritium reaction. The plasma density, deuterium and tritium ions, is $8x10^{13}/cm^3$ and the operating energies for the ions and electrons are 11.1 and 11.0 kev. The average confinement time will be 14.2 seconds. Under these conditions, the reaction is thermally unstable and a feedback mechanism is necessary to control the reaction. The reaction could be made thermally stable by increasing the confinement time, the reaction energies, and the magnetic field, and by decreasing the density. However, a fifty per cent increase in the cost of the magnets would result. This may have to be done anyway if a satisfactory feedback control cannot be found.

The DT reaction reaches it peak probability at lower temperatures and yields more energy than most of its competitors. The disadvantage of this reaction is that, although deuterium is plentiful in nature, tritium is not and is radioactive. However, the tritium can be made from lithium by the following nuclear reactions:

$^6Li + n \rightarrow T + {}^4He + 4.8$ Mev.

$^7Li + n \rightarrow T + {}^4He + n + 2.6$ Mev.

UWMAK I uses lithium as a heat transfer fluid in the cooling blanket where it can react. Neutrons from the fusion reaction pass out of the plasma quickly, since the magnetic field does not affect them, while the charged alpha particles that hold less energy, remain in the plasma to keep heating it. The high energy neutrons enter the cooling blanket and collide with lithium atoms in the blanket breeding tritium. Externally, the lithium-tritium mixture is processed and the tritium is removed. Molten lithium, however, is less than an ideal transfer fluid since it requires energy to pump it through a magnetic field, which induces eddy currents. The design uses low velocity flow perpendicular to the field to depress this effect. Lithium also presents a serious fire hazard should the system ever be broken.

The power level chosen for the reactor was 5000 megawatts thermal energy which will produce 1500 megawatts of electrical output. This output is comparable to that of a fission reactor in operation today. The desired cycle if it can be attained would be 2000 seconds on and 150 to 200 seconds off. The shutdown is necessary in order to pump out the chamber. Impurities in the plasma that have been bombarded out of the walls by the neutrons interfere with the reaction by cooling the plasma and must be removed. During the 2000 second operating period refueling must be constant in order to maintain the reaction, since the average particle confinement time is only 14 seconds. At present the longest confinement time achieved is .01 seconds. However, the confinement time will increase as the temperatures approach the ignition point because, as the velocities increase, each ion spends less time near any other particular ion and, thus, is scattered less by that ion.

The startup begins with a low density plasma, $3x10^{13}/cm^3$. A gradually rising current in the transformer coils running parallel to the minor axis produces a time-varying magnetic field which induces a current in the plasma, heating the plasma. This ohmic heating alone cannot bring the plasma to its ignition point. UWMAK I injects 20 alternate deuterium and tritium neutral beams of 350 to 500 kev tangent to the minor axis to reach the operating point. The low density start is to allow for this addition of fuel to the plasma. Neutral beam theory at present is still incomplete and its use in this design is a large extrapolation of technology. The energy required to start the reactor is 15 megawatt hours. If the reactor is brought to operation in 100 seconds as proposed, the input power would be 540 megawatts. Bringing the reactor up faster would improve the duty factor, (time on/time off), but it would require more power. Power much greater than 500 megawatts, which would have to come from other power plants for the first start, is not readily available.

Once the reactor is operating, the energy for following restarts will come from an inductive storage device, a superconducting toroidal magnet which will be energized gradually to about ¾ capacity during each cycle. The remaining quarter capacity will be drawn from the reactor magnets at the time of shutdown by reversing polarities.

During the operating cycle when the neutral beams are no longer needed, the plasma density must be maintained. UWMAK I uses an electrostatic particle accelerator to accelerate micron to milimeter size pellets of deuterium-tritium ice to an energy of 2-100 kev and then fires them into the reactor to penetrate the plasma.

