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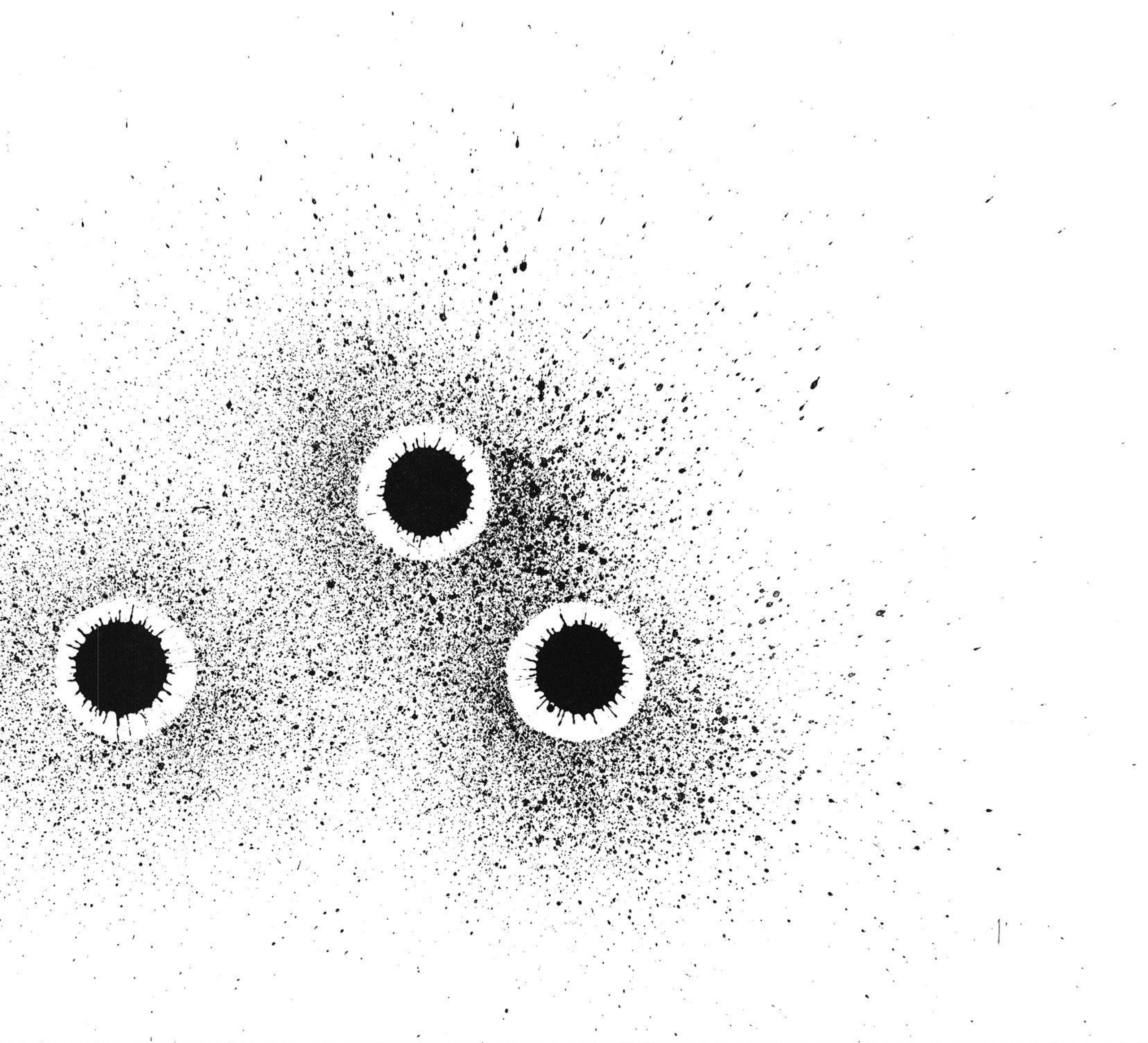
JANUARY, 1962 • 25 CENTS
MEMBER E. C. M. A.

THE WISCONSIN ENGINEER



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Here Assistant Professor Aziz Fouad of Iowa State University's Electrical Engineering Department, University of Michigan student Nicolas Spewock and Detroit Edison Senior Engineer Ray Pillote examine a problem of extra high voltage transmission, using the System Analogue and Network Computer.

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VOLUME 66, NUMBER 4 JANUARY, 1962

ARTICLES

THE WISCONSIN ENGINEER

The Student Engineer's Magazine Founded in 1896

DEPARTMENTS

THIS MONTH'S COVER

With each nuclear fission there is also a large amount of accompanying radiation. The sketch on this months cover tries to convey that phenomenon.

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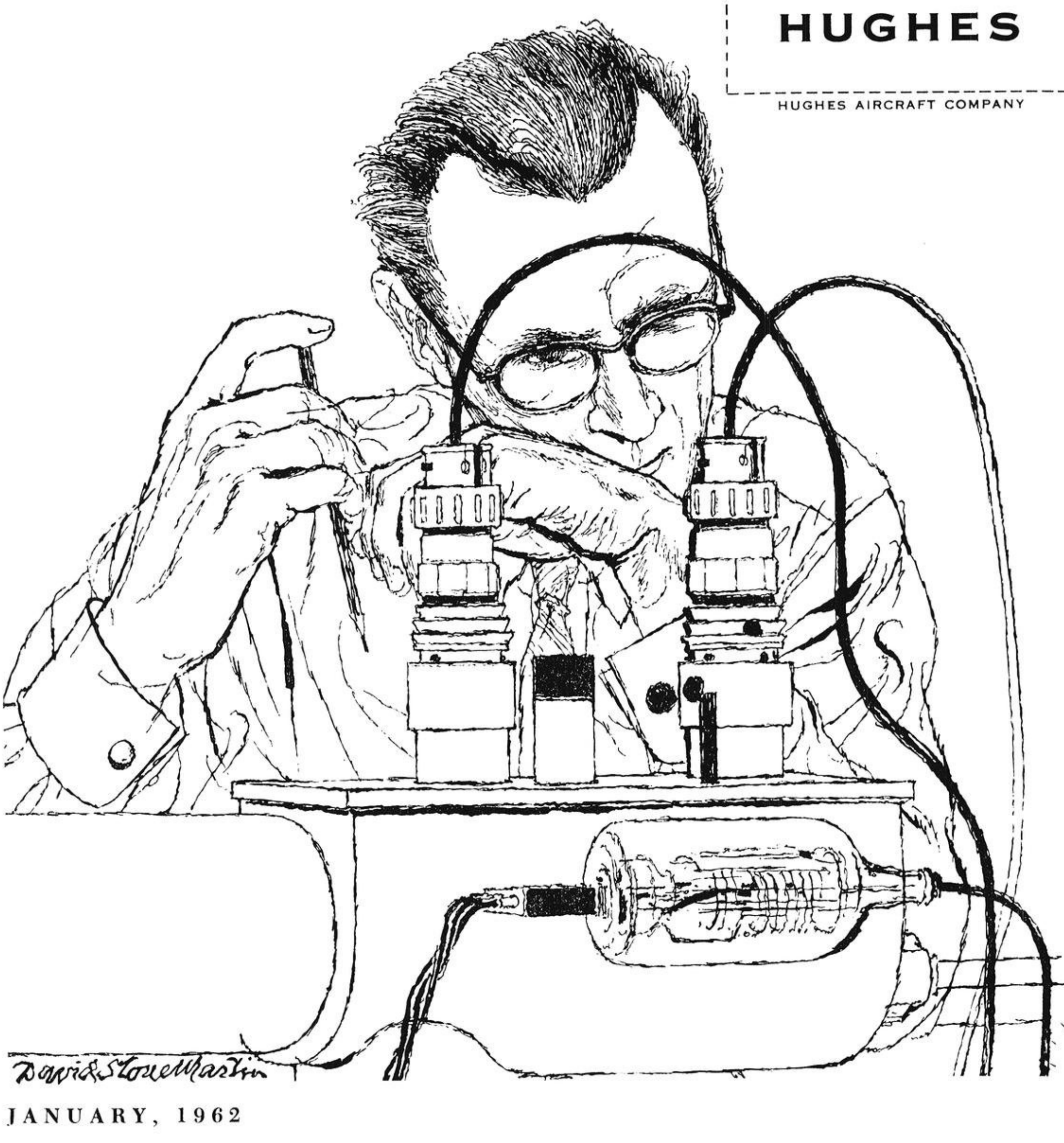

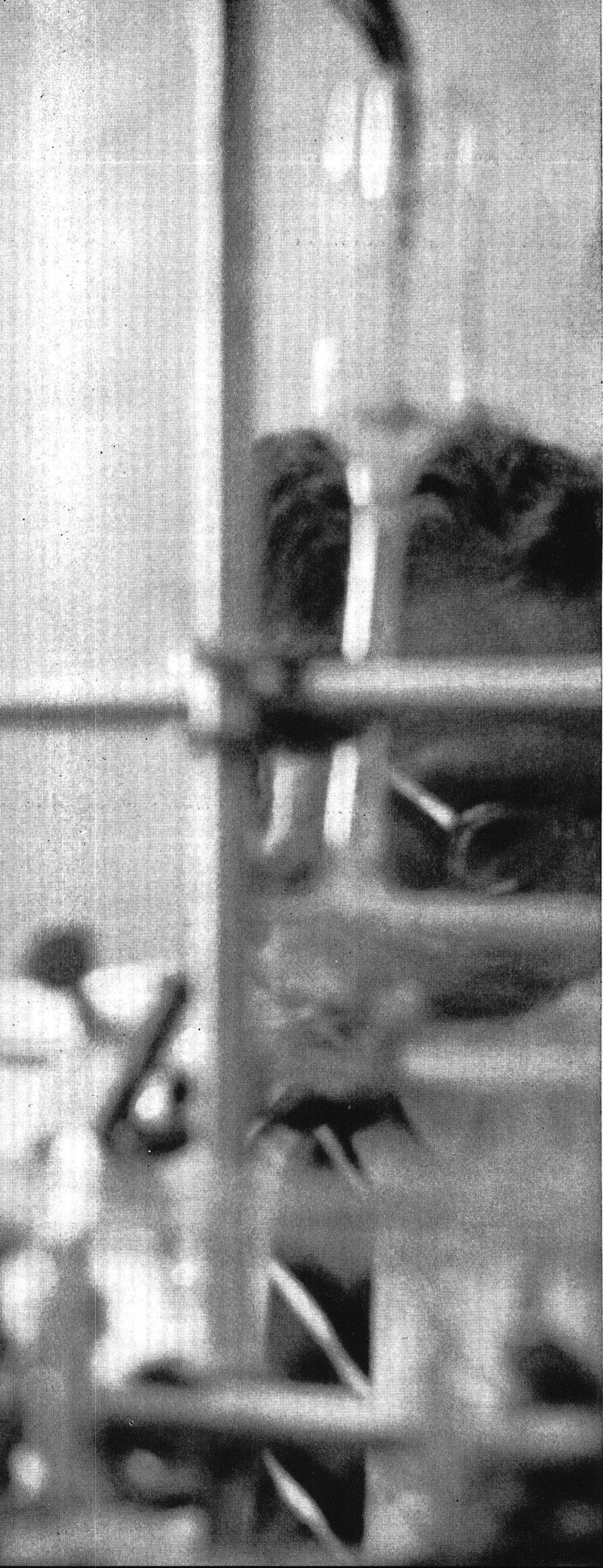

Edward M. Davis, Jr. (B.S.E.E., Carnegie Tech '55; M.S., Cal Tech '56; Ph.D., Stanford '58) is directing micro-electronic device development at IBM's Poughkeepsie, New York Laboratories.

DR. DAVIS AND MICRO-DEVICES

When Dr. Edward M. Davis was working for his bachelor's degree, miniaturization was a novelty. Today, with the transistor and the printed circuit commonplace, micro-miniaturization is one of the newest challenges in electronics. Ed Davis is helping to meet that challenge.

Today's computer operations take only millionths of a second; tomorrow's may accelerate to billionths. In a billionth of a second, however, even light can travel only about a foot, and the physical size of an electronic circuit may slow its operation critically. The answer is in micro-electronics where complete circuits are packaged on minuscule substrates, and each transistor may occupy less than a thousandth of a square inch.

Since early in 1961, Ed Davis has been in charge of an IBM engineering project exploring the parameters of advanced micro-devices. His work may very well help establish the technology of future computers. Equally important, he and his colleagues are already gathering significant knowledge in the advanced study of solid state electronics.

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Nuclear Power for Aircraft

by J. A. Udkler me'62

IN THE fall of 1938 the discovery of Uranium fission by Otto Hohn and Lise Meitner, two German Scientists, gave to the world a new means of releasing energy. The following year the United States Navy was contacted as to the possibility of nuclear fission for military use. Following the initial use of this energy as an explosive the Navy in 1955 launched the first nuclear vehicle, the submarine Nautilus.

Already in 1946 the Air Force had considered a nuclear rocket development program for which some research was done. Because of the development possibilities of chemical rockets at a much lower cost the nuclear rocket program was dropped.

Nine years were to pass before a nuclear rocket propulsion program was again initiated. In 1951 the feasibility of a nuclear-powered aircraft was demonstrated in theory. For the past ten years research has been directed toward development of a nuclear-powered aircraft. The advancements which have been made in these ten years have been surrounded by secrecy. However, early this year this secrecy was lifted enough to announce that nuclear aircraft power plants have been ground tested successfully.

Nuclear Aircraft vs Chemical Aircraft Power

The principle reason in desiring a nuclear-powered aircraft is the practically unlimited range which a nuclear aircraft will have. Not only will the range be unlimited but the payload or cargo which it can haul will not affect the range. In conventional chemical powered aircraft the range is a function of the fuel capacity. As the range is increased, the fuel capacity must increase at a loss to payload. Furthermore, the speed of a nuclear aircraft would be constant for any range, whereas with a chemically powered airplane the range is decreased as the speed increases. (Figure (1) below shows the above comparison.)

Another factor directly related to the unlimited range of a nuclear aircraft is the elimination of refueling in remote areas. Not only will fewer refueling stops save ground facility expense but their elimination will also mean more hours in the air which is, of course, the only place where any aircraft shows a profit.

Before going into details and the problems involved, I would like to describe the probable size of a nuclear powered aircraft. Such an aircraft might weigh approximately 1,000,000 pounds, have a length of about 300 feet, a wingspread of some 300 feet and capable of carrying a 400,000 pound payload. By comparison a present day Boeing 707 weighs 200,000 pounds, has a length of 152 feet, a wingspan of 142 feet and is capable of carrying only a 45,000 pound payload.

