

COLORADO

Engineer



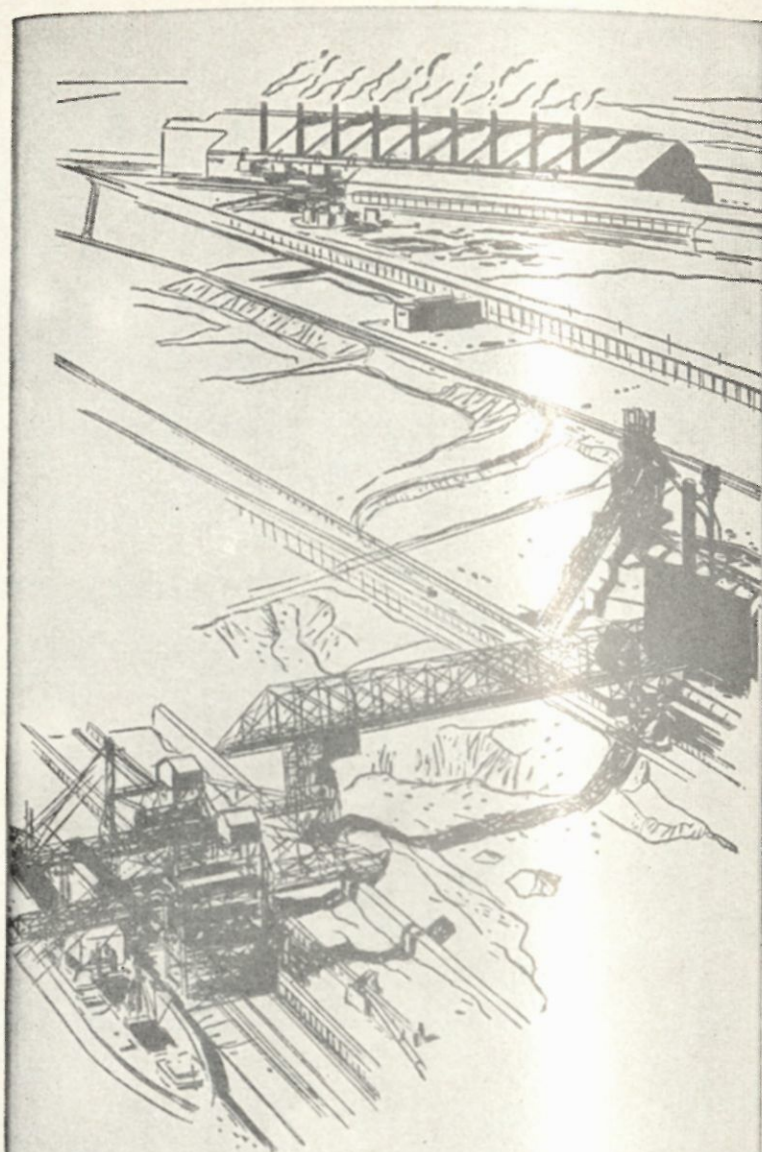
May 15, 1960

What kind of a person
would read a book
like this?

This book isn't fancy. Its actual size isn't much bigger than what you see here. But it tells a lot about U.S. Steel. Its operations. Facilities. Growth. Working benefits. It gives a rough idea of the Corporation's many career opportunities. (Imagine how many engineers are needed in a company this size.) A reader won't find any flowery phrases in this book about success. That part is up to the individual. U.S. Steel wants men with drive and initiative who aren't afraid of competition. A lot of people like that have already read this book. They work for us now. Are you that kind of person? *Send the coupon.*

USS is a registered trademark

USS United States Steel



Basic Facts

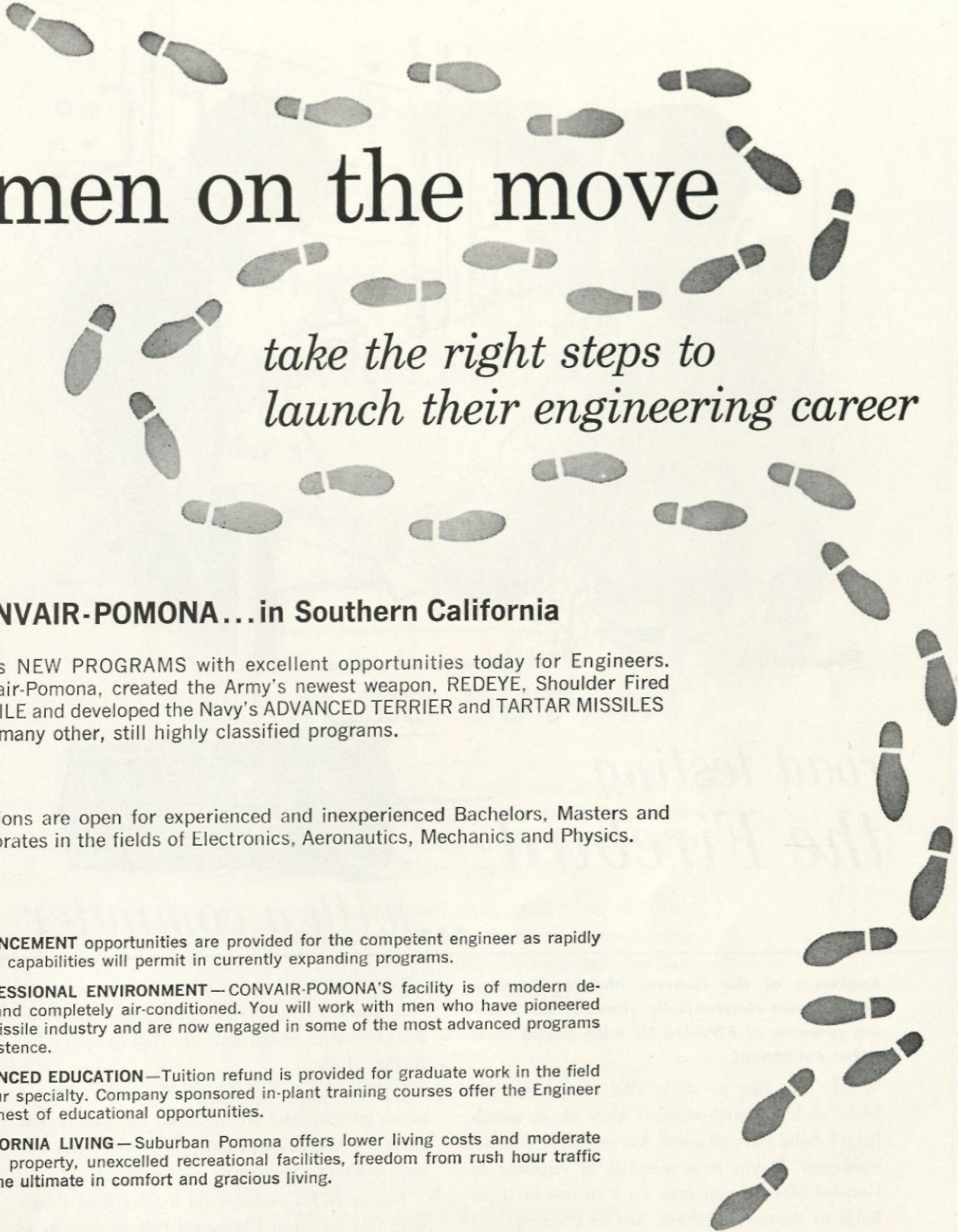
about

U.S. STEEL

United States Steel Corporation
Personnel Division
Room 6085, 525 William Penn Place
Pittsburgh 30, Pennsylvania

Please send me the free book, "Basic Facts about U.S. Steel."

Name _____
School _____
Address _____
City _____ Zone _____ State _____



men on the move

*take the right steps to
launch their engineering career*

CONVAIR-POMONA...in Southern California

offers NEW PROGRAMS with excellent opportunities today for Engineers. Convair-Pomona, created the Army's newest weapon, REDEYE, Shoulder Fired MISSILE and developed the Navy's ADVANCED TERRIER and TARTAR MISSILES and many other, still highly classified programs.

Positions are open for experienced and inexperienced Bachelors, Masters and Doctorates in the fields of Electronics, Aeronautics, Mechanics and Physics.

ADVANCEMENT opportunities are provided for the competent engineer as rapidly as his capabilities will permit in currently expanding programs.

PROFESSIONAL ENVIRONMENT—CONVAIR-POMONA'S facility is of modern design and completely air-conditioned. You will work with men who have pioneered the missile industry and are now engaged in some of the most advanced programs in existence.

ADVANCED EDUCATION—Tuition refund is provided for graduate work in the field of your specialty. Company sponsored in-plant training courses offer the Engineer the finest of educational opportunities.