The magnet system consists of the main, the transformer, and the divertor coils. All three sets are superconducting and fully stabilized. Liquid helium cools the magnets to their operating temperature near absolute zero. Fully stabilized means that the niobium-titanium core of the conductors is surrounded by copper, which could carry the current momentarily without a significant heat rise in case the superconductor went into the normal conducting state. If the temperature does not rise much the superconducting state will return shortly. This is a slightly conservative outlook because the probability of the magnets going normal is very slim and some claim nonexistant. However, if part of a nonstabilized superconductor were to go normal, the heat dissipated in the normally conducting region would spread and cause the entire magnet to go normal resulting in the dissipation of a huge amount of heat and the destruction of the coil. If one main coil goes out of service the entire field becomes unbalanced and dangerous stresses occur.

The 12 main coils are D-shaped and produce a confining magnetic field of about 40 kilogauss. The transformer and divertor coils run around the torus parallel to the plasma and produce a plasma current of 20 million amps. The transformer and divertor coils act as a transformer primary, the transformer secondary being the plasma. When the reactor is shut down this transformer action reverses and the plasma current induces a current in the coils which can be stored for the restart as mentioned earlier.

$D+D \rightarrow T+p+3.25$ Mev.

$D+D \rightarrow {}^3He+n+4.0$ Mev.

$D+T \rightarrow {}^4He+n+17.6$ Mev.

$D+{}^3He \rightarrow {}^4He+p+18.3$ Mev.

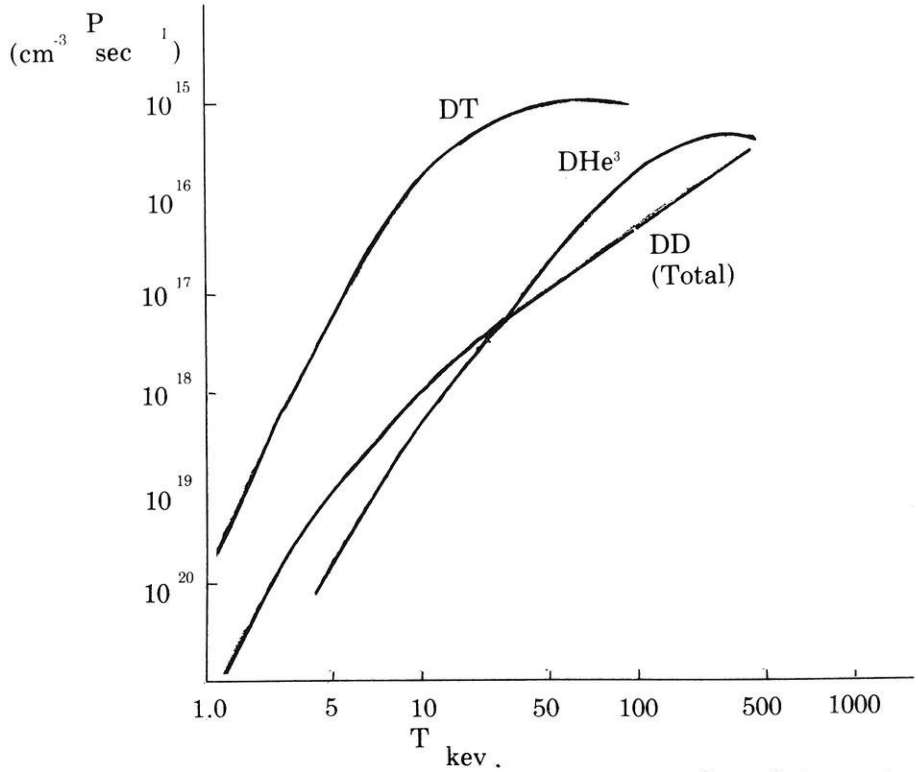


Fig. 3 Reaction Probabilities vs. Ion Energies

from *Astronauts and Aeronautics*

The superconducting coils are the major initial investment. UWMAK I found its main magnets and auxiliary coils would cost $200 million and the storage device $50 million. The entire plant, including generators, turbins, refrigeration and the rest would cost about $500 million. Most continuing costs, such as fuel which costs less than one per cent of what coal costs, and wall replacement, are insignificant when compared to the major continuing cost, the interest on the loan to build it. At an annual interest rate of 12 per cent $500 million would cost $60 million a year. This cost compared to the value of the power, will determine whether or not this or any fusion reactor is built.