Nuclear Power Plants

The introduction of a nuclear power plant does not completely eliminate the conventional engine, but merely provides for the addition of heat in a different manner. As any student of thermodynamics knows, in a power plant heat en-

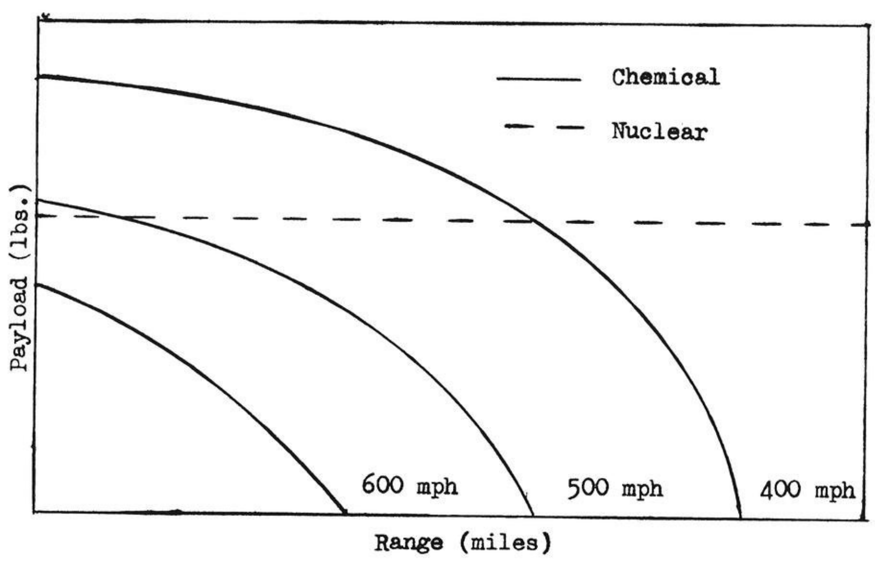


Fig. 1.

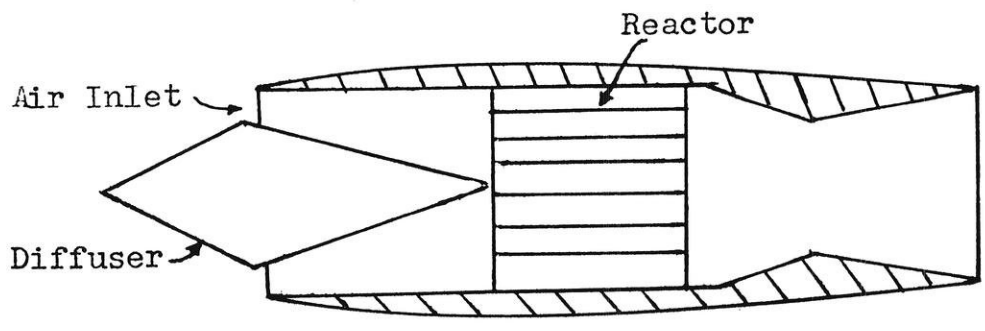


Fig. 2.

ergy is converted to mechanical energy. The basic engine used to propel a nuclear aircraft will not differ very much from the conventional engine, except that the addition of heat will take place in a nuclear reactor instead of in a chemical combuster fired by hydrocarbons. There are several basic engines which can be adapted to nuclear use:

These engines are described in detail as follows; (1) ramjet; (2) rocket; (3) turbojet; (4) turboprop.

Ramjet

The ramjet is undoubtedly the simplest engine of all thermal engines and lends itself to use with a nuclear reactor. In a ramjet, air is aerodynamically compressed and then energy is added in the form of heat, after which it passes through a suitable nozzle and expands to the atmosphere, producing thrust. The only difference between a conventional chemical ramjet and a nuclear ramjet would be the substitution of a reacter for a combuster. (See Figure 2.)

The simplicity of the ramjet makes it very tempting as a nuclear power plant. However, there are several inherent drawbacks. The first of these is a pressure drop to which ramjet engines are very sensitive. The basic problem in chemical ramjets has been to develop complete combustion with little pressure drop through the combustor. The necessity of passing the intake air through numerous fuel elements will cause large pressure drops, which in turn means loss in thrust.

A second inherent disadvantage is that a ramjet developes no static thrust. If not forward motion exists, no air is forced into the reactor. Therefore, the ramjet powered plane requires some form of auxiliary engine to get it airborne. The third disadvantage is one which will be inherent in any jet engine using an open cycle.

An open cycle is one in which the working flow comes directly in contact with the fuel elements before being discharged to the atmosphere. As the air passes through the reactor core it will become highly radioactive. This means a trail of radioactivity follows the jet. Such activity can be harmful to people, especially at low altitudes. The three disadvantages stated just about eliminate the ramjet as a nuclear power plant. The first two problems could possibly be solved, but the elimination of the third would require a closed cycle which defeats the principle of simplicity of the ramjet.

Rocket Engine

A rocket engine is not too much unlike a ramjet in operation, except that it derives its impulse from energy added to a propellant which is carried on board the vehicle. In the conventional rocket engine the energy is added from chemical fuels which, when exhausted, provide the impulse. The relationship between impulse, energy added, and mass of propellant is given by the equation:

$$I \propto \sqrt{\frac{E}{M}}$$

where E is the energy added and M is the mean molecular weight.

Inspection of this equation reveals that high impulse requires the addition of high energy and a propellant of low molecular weight. The best chemical propellants have a molecular weight in the range of 15–20. The use of a reactor to add energy to a propellant which doesn't take part in the reaction permits a low molecular weight material such as hydrogen. Hydrogen with a molecular weight of 2 greatly increases the specific impulse over that of chemical fuels. Like the nuclear ramjet, the nuclear rocket also rejects radioactive material in its exhaust. Unlike the ramjet, however, the rocket doesn't de-

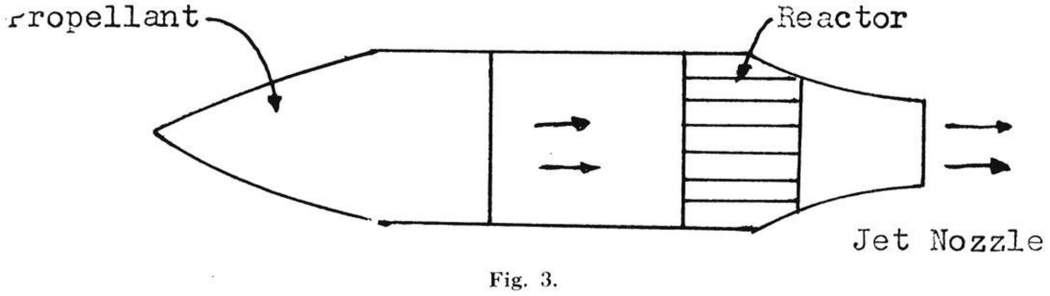


Fig. 3.

pend on atmospheric air for thrust and can be used in outer space. The marriage of a nuclear rocket to a chemical booster could carry it out of the earth's atmosphere. The nuclear reactor could then operate without endangering lives on the earth. Ground testing of a nuclear rocket engine is now under way and in the next few years should be ready for flight testing.

Turbojet

The previous types of engines discussed had inherent disadvantages which were very undesirable to the propulsion of a nuclear-powered aircraft. The turbojet engine also has one of these disadvantages, the trail of deadly radiation left in its wake. However, this disadvantage can be overcome by the use of a closed cycle system. Because the turbojet can be operated as a closed cycle process, it has great possibilities of being the type of power plant used in the first nuclear aircraft. Because it is the general trend of thought that the turbojet will be used as the first nuclear engine to power an airplane, perhaps we had better discuss its operation in more detail.

The conventional turbojet operates on the Braton cycle principle which consists of compressing intake air and adding heat from combustion and expansion of the air through the exhaust which provides the forward thrust. Some of the expansion of the exhaust gases also serves to drive the turbine which operates the compressor. Figure 4 schematically shows the operation of a turbojet engine.

Open Cycle Turbojet

The open cycle system compares to that of the ramjet and rocket engines already described. The open cycle consists of all of the normal components found in a conventional turbojet except for the chemical combuster which is replaced with a nuclear reactor.

The simplicity of the open cycle nuclear powered engine is very attractive for use in an airplane. The inherent problems related to this processes are the radioactive exhaust, pressure loss through the core, and engine control. The problem of radioactive exhaust is one which can't readily be solved unless the closed cycle is used. The pressure loss through the core has been solved satisfactorily to allow efficient operation. The problem of engine control has also been solved

The control of a nuclear reactor is maintained by inserting or removing control rods which are neutron absorbers, the power level of the reactor being increased or decreased by either removing or inserting the rods. Even with the use of control rods, which travel with a high rate of speed, there is a time lag in the power level. In addition, there is a time lag in the heating of ducting which conveys the air from compressor to reactor to turbine. To illustrate the problem, imagine the throttle advanced for increased power. Immediately the rods move out the amount which is indicated by the power level controls. There is then a time lag in the reactor core itself before it reaches this new power level. Next the air passing through the core begins to increase in temperature and as it passes through the ducting heats the ducting, itself losing heat. The time element involved would depend upon the change in power levels. It is common knowledge that the most desirable trait of an aircraft engine is high acceleration. To provide the needed response a chemical combustor is added into the system. This chemical combustor also serves a second purpose, that of maintaining a preset power level. Because the output of a nuclear reactor will vary slightly, the exhaust temperature can be held constant by the proper regulation of this combustor. The speed of the aircraft can also be controlled by varying the exhaust nozzles.

For the past 10 years the General Electric Company has been conducting tests using a nuclear reactor to drive conventional J–47 turbojet engines. Only recently was the secrecy lifted from this project. The most advanced results of their design and testing is a nuclear reactor powering two J–47 turbojet engines in parallel. The total power developed was 30 MW megawatts with an air temperature of 1,435° F. It is highly possible that this same system could power even larger engines.

Closed Cycle Turbojet

Having reviewed some of the problems associated with the open cycle, let us now turn to the closed cycle. The one problem left unsolved for all of the previous types of engines was the radioactive exhaust. By use of the closed cycle the exhaust is clean, which means that in ground operation there would be no danger to people in the immediate vicinity nor a path of radioactive exhaust left in the atmosphere. The solution of this problem, however, introduces other problems and much complexity.

The typical arrangement of a closed cycle system involves a compressor, heat exchanger, working fluid, pumps, reactor and compressor. Figure 5 is schematic diagram of a closed cycle system.

In the operation of a closed cycle turbojet the intake air passes out of the compressor through a heat exchanger and then expands through the turbine, never coming in direct contact with the reactor core. The addition of a second working fluid involves the use of pumps, heat exchangers, and controls.

The working fluid, which is the heat transfer medium between the reactor and air heat exchangers, must have excellent heat transfer

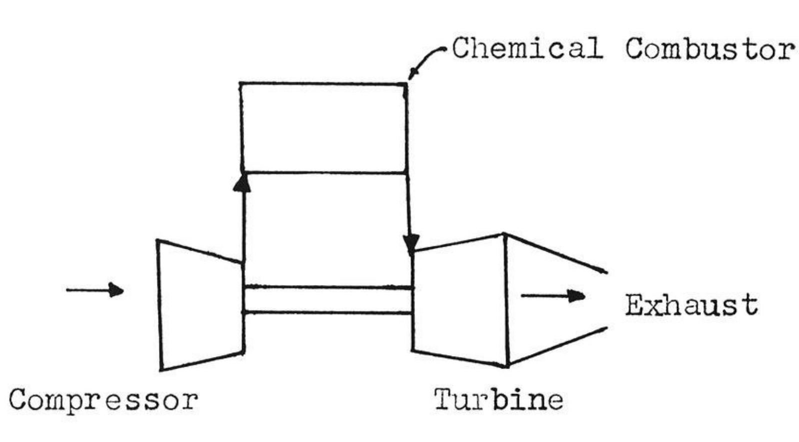


Fig. 4.

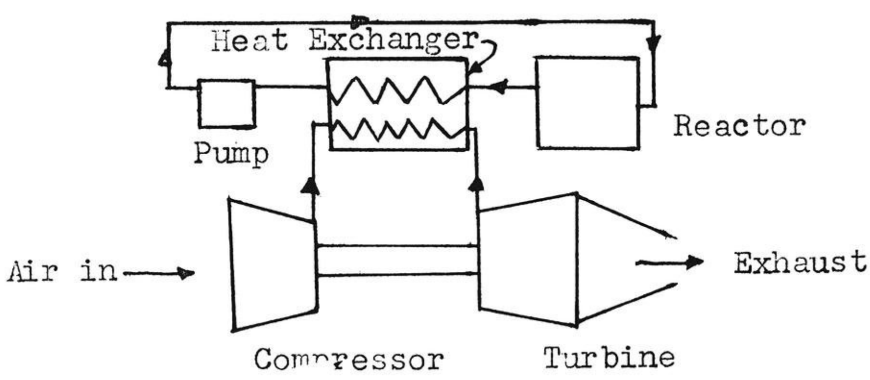


Fig. 5.

properties. Liquid sodium with its outstanding heat transfer properties at low pressures has been used successfully as the working fluid. Here again you find that the solution to one problem brings another. With all of its desirable liquid properties, sodium doesn't liquefy until a temperature of 250° F. is reached. This means preheating the complete system. The preheating can be accomplished by using helium which is pumped through a chemical combustor and then through the sodium lines. The highly oxidizing characteristics of sodium require an inert gas such as helium.

As was previously stated, the control of a nuclear reactor has a time lag and fluctuation which in the open cycle was overcome by use of a chemical combustor. The closed cycle system control problem will be even more difficult because of two working fluids. When the power level of the reactor is increased or decreased, the flow rates of the liquid sodium will have to vary in direct proportion. If the flow rate were not varied at high power, inadequate flow could cause burn up. If at low power and high flow, the inlet temperature of the heat exchanger could become too low for effective heat transfer. To eliminate some of the variables and provide the safest means of control, the reactor is run at a constant power level and air bled off between the heat exchanger and turbine. By bleeding the air after the heat exchanger, the sodium flow rate could be constant. This type of control would provide excellent acceleration which is desirable.

This closed system, being more complex, is still in development.

Turboprop

The turboprop engine operates on the same principle as the turbojet, except that all of the exhaust expansion takes place across the turbine in turn drives the compressor and the propeller. The turboprop engine could operate as a closed unitary system; this having one working fluid which would pass through the core and the rest of the components. A system of this type would provide simplicity, but radioactive contamination of the engine components would make maintenance difficult. Once again the way around radioactivity is by the use of a binary system, using working fluid through the core, another through the engine. Like the closed system turbojet, the two working fluids could be liquid sodium and air Turboprop engines are directly related to turbojets and the problems involved are mutual, so the turboprop is discussed only briefly here.

Shielding

One of the major problems previously discussed in regard to engines was radioactivity. This problem does not end at the engines. An inherent problem of all nuclear power plants is the shielding of the reactor to safe-guard human beings. In the construction of based reactors shielding can be bulky and heavy. There is no real limitation on size and weight. The reverse is true in regard to a nuclear-powered airplane where shielding must be effective, compact, and light.

Shielding can be designed in several ways. First, let us consider a military aircraft such as a bomber. An airplane of this type could be constructed with the reactor at one end of the fuselage and the crew at the extreme other end.

The above arrangement would provide a long distance from reactor to crew, which would in itself reduce the required shielding. Secondly, the shielding could be arranged to provide maximum protection only in the direction of the crew. Figure 6 schematically shows the protected cone shaped area.

The shielding could be further reduced to a point where the crew would be exposed to low level radiation. This would mean that accurate records be kept of dose rates received by each crew member. Limited shielding of this type would mean that crew hours in the air per year would be limited. Once a crew member had reached the maximum dose allowable for the period he would be taken from flying status.