CALIFORNIA LIVING—Suburban Pomona offers lower living costs and moderate priced property, unexcelled recreational facilities, freedom from rush hour traffic and the ultimate in comfort and gracious living.

Contact your placement office immediately to assure yourself of a campus interview with Convair-Pomona.

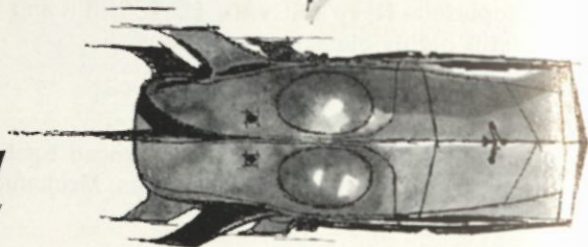
If personal interview is not possible send resume and grade transcript to B. L. Dixon, Engineering Personnel Administrator, Dept.

CM-516 Pomona, California

CONVAIR/POMONA
Convair Division of
GENERAL DYNAMICS
CORPORATION
Pomona, California



road testing the Firebird



...with a computer

Engineers at the General Motors Research Laboratories electronically simulate the steering response of Firebird III with analog computer equipment.

Would you like to work with computers, the brain child of mathematics? How about metallurgy? Solid state physics? Automobiles? Inertial guidance? If you're a scientist or engineer at General Motors, you may work in one of these fields or dozens of others, just as exciting, just as challenging.

There's real opportunity here. No roadblocks

either. Real opportunity to move up, increasing your knowledge and responsibility, perhaps shifting to another department or division to develop further skills.

GM provides financial aid for those who go on to postgraduate studies. And for undergrads, there's a summer program with which they can gain valuable experience.

For more information on a rewarding future with GM, see your Placement Officer or write to General Motors, Salaried Personnel Placement, Personnel Staff, Detroit 2, Michigan.

GENERAL MOTORS

GM positions now available in these fields for men holding Bachelor's, Master's and Doctor's degrees: Mechanical, Electrical, Industrial, Metallurgical, Chemical, Aeronautical and Ceramic Engineering • Mathematics • Industrial Design • Physics • Chemistry • Engineering Mechanics • Business Administration and Related Fields

**ENGINEERS
CHEMISTS
PHYSICISTS
MATHEMATICIANS**

Looking for Opportunity?

LOOK TO DU PONT!

Today is a time of rapid growth and expansion at Du Pont. Development activities are being accelerated, and new processes are being installed at plants new, old and under construction.

This creates need for technical graduates: chemists (all specialties), physicists, mathematicians; engineers of almost every specialty—chemical, mechanical, industrial, electrical, metallurgical.

LOCATIONS: Eastern half of U. S. primarily

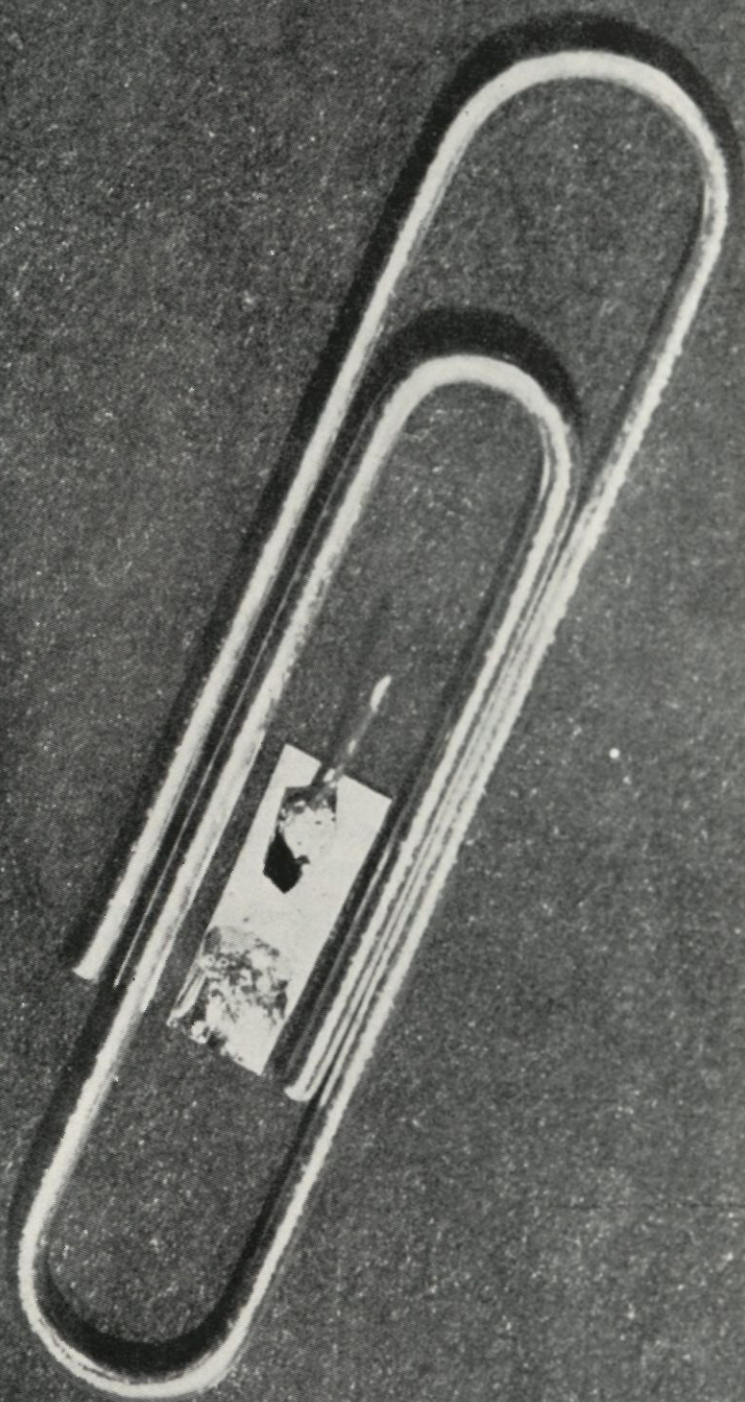
REQUIREMENTS: Recent Bachelor's, Master's or Doctor's degree

Write to . . .

2420-4 Nemours Building
E. I. du Pont de Nemours & Company (Inc.)
Wilmington 98, Delaware



BETTER THINGS FOR BETTER LIVING . . . THROUGH CHEMISTRY





STAFF

EDITOR-IN-CHIEF DALE E. NORBLOM

BUSINESS MANAGER —
— RONALD COWGILL

FACULTY ADVISERS — George J. Maler
Burton G. Dwyre

Articles Editor — N. Krishnamurthy

Production Manager — Larry Hazzard
Assistant — William DeReemer

Editorial Board Chairman — Allan Angland

Proofreaders — Carl Sandstrom
Dick Baker

Sections Editor — Thomas Clark
Campus News — Gary Janda
This Today — Joseph Lischka
Book Reviews — John C. Woolum
Colorado Industries — Lowell Brooks
Humor — Jack Bishop, Jr.

Cover Editor — James Garrison, Jr.
Illustrator — Jerry Crosetti
Photographer — David Gould

Assistant Business Manager — John K. Jerome

Advertising Manager — Richard Bird
Assistant — Bill Hein

Circulation Manager — Ronald Steinberg

CIRCULATION: 1800

Published Four Times a Year, on the Fifteenth of November, January, March, and May by the Students, Faculty, and Alumni of the College of Engineering.

Publisher's Representative — Littell - Murray - Barnhill, Inc., 369 Lexington Avenue, New York 17, N. Y., and 737 North Michigan Avenue, Chicago 11, Illinois.

Entered as second-class matter March 9, 1916, at the Post Office at Boulder, Colorado, under the Act of March 3, 1879.

COLORADO ENGINEER—May, 1960

The COLORADO Engineer

VOLUME FIFTY-SIX

NUMBER 4

MAY 15, 1960

COLLEGE OF ENGINEERING • UNIVERSITY OF COLORADO

ARTICLES

- Heat Pumps for Space Heating and Cooling*
By H. PAUL JOHNSON 10
- The Concepts and Capabilities of Molecular Electronics*
By DR. S. W. HERWALD 12
- The Naval Electronic Warfare Simulator*
By WILLIAM A. ROBBINS 16
- The Big Dish*
By FRANK C. TYRRELL 20

SPECIAL FEATURES

- Editorially Speaking*
By DALE E. NORBLOM 7
- Dean's Page*
By DEAN CLARENCE ECKEL 9
- E. Days—1960* 26
- St. Patricia, 1960* 30
- We Honor*
By THOMAS A. CLARK 36

SECTIONS

- Colorado Industries*
RAMO-WOOLDRIDGE, INC. 28
- This Today* 28
- For Your Library* 32
- About Our Authors* 44
- Chips* 48

FRONTISPIECE (opposite page)

Nestled easily inside a paper clip, the tunnel diode promises to be one of the most important new developments in the miniature world of molecular electronics. For more on these revolutionary solid state devices see page 12.