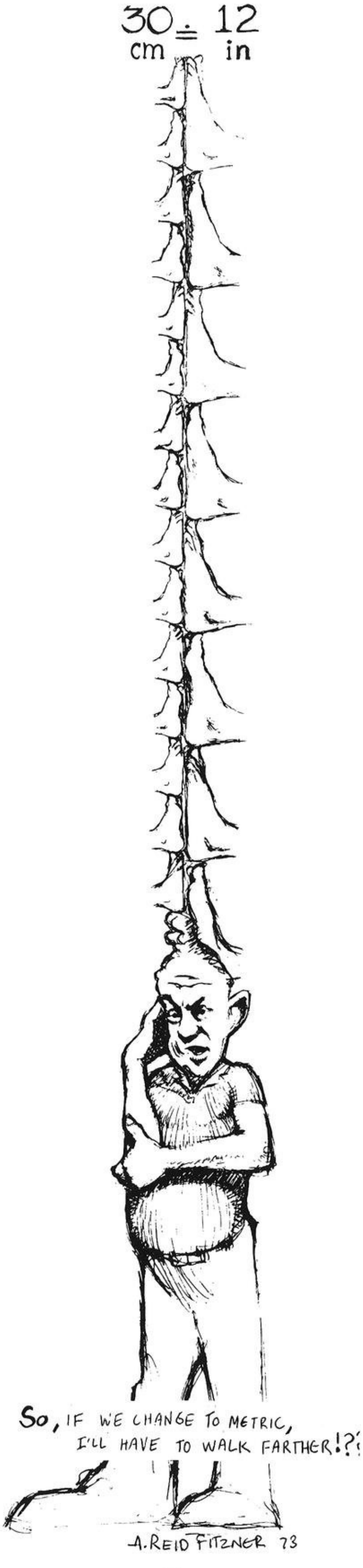
UWMAK I also considers variations on its basic design with emphasis on the change in cost. One variation is the stellarator which does not heat the plasma ohmically but, instead by radio or microwave resonance. Another major variation which eliminates many of the dangers and problems involved in using lithium for heat transfer, uses a separate breeder reactor to produce the tritium.

Princeton University is also doing a major study. However, it is finding different answers by making more liberal assumptions; for instance that refractory metals and unstabilized magnets will be satisfactory.

The Atomic Energy Commission has set the goal of feasability for 1980 and the goal of practical operation for 2000. With the present energy crisis funds are becoming available in ever increasing sums for fusion research. Conceivably these goals could be reached much sooner, particularly the goal of practicality. WE

Inching Along Toward Change

by Jeff Kratz
of the Engineer Staff



The United States still displays many traits of its former association with Great Britain. The country's official language is English, the favorite American sports of baseball and football were developed from English cricket and rugby, and the recent wedding of Princess Anne probably had as large a viewing audience in this country as it had in England.

Another item inherited by the United States is the English unit of measurement system. The pound, foot, and the gallon were all given to us by Great Britain. Today, those with overactive imaginations see the English measurement system as a curse put on the United States by an unhappy England that determined its former colonies would forever suffer because of their rash decision to become independent.

The English measurement system is certainly a curse to the engineer in today's America. Forced to work with one system and live with another, his life is constantly cluttered with conversion charts and the necessity to know immediately how many cubic centimeters there are in five and three quarters gallons.

Yet, the days of the English curse may be numbered. For many years there has been a movement to replace this country's archaic and arbitrary measurement system with the System International (S.I.), the internationally recognized metric system.

Such a conversion would indeed be a welcome relief for the American engineer, but its future implementation in this country depends on how well the general public can be sold on the idea.

One part of the movement to implement a metric system of measurement in this country was taken by the United States Congress. In 1968 the House and Senate passed a law directing the Secretary of Commerce to begin a study to "determine the advantages and disadvantages of increased use of the metric system in the United States".