The shielding of nuclear-powered commercial airplanes will be much more difficult. The distance between passengers and reactor will not be nearly as favorable as in a bomber type airplane. Also, the radiation dose to a passenger will have to be low. What this adds up to is complete shielding of the reactor, a heavy and bulky process. One reason for the large difference in size between conventional and nuclear aircraft is the large amount of shielding needed. The larger the plane becomes, the smaller percentage of the weight will be in reactor and shielding.

General Design Problems

Not only will a nuclear powered airplane be large in size, but also

(Continued on page 37)

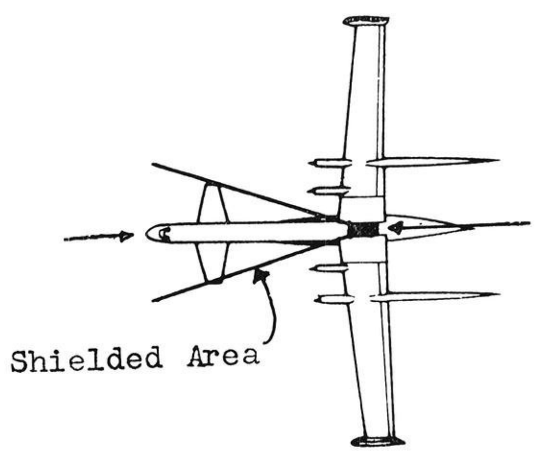
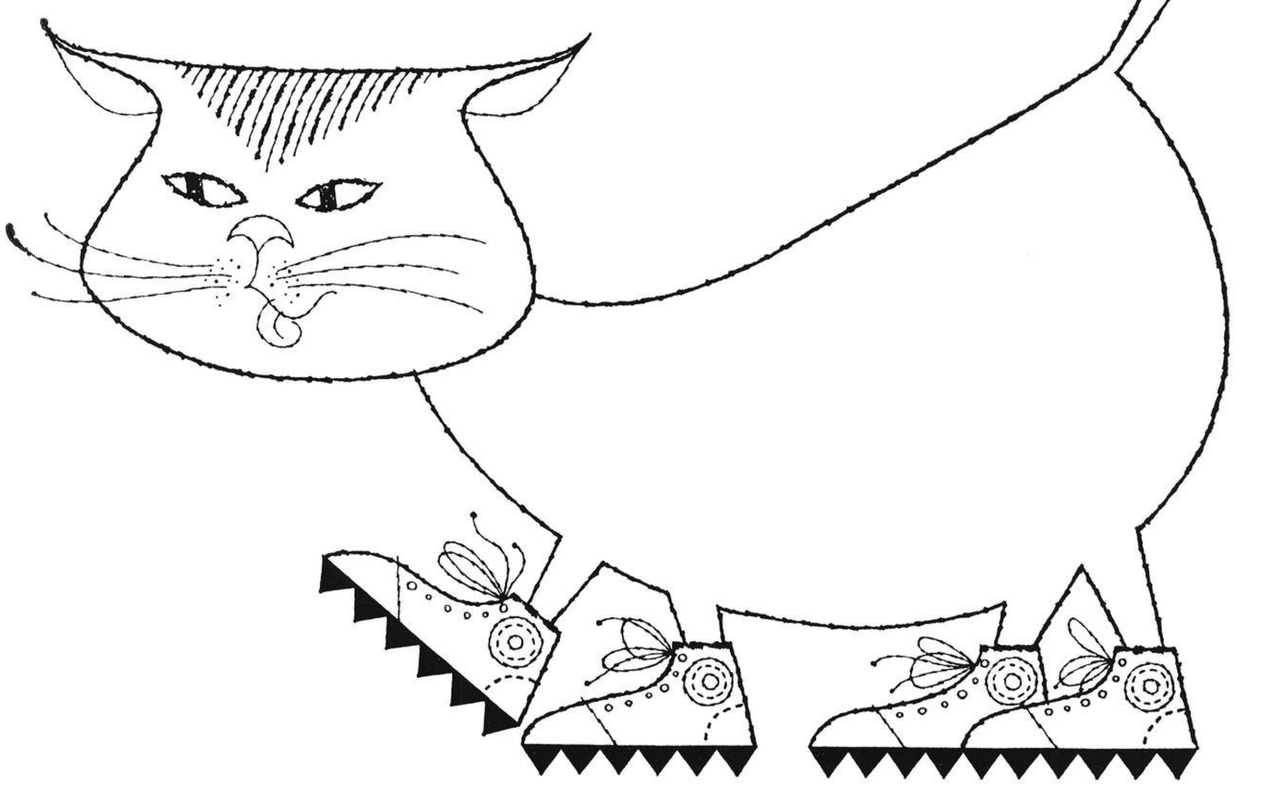
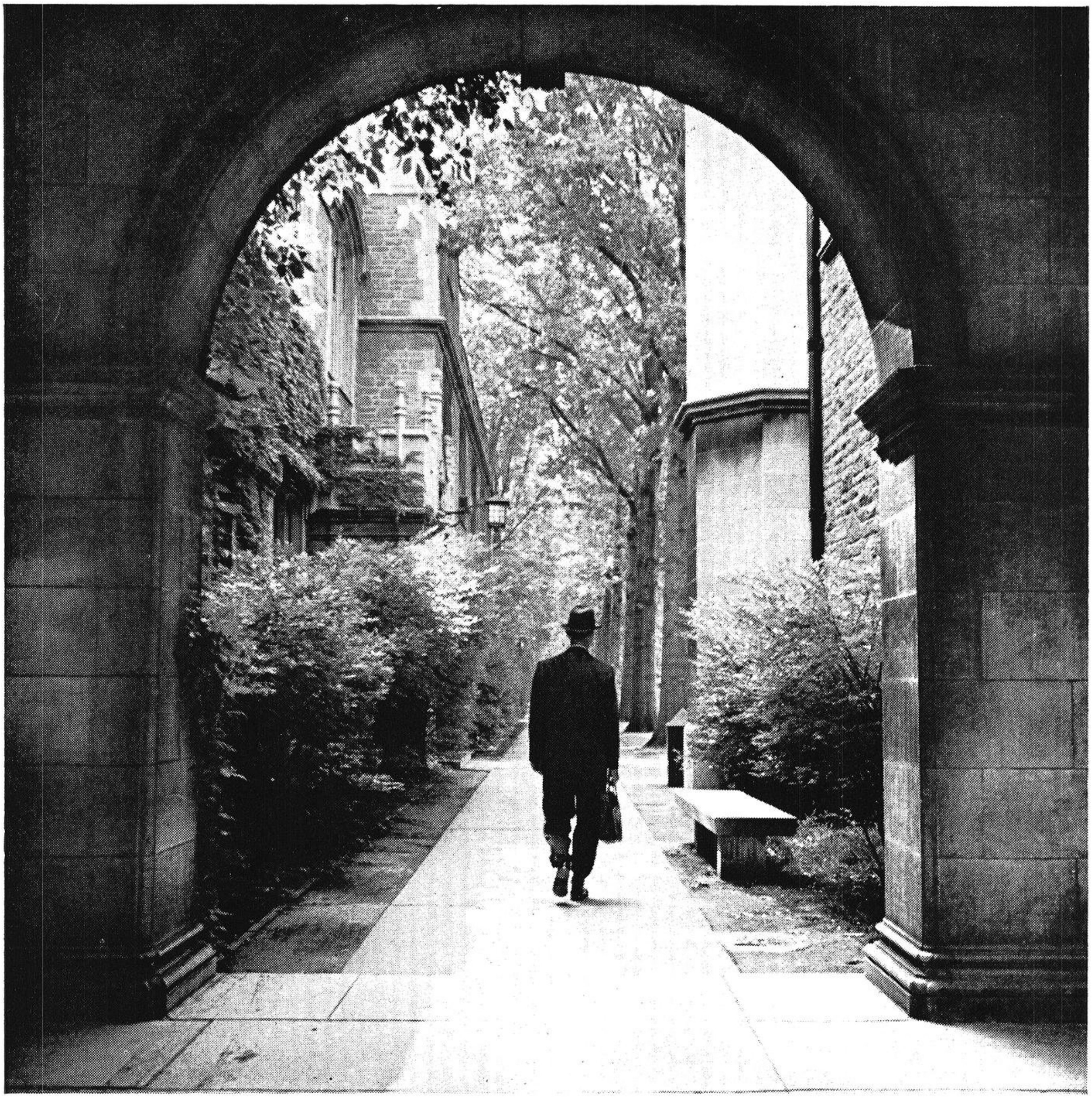


Fig. 6.

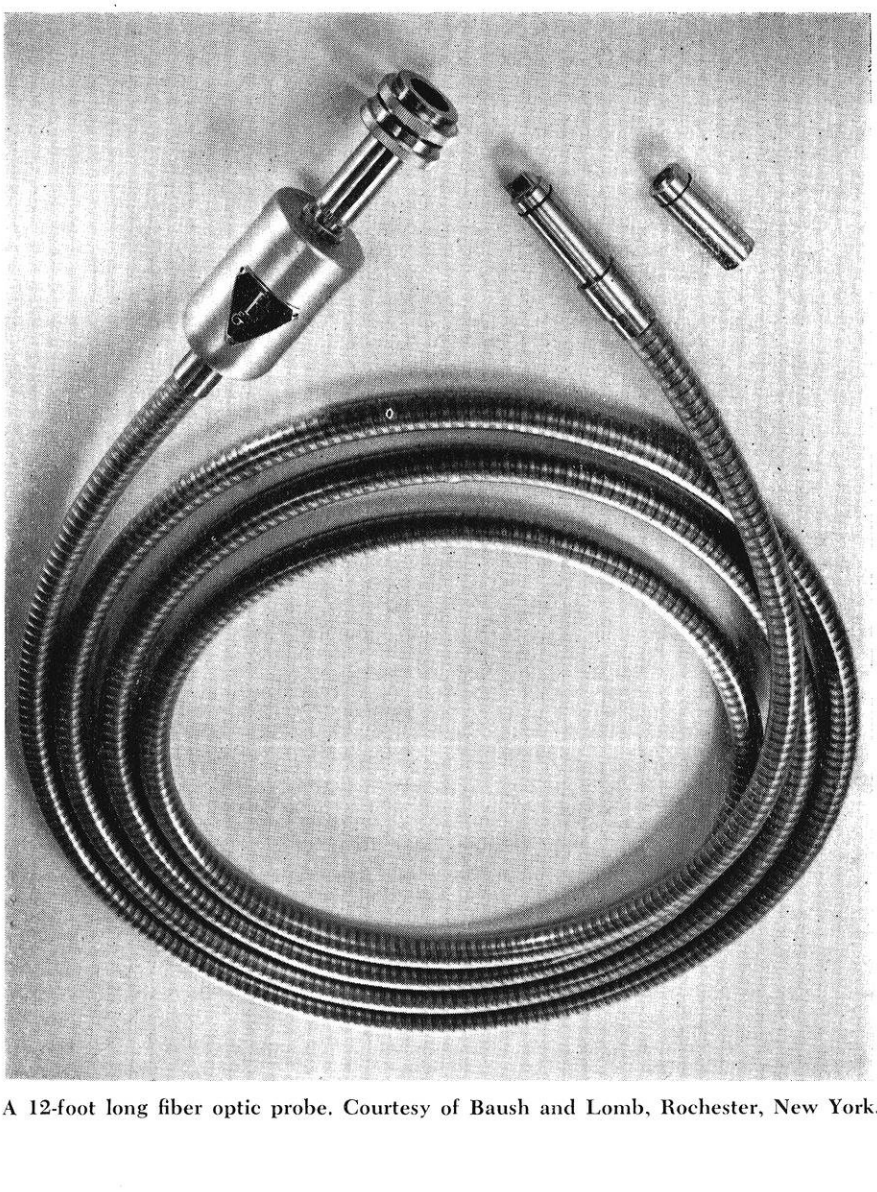




Fiber Optic Light Transmission

by T. O. Manning me'63

LOOK in any mechanic's tool box and you will probably find some sort of small hand mirror. What does he need a hand mirror for? He finds that a mirror enables him to see portions of a machine which are normally hidden from direct view. Suppose, however, that the details he wants to observe are well hidden behind many machine members. He would have to use a chain of several mirrors to project an image so it could be viewed. This is a rather complex way of examining hidden details and until recently, it was the only method a mechanic had at his disposal. Thanks to "fiber optics", a more versatile and efficient method of viewing hidden details has become a reality. Light pipes, made of transparent fibers, now carry images from places where image projection with mirrors would be impossible; places like the human stomach for instance.



A 12-foot long fiber optic probe. Courtesy of Baush and Lomb, Rochester, New York.

Fiber optic instruments not only lend themselves well to image projection, but also can be used to carry light for illumination purposes. Recent research in fiber optics has resulted in useful applications involving image shape alteration for photographic purposes. These few basic applications promise to make fiber optics a very useful tool for the engineer, the scientist, and the physician. Since visual observation is a very important aspect of research and development in engineering, science and medicine, it is natural that fiber optics should play an important role in these fields.

What is Fiber Optic Light Transmission?

Light transmission through any transparent media, be it glass, plastic, air or outer space, has puzzled man since the beginning of his existance on this earth. Many theories have been presented as to the nature of light, yet it was not until the twentieth century that light movement was successfully explained. Light is now considered to exist in the form of "electromagnetic waves" similar to radio waves.

The wave concept can be used to explain light behavior in all mediums, but it is rather difficult for the layman to understand the theory involved. Another theory of light transmission called the "ray theory" provides a simpler means of explaining light behavior in optical instruments containing lenses or transparent fibers. This theory holds that light consists of rays traveling in straight lines through optically homogeneous media. An image is made up of many such light rays.

To explain fiber optic light transmission it is convenient to use the ray theory. This theory accurately predicts light behavior in fibers having diameters greater than 2 microns (.00008″). The wave theory must be used to explain light behavior in smaller fibers because of reasons which will be explained later.

A single ray of light entering one end of a fine transparent glass, plastic or quartz fiber with very smooth surfaces is the basic model for all fiber optic instruments. The light ray will pass through the fiber and no matter how many curves are made in the fiber, some light will emerge from the other end. This phenomenon has been given the name "fiber optic light transmission". If an image composed of many rays is projected on one end of a fiber bundle, each fiber will serve as a conductor for a portion of the image. Similar arrangement of the fibers at both ends of the bundle permits a faithful reproduction of the original image when the rays emerge from the other end. The image will inevitably be grainy but this condition can be greatly improved by methods to be discussed later.

At first it appears that a light ray must bend as it passes through curved portions of a fiber. In reality, the ray does not curve; it merely follows a zig-zag path through the fiber, bouncing from wall to wall. A typical example of this is shown in Figure 1 where the zig-zag path is contained within the walls of the curved fiber. Even though the glass wall surfaces are transparent, very little light escapes each time the ray strikes the glass-air interface. The ray is retained in the fiber by a process of reflection called "total internal reflection". This type of reflection has been employed for many years in such optical equipment as the prism binoculars and the prism periscope. To see how total internal reflection works in a transparent optical fiber we must first establish a model to illustrate the phenomenon of "internal reflection".