COVER

The final cover for the *Engineer* is dedicated to the graduating Senior Engineering Class, 1960.

Albert Einstein pictured in his own element, "It is not enough that you understand about applied science in order that your work may increase man's blessings. Concern for man himself and his fate must always form the chief interest of all technical endeavors, concern for the great unsolved problems of the organization of labor and distribution of goods—in order that the creations of our mind shall be a blessing and not a curse to Mankind. Never forget this in the midst of your diagrams and equations."

MEMBER OF

ENGINEERING COLLEGE MAGAZINES ASSOCIATED

Stanley Stynes, Chairman

Wayne State University

Detroit, Michigan



The care and feeding of a missile system



It takes more than pressing a button to send a giant rocket on its way. Actually, almost as many man-hours go into the design and construction of the support equipment as into the missile itself. A leading factor in the reliability of Douglas missile systems is the company's practice of including all the necessary ground handling units, plus detailed procedures for system utilization and crew training. This complete job allows Douglas missiles like THOR, Nike HERCULES, Nike AJAX and others to move quickly from test to operational status and perform with outstanding dependability. Douglas is seeking qualified engineers and scientists for the design of missiles, space systems and their supporting equipment. Write to C. C. LaVene, Box 600-F, Douglas Aircraft Company, Santa Monica, California.

Alfred J. Carah, Chief Design Engineer, discusses the ground installation requirements for a series of THOR-boosted space probes with Donald W. Douglas, Jr., President of **DOUGLAS**

MISSILE AND SPACE SYSTEMS ■ MILITARY AIRCRAFT ■ DC-8 JETLINERS ■ CARGO TRANSPORTS ■ AIRCOMB® ■ GROUND SUPPORT EQUIPMENT

A Need For ENGINEERING MANPOWER

For the second consecutive year, enrollment in America's accredited engineering colleges has dropped. This year 240,063 students registered in engineering; last year there were 249,950 students, and in the year before the total was 257,777.

In the industrial complex of this country, rising productivity has been an essential factor in increasing the Gross National Product. Engineering has been an important element contributing to technological developments that have permitted higher productivity. Engineers are concerned with the efficient operation of our productive resources and play the critical role in determining continuation of increased national productivity.

The rate of increase of our Gross National Product is then dependent on on the availability of an adequate supply of qualified engineers. Our ability to expand the production of consumer goods to satisfy the requirements of our multiplying population depends upon an increasing supply of well educated engineers.

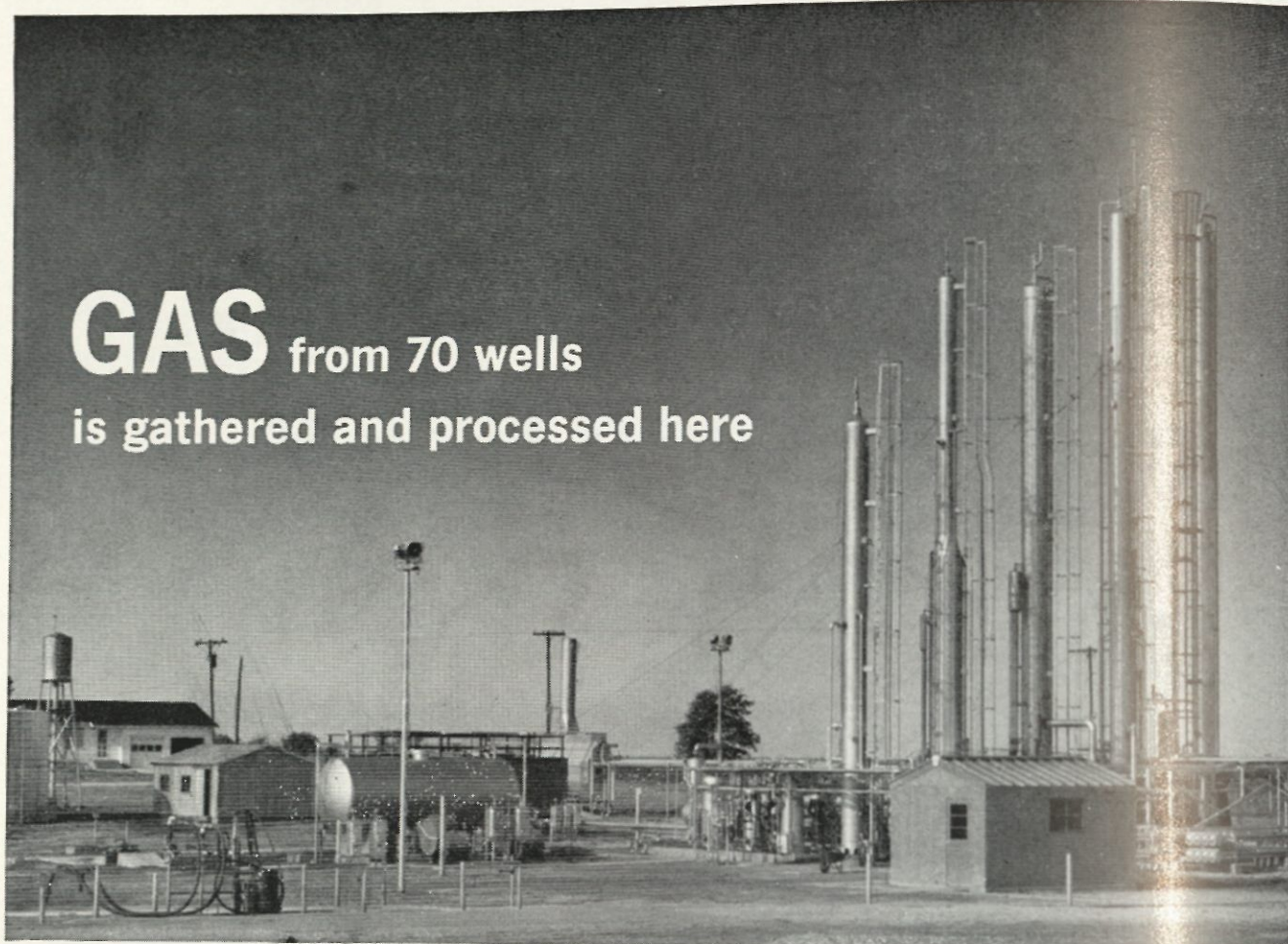
The demand for more engineers will increase in future years, and will have to be met by students presently enrolled in engineering schools and those who will enroll in the next few years. We must, therefore, utilize our available manpower more effectively. It is not only vital that the country have more engineers, but it's perhaps even more important to have better engineers. Tomorrow's engineers will need to have greater capabilities and wider horizons. They will necessarily have to be more effective than the scientific manpower of today.

Other nations face the same problem—the increasing technical character of modern civilization, with resulting demand for scientific and engineering manpower. The U.S.S.R. has recognized this trend and its implications and has deliberately channeled its youth into desired fields. Under the American democratic concepts of freedom of individual choice, such state organization of human resources is precluded. Our nation must find other means of filling its needs and developing its resources.

Two basic objectives must be sought: the supply of new graduates must be made sufficient, and our available manpower must be used effectively. Perhaps the supply of engineers could be met by improved communications with the public; conveying to the parents, counselors and students clear concepts of the background preparation and other requirements as well as opportunities in the technical fields. But increasing the effectiveness of our present scientific manpower may only be accomplished by individual effort. Each and every engineer can do his full share only when he adds to his own knowledge, extends his own horizons, increases his own efforts, and steps up to his own effectiveness, as an engineer and as an individual.

DEN

GAS from 70 wells is gathered and processed here



"JENKINS valves give us the dependable performance our operations demand."