The report was completed three years later. Entitled "A Metric America — A Decision Whose Time Has Come", it strongly recommended that the United States "change to the International Metric System (S.I.) through a coordinated national program over a period of ten years, at the end of which the nation will be predominately metric".

The System International has six basic units of measurement.

They are:

LENGTH — meter (m) The meter is defined as 1,650,763.73 wave lengths in vacuum of the orange-red line of the spectrum of krypton-86.

TIME — second (s) The second is defined as the duration of 9,192,631,770 cycles of radiation associated with a specified transition of the cesium atom. It is realized by tuning an oscillator to the resonance frequency of the cesium atoms as they pass through a system of magnets and a resonant cavity into a detector.

MASS — kilogram (kg) The kilogram is a cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures in Paris. It is the only base unit still defined by an artifact.

TEMPERATURE Kelvin (K) The Kelvin scale of temperature has its origin or zero point at absolute zero and has a fixed point at the triple point of water defined as 273.16 Kelvins.

ELECTRIC CURRENT — ampere (A) The ampere is defined as the magnitude of the current that, when flowing through each of two long parallel wires separated by one meter of free space, results in a force between the two wires, due to their magnetic fields, of 2x10 - newton for each meter of length.

LUMINOUS INTENSITY — candela (cd) The candela is defined as the luminous intensity of 1/600,000 of a square meter of a radiating cavity at the temperature of freezing platinum (2042 K).

Other units of measure, such as the ones used for volume and speed, are derived from these six standards.

According to the study, the only countries in the world that do not now use the S.I., or are not in the process of converting to it, are the United States and a handful of Caribbean and Black African nations. Even Canada, despite an economy linked heavily with the United States, and therefore to the United States system of measurement, has decided that it will change to the International Metric System.

The debate today to change the units of measurement in America is nothing new. The history of the United States shows a continuous struggle to achieve some semblance of order in our measurement system.

Among units used in the United States today, the U. S. gallon comes from the British wine gallon, which was standardized at the beginning of the 18th century. It is about 20 per cent smaller than the Imperial gallon adopted in 1824, and this explains why a gallon of gasoline in Canada seems to last longer. It's because it's bigger.

Other units, such as inches and pounds, do not have a set origin. Instead, they have developed as a combination of Anglo-Saxon, Roman and Norman-French measures that became standardized through the years.

The discussion about adopting a new measurement system here came shortly after the French developed the foundations of the present day metric system during the early 1800's. These new measures were the result of an attempt to create a new system of measurements strictly based on natural phenomena.

As early as 1821 the United States was asked to consider adopting the French metric system by John Quincy Adams. Adams suggested four different plans for regulating and systemizing the units of measurement, but could convince only a few congressmen to back his ideas.

In 1866 the Kasson Committee, set up by President Lincoln, reported favorably on ideas to establish some use of the metric system in this country. Congress adopted three bills at about this time on metric use in America, primarily in the Post Ofice Department to facilitate the handling of foreign mail. This was necessary because more and more countries were adopting the metric system worldwide.

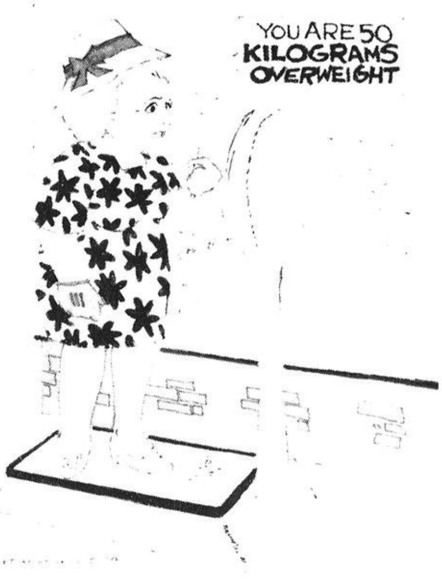
An attempt was made by some congressmen to convert the nation to a metric system in 1896, and for a while it looked like it might succeed. Supported by the Committee on Coinage, Weights and Measures, a bill directing the Government to start using the metric system passed the House of Representatives by a two vote margin, 119 to 117. However, various parlimentary devices used by opponents of the bill forced its reconsideration, and eventually lead to its death without ever being considered by the Senate.