Suppose a light ray traveling inside a transparent material like glass strikes the boundary or interface between glass and the surrounding air. Even if the ray is perpendicular to the interface when it strikes, not all the light would pass across the boundary. Some light would be reflected, and is therefore given the name "internally reflected light". When the angle between the incident light ray and the perpendicular is increased from zero, the amount of reflected light begins to increase slightly. When this angle, called the angle of incidence, is increased enough, a condition occurs where no light passes across the boundary into the air. This angle of incidence is called the critical angle because at this point most of the light travels along the glass-air interface and the rest is reflected. Once the angle of incidence is increased past critical, all the light is reflected into the glass. Whenever light strikes the boundary at angles greater than critical, the entire amount of light is reflected and is given the name "total internal reflected light".

Within a glass fiber, the light ray will be reflected from wall to wall as long as the angle of incidence is greater than critical. A ray of light striking the wall of a straight fiber at an incident angle of 60° will undergo approximately 7000 reflections per foot in some of the thicker fibers used. An increase in the number of reflections occurs as the fiber diameter is decreased. With so many reflections occurring in a 12 inch long fiber it is evident that the amount of light escaping with each reflection must be very small. As long as the fiber curvature is not too extreme, incident light will strike the walls at angles greater than critical, and the amount of light escaping will be negligible. Most of loss in light intensity will be attributed to absorption.

Total internal reflection is the most effective means of reflection known and this is the reason for using internally reflecting prisms instead of mirrors in the best quality binoculars.

Basic Applications of Fiber Optics

Image transmission is definitely the most important application of fiber optics. Optical bundles composed of many glass fibers carefully arranged and covered with a protective flexible casing enable man to observe many things normally hidden from direct view. He can look around corners, observe developments within a nuclear reactor, or even see inside the human stomach.

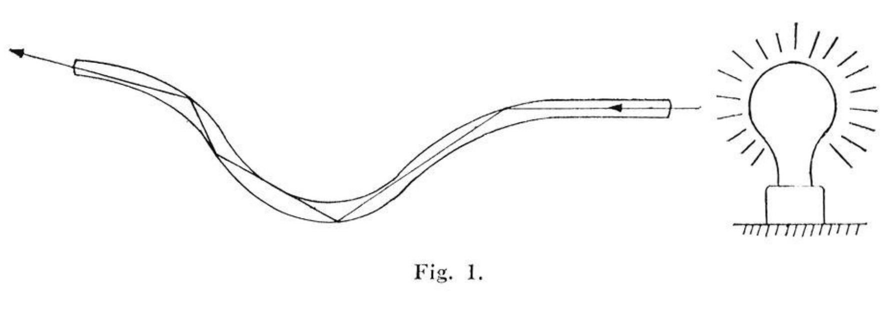


Fig. 1.

Fiber bundles having no aligned arrangement of the fibers can not carry an image through the bundle without scrambling it. This however is not a disadvantage because bundles of this type have two important uses. First, the bundle can provide a means of carrying bright light into dark recesses for illumination purposes. Second, the bundle can serve as a coder-decoder device. A photograph can be made through a bundle of scrambled fibers so that the image on the photograph will be a maze of colored spots. These spots, nevertheless, represent as many units of information as the original image that entered the objective end of the bundle. If the photograph is viewed through the objective end of the bundle, the observed image will be the same as the original. A duplicate of the original bundle, having the same fiber order and the same number of scrambled fibers, could be kept by one man for the purpose of unscrambling photographs made by another man with the original fiber scrambler. This application would be of definite interest to our Armed Forces since it would be impossible for an enemy to read scrambled information without the correct fiber bundle.

Fiber optic bundles called "image tranducers" are used to change the shape, appearance or size of a transmitted image. Bundles which change image shape usually start with a square shaped objective end. The bundle then tapers down to a thin line of fibers on the other end. This bundle can turn a normal image into a narrow slit of light, containing the same amount of information as the original image. Use of this bundle with a motion picture camera would permit extremely high speed photography. The images formed on film would be a series of slits instead of a series of square images; therefore the film would not have to move as fast to record the same amount of imformation. After the film was developed, the images could be projected back through the image transducer with the result being a pictorial reconstruction of the original details on a projection screen.

Image transducers which are drawn out so that the bundle is narrower at one end than the other can be used as light funnels. These funnels increase light intensity when the light enters the bundle's large end and emerges from the small end. Image magnification or reduction can be accomplished with a light funnel having a similar arrangement of fibers at both ends.

Construction Techniques Used to Increase Light Transmission Efficiency

The fibers used for light transmision are usually made with two types of glass: a main cylindrical fiber of high-refraction glass (small critical angle), coated with a thin layer of low-refraction glass (larger critical angle). The center fiber is drawn from a thick high-refraction glass rod in a special furnace, and it is then inserted in a lower-refraction glass tubing. The two glasses are then drawn together to a precise diameter; diameters of 0.001 inch can be achieved for a single fiber. Still finer fibers can be made by fusing several hundred 0.001 inch diameter fibers together, and drawing this bundle out. The result will be a "multifibered fiber" having individual units 0.00008 inch in diameter.

Since fiber bundles give rather grainy images, the resolution of fine detail is limited. Naturally the finer the individual fiber is, the greater the resolution obtainable. A bundle of fibers of the 0.001 inch size can be used to distinguish between lines 1/20 of a millimeter apart. A bundle of fibers of the 0.00008 inch size can be used to distinguish between lines 1/250 of a millimeter apart. Fibers are never drawn finer than 0.00008 inch in diameter because finer fibers act as wave guides, not ray guides, and the entering light rays will no longer stay isolated from one another as they pass through the bundle. The coating between fibers in a bundle must be thick enough to keep stray light from traveling between fibers when the fiber diameters approach 0.00008 inch. For visible light, a coating separation of one wavelength is sufficient under most circumstances.

Total light reflection occurs at the glass-glass interface of the fiber. The glass coating separates the cylindrical fibers from one another and protects the highly polished surface of the light conducting fiber. Without the coating, bending of the fiber bundle during service would greatly shorten the bundle's service life because of wear damage to the polished surfaces. Roughening these surfaces would greatly increase light loss. Light intensity loss in properly made fibers is mostly due to absorption in the glass, not to reflection losses. Even the absorption loss is not too excessive; about 1/4 percent per inch of fiber length. A 7-foot bundle can emit 50 percent of the entering light and 25 feet would just about be the maximum useful bundle length.

Colored photographs made through fiber optic lenses show that details in color are reproduced just as well as details in black and white.

Glass is now available that makes it possible to produce optic fibers with a critical angle as small as 50 degrees. Such a fiber could gather light from a cone-shaped field 180 degrees wide. This is an extremely good light gathering capability. Lenses have also been fitted on the ends of fiber bundles to increase the amount of light gathered and to focus the image before it passes through the bundle.

Generally, fiber bundles are enclosed in a rubber or metallic casing to protect the loose glass fibers. These fibers are bonded at the ends only and the remaining portions are left loose so the bundle can flex. Sometimes a difficult problem occurs when the object to be viewed through a fiber bundle is not sufficiently illuminated. This illumination may be accomplished by enclosing the aligned fiber bundle in a sheath of unaligned fibers. The unaligned fibers carry light from a bright lamp to illuminate the object, and the aligned fibers transmit an image of the illuminated object.

Fiber Optic Applications in Industry and Engineering

Fiber optic bundles are definitely becoming very useful tools for achieving better product inspection. The bundles enable inspection personnel to examine blind cavities and bores inside castings and weldments. Research personnel use fiber bundles to observe the manner in which hidden machine parts operate when the machine is in motion.

Mechanics can use the bundles to facilitate removal, repairs, and assembly of hidden machine components within assembled complex machinery.

Fiber bundles are being used to transmit light to photoelectric fire detectors. In situations where the ambient temperature is too high for a photoelectric cell to operate, a fiber bundle is used to transmit sufficient light from the flame area to the cell. Such a fiber bundle—photocell system could be used to monitor the burners in a large boiler installation or to detect jet-engine flameout. The optic fiber-photocell combination can be used in still another way. First a single uncoated glass fiber (rather thick in diameter) is immersed in a liquid medium. The critical angle for light traveling within the fiber is now dependent on the difference between the glass refractive index and the liquid refractive index. The fiber's refractive index is constant but liquid's refractive index is dependent on liquid composition. A small variation in composition therefore, changes the liquid's refractive index and the result is a change in the critical angle. If the cone of light which the fiber's objective end can gather is kept constant, the amount of light that reaches the other end varies with changes in the liquid's refractive index. Light emerging from the fiber is focused on a photoelectric cell. The electric output of the cell varies with changes in light input; therefore light variations due to liquid composition variations are indicated by the electrical output. The fiber-photocell system can detect refractive index changes with extremely good accuracy. By using a different refractive index, it is possible to determine refractive index changes in almost all fluids and solutions. The system works equally well for opaque liquids as well as transparent liquids. Feeding the photocell output into an appropriate servo system for chemical process equipment provides an automatic control of chemical processes.

Tapered fiber bundles called light funnels have also been used with photoelectric cells. The bundles gather weak light from a distant source and concentrate it directly on the photocell cathode thereby supplying a stronger incoming light source.

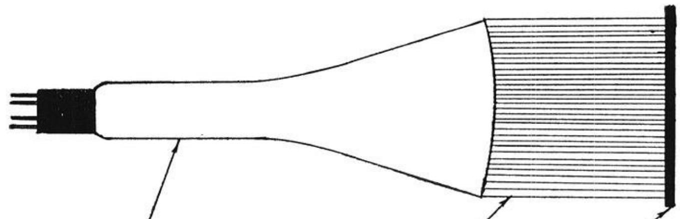


Fig. 2.

Fiber Optic Application in Photography

Light emitted from the cathode ray tube of a television set or an ocilloscope scatters and rapidly loses intensity; therefore some difficulty is encountered in getting enough light to make a good photograph of images formed on the tube screen. Figure 2 shows how a fiber optic lens has been made with a concave surface which exactly fits the tube surface. The fibers gather light which normally would be scattered, and they channel it directly to the photographic plate where it produces a good quality photograph.

Use of fiber optic bundles for high speed photography and image scrambling and unscrambling has been mentioned earlier in this article. One other important application is the formation of compound lenses for the purpose of correcting optical distortion. Images that normally enter a camera pass through a very small portion of the camera lens. The entire lens is not used because of the undesirable image distortion that would occur. Partial lens use does not utilize the entire amount of light which strikes the lens surface; therefore the amount of light which strikes the photographic film is limited. This results in longer exposure times. Coupling a lens of optical fibers with the regular lens corrects optical distortion and permits the entire lens to be used. More light can then enter the camera and exposure time will be reduced.

Medical Applications of Fiber Optics

As previously mentioned, a flexible fiber bundle called the endoscope has been produced for purposes of examining the inside of human organs (i.e. the stomach, the duodeum and portions of the kidney). Efforts are also being made to produce a slender fiber bundle which would pass through blood vessels making even the interior of the heart visible. Problems in making such a small fiber bundle are not difficult. The real problem occurs in providing a safe means for manipulating the bundle within the body.

Conclusions and Prospects for the Future

This report has presented most of the fiber optic applications that have been made to date. You have seen what a handy tool the fiber optic bundle can be when it is used to transmit images of objects normally hidden from direct view. You have also seen how a fiber bundle can change the shape of an image and how a bundle can carry light for illumination purposes.

Since the field of fiber optic light transmission is quite new, the optical instrument manufacturers are not yet mass producing a standard line of fiber optic instruments. Most of bundles now being used in medicine and in industry are custom built. These custom built bundles have proved to be extremely useful and the list of possible future applications is rapidly increasing. The few companies now producing these bundles have predicted that the future demand for these instruments will create a multi-million dollar business within the next two years. Most of this business will come from industrial firms because fiber optics is rapidly proving to be an indespensible tool in indus-

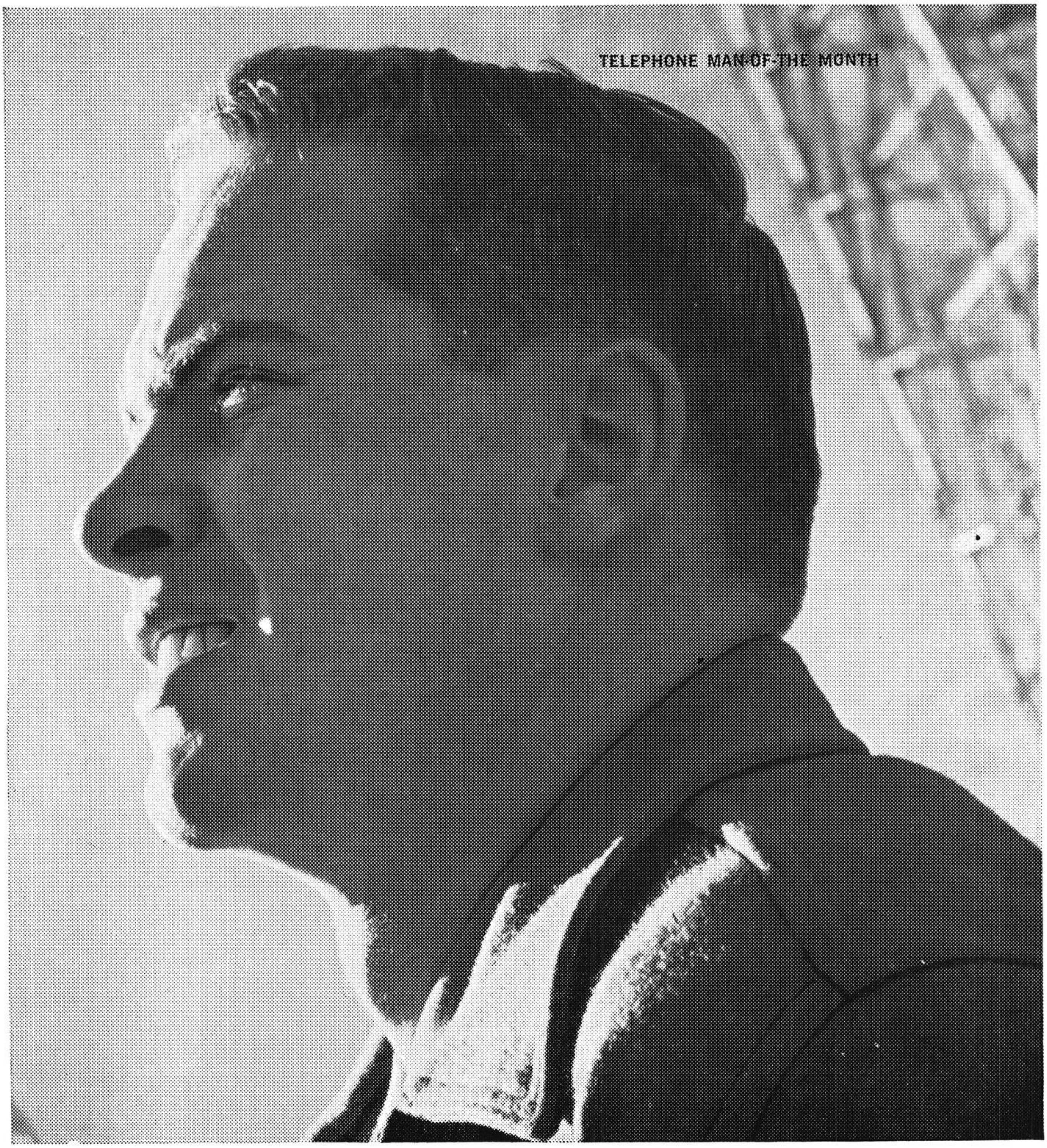
(Continued on page 37)

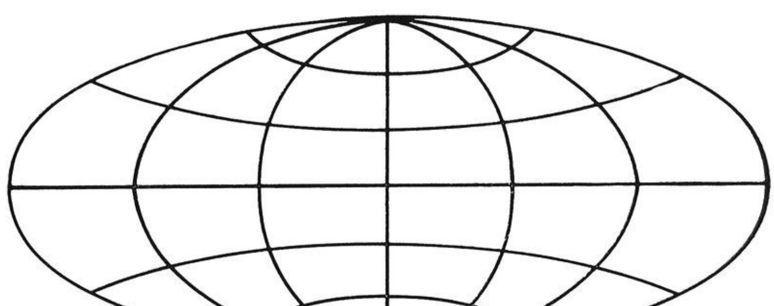
THE BELL TELEPHONE COMPANIES SALUTE: BILL PIGOTT

Six years ago Bill Pigott graduated from college with an engineering degree. Today he is responsible for the performance of 12 microwave relay stations, numerous communications cables, and other equipment. He also supervises the work of some sixty transmission specialists.