— states Kerr-McGee Oil Industries, Inc., Oklahoma gas producer

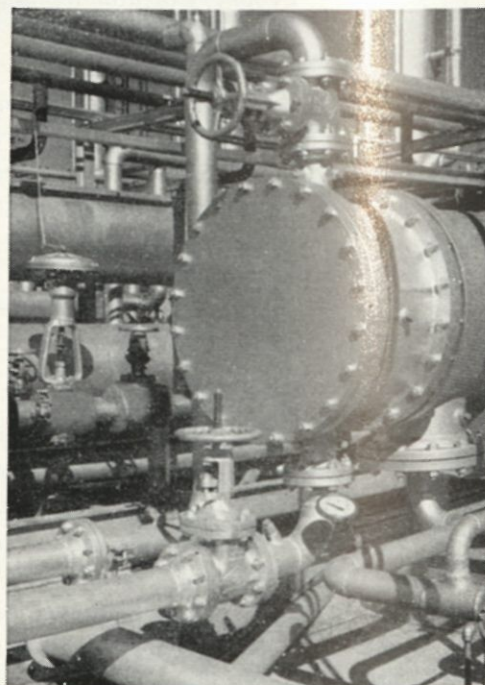
How Kerr-McGee's field processing plant in Lincoln County, Oklahoma, gathers and extracts valuable hydrocarbons from gas before delivering it to the consumer is an interesting story, briefly told below. But you need not know the process to appreciate the fact that maximum reliability in valves is a "must".

The valves that assure Kerr-McGee of dependable, trouble-free performance bear the same name as that written on piping layouts of critical jobs of all kinds for almost a century. Experienced engineers, contractors and operating executives know that "JENKINS" stands for an extra-measure of quality. They know it is the best guarantee of long, trouble-free service. There's no extra cost attached to this specification for extra quality, so you can use it for any job. Jenkins Bros., 100 Park Ave., New York 17.

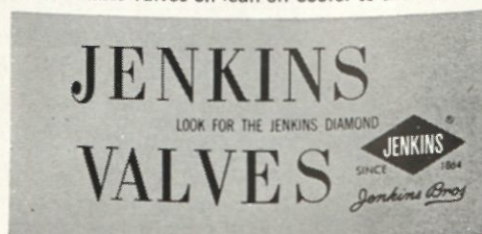
HOW THE GAS PROCESSING PLANT WORKS...

Because it is a vapor at low pressure, gas is first compressed and injected into the bottom of a tall tower, called an absorber; oil is injected at the top. As the oil goes down, the gas goes up . . . the gas products are absorbed by the oil. The gas enriched oil is then processed to remove valuable light hydrocarbons.

Sold Through Leading Distributors Everywhere



Jenkins Gate Valves on lean oil cooler to the absorber



DEAN'S PAGE

During recent years, the importance of public education has been uppermost in our thinking. Much criticism has been directed at the public school system, and even at our colleges and universities. Probably we should take a sober look at what we have been doing and try to find out where we are, where we are going, and how to get there.

Teaching

Much of our present teaching practice is pragmatic in nature, and preconceived opinions are often assumed to be factual. For instance, there is a fixed idea that a large university cannot have standards of excellence. Dean Dayton McKean explodes this prejudice nicely in his paper, "In Defense of the Large University." In many instances only a large institution can provide the expensive facilities that are so necessary for upper-level instruction. Another fetish has been classes small in size and a low teacher-student ratio, when probably it can be said that the quality of instruction depends on the quality of the teaching.

There is a popular prejudice that only certain types of subject matter and curricula are respectable. Strenuous efforts have been made to belittle professional education as contrasted with the liberal arts and sciences. We need professional programs and liberal curricula as well as many others, and here it may not be inappropriate to suggest that the liberal arts student might be very much better educated than he is if he had some understanding of science and engineering.

I think the College of Engineering should have an honors program for superior students, but here again I must suggest that quality in education is related to scholarly progress rather than to the basic mental equipment of the students.

We need to know more about how superior teaching can be extended to a great number of students. Class size, classroom conditions, and many other questions need study. For instance, we do a great deal of our teaching by analysis, in that a given situation is broken down to its component parts and these are studied individually. May I suggest that analy-

sis is not creative and that creativeness is really a process of synthesis. We should learn to recognize sparks of creativity and develop these to the utmost. Talent must be identified early so that it may be properly directed.

Engineering education has long emphasized the value of the social-humanistic studies. Engineering students are expected to learn about our cultural heritage and the social-humanistic major should also know something about the impact of science and engineering on our total culture.

I think that we must improve our attitude toward scholarship. Universities will not be good until the public wants them to be, and as long as we honor football players and coaches more than scholars and teachers, we will not improve.

College of Engineering Self-Study

With these ideas in mind, the College of Engineering Self-Study Committee spent last year in a careful, critical analysis of the entire engineering program at the University of Colorado. The Committee has described the goal of engineering education at the University of Colorado with the word "excellence." Achievement of this goal calls for many accomplishments. Among these are the recruitment of vigorous, inspired, and well-trained faculty and an increase in stature of the present faculty. There is a genuine shortage of well-qualified professors and this shortage becomes more critical year by year.



DEAN ECKEL

To achieve greatness, a university must attract and hold able and distinguished professors. Adequate salaries and an atmosphere which promotes scholarly growth are essential.

In recognition of the rapid advances of technology, there must be a drastic increase in graduate research activity, and constant revision, modernization and improvement of curricula and teaching methods. Increasingly careful advising and testing in the selection of students with particular attention to motivation and other factors leading to success will be required. Attention must be given to the factors which produce an educated man with breadth and depth of understanding, not only of science and technology, but of the civilization in which he has a part.

Engineering education is faced not only with the problem of quality and the rapid increases in knowledge but with growth and physical size to keep pace with the generally increasing demand. This problem is especially critical in Colorado with its rapid growth in population, its tremendous potential for attracting a high type of industrial activity, and its large and promising supply of students.

Location of Engineering Complex

The Committee has recommended that the entire College of Engineering be moved to a new site south of Pennsylvania Avenue between 24th and 28th Streets.

This proposed move of the College of Engineering provides a unique opportunity to implement a recommendation from the evaluation of the engineering program undertaken by the Committee for the Study of the College of Engineering during the academic year 1958-59. The basic findings of this Committee are also reinforced by the November, 1959, statement of the Education and Accreditation Committee of the Engineers Council for Professional Development which may be summarized as "the need for excellence." The thesis of the Study Committee's report is that, because of the great and accelerating growth of technical knowledge, colleges of engineering must constantly improve and at a rapid rate. The State of Colorado urgently

(Continued on page 41)

HEAT PUMPS

For Space Heating And Cooling

By H. PAUL JOHNSON, M.E. '60

A heating and cooling device combined into one unit which requires no chimney or fuel storage—this brief description suggests a few of the advantages of the heat pump.

Stoecker¹ defines a heat pump as a refrigeration system which has as its primary purpose the utilization of heat rejected at the condenser. The heat pump (sometimes called a "reverse-cycle air conditioner") is essentially a refrigeration system which is designed to operate in both directions. In the summer the unit removes heat from the inside of the building and rejects it outdoors. During the heating season the heat pump removes heat from the outside and delivers it to the inside.

The significance of the heat pump as a method of residential heating and cooling is developed in the following analysis.

A. PRINCIPLES OF OPERATION

The majority of heat pumps operate on the "vapor compression cycle," one that is commonly used in conventional refrigerators and air conditioners.

The vapor compression cycle is based on the ability of substances called "refrigerants" to boil (that is to change from a liquid to a vapor) at a low temperature. The stages and equipment involved in the vapor compression cycle are as follows:

1. *Compression* is performed by a compressor. The compressor may be a reciprocating, rotary, or centrifugal type.
2. *Condensation* of the refrigerant is performed by a heat exchanger which is called a condenser.
3. *Throttling* (or expansion) function is performed by either an expansion valve or a capillary tube.
4. *Evaporation* is accomplished by another heat exchange called the evaporator.

The refrigerant flow may be traced around the circuit with the aid of Figure one.

The compressor receives refrigerant vapor at low pressure and delivers it

at a high pressure to the condenser. The refrigerant is still a vapor as it enters the condenser. The energy which is used to power the compressor is the electrical energy which represents the cost of operating the unit.