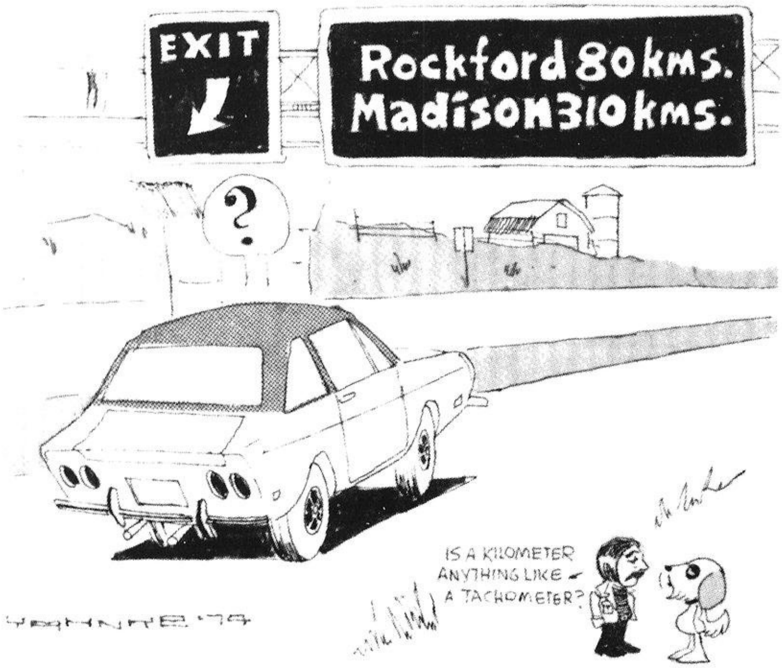
Since the turn of the century there has been much talk and little action in the area of conversion. Congress was asked repeatedly to study the possibility, but only responded when outside pressures became too great to ignore. The launching of Sputnik, the decision by Great Britain to go metric in 1965, and the continuing pressure from scientific groups in the United States were all important to the creation of the 1971 study. However, this is where it stands today — being studied — but with no definite commitment to action in the future.

Both those favoring conversion and those against it try to buttress their argument by concentrating on three different areas: which system is more convenient, problems the United States would have with the metric system, and the implications a change in measurements would mean for the future.

Those favoring the current system contend that customary units are related to everyday experience. They say the units now in use here are easily grasped, and that the metric units are many times too abstract or complicated.

Those favoring the metric system claim their system is less complicated. They cite the relationship with the decimal system and believe metric units, if taught from an early age, would be as easy to understand as customary units.





Arguments over confusion, inconvenience and created expense are involved when talking about problems the United States may have when going metric. Proponents agree all will be present to some degree, but say that these are necessary evils that must be dealt with in order to replace or come into line with the rest of the world.

As far as the future is concerned, both groups agree a change may be necessary. But those favoring the present system warn the transition period may be very costly, and may play havoc with the nation's economy at a time when economic stability is very important. Those promoting the changeover respond that the nation is already heading toward a metric system, that it is just a matter of time before the change will become inevitable. They say the changeover should be organized in order to assure maximum efficiency at minimum cost.

Drug manufacturing and production of anti-friction bearings have changed to a metric system.

United States drug manufacturers changed to the metric system during the 1950's. They are apparently well satisfied with the change. Among the specific advantages that some of the companies felt they gained by the changeover were easier training of personnel, reduction in errors, and economies in the actual manufacturing stage.

The drug companies generally say they have experienced no disadvantages because of the changeover. However, it must be realized that the industry's principle users, physicians and pharmacists, already had been trained in the use of the metric system and therefore had little or no problem in adjusting.