Bill Pigott of Pacific Northwest Bell Telephone Company, and the other young engineers like him in Bell Telephone Companies throughout the country, help bring the finest communications service in the world to the homes and businesses of a growing America.

BELL TELEPHONE COMPANIES





Thermoelectric Conversion of Heat to Electricity

by J. L. Kurz me'62

Our life revolves around electricity and its many uses. Most of us take electricity for granted. Yet many recent press releases and technical journals have announced advances in methods of converting heat directly to electricity. What is such a process? Is it new? What application does it have? Will it replace conventional methods of producing electrical power?

Although there are many methods known, one of the most promising is thermoelectric conversion of heat to electricity. This method of generation depends on the use of thermoelectric materials which produce a current when heated.

THREE principal thermoelectric effects were discovered over 100 years ago. In 1822 the German physicist Seebeck discovered that a voltage was developed in a loop containing two dissimilar metals, provided the two junctions were maintained at different temperatures. This was followed in 1934 by the French physicist Peltier's discovery that the passage of an electric current across the junction between two dissimilar conductors was accompanied by the evolution or absorption of heat. Some years later, in 1854, the great English physicist Lord Kelvin predicted that a temperature gradient existing in an electrically conducting material should be accompanied by a potential gradient. He also established a theoretical expression relating the findings of Seebeck and Peltier.

To many it seemed apparent that the Seebeck effect, if large enough, could become the basis of a very simple method of converting heat directly into electricity. In 1885, Rayleigh gave an approximate theory deriving the efficiency of such a process. Until recently, the maximum efficiency obtainable was less than one per cent, due to the very low thermoelectric voltages generated in the available materials, even at large temperature differences. No serious attempt to develop better materials was made before the 1930's, when Maria Telkes at the Westinghouse Research Laboratories made a thorough study of the Pb-ZnSb thermocouple. Through her work the potential thermal efficiency of thermoelectric conversion was raised from 0.5% to 5.0%. However, no practical use was made of her materials, presumably because of their lack of thermal stability.

The present resurgence of interest in thermoelectricity stems primarily from advances in solid state physics since World War II, and the desire of physicists to make practical applications in this field. As a result of this work a new class of materials, called semiconductors, has been developed. From some of these new materials it has been found possible to construct batteries of thermocouples (thermopiles) using semiconductor compounds which have higher performances than metals and alloys previously investigated. They have been used on a limited scale in the Soviet Union for direct conversion of heat to electricity. In the United States an Atomic Energy spokesman is reported to have said, "the next 20 years should see the replacement of conventional electrical generation equipment by thermoelectric devices in nuclear power stations."

Theoretical Principles

The physical properties of most materials are dependent upon the manner in which the electrons are distributed around the atom in the crystal lattice. As described by modern Bohr theory, the electrons occupy various energy bands in the atoms. It is the difference between the valence and the conduction energy states which determine whether a material is a metallic conductor, semiconductor, or insulator. In metals the energy difference is zero and the electrons are free to conduct thermal or electrical energy through the crystal lattice. In semiconductors the difference ranges from 0.1 to about 0.4 electron volts, and either thermal or optical excitation may cause the electrons to bridge this gap of energy difference. In insulators there are much larger gaps, across which the electron cannot be excited.

Once the electron has entered the conduction band, it and the positive hole it has left can take part in electrical conduction. The actual escape of electrons to create the flow of electricity can be compared to an ordinary steam cycle. In the steam cycle the steam molecules escape from the liquid phase to the gaseous phase at high temperatures, whereas in the thermoelectric process the electrons escape from a material A to a material B at high temperatures. At low temperatures the steam is condensed and transferred back to the liquid phase. In the thermoelectric process the electrons are transferred from material B to material A at low temperatures.

Many semiconductors possess a Seebeck coefficient much larger than metals. This property makes these materials very valuable as thermoelectric generators. Although other concerns have been investigating such materials, Westinghouse Corporation has been particularly active in the development of efficient thermoelectric materials. They have found that mixed valence compounds (oxides, sulfides, selenides, or tellurides) of transition metals (Mn, Fe, Co or Ni) which have a charge carrier built into them are effective thermoelectric materials at elevated temperatures. An example is $Li^{+}_{x}Ni^{++}_{1-2x}Ni^{+++}_{x}O$. In this case lithium ions are incorporated into the NiO lattice as a charge carrier. Every lithium ion introduced results in a surplus Ni(II) ion becoming a Ni(III) ion, since each oxygen atom wants to acquire two electrons. About 8 per cent of the transition ions are replaced by lithium ions.

These mixed valence compounds have several advantages over most other semiconductors:

1. They can be made from relatively abundant and inexpensive materials.
2. Since they are of a ceramic nature, they can be used at very high temperatures without decomposing or reacting.
3. They are not susceptible to traces of impurities.
4. They will not deteriorate on exposure to radiation.

Due to increased interest in thermoelectricity, other materials have been developed which compare favorably with known compounds. Just recently, Westinghouse developed a new material, an indium arsenide phosphide semiconductor. This material operates in a temperature range between conventional semiconductors and the mixed valence compounds. It helps to fill the gap in the spectrum of thermoelectric materials.

The potential performance of a thermoelectric material is governed by a material property of the semiconductor. This property is called the figure of merit, Z. The figure of merit depends on only three material characteristics:

S: Seebeck Coefficient
K: Thermal Conductivity
p: Electrical Resistivity

A Russian, Professor Jeffe, in his book "Semiconductor Thermoelements and Thermoelectric Cooling" uses the relation

$$Z = \frac{S}{pK}$$

to relate the figure of merit to the three material characteristics S, K, and p.

Thermal efficiency of thermoelectric generation is defined as the ratio of useful electrical energy delivered to the external circuit to the energy consumed from an external heat source. This efficiency is

$$\eta_{TH} = \left(\frac{T_1 - T_0}{T_1}\right) f(M, T_1, T_0, Z)$$

where T_1 is the mean temperature of the hot junction,
T_0 is the mean temperature of the cold junction,
M is the ratio of the external load resistance to internal load resistance,
Z is the figure of merit.

The first term is the expression for the efficiency of a reversible (Carnot) engine and the second term represents the reduction due to heat losses by conduction. The nearness of approach to the efficiency of a Carnot cycle is a function of the material property of Z and the ability to operate at high temperatures.

Design of a Thermoelectric Generator

A basic thermoelement (shown below in Fig. 1) consists of two blocks of semiconductors, electrically connected to each other and either to an external load or to other thermoelements. The supply and the removal of heat at alternate junctions maintains the temperatures at T_1 and T_0, respectively.

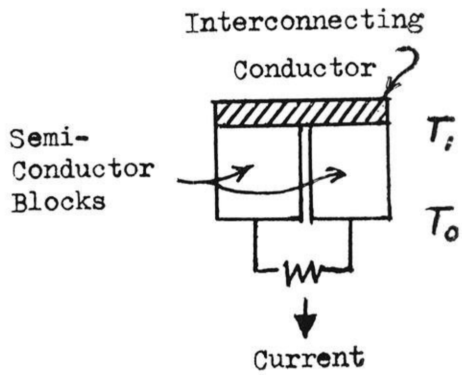


Fig. 1.

Construction of the thermopile is simply an assembly of thermoelements connected together either in series or in parallel to obtain the desired voltages or currents. Physically the elements are joined in parallel, as it is desirable to have all the hot junctions at one temperature and all the cold junctions at another. Fig. 2 shows the thermoelements in electrical series to form a thermopile.

The configuration of the thermoelectric generator is dependent upon the temperatures, pressures, and heating and cooling fluid flows associated with any particular system. Design of a practical generator involves provision of channels

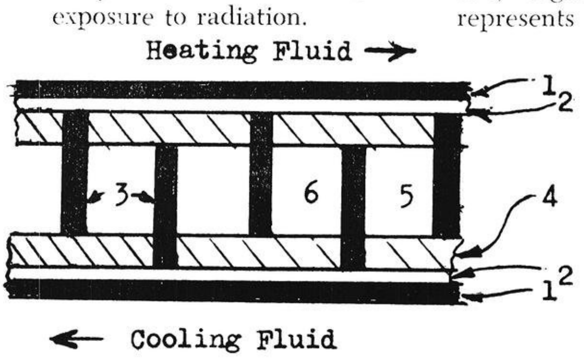


Fig. 2. Thermoelements connected in series to form a thermopile.

1. Cladding.
2. Material with good thermal conduction.
3. Material with good electrical and thermal insulation.
4. Interconnecting conductors.
5. & 6. Semiconductor blocks.

and headers for the flow of the heating and cooling fluids, and suitable electrical and mechanical connections.

The most obvious type of construction is a tube or a plate configuration as shown in Fig. 3 on the bottom of the page. In the tube construction it is favorable to have a low ratio of the external to internal diameter, as otherwise the variation of heat flux through the thermoelement is very wide. To improve the heat transfer coefficient the internal diameter should be kept small. The tube construction has the advantage of increasing the thermal and electrical contacts, since expansion will result as the high temperature medium is passed through the inner channel. This requires that the outer cladding possess a fairly high tensile strength.

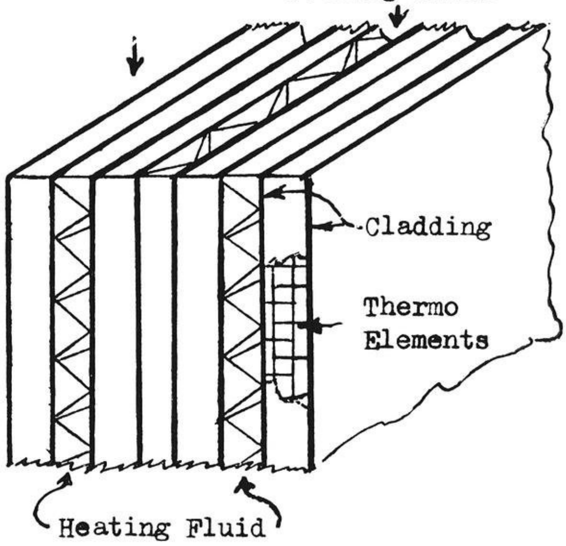


Fig. 4.

The plate type construction (Fig. 4) permits independent variation of the dimensions of the heating and cooling channels. The main disadvantage of this system is that distortion by thermal stress may limit the permissible heat flux, since the provision of strong cladding results in temperature losses through the cladding.

Design of a practical thermoelectric generator is influenced by available heat sources and heat sinks (low temperature heat rejection reservoirs). Fossil fuels may be burned to give high temperature gases which can transfer heat directly to the cladding surface of the hot junctions or to an intermediate medium, such as a circulating fluid. An intermediate transfer medium such as a gas or a liquid is usually used for nuclear fuel sources.

In order to obtain uniform power generation, it is highly desirable that the hot and cold junctions of the thermopile be maintained at constant and uniform temperatures; in other words the heat source and heat sink should be isothermal. For this consideration, liquid heating and cooling is advantageous, since isothermal conditions are nearly always achieved.

Heat transport is a function of the mass flow, specific heat, and temperature difference. The pumping power is proportional to the pressure and to the volumetric flow. A brief review of thermodynamics confirms that less work is needed to pump a liquid than a gas for the same heat transfer. Economics of the process also indicate that liquid heating and cooling is the most advantageous.

Rejection of heat will be ultimately to the atmosphere or to available cooling water. In most cases water is the best choice for a primary coolant. Only in small units, where a sacrifice in efficiency could be tolerated, could an air-cooled device be used.

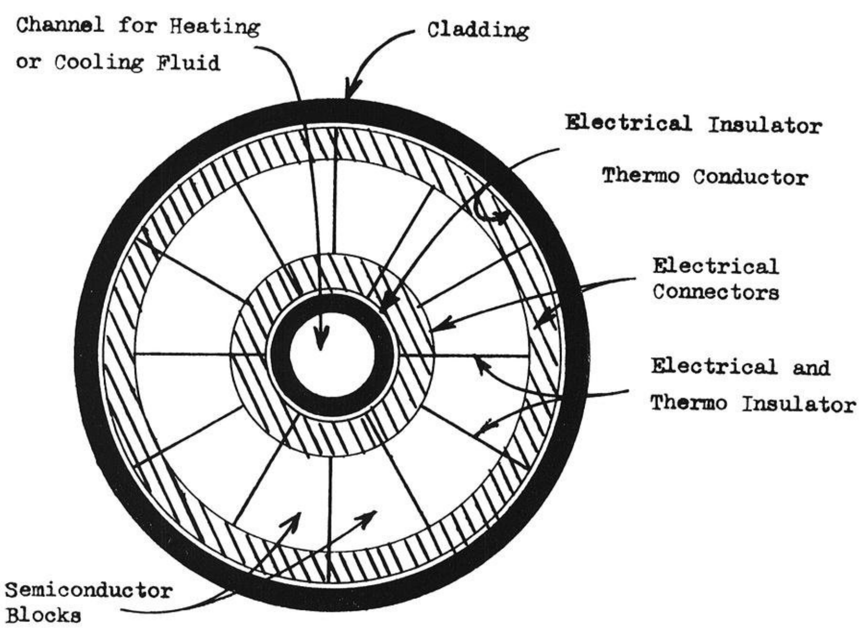


Fig. 3.

Applications of Thermoelectric Generators

Provided suitable heat and cooling arrangements can be made with an available heat source and cooling water, a wide range of applications are possible. Thermoelements can be multiplied indefinitely and the size of a power station would only be limited by economic considerations.