The condenser receives the refrigerant vapor at a high pressure, transfers heat from the refrigerant, and delivers the refrigerant as a liquid to the expansion device. Since the pressure of the refrigerant vapor is high when it enters the condenser the phase change from vapor to liquid occurs at a high temperature. This high temperature—high pressure relation is important because the heat given off at the condenser is at a high enough temperature to be used

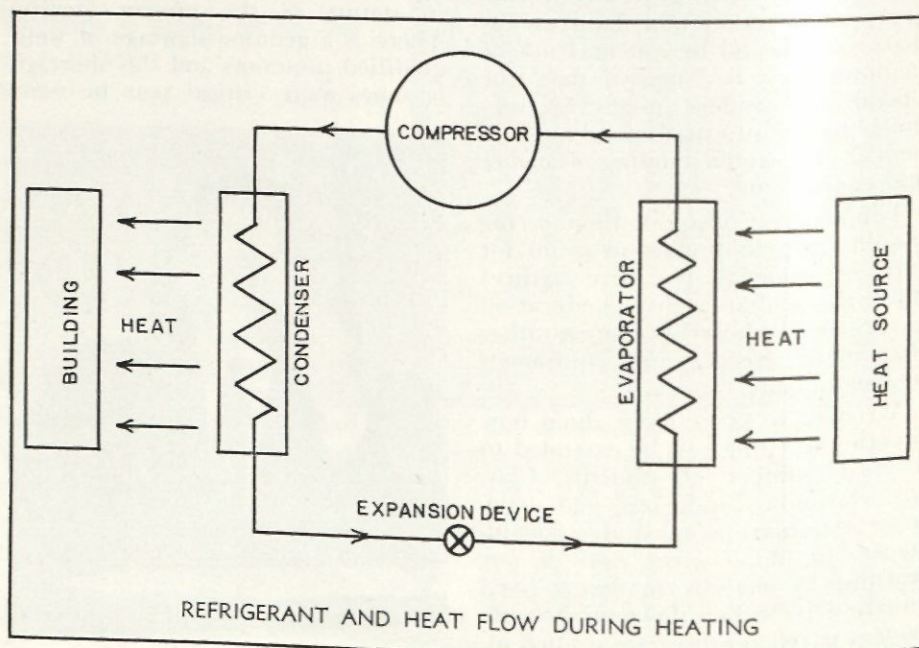


Figure 1.

for space heating purposes.

After condensation to the liquid phase the refrigerant is throttled (reduced in pressure) down to the evaporator pressure. The only purpose of the throttling process is to reduce the pressure of the refrigerant as efficiently as possible. The refrigerant, after throttling, is usually a two-phase mixture of liquid and vapor.

After leaving the expansion device the refrigerant enters the evaporator. Heat is added to the refrigerant, which is at a low pressure, and the refrigerant boils (completely changes to a vapor.) Since the refrigerant is at a low pressure, the temperature at which the refrigerant boils or takes on heat is also very low. Thus the refrigerant may receive the heat necessary to boil at a very low temperature such as the temperature of outside air on a cold winter day.

Figure two shows the same equipment cooling a building. In this case

ing the necessary ductwork and electrical connections.

Versagi² describes three possible variations in installation of the packaged units.

- (a) Self-contained central system fits in basement, attic, or closet. Ducts connect the evaporator and condenser to the house interior and the outside. See figure 3a.
- (b) Split system has one heat exchanger and compressor on slab outside with refrigerant piped to the other coil inside. Inside ducts carry warm or cool air through the house as needed. See figure 3b.
- (c) Room size unit smaller than other units, operates exactly like larger units. With half of the unit inside and half outside no ducts are required. See figure 3c.

At the present time the compression function is generally performed

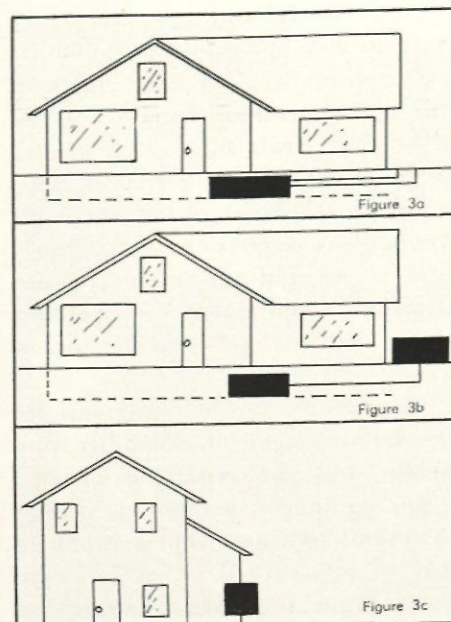


Figure 3.

fins to increase the area of the heat exchanger in contact with the air.

The expansion device is usually a capillary tube since this device works equally well in both directions.

The auxiliary equipment which is generally needed is as follows:

1. Electrical connections of sufficient capacity to deliver the required power to the unit.
2. Blowers and fans to circulate the air through both heat exchangers (condenser and evaporator).
3. Thermostats and related control equipment which make the unit completely automatic for both the heating and cooling function.

C. FACTORS AFFECTING PERFORMANCE

Performance Factor

Many factors influence the performance of the heat pump. In order to compare the quantitative effect of these factors Stoecker¹ defines a "performance factor" as follows:

$$\text{Performance Factor} = \frac{\text{Useful effect}}{\text{Electrical energy input}}$$

For the heating function this ratio becomes the quantity of heat transferred to the building interior over the electrical energy input (or consistent units). For the cooling function the expression becomes the ratio of the heat removed from the interior to the electrical energy input.

Spofford³ reports the following performance factors as typical for a heat (Continued on page 40)

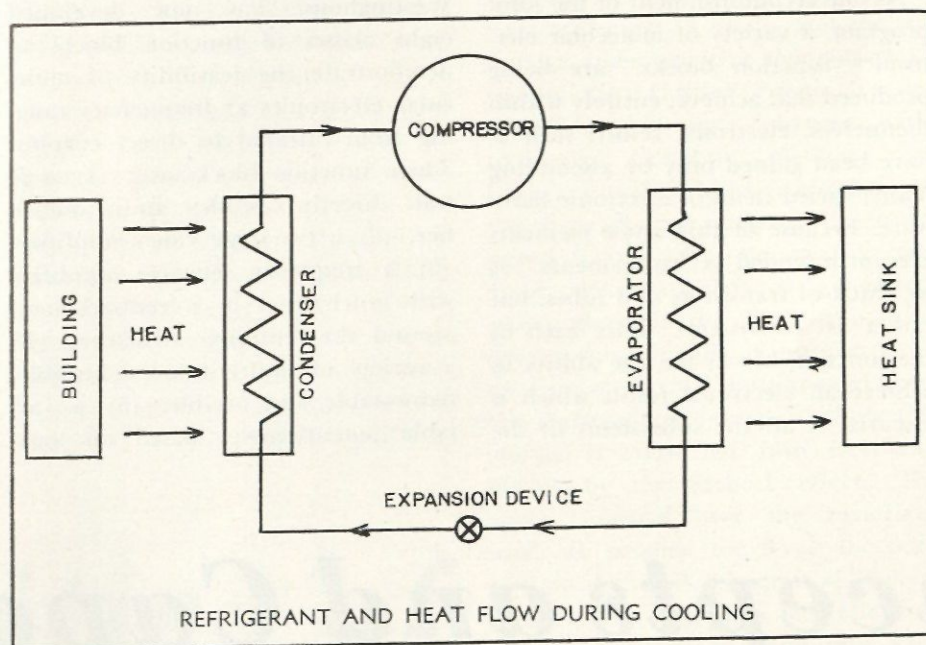


Figure 2.

the equipment is the same except the condenser and evaporator have exchanged functions.

B. DESCRIPTION OF A TYPICAL UNIT

The majority of heat pumps in use at the present time are package units. They are, of course, factory assembled and tested. The installation consists of locating the package unit and mak-

ing by single-stage, single-cylinder, reciprocating compressors powered by an ac-motor. Both the hermetically sealed type and the "open-type" compressors are being used.

Both the evaporator and the condenser are usually heat exchangers of the "extended-surface" type. This type of heat exchanger resembles an automobile radiator since both have

Efforts to elevate air and space craft to new plateaus of capability are continually made more difficult through a technical paradox. As we make these craft more sophisticated through the use of advanced electronic gear, the risk of failure among components and connections grows. And as we add this more complex electronic equipment it becomes more difficult to provide for its weight and size.

As a result, focused programs for the improvement of reliability plus weight and size reduction of electronic equipment are now underway in several locations. These problems may be approached in several ways. For example, improved reliability can be realized by better quality control on components and connections. However, the probability of simultaneous successful operation of all components in any system is the product of all the individual probabilities of a component functioning without failure, and better quality control does not invalidate this limitation imposed by the laws of probability. Smaller and lighter components in more compact packages can be obtained by miniaturization; but such techniques, while exploiting modern technology, do not yield maximum reliability. On the contrary, the emphasis placed on size and weight reduction has usually meant that components and internal connections become so critical that they must be built with extreme precision if their failure rate is to be acceptable.

Recently, a substantial part of the research and development effort has been focused on a new and quite distinct approach to both problems. It exploits a new concept in the design and function of electronic systems. In fact, it is a broader concept of electrical engineering called "molecular electronics" to indicate its dependence on phenomena occurring within or between domains of molecules in the solid state.