Producers of anti-friction bearings also seem pleased over their change to the S.I. They say their international market has increased, and they have been able to eliminate many superfluous types of bearings.

One interesting note is that the producers say the major problem was the "retraining" of the engineering staffs, which now had to deal with centimeters instead of inches. The companies do report this was a very minor problem.

The S.I. has become the accepted system of measurement in other industries in this country. Swimming pool manufacturers, NASA, some areas of the automobile industry, film and camera producers and the armed services have all adopted the metric system.

Many engineers live with the hope that someday they can live in a country that uses the same units to measure the distance between wave lengths and the distance between Madison and Milwaukee. But, some engineers believe changeover may not necessarily be a desirable goal.

Stuart Clark, a plant engineer at the Electric Reduction Company of Canada, Ltd. sees problems with any conversion attempt.

"Some basic sizes will have to be altered," he wrote in the July 27, 1972, issue of *Plant Engineering*. "A 4x8 piece of plywood would be 1.219x2.428 meters."

The size of the plywood piece would then be rounded off meter lengths, and would not exactly fit with an old 4x8 sheet.

Clark also warns that changeovers may involve machinery replacement, and this could become an expensive process. Companies may not be able to afford to replace all their machines at once, but suppliers would have to compete with foreign companies and their already proven metric scaled machinery.

This would make spare parts for conventionally calibrated machinery extremely hard to find, according to Clark.

This may not be true in all cases, however, because the anti-friction bearing producers say they have been able to make metric bearings on the same machines that they used to produce bearings based on the English system.

The future of the metric system in America is in a limbo. Numerous people in the scientific community want the change, a government financed study has recommended the change, and the change is being slowly implemented in this country by certain industries despite the lack of an official government program.

Yet complete change is not going to happen overnight. The government study suggested a ten year period as the time needed for an orderly change. Others think it may take longer.

Until, and if, the day comes when the United States accepts the S.I. measurements, engineers in this country must be resigned to live with their "English curse" and perhaps wish that the French had won the Seven Year's war in 1763. Then the American colonies would have been under French control and therefore subject to the French system of measurement.

Packaging engineer from Michigan State University. She has recently been making cartons of merchandise identify themselves electronically to the computers.

Mechanical engineer from Michigan Technological University. She designs intricate machines that spool film and must operate perfectly in the dark. Turning on lights to check them out would spoil the film.

Chemical engineer from University of Rhode Island. She investigates possibilities for easier conversion of exposed film to finished pictures.

Industrial engineer from University of Wisconsin. She has devised work-shift programs that take into account not only production requirements but also personal preferences in working hours.

Mechanical engineer from Clarkson College of Technology. She combines physical and fiscal planning for new machine rooms where movie film acquires its sound stripe.

Chemical engineer from Youngstown State University. She recaptures silver and other film ingredients from waste.

Mechanical engineer from University of Minnesota. She designs and troubleshoots hydraulic systems, bearings, and shaft seals. She is a specialist on friction, wear, and lubrication.

Architectural engineer from Tennessee State University. She works on interior design of Kodak marketing and distribution offices throughout the U.S.A.

Industrial engineer from University of Miami. Now production supervisor responsible for bringing together people, parts, and tools to satisfy demand for those new Kodak movie cameras you see on TV.

Mechanical engineer from Rochester Institute of Technology. With full responsibility for scheduling and cost control, she designs equipment that provides production machinery with such essentials as compressed air.

Industrial designer from Pratt Institute. She uses form, color, and graphics to relate the technology of the personal camera to people and their sense of the appropriate.

Chemical engineer from State University of New York at Buffalo. She is studying technical factors in photo-processing plants that will be handling future films.

Industrial engineer from The Pennsylvania State University with a mathematics degree from Hunter College of C.U.N.Y. Mathematically she analyzes the problem of maintaining proper color in photographic paper.

Chemical engineer from Youngstown State University. Photographers don't mix chemicals much anymore. She makes a better product by the ton, packaged so it's never even seen.