Immediate use of thermoelectric generators appears to center about special applications rather than replacement of steam cycle power stations. One application which has received quite a bit of attention is the use of thermoelectric generators for the direct conversion of solar energy to electricity. At present this method of harnessing this enormous influx of energy appears to be the most promising, as conventional methods seldom approach 10 per cent efficiency. Researchers all over the would have been working on methods of using solar energy to heat houses, cook food, pump water, and air condition. Two outstanding men working on these problems are Dr. Farrington Daniels and Dr. John Duffie of the University of Wisconsin Solar Energy Experiment Station. They are currently developing a solar powered unit using a Westinghouse thermoelectric generator.

Another prominent application is the generation of electricity for man-made satellites. It is conceivable that thermoelectric devices could use waste heat from rocket exhaust or waste heat from other sources. Another application is for stand-by emergency power. Within a few years we may see thermoelectric generators used in conjunction with nuclear power plants. Many other applications will undoubtedly be found in the future.

Current Developments

Applications of thermoelectric generators are dependent on the development of new materials and devices. Various developments are indicated in the following paragraphs.

As mentioned before, Westinghouse has developed a new thermoelectric material, an indium arsenide phosphide semiconductor. This material operates about the temperature range of conventional semiconductors but below the temperature range of the ceramic-like, mixed valence compounds. It fills the gap in the spectrum of thermoelectric materials.

Westinghouse and Carrier Corporation have received a contract from the U.S. Navy Bureau of Ships to build 5000 watt thermoelectric units. These units are in service at the present time. Diesel oil is the primary heat source although other fuels are also used. Sea water is used directly or fresh water, cooled by sea water, is used to maintain the cool side of the generator. The absence of moving parts makes these units particularly suitable for naval applications since detection is very difficult.

The Navy has issued a contract to Westinghouse to build a thermoelectric unit combining an air conditioner, space heater, and refrigerator-freezer in a single system. This unit will be tested for shipboard use.

A thermoelectric generator has been developed by Westinghouse for the Air Research and Development Command that has at least ten times the electrical output of any similar device ever built in the United States. The power delivered per pound is three times more than any previously developed generator of this type. It has been designated TAP–100 (terrestrial auxiliary power, 100 watt). The unit weighs 40 pounds and operates at 850 F. Although the original model burned propane, gasoline or kerosene could also be used. Currently Westinghouse is working on a model that will be fueled by radioisotopes.

Boeing Airplane Company and Westinghouse have jointly developed a thermoelectric device which operates on solar energy. The power unit weighs 3 pounds, is 20 inches long, and delivers 2.5 watt of power. Its weight and size make it ideal for space applications. For example, it could be used as a power source for radiotransmission.

Future Outlook

Future development of thermoelectric devices on a large scale will depend primarily on the economics involved, efficiencies, and specific uses for the devices. The Westinghouse people have indicated that they do not believe that thermoelectric power will replace large scale conventional systems of power generation. Rather it seems more logical that thermoelectric power will supplement current methods and find applications in special fields.

At the present time, thermoelectric materials are quite expensive. Therefore their use is prohibited by cost considerations, except in special, high priority situations. However, once technology is well developed it should be possible to manufacture thermoelectric generators more cheaply than conventional power systems, since thermoelectric devices have no moving parts.

Dr. Clarence Zener of the Westinghouse Research Laboratories has predicted that, in the foreseeable future, efficiencies up to 35 per cent will be obtained. This efficiency would be obtained by careful selection of certain thermoelectric materials, each of which when combined in series, would have a maximum electrical output over a certain temperature range. The materials would be used in stages to operate from a maximum of about 3500 F down to ambient temperature. Waste heat from one stage would be used as the heat source for the next stage.

It must be noted, however, that the cost factor is not always of primary importance in all instances. There are many important space projects that require small, efficient power systems. In many cases thermoelectric generators are the only logical choice and cost becomes a relatively insignificant factor.

Judging from the intense interest and research activity in thermoelectricity currently, it seems evident that thermoelectric devices are a welcomed addition to the conventional power systems now in existance.

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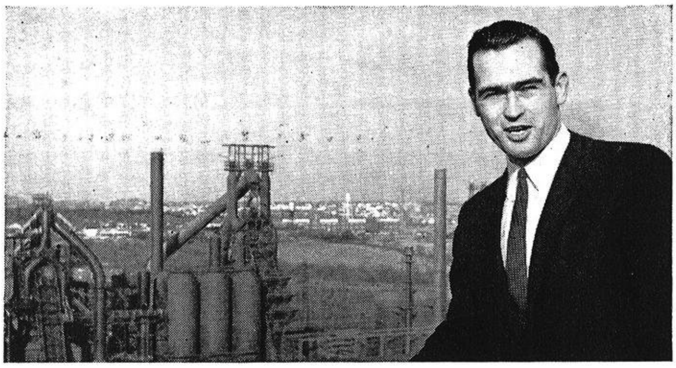
M.E.: "What well developed arms you have."

Coed: "Yes, thank you. I play tennis."

M.E.: "Ride horseback too?"

• One in a series of messages on how to plan your career



Hopping or marching— two paths to a career

A career is sometimes defined as a succession of jobs, whether with a succession of employers, or within a single company.

A man is commonly said to be "hopping" when he progresses by switching from one employer to another.

The man who sticks with a single employer can be said to progress by "marching."

Marching Pays Off—There are many advantages to a one-company career. It's obvious that tenure is accompanied by status, security, and benefits that build in value as the years go by. More significant, perhaps, are the *intangibles*. You can't put a dollar value on your familiarity with the organization and the people in it. And the respect they have for you is equally important. The man who is dedicated to his employer, and confident of his ability to progress without looking afield, is free of distracting tensions, free to concentrate his full energies on the job at hand. And, especially to the family man, just "being settled" is mighty reassuring.

Finding the Right Employer — The problem facing a graduating senior is to locate a prospective employer that offers an ambitious man promising opportunities for a truly rewarding and satisfying career. The best answer we know of is to look for a company with a firm policy of "promotion from within." And a second consideration is the size and scope of the organization.

Loopers are Career Men—Every year Bethlehem Steel Company enrolls a group of graduating seniors in the Loop Course—the entire class makes an observational circuit (or "loop") of a steel plant during the basic training period. We select qualified men for the Loop Course on the basis of their potential for careers in management, and we train them accordingly. There are about 2,000 loopers on the job at Bethlehem, at all supervisory levels, and in all of our diverse operations.

The Loop Course—New loopers report to our general headquarters, in Bethlehem, Pa., usually early in July. They attend a basic course of five weeks, including lectures, classroom discussions, educational films, and daily plant visits. The Loop Course is *not* a probationary period. After completion of the course, every looper receives his first assignment. Then, after reporting to a plant, yard, or home office division, he receives further orientation before beginning on-the-job training. Bethlehem loopers embark on their careers with thorough training behind them.

Big and Diversified—Because of its size and diversity, Bethlehem Steel offers unlimited opportunities to "get ahead." One of the nation's largest industrial corporations, with over 140,000 employees, we are engaged in raw materials mining and processing; basic steelmaking and the production of a wide range of steel products; manufacturing; structural-steel fabricating and erecting; and shipbuilding and ship repair. A new centralized research facility, the Bethlehem Steel Company-Homer Research Laboratories, costing in excess of $25 million, located in Bethlehem, Pa., rivals the finest in any industry.

Read Our Booklet—The eligibility requirements for the Loop Course, as well as a description of the way it operates, are more fully covered in our booklet, "Careers with Bethlehem Steel and the Loop Course." It will answer most of your questions. Copies are available in most college placement offices, or may be obtained by writing to Manager of Personnel, Bethlehem Steel Company, Bethlehem, Pa.

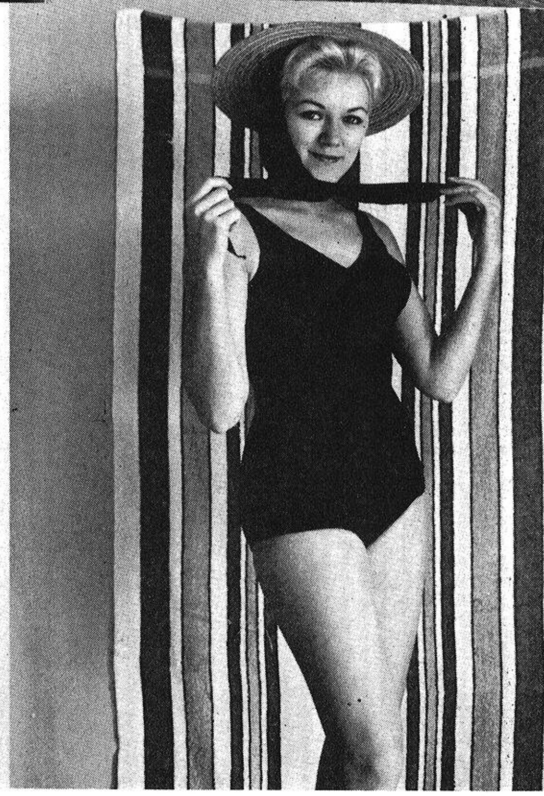
All qualified applicants will receive consideration for employment without regard to race, creed, color, or national origin.

Steel

BETHLEHEM STEEL

BETHLEHEM STEEL



"GIRL OF THE MONTH"

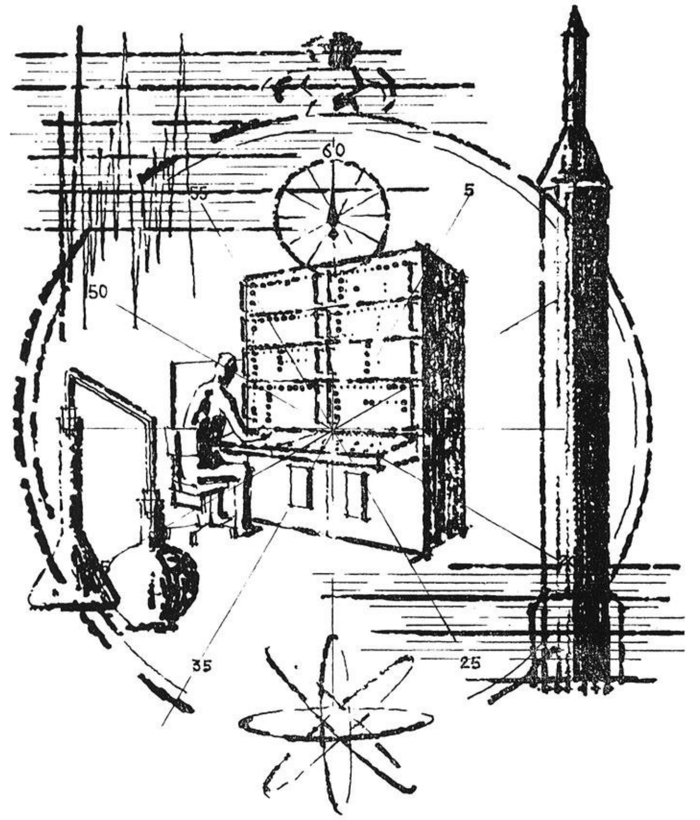
One night while looking for a place to eat and drink, we were happy to be approached by a beautiful blond waitress at the place where we stopped.

While chatting with her, we found that Miss Nancy Duzinski was a part-time waitress working her way through the "U" while studying art.

Nancy is a senior in art, 22 years old and 5′–7″ tall. She is now a Madison resident, having moved here from Reedsburg four years ago.

Her hobbies include swimming, ice skating, horseback riding and bicycling.

At the present time the photo editors are looking for a bicycle built for three.



SCIENCE HIGHLIGHTS

by John C. Ebsen ee'65

2 CYCLE ENGINE WITH OIL CAP

A new DKW engine with a revolutionary automatic oil injection lubrication system was announced today by Lon A. Fleener, president of Mercedes–Benz Sales, Inc. exclusive distributor for Mercedes–Benz and Auto Union–DKW cars in the U. S.

"The new oil injection system is tantamount to an automotive engineering break-through," Fleener stated, "since no other automobile engine is lubricated at all times by metered amounts of oil. The idea of an automatic oil injection system is not new and has probably been the long time hope and goal of every manufacturer of two-cycle engines. Indeed, this new technological developement is so significant that it opens up an entirely new dimension for automotive engine design and economy of operation since the ratio of oil to gas is now greatly reduced from 40-to-one to 100-to-one for normal driving and can go as low as 200-to-one depending on engine speed and load," Fleener reported.

The amount of fresh oil injected into the engine at the carburetor is dependent on engine revolution and load. With a light load or or when the engine is operating out of gear or in an idling position the amount of oil will be relatively small. Conversely, when the engine is operating at full throttle, the injection system will automatically meter the required amount of oil to properly lubricate the engine. Consequently, spark plug fouling, common to less advance two-cycle engines, due to too "rich" a combination of oil and gas is impossible. Fresh oil lubrication has the added advantage of increasing the life of the engine.

Fleener reported that the immediate advantages of the new DKW engine is that it now offers the convenience of four-cycle engines with the proved advantages of the two-cycle power plants. Offensive "smoking" common to conventional two-cycle automobiles has been completely eliminated with the development of the new metered oil injection system, Fleener added. There is no oil to change or filter to clean or replace. Another advantage of the automatic lubricating system is the provision of a separate oil reservoir with an oil supply indicator light mounted on the dashboard. Previously, oil was mixed in the gas tank.

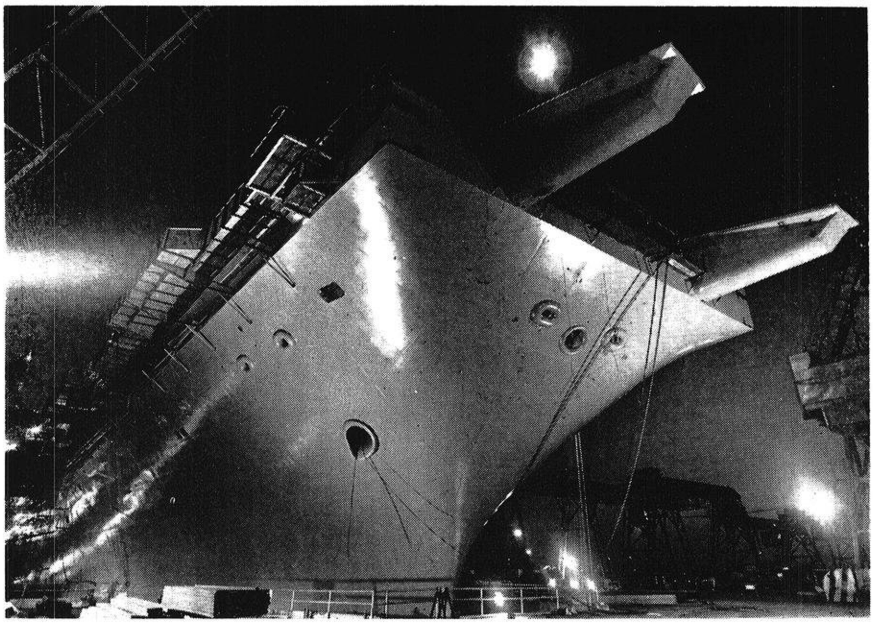
The engine also features pistons of a new alloy metal requiring considerably less lubrication while the main bearings are permanently sealed in a special lifetime lubricant. Torque for the new 800 c.c. engine has been increased from 47 to 52 at 2,500 r.p.m.