Recognizing the potential importance of this concept to defense, the Wright Air Development Division's Air Force Electronic Technology Laboratory has directed the employment of Westinghouse facilities in a program to prove its feasibility. Specific objectives were: to determine to what extent molecular electronics can be used to perform complex functions in several system of basic importance to the Air Force; to develop subsystems for use in those systems; and to develop new materials that will advance the usefulness of the concept.

As one accomplishment of the joint program, a variety of molecular electronic "function blocks," are being produced that achieve, entirely within themselves, electronic results such as have been gained only by assembling many, varied items of electronic hardware. Because of this, these elements are not intended as "components," as we think of transistors and tubes, but rather as "subsystems" since each of the function blocks has the ability to achieve an electronic result which is essential if all the subsystems in the

entire system are to work together effectively. Examples of functions performed by function-blocks are such electronic operations as amplification, oscillation, and telemetering.

Because there are no internal connections or components, and the only external connections needed are those for coupling inputs and outputs to the complete system, we are able to build subsystems whose risk of failure should be equal to or less than that of familiar solid-state devices and perhaps one-thousandth of that for a subsystem built of many parts for the same purpose. Also, because their internal functions involve distances of the order of a few atomic spacings, these function blocks are almost microscopically small and virtually weightless. For example, weight of the light telemetry subsystems was reduced from about one ounce to one quarter of an ounce, the weight of the monolithic element to about seven ten-thousandths of an ounce.

As a result of the joint program, Westinghouse has now developed eight classes of function blocks to demonstrate the feasibility of molecular electronics at frequencies ranging from infrared to direct current. These function blocks are: (1) a 5-watt directly cascaded audio amplifier, (2) a two-stage video amplifier, (3) a frequency selective amplifier with notch filter in a feedback loop around the amplifier structure, (4) a variety of multivibrators—bistable, monostable and astable, (5) a variable potentiometer based on loga-

The Concepts and Capabilities **MOLECULAR ELECTRONICS**

By DR. S. W. HERWALD, Vice President, Research, Westinghouse Electric Corporation

rhythmic addition of two inputs, (6) a variety of multiposition switches (including an "OR" switch, a multiple NPN Dynistor switch, and a multiple NPN Trinistor switch with firing electrode), (7) an analog-to-digital converter employing an NPN relaxation oscillator, and (8) a two-stage cooler, employing the Peltier effect, covering frequencies from 1 cycle or less to 3 megacycles, for cooling infrared detectors to proper operating temperatures.

As the basis for these molecular electronic subsystems, we have a very substantial knowledge of solid state phenomena developed over the past 30 years. It is simple now to create materials having excessive positive or negative electrical charges and, by placing these materials in physical contact with related materials, to bring about such phenomena as rectification or amplification, as in diodes and transistors. Also, we can readily take advantage of the ability of radiation to cause charge paths to occur in a semiconductor material along which current will flow when the material is irradiated.

Effects of this general type are used in molecular electronic blocks by creating—usually in single crystals—a number of distinct operative domains, which can be regarded as molecular "communities" having a common civic purpose, in that each domain will sustain a desired electronic occurrence. The domains border one another at boundaries called interfaces, which are like political

frontiers in their ability to initiate phenomena different from those occurring inside the molecular domains.

As a simple example in the element in Figure 1 we see that it is composed of two domains which meet physically at one interface. One of these domains is composed of a resistive material selected and shaped to present a resistance R_1 to the passage of current; the other domain is also resistive, but is so planned that it has a resistance R_2 . At the interface, the interaction between domains causes a capacitive effect. Thus, in one tiny element we have a subsystem equivalent to a time-delay circuit.

Another illustration of the uses of domains and interfaces is a function clock designed as an ac-to-dc power supply for transistor circuits. It makes use of the Seebeck effect for the thermoelectric generation of electricity to convert 110-volt alternating current to 9-volt direct current power. In contrast, the conventional circuit requires five individual components—a transformer, a diode, and the inductive and capacitive elements making up the LC filter circuit. To accomplish this same purpose with molecular electronic methods, we have a function block comprised of the three separate domains. When a-c power is applied to the resistive domain, the heat that is generated passes through the domain at the center—this domain is an electrical but not a thermal insular—and into the thermoelectric domain where the energy is converted into electrical energy by the Seebeck effect. By proper control over the materials used, we provide the 9-volt d-c output we desire. An interesting aspect of the power supply is that elimination of ripple as an undesirable variation in voltage is inherent since heat flows from the resistive domain to the thermoelectric domain at practically a constant rate.

As these two examples suggest, the concept of molecular electronics makes no use of the traditional circuit-and-component approach to electronics. Instead, the objective is to use our knowledge of the structure of matter to synthesize monolithic



Light telemetry subsystem in which single light-responsive monolithic element delivers an output whose frequency is measure of light intensity.

function blocks whose arrangement and composition permit each to serve as a substation to perform an electronic function in the control or transformation of energy.

To achieve function blocks with this capability, a number of effects and phenomena of the solid state are available. The only firm limitations on choice are that the effect must not react adversely on system reliability and must lend itself to consistent results when included in a function block. Methods typical of practice so far include: solid-state phenomena, such as Seebeck generation, Peltier cooling, and Hall-effect multiplication; the use of PN semiconductor junctions arranged to produce a result which would otherwise require numerous individual components; and when necessary, fabrication of circuit elements within a function block. Although such phenomena will be most often used for the control of electrical signals, they will also be suitable when quantities like electromagnetic radiation, heat, and mechanical displacement are inputs or outputs.

The design of a subsystem begins with the designers' analysis of the requirements of the system, to establish the functions to be performed by the function block. After logic processes are determined and suitable physical

ilities of RONICS

effects settled upon, a topologist—a mathematician who works with shapes—determines the structure of the block by designing, on paper, the arrangement of domains and interfaces that is to control the flow of energy in the block. The block is then produced by the materials engineers who use germanium and silicon as the basic semiconductor materials.

In producing these blocks we do not assemble them from various tiny components. Rather, we start with a basic semiconductor wafer and produce the necessary domains and interfaces by techniques used in the production of conventional semiconductor devices, including diffusion, plating, electron beam machining, etching, cutting, radiation, alloying, and photographic processes. Although the function block so produced can now perform its function, additional processing steps are required to encapsulate the block, protect it against shock and vibration, and make it stable under the conditions of temperature and radiation it will encounter.

As we have observed, the dominant theme, the essential philosophy of molecular electronics is that we can now create, modify, and process materials to endow them with the ability to accomplish electronic tasks through solid-state phenomena. The foundation of our success has been our ability to develop new materials and to process available materials in new ways.

One important illustration of the contributions made by materials scientists is the development of a method for the rapid production of semiconductor crystals in a form that requires no removal of material to

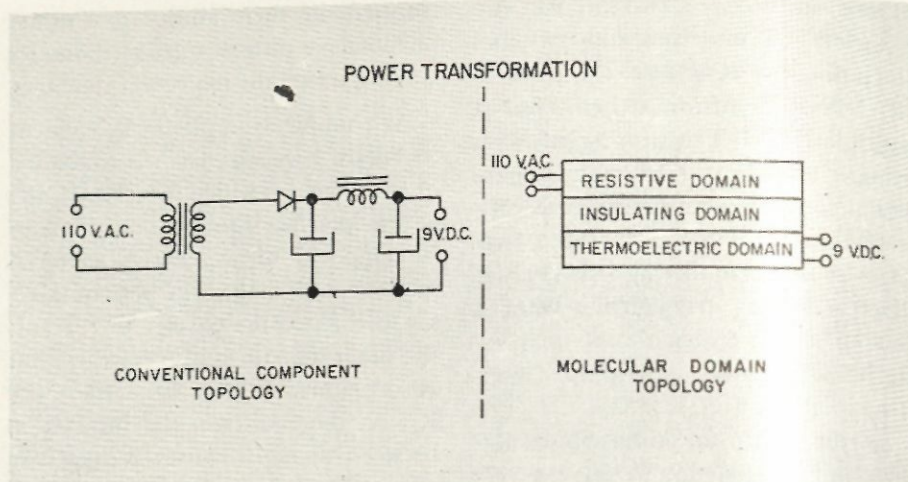


Figure 2. Schematic drawing of a-c to d-c power supplies showing (1) molecular element with resistive, electrical-insulating, and thermoelectric domain and (2) conventional method using transformer, diode, and filter circuit.

make them into suitable wafers for use as transistors or as the basic elements of molecular electronic elements. This is the dendrite process announced several months ago, in which germanium crystals in the form of ribbons about one-eighth of an inch wide and a few thousandths of an inch thick, are produced by drawing them from a molten mass. In contrast, in the conventional method, germanium crystals are grown as thick ignots, or boules, which require X-ray or crystallographic inspection before they can be sawed into precisely oriented wafers and then must be lapped, etched, and polished to obtain a satisfactory working surface. In addition to the waste of material and the cost of machining involved in the standard method, a serious disadvantage to its use for the production of molecular electronic blocks is the wide variation in characteristics frequently displayed by wafers, even by those cut from adjacent regions of a

single ingot and processed identically. In the production of transistors, this difficulty can be circumvented by testing a production run to select those with proper values. In molecular electronics, however, it is necessary to build junctions in adjacent portions of the same crystal; thus it is essential to have materials whose characteristics are uniform if the yield is to be acceptable.