Electrical engineer from South Dakota School of Mines. Her machines are three stories high, a football field long, and work to the tolerances of an expensive watch in depositing emulsion layers on color film.

This picture could be misleading. Engineering jobs at Kodak are not restricted to ladies. Whatever your sex, if you want to know about current opportunities in Rochester, N. Y., Kingsport, Tenn., or Longview, Tex., for mechanical, chemical, electrical, or industrial engineers, make yourself known to Eastman Kodak Company, Business and Technical Personnel, Rochester, N. Y. 14650.

Or just tell your placement office of your interest.

Kodak

An equal-opportunity employer m/f

Development and Design. Is this the kind of engineering for you?

Trying to figure out the exact kind of engineering work you should go into can be pretty tough.

One minute you're studying a general area like mechanical or electrical engineering. The next you're faced with a maze of job functions you don't fully understand. And that often are called different names by different companies.

General Electric employs quite a few engineers. So we thought a series of ads explaining the work they do might come in handy. After all, it's better to understand the various job functions before a job interview than waste your interview time trying to learn about them.

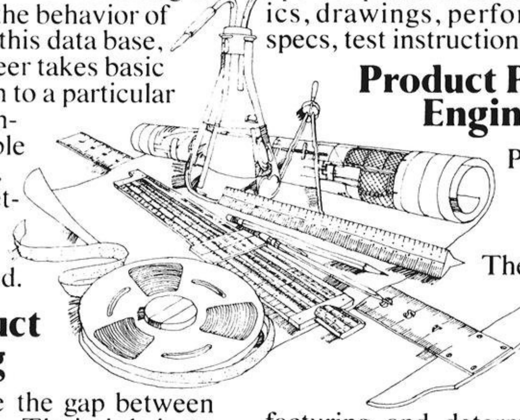
Basically, engineering at GE (and many other companies) can be divided into three areas. Developing and designing products and systems. Manufacturing products. Selling and servicing products.

This ad outlines the types of work found in the Development and Design area at GE. Other ads in this series will cover the two remaining areas.

We also have a handy guide that explains all three areas. For a free copy, just write: General Electric, Dept. AK-1, 570 Lexington Avenue, New York, New York 10022.

Basic/Applied Research Engineering

Motivated by a curiosity about nature, the basic research engineer works toward uncovering new knowledge and understanding of physical phenomena (like the behavior of magnetic materials). From this data base, the applied research engineer takes basic principles and applies them to a particular need or problem (such as increasing the energy available from a permanent magnet). Output is aimed at a marketable item. Both work in laboratories and advanced degrees are usually required.



Advance Product Engineering

Advance engineers bridge the gap between science and application. Their job is to understand the latest advances in materials, processes, etc., in a product area, then use this knowledge to think up ideas for new or improved products or to solve technical problems. They must also prove the technical feasibility of their ideas through laboratory testing and models. Requires a highly creative, analytical mind. A pioneering spirit. And a high level of technical expertise. Output is often a functional model.

Product Design Engineering

Design engineers at GE pick up where the advance engineer leaves off. They take the product idea and transform it into a product design that meets given specs and can be manufactured. Usually, they are responsible for taking their designs through initial production to prove they can be manufactured within cost. Requires a generalist who can work with many experts, then put all the pieces together to make a product. From power plants to toasters. Output is schematics, drawings, performance and materials specs, test instructions and results, etc.

Product Production Engineering

Production engineers interface between the design engineer and manufacturing people. They interpret the product design intent to manufacturing. They maintain production scheduling by troubleshooting during manufacturing and determining deviations from specs. When necessary, they help design adaptations of the product design to improve quality or lower cost without changing the essential product features. Requires intimate familiarity with production facilities.

Engineering Management

For people interested in both engineering work and management. Engineering managers plan and coordinate the work of other engineers. They might oversee product development, design, production, testing or other functions in marketing and manufacturing. Requires a strong technical base gained through successful engineering work. Sensitivity to business factors such as cost and efficiency. Plus the ability to work with people.

GENERAL ELECTRIC

An Equal Opportunity Employer