BETTER TOOTHPASTE

A dentifrice that requires no brushing and is in tablet form is due to appear on the market, says Chemical Week, McGraw–Hill publication. The single-use foaming tablet is simply swirled about in the mouth.

ELECTRONIC TYPEWRITER

Electric typewriters are still replacing hand-powered models, and now an electronic typewriter has been developed, Electronics, McGraw-Hill publication, states. The electronic machine uses a "type wheel" instead of individual type bars, permitting rapid writing, precise letter alignment and fast, easy type-face changes, simply by lifting off one type wheel and putting on another.



The Enterprise.

WORLD'S MOST POWERFUL ATOMIC ENGINE TO DRIVE CARRIER ENTERPRISE

The aircraft carrier Enterprise, christened at Newport News, Va., on September 24, will have a nuclear propulsion plant capable of driving this largest ship ever built at a speed of over 25 knots. The Enterprise's propulsion system will use eight reactors to supply the power to drive four propellers, each the height of a two-story house.

The atomic reactors were developed and designed by Westinghouse Electric Corporation under the direction of and in technical cooperation with the Naval Reactors Branch of the Atomic Energy Commission. The work was done at the Bettis atomic power laboratory, Pittsburgh, Pa., which Westinghouse operates for the AEC.

Philip N. Ross, general manager of the Bettis labtoratory, said that eight reactors will run the Enterprise for years without refueling. It is estimated that nuclear power will multiply by some 20 times the distance the Enterprise can travel at full speed without refueling as compared with the conventional oil-fired carriers. Dependence on far-flung bases and auxiliary ships is thus minimized.

While the Enterprise propulsion system is unique in naval history both in design and power, its prototype already has proved its feasibility. In 1956, the AEC began construction of a land-based prototype nuclear power plant for the Enterprise. This prototype plant consists of the machinery for one of the four shafts of the carrier and includes two nuclear reactors. This prototype is located at the Naval Reactor Facility in the Idaho desert and is housed in a replica of a section of the ship's hull, complete in every detail.

In September, 1959, the two prototype reactors of this "desert ship" were operated in tandem to drive a single propeller shaft at full power —the first time two reactors had ever been harnessed together.

The Newport News Shipbuilding and Dry Dock Company was responsible for construction of the Enterprise and also the surface ship prototype in Idaho. The reactor plant components for the Enterprise and her prototype in Idaho were supplied by hundreds of United States industrial firms.

Each reactor in the Enterprise system includes a steel pressure vessel, which houses the nuclear core. Pressurized water picks up heat generated in the core, and then flows through heat exchangers, to produce steam for the steam turbines that drive the propeller shafts of the Enterprise.

The propulsion units were manufactured by Westinghouse at its steam division at Lester, Pa. Each of the carrier's engine rooms has giant turbines, reduction gears, condensers and associated machinery.

Heavy jet bombers and fighters aboard the Enterprise will be ferried to the flight decks by elevators supplied by the Westinghouse elevator division, Jersey City, N. J.

Hydraulically powered, the elevator platforms weigh about 210,000 pounds each and have an area of almost 4000 square feet. Each of the four giant deck-edge elevators will be capable of lifting a 45-ton bomber from hanger to flight deck in 15 seconds. Thus, the four elevators combined can ferry four planes every minute to the flight deck. Pilots aboard the carrier will also be speeded to their planes by two Westinghouse passenger elevators.

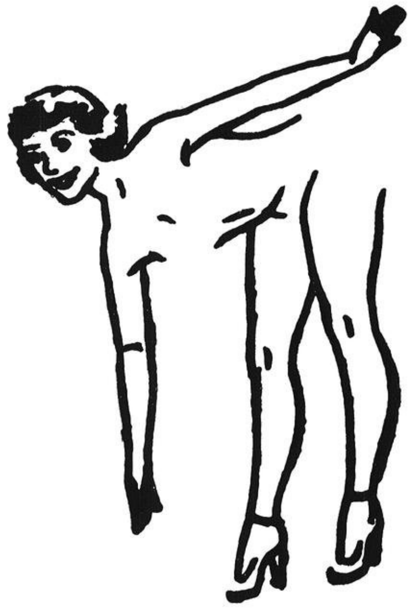
Westinghouse is also supplying the Enterprise with auxiliary generators and switchgear from its East Pittsburgh division; motors and control equipment from Buffalo, N. Y.; standard control equipment from Beaver, Pa.; transformers from Sharon, Pa.; and ventilator fans from the Sturtevant division, Hyde Park, Mass.

STEERING KNOBS

Knobs soon may replace the conventional steering wheel in cars, states Product Engineering, McGraw–Hill publication. The two knobs, interconnected, are arranged on a board and mounted on the standard steering column, to permit steering with either one or two hands. (Ed. Note: General Motors has announced plans to introduce the innovation on certain models of its 1962 Oldsmobile.)

ELECTRONIC NOSE

Midwestern research workers are trying to build an electronic nose that would detect smells according to changes in the electrical potentials on its surface, Electronics. McGraw–Hill publication states. The nose could be used in studying food aromas, food spoilage, industrial or military warning systems and even for finding out if there are smells in space.



Fill in your Own Lines

by Ronald Neder

The freshman's father paid his son a surprise visit. Arriving at 1 a.m. he banged on the fraternity house door. A voice from the second floor yelled, "What d'ya want?"

The father answered, "Does Joe Jones live here?"

The voice answered, "Yeah, bring him in."

° ° °

A farmer was phoning a veterinarian. "Say, Doc," he said, "I've got a sick cat. He just lays around licking his paws and doesn't have any appetite. What shall I do for him?"

"Give him a pint of castor oil," said the vet.

Somewhat dubious, the farmer forced the cat to take a pint of castor oil. A couple of days later he met the vet in town.

"How's your sik calf?" inquired the vet.

"Sick calf! That was a sick cat I had."

"My gawd, did you give him the pint of castor oil?"

"Sure did."

"What, what did he do?" asked the vet.

"Last time I seen him," said the farmer, "he was going over the hill with five other cats. Two were digging, two were covering up, and one was scouting for new territory."

° ° °

Everyday the guards in the Russian work camp checked out the workers as they left the grounds, to prevent stealing. For several days a guard had been closely watching a particular worker pushing out a wheelbarrow full of old straw and hay. Everyday the guard examined the straw, very suspiciously, but could find nothing hidden in it.

One day, after inspecting the wheelbarrow, he said, "Look, comrade, tomorrow I'm being transferred to Siberia. I'll never see you again and I promise to keep your secret . . . What in the Devil are you stealing?"

"Wheelbarrows," he whispered.

° ° °

"Let me kiss those tears away, honey," begged the ardent lover. She fell into his arms, and he was very busy for a few moments; still the tears flowed on.

"Will nothing stop them?" he asked breathlessly.

"No," she murmured, "it's hay fever, but go on with the treatment."

° ° °

Three ways to break up a dinner conversation: 1. Ask the lady on your right if she is married. If she says yes, ask her if she has any children. If she says no, ask her how she does it. 2. Ask the lady on your left if she is married. If she says no, ask her if she has any children. 3. Lean across the table and ask the lady facing you if she has any children. If she says yes, ask her if she is married.

EE.: "Thought you were going to visit that blonde in her apartment."

C.E.: "I did."

E.E.: "How come you're home so early?"

C.E.: "Well, we sat and chatted awhile. Then suddenly she turned out the lights. I can takea hint."

° ° °

A man in the insane asylum sat fishing over a flower bed. A visiting sociology student, wishing to be affable, asked, "How many have you caught?"

And the fisherman returned "You're the ninth."

° ° °

The husband answering the phone said: "I don't know; call up the weather bureau," and hung up.

"What was that?" asked his wife.

"Some fellow asking if the coast was clear."

° ° °

Two morons each had a horse, but they couldn't decide which belonged to whom. So they cut the mane off one to differentiate, but it soon grew back. Next they cut the tail off one, but that also grew back. Finally they measured them and found that the black one was four inches taller than the white.

° ° °

Professor: "I won't begin the lecture until the room settles down!"

Voice from the rear: "Why not just go home and sleep it off?"

(Continued on page 34)

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For detailed information, visit your placement director, obtain the brochure, "Raytheon's Advanced Study Program," and arrange an on-campus interview. Or you may write directly to Mr. G. C. Clifford, Coordinator of College Relations, Raytheon Company, Gore Bldg., Watertown, Massachusetts.

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LIFE OF A JOKE

One minute: Freshman thinks of a joke and tells it to his girlfriend.

One day: Joke circulates through girl's dorm and then is told to senior engineer by his date.

One week: Senior sends joke to campus magazine (us), claiming origination to himself. Humor page writer thinks joke is miserable, but since deadline is overdue, and he is desperate for five lines, he decides to use it.

One month: Joke appears at bottom of gag page. Humor page writer is forced into exile.

One year: Joke circulates through every engineering college magazine from Alabama to Canada, and from New York to Oregon.

Two years: Gag writer for radio program finds local college magazine on bus and sees joke. Joke appears on Disc Jockey program. Gag writer loses union card.

2½ years: Reader's Digest prints joke from radio program.

4 years: College professor finally gets around to reading the issue of Reader's Digest and laughs heartily at joke.

5-30 years: College prof uses joke to start off his lectures at beginning of each term.

35 years: Joke passes on as does college professor.

* * *

Connect 20,000 volts across a pint. If the current jumps it, the product is poor. If the current caused a precipitation of lye, tin, arsenic, iron, slag, and alum, the whiskey is fair.

If the liquor chases the current back into the generator, you've got good whiskey.

Then there was the forlorn engineer who, on seeing a pigeon flying overhead, exclaimed, "Go ahead, everyone else does."

* * *

Getting a Joke Column is Rough. If it's funny enough to tell, it's been told; if it hasn't been told it's too clean; and if it's dirty enough to interest an engineer the editor gets kicked out of school.

* * *

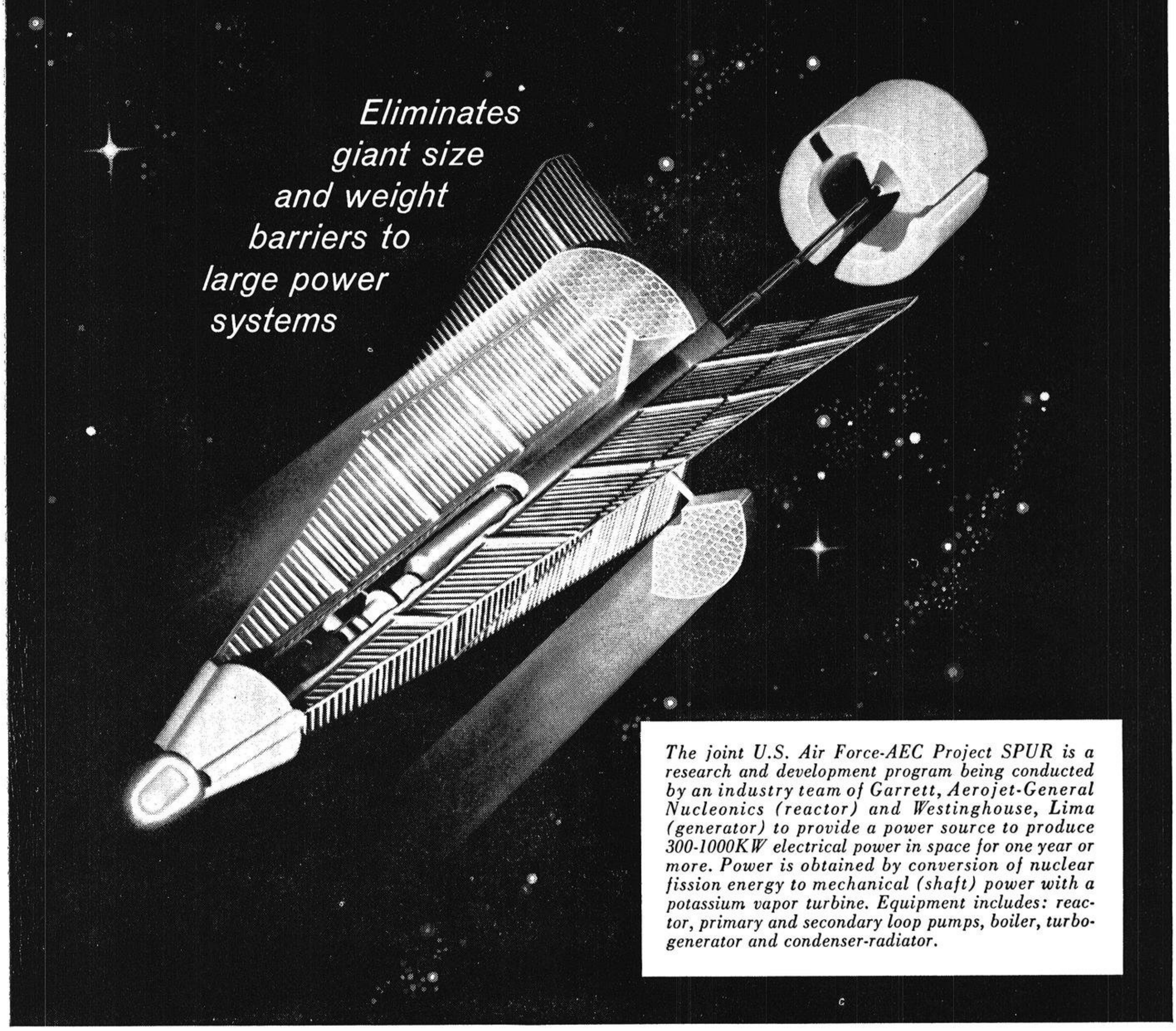
Engineers are continually surprised to find that girls with the most streamlined shapes offer the most resistance.

* * *

Nothing helps a girl stay on the straight and narrow so much as being built that way.

GARRETT-U.S. AIR FORCE 'SPUR'

..one answer to America's future power needs in space



The joint U.S. Air Force-AEC Project SPUR is a research and development program being conducted by an industry team of Garrett, Aerojet-General Nucleonics (reactor) and Westinghouse, Lima (generator) to provide a power source to produce 300-1000KW electrical power in space for one year or more. Power is obtained by conversion of nuclear fission energy to mechanical (shaft) power with a potassium vapor turbine. Equipment includes: reactor, primary and secondary loop pumps, boiler, turbogenerator and condenser-radiator.

Long lead time is essential to the development of large nuclear space power systems. Present methods of power generation would require an impractical heat rejection surface nearly the size of a football field for a power output of one megawatt—power which will be needed for critical space missions already in the planning stage.

Garrett's AiResearch Divisions have now completed the initial SPUR design studies and proved the project's feasibility to supply continuous accessory power and low thrust electrical propulsion in space for long periods of time.

Cutting projected 1 MW power systems to 1/10th the size and 1/5th the weight of present power systems under development will be possible because of SPUR's capability to operate at higher temperatures, thereby sharply reducing the required radiator area.

Garrett has been working with the Air Force and the Atomic Energy Commission on SPUR as the prime contractor for more than one year and has more than five years of experience in space nuclear power development. Also an industry leader in high speed rotating machinery, heat transfer equipment, metallurgy and accessory power systems, the company is developing design solutions for SPUR in these critical component system areas.

For information about a career with The Garrett Corporation, write to Mr. G. D. Bradley in Los Angeles. Garrett is an "equal opportunity" employer.