Other advantages of this dendritic method of importance to molecular electronics are these:

It is essentially a continuous process in which the germanium ribbon grows at a rate of 6 to 12 inches per minute and in the precise direction of crystal growth we require for application. Thus, no X-ray or crystallographic examination is necessary, and the surfaces of the ribbon are always correctly oriented, optically flat, and immediately usable as working surfaces. An additional advantage is that if a contaminant enters the melt during the process, the resulting inclusion is "self-healing" so that when the process is completed, the affected portion can be cut away and the unaffected portion put to use.

Now, although this dendritic method has immediate usefulness in molecular electronics today, we are confident that its greatest significance is its ability to bring about a number of completely new processes for pro-

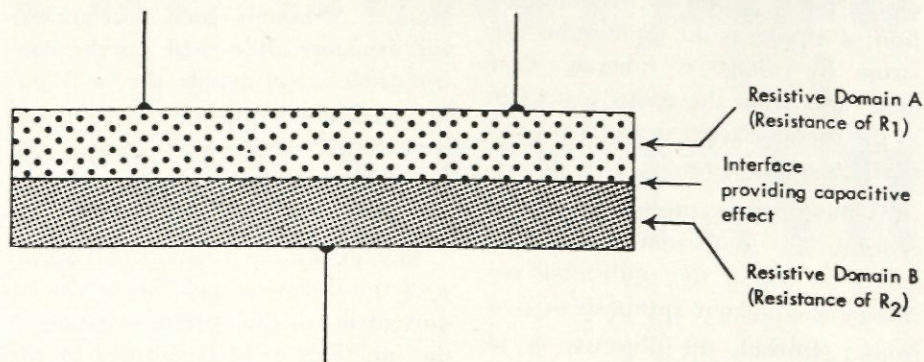
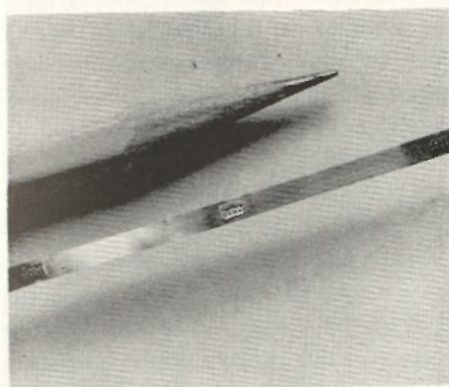


Figure 1. Schematic drawing of function block of two resistive domains and one capacitive interface, whose total effect is that of an RC or time-delay circuit.

ducing functional blocks. We are now most interested in a recent modification which makes it possible and practical to carry out diffusion, plating, and evaporation processes directly on the crystal as it grows from the furnace melt. With this technique, we are able to create semiconductor devices ready for the attachment of leads. One of the first uses has been to grow transistors in the form of a long germanium crystal.

When the ribbon-like crystals are cut into segments, only simple processing is needed to produce transistors at a yield very near 100 percent. By this method we have produced lengths of ribbon along which small multiple-junction subsystems are distributed, Figure 5. Since these ribbons can easily be processed to become a long series of tiny amplifiers, it is not at all facetious to say this ribbon can be snapped into lengths to give us amplifiers of whatever gain we desire.

A more recent and extremely significant achievement resulting from our research is that we have now discovered how to grow multizoned crystals



Ribbon bearing multiple-junction systems on germanium crystal produced by dendrite process.

as dendrites, directly from the furnace melt. We regard this development as a major event in new technology of molecular electronics. It makes available to us basic building blocks having at least three layers of zones and two interfaces. Thus it will no longer be necessary to perform many operations to create multizone elements.

In considering the implications of this basic method for crystal growth, one most interesting possibility is that



(Not referenced in text.) Demonstration of high-level amplifier as d-c amplifier. Intensity of light impinging on solar cell is fed to function block as d-c signal voltage. Supplied from battery, function block amplifies signal and delivers matching d-c output to head lamps.

it will prove practical to combine our ability to grow multizoned crystals with our ability to perform operations on the crystal at the time it is growing in the furnace. Admittedly, to achieve near-automatic production of semiconductor devices and molecular electronic function blocks is a long-range objective, but it is probable that we will eventually be able to "grow" from a pool of molten semiconductor materials some items of electronic equipment that today are of the order of complexity of radio receivers and amplifiers.

Fortunately to achieve these and other objectives, we are not forced to rely on "wild-catting" methods of prospecting for new materials. Instead, present programs of planned research will yield solutions to such problems as the development of materials that will withstand very high temperatures and intensive radiation and the development of function blocks that will have high power handling capacities.

Investigation now underway with the so-called 3-5 compounds supports our approach to the development of heat-and radiation-resistant materials. And our ability to produce large, perfectly flat working surfaces on crystals of germanium will be basic to increasing the power-handling

capacity of molecular electronic function blocks.

We are confident that the urgent need for light, small, and highly reliable electronic systems can be answered by application of the molecular electronic concept. At first, of course, application will be limited by cost and the necessities of defense to uses where the need for reliability, lightness, and compactness is greatest, as in airborne systems; later, as we gain experience in developing and fabricating molecular electronic blocks, they will find application in land-based military equipment and, ultimately, in commercial and industrial applications.

Although there was a 20-year interval between the invention of the vacuum tube and its first significant application, and an 8-year interval between the development of the transistor and its first uses, it is almost certain that no such delay is likely for molecular electronics. In my opinion, in three to five years we will see the molecular electronic concept widely applied in air/space electronic systems for such important applications as telemetering, fire control guidance, communications, counter weapons, and flight control systems.

THE OPINIONS AND ASSERTIONS
CONTAINED HEREIN ARE NOT
NECESSARILY THOSE OF
THE NAVY DEPT.

"Wargaming", a term coined by the United States Naval War College, Newport, Rhode Island, is the art of playing a war game. Although playing war is as old as war itself, only recently has wargaming become one of the most important steps in preparing a man to take the responsibilities of making decisions in time of war. Wargaming may be played using actual equipment and men; however, the expense incurred in such a game is not always justified by the results.

Another means of wargaming is through the use of tokens, models, pins, and maps to represent the tools and terrain of the action. This method entails long and tedious calculations and leads to much unwanted delay between interactions. Wargaming in this manner sufficed when warfare consisted of only depth charges, bombs, subsonic aircraft, and other comparatively slow instruments of war. However, today, with weapons that are automatically aimed, flown at supersonic speeds, and that possess a thousandfold effectiveness in comparison to older weapons, wargaming in this manner has become as outdated as the Model "T" Ford. Maneuvers actually using these newer weapons have become extremely expensive and even otherwise impractical. Therefore, a revolutionary means of conducting a war game to proceed at a rate which simulates actual combat conditions and gives the players gratifying results became imperative.

The new means of wargaming entail the extensive use of analog computers, binary counters, servo mechanisms, indicators, and over 18,000 electron tubes. This massive and intricately interconnected collection of electronic equipment is called the NEWS, The Naval Electronic Warfare Simulator, which occupies an

entire wing of a large building at the U.S. Naval War College, Newport, Rhode Island.

Following an interaction through the equipment will give a simplified version of how the various parts of the equipment work together to enable a war game to be played at clock speed.

Inevitably there are two teams in almost any game and the war game is no exception. A White team is selected to play against a Green team. Each team is then broken down into small groups; each group will have control over one of the several forces that represent each side. Each group is then detached to its respective command center. The command center represents the post that the man in charge (force commander) would command during actual battle.

This command center is flexible so that it may represent anything from a single airplane to an aircraft carrier commanding hundreds of airplanes. Once in the command center the commander has at his disposal a modified radar display of the area that concerns his force. The distance his radar can see, "look," is limited

to the "look" of a radar that would be available to his particular type of force. The ships and planes around him would be represented on the radar by pips that continuously show the relative position and direction of motion of each force within his radar's look. Each pip appears to be a continuous light; however, it is coded. The code is carried by intensity modulating the pip, giving each force its own code. By aiming a photoelectric cell at the dot of light, pip, the code can be read and converted into electrical pulses which will cause a stepping switch to rotate to the position allocated to the force being read. This position of the stepper switch will connect the commander's presentation board to the circuitry for this force. The presentation board will give the commander all the intelligence information normally available from radar, picket ships, and aircraft. This information will include friend or foe, direction, speed, number of forces, type of force, and other facts that the umpires of the game deem necessary.

As a White and a Green force approach each other, the respective

THE NAVAL ELECTRONIC WARFARE SIMULATOR

By WILLIAM A. ROBBINS, E.E. '63

commanders must decide when to fire and how many rounds of which weapon to fire. At 12:35 White-4 commander, in command of a destroyer, received a report that Green-35, an enemy single engine aircraft, is approaching from the northeast at 635 mph. still out of range of his weapons. At 12:40 the Green craft, known as a boggy to White, is in range. The commander decides to fire. He steps to a panel and closes a switch; this in effect aims the weapons at the boggy. He waits until the opportune moment—then presses the weapon-fire lever.

In the meantime this entire action has been under observation in an area known as the umpire area. The umpire area is the floor of an auditorium in the NEWS. The action is observed on what appears to be a large television screen, fifteen feet on a side, at the front of the auditorium. This screen, known as the master plot screen, is actually constructed of plexiglass. Each force is represented on this screen by a point of light which moves by a projection system that automatically aims the light to mark each force's relative position and motion in the game. A map of the game area is drawn on paper to fit the screen and is hung behind the plexiglass. Behind this, ultraviolet light is shined to make the outlined land areas more pronounced.

It is often desirable to retrace the movement and interactions of a force after the game, so during the game a crew of men trace the path and mark all interactions of each dot of light with luminous crayon on the back side of the map. This enables the umpires to maintain an unobstructed view of the action.

The umpires have a picture of the total action on the master plot screen and, with special equipment available to them a repeat of any force's radar presentation may be observed on one of the umpire's radar screens. By using the very same method the commander used to determine intelligence about a force, the umpire can determine just what information is available to the commander. This

knowledge enables the umpires to determine if the interaction is plausible or if an equipment failure is creating the existing situation.

To make the actions on the master plot screen easier to follow, the forces may be individually flashed on and off for identification. The Green forces are projected on the screen through a green lens, and the White forces are projected on the screen through a clear lens. A polar plot (compass card) may be projected around each force, one at a time, to aid the umpires in determining distance and direction of one force from another.

To enable the umpires to realize an interaction is taking place, a massive system of lights shows each acquisition and firing. This system is a grid of lights that indicates to the umpires at a glance which weapon of which force is aimed at which force of the opposition. A steady light indicates an acquisition, the aiming of a weapon at the target; and a blinking light, which continues to blink for twenty-five seconds, indicates that the weapon was fired. If the commander decides not to attack the target, he may release his acquisition making the weapon ready for further use. This, of course, will extinguish the target-acquisition light in the umpire area.

At 12:40 White-4 aimed his weapon "Able" at Green-35. On the grid in the umpire area a steady light came on that was common to both White-4 weapon A and force Green-35. This told the umpires that White-4 was intending to fire on Green-35, enabling the umpires to analyze the situation before allowing the action to go further. A few minutes later White commander fired his weapon; this blinked the light. Satisfied with the action, White commander then released his target; this extinguished the light.

Did White-4 hit Green-35? Range is the major determining factor; if the target is within range then a hit or a miss becomes a matter of statistics, but if the target is not within range there will be a miss. The statis-

tical information and range is automatically computed to determine the probability of a hit. The probability is then combined with a chance factor to obtain a yes or no for the hit.

Range is three-dimensional; not only must lateral and longitudinal direction be figured, but, in the case of airplanes and submarines, altitude must also be figured. The resultant is known as the "slant range." So that computers may figure the range, it has been made a function of voltage. If the master plot screen were marked off with a grid one hundred squares on a side, an X-Y axis could then be drawn through the center of the screen. This center position would be (0,0); the extreme positions on the axis would be: right + 50 volts, the left -50 volts, top + 50 volts, and bottom -50 volts. Thus a force could easily be placed anywhere on the screen by assigning an X voltage and a Y voltage. A force at (50,50) would be in the upper right hand corner, and a force (-50,-50) would be in the lower left hand corner. By properly choosing a scale, one volt could equal one mile, ten miles, or nearly any distance demanded by the parameters of the game to be played.

Altitude is not indicated on the screen; however, it is important in figuring the range. The range from a ship to an airplane figured on a flat surface is much different than its slant range when it is at 20,000 feet. For engineering reasons, mostly to keep the equipment within the confines of one building, five altitude bands were selected:

500 Feet to 0 Feet	Band One	Subsurface
0 Feet	Band Two	Surface
700 Feet to 2,000 Feet	Band Three	
2,000 Ft. to 20,000 Ft.	Band Four	
20,000 Feet plus	Band Five	

Each band is set at a voltage proportionate to the average altitude. With this information the computation of the slant range between any two forces is a simple algebraic process.

White-4 is on the surface at (-2,25), and is aiming its weapon "A" against Green-35 which is located at (1,22) in band four. If the game is being played on an area of the ocean that is scaled to represent 100 miles by 100 miles, the slant

THE BIG DISH

By FRANK C. TYRRELL, C.E. '28

Reprinted from the
Civil Engineering, Nov. 1959

The "Big Dish," a parabolic antenna of 600-ft. diameter, is under construction near Sugar Grove, W. Va. This steerable radio telescope, being built for the Office of Naval Research, will be of unprecedented size and more complex than any similar equipment anywhere in the world. The antenna will be capable of altitude rotation from the horizon to the zenith while the entire structure will be able to rotate up to 450 deg in a horizontal plane. Its cost is expected to be approximately \$79,000,000.

The largest similar device now in use is the radio telescope at Jodrell

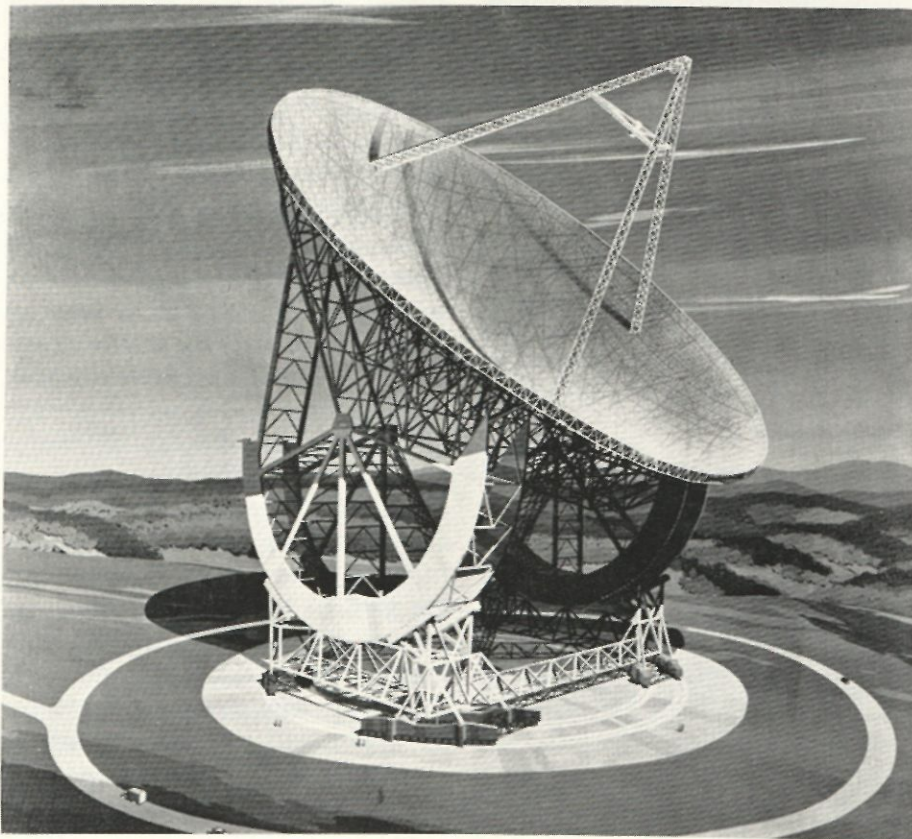
Bank, England, which is 250 ft. in diameter. The Soviets may be building a unit of 350-ft. diameter. The Naval Research Laboratory at Washington, D. C., already is operating instruments of 50, 60, and 84 ft. in diameter. The National Science Foundation is sponsor for the construction of radio telescopes of 85- and 140-ft. diameter at Greenbank, W. Va., 30 miles from the site of the Big Dish. A similar 85-ft. telescope is in use at the University of Michigan