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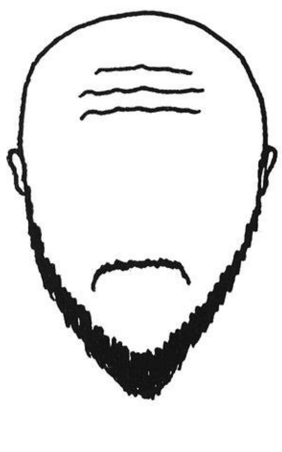

BRAIN BUSTER

by L. L. Chambers

1. A C. E. has been asked to lay out a road around a new townsite on a ten mile square plot of land. The town's developers have two requirements for the road; it must be as short as possible but must also enclose as much of the townsite as possible. Also the road is to be entirely within the townsite. What shape must the road have?

2. Four Wisc. engineers and an M.E., E.E., C.E., and a Chem. E., met at a party many years after graduation. All had married. Their wives were a Wisc. girl, an S.M.U. girl, a Texas girl, and a hometown sweetheart though not respectively. At one time during the evening the Wisc. girl was dancing with the M.E., the S.M.U. girl was dancing with the Texas girl's husband, the hometown girl was dancing with the S.M.U. girl's husband, the C.E. was dancing with the Chem. E.,s wife and the Chem. E. was dancing with the M.E.'s wife. Who was married to whom?

3. Snow began to fall in a northern city one morning. At noon a snow plow set out to clear a road. The plow was able to clear one mile during the first hour and a half mile the second hour. Assuming that the snow falls at a constant rate and that the plow can remove a given amount of snow per hour, what time did it start snowing?

4. If 'm,' 'c', and 'p' represent common fractions; and in the freshman class 'm' of the freshmen flunk math, 'c' flunk chemistry, and 'p' flunk physici: what is the least possible number of freshmen who flunked all three of these courses?

5. Some men sat in a circle so that each had two neighbors; and each had a certain number of dollar bills. The first had \$1 more than the second, who had \$1 more than the third, and so on. The first gave \$1 to the second, who gave \$2 to the third, and so on, each giving \$1 more than he received, as long as possible. There were then two neighbors, one of whom had 4 times as much as the other. How many men were there? How much had the poorest man at first?

5. Given two equal squares, in different horizontal planes, having their centers on the same vertical line, and so placed that the sides of each are parallel to the diagonals of the other, and at such a distance apart that, by joining neighboring vertices, 8 equilateral triangles are formed. Find the volume of the solid thus enclosed. Assume that each side of each square = 2.

The following answers are for the December Brain Busters.

The sequence is the same as that of the problems.

The answer to this problem is not 60, but 55 sheep. If it takes 10 sheep 10 minutes to jump a fence —the time being measured from the jump of the first sheep to the jump of the tenth—then the interval between jumps is 10/9 of a minute. There are 60 ÷ 10/9 or 54 such intervals in an hour, so that 55 sheep jump the fence in this time.

Imagine that 100 people pass Hans walking North at 4 miles an hour, and 100 pass him walking South at 4 miles an hour.

The Renzi, if driving North at 4 miles an hour *wouldn't pass any* walking North at the same rate, but he would pass 200 walking South! or the same number in all. What he said was wrong.

Egbert, if driving North at 8 miles an hour, would pass 100 people walking North and 300 walking South. Hence he'd pass 400 in all. His statement was right.

Pedro, driving North at 12 miles an hour, would pass 200 walking North and 400 walking South. That is, 600 in all, or 50% more than Egbert. What he said was wrong, but he has the right idea.

A = 10430
B = 3970
C = 2114
D = 386

93 feet

1st trip = 15 m.p.h.
2nd trip = 45 m.p.h.
3rd trip = 90 m.p.h.

Eldest	\$ 75
2nd	\$375
3rd	\$525
Hospital	\$825

Three miles

Sally is 22 years and eight months old.

Fiber Optic Light Transmission

(Continued from page 17)

trial research and product development and control.

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Nuclear Power For Aircraft

(Continued from page 11)

it will have a high concentration of weight in the form of reactor and shielding. The highly concentrated mass of reactor and shielding will be something new. In chemical aircraft, structural load relief can be obtained by distributing fuel in the wings. In a nuclear-powered aircraft, the total fuel supply will be in the reactor eliminating fuel storage in the wing. Some load distribution can be obtained by placing the heat exchangers between primary and secondary cycles in the inboard sections of the wings, that is, considering a closed cycle system turbojet is used.

Another new concept for structural engineers will be the design of landing gear. In present day aircraft, especially bomber type planes, the landing weight is assumed to be considerably less than take off weight because the fuel supply has been depleted. Take off weight and landing weight of a nuclear aircraft will be constant. The weight of fuel used measured in grams will reduce landing weight by nothing.

Flight Reliability

Directly related to the design of an airplane is the reliability of the plane.

The present day chemical-powered airplane has high reliability designed into it. By "reliability," I

(Continued on page 38)

Nuclear Power For Aircraft

(Continued from page 37)

mean the absence of total failure, which in the case of a four engine plane could be the loss of two engines. High reliability has been achieved by excellent design, development, testing, many years of working experience and redundancy of systems. The one characteristic which has provided the greatest reliability is the redundancy of components and systems. Because items like spark plugs, magnetos, fuel pumps, and other multi-installed accessories make up a small percentage of total weight, it is possible to duplicate them.

Flight reliability of a nuclear aircraft will also depend upon redundancy where feasible. Unduplicated components, such as the reactor and heat exchangers, will have to be designed and tested for high reliability, unless a dual reactor system were to be installed which seems quite remote at the present time.

Conclusion

Since reliability and safety play major roles in all aircraft design, they will greatly influence the many decisions to be made in regard to a nuclear-powered aircraft. The nuclear aircraft has added even greater importance to the word safety. Not only is there the safety of the flight crew and ground crew to be considered, but also the inhabitants of the world which it passes over.

Reliability-wise the open cycle turbojet is much less complex, but safety-wise the closed cycle turbojet doesn't leave a trail of radioactive exhaust. It is my personal opinion that although at the risk of endangering human lives for the sake of achieving an engineering goal, a nuclar-powered open cycle turbojet could be fitted into a large, present day bomber and flown. However, I believe that now with the announcement of the successful ground tests of the open cycle engine it could be done in less than a year.

Unless the need of accomplishment becomes too great, I feel the first nuclear aircraft flown by the United States will be a closed cycle turbojet engine power by a nuclear reactor in an airplane designed and constructed solely for this purpose. Considering there is a vast amount of design and development required for a complete new airplane, it is more than likely the first nuclear plane will not be flown for the next two to three years. After this, there will still be many years pass before you and I will step up and purchase a ticket for commercial nuclear air flights.

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* * *

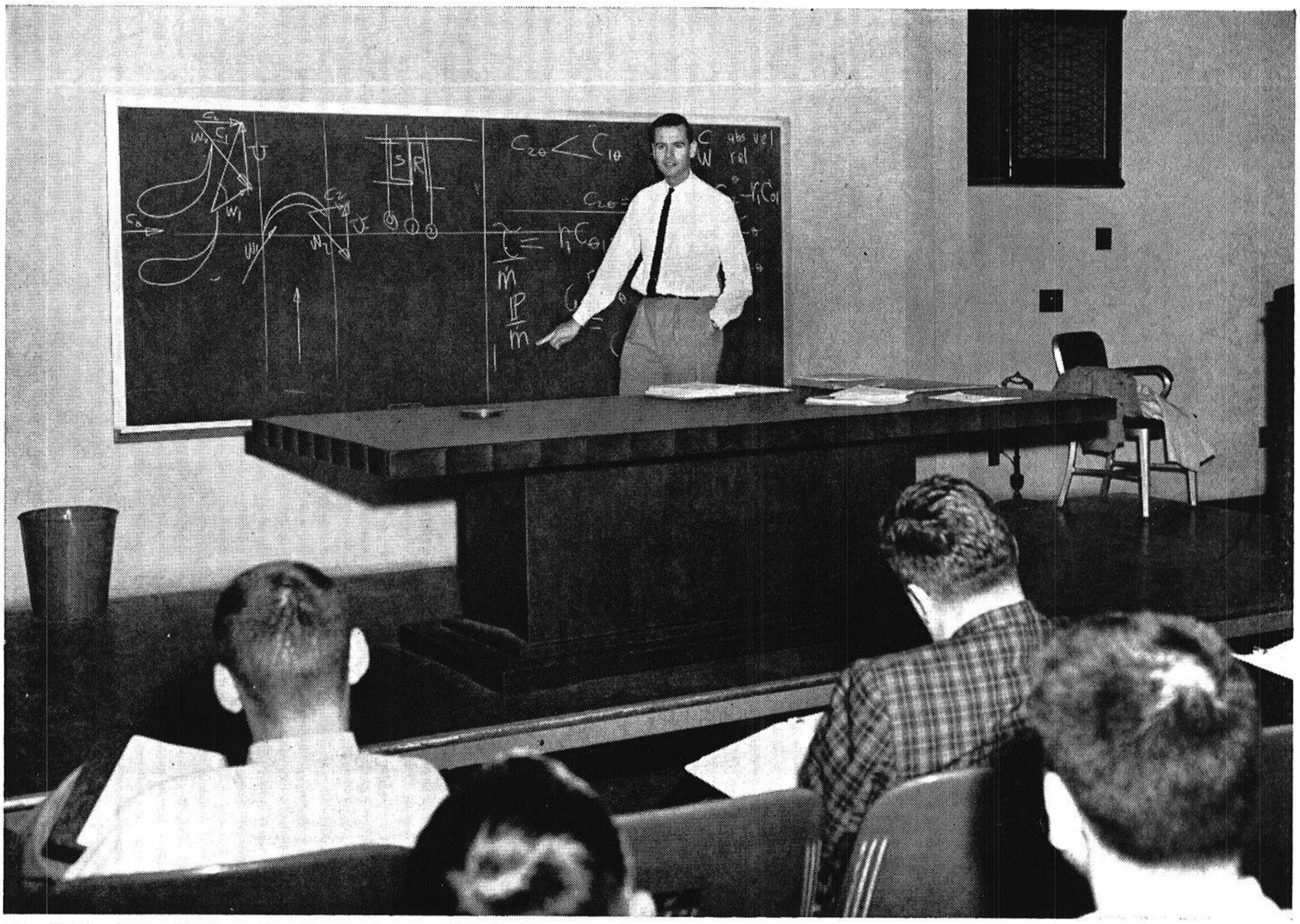
A newly married couple boarded the Golden State Limited for their honeymoon. They were in their berth and the bride about every two minutes would exclaim: "Johnny, I just can't convince myself that we are married." This went on and on for half an hour. Finally a voice from the other end of the car shouted, "Johnny, will you convince her so we all may go to sleep?"

* * *

We understand the fire department in Prairie Grove has, as its only equipment, one fire truck and two dogs. The dogs, of course, are used for finding the hydrants.

* * *

An engineer caught his girl in a fraternity brother's arms. To their startled expression he calmly replied. "I don't mind if you neck with my girl, but there is going to be one helleva fight if you don't take your hand off my fraternity pin."



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We believe that the right man in the right job will *enjoy* what he's doing. He'll find the competition stimulating, the challenge exciting. He'll be eager to get to work in the morning, simply because his work is *fun*. And this enthusiasm is bound to rub off on the paycheck, make no mistake about that.
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5-63

One of a series . . .

Interview with General Electric's Dr. J. H. Hollomon

Manager—General Engineering Laboratory

Society Has New Needs and Wants—Plan Your Career Accordingly

DR. HOLLOMON is responsible for General Electric's centralized, advanced engineering activities. He is also an adjunct professor of metallurgy at RPI, serves in advisory posts for four universities, and is a member of the Technical Assistance panel of President Kennedy's Scientific Advisory Committee. Long interested in emphasizing new areas of opportunity for engineers and scientists, the following highlights some of Dr. Hollomon's opinions.

Q. Dr. Hollomon, what characterizes the new needs and wants of society?

A. There are four significant changes in recent times that characterize these needs and wants.

1. The increases in the number of people who live in cities: the accompanying need is for adequate control of air pollution, elimination of transportation bottlenecks, slum clearance, and adequate water resources.

2. The shift in our economy from agriculture and manufacturing to "services": today less than half our working population produces the food and goods for the remainder. Education, health, and recreation are new needs. They require a new information technology to eliminate the drudgery of routine mental tasks as our electrical technology eliminated routine physical drudgery.

3. The continued need for national defense and for arms reduction: the majority of our technical resources is concerned with research and development for military purposes. But increasingly, we must look to new technical means for detection and control.

4. The arising expectations of the peoples of the newly developing nations: here the "haves" of our society must provide the industry and the tools for the "have-nots" of the new countries if they are to share the advantages of modern technology. It is now clearly recognized by all that Western technology is capable of furnishing the material goods of modern life to the billions of people of the world rather than only to the millions in the West.

We see in these new wants, prospects for General Electric's future growth and contribution.

Q. Could you give us some examples?

A. We are investigating techniques for the control and measurement of air and water pollution which will be applicable not only to cities, but to individual households. We have developed, for example, new methods of purifying salt water and specific techniques for determining impurities in polluted air. General Electric is increasing its international business by furnishing power generating and transportation equipment for Africa, South America, and Southern Asia.

We are looking for other products that would be helpful to these areas to develop their economy and to improve their way of life. We can develop new information systems, new ways of storing and retrieving information, or handling it in computers. We can design new devices that do some of the thinking functions of men, that will make education more effective and perhaps contribute substantially to reducing the cost of medical treatment. We can design new devices for more efficient "paper handling" in the service industries.

Q. If I want to be a part of this new activity, how should I plan my career?

A. First of all, recognize that the meeting of needs and wants of society with products and services is most important and satisfying work. Today this activity requires not only knowledge of science and technology but also of economics, sociology and the best of the past as learned from the liberal arts. To do the engineering involved requires, at least for young men, the most varied experience possible. This means working at a number of different jobs involving different science and technology and different products. This kind of experience for engineers is one of the best means of learning how to conceive and design —how to be able to meet the changing requirements of the times.

For scientists, look to those new fields in biology, biophysics, information, and power generation that afford the most challenge in understanding the world in which we live.

But above all else, the science explosion of the last several decades means that the tools you will use as an engineer or as a scientist and the knowledge involved will change during your lifetime. Thus, you must be in a position to continue your education, either on your own or in courses at universities or in special courses sponsored by the company for which you work.

Q. Does General Electric offer these advantages to a young scientist or engineer?

A. General Electric is a large diversified company in which young men have the opportunity of working on a variety of problems with experienced people at the forefront of science and technology. There are a number of laboratories where research and advanced development is and has been traditional. The Company offers incentives for graduate studies, as well as a number of educational programs with expert and experienced teachers. Talk to your placement officers and members of your faculty. I hope you will plan to meet our representative when he visits the campus.

A recent address by Dr. Hollomon entitled "Engineering's Great Challenge — the 1960's," will be of interest to most Juniors, Seniors, and Graduate Students. It's available by addressing your request to: Dr. J. H. Hollomon, Section 699-2, General Electric Company, Schenectady 5, N.Y.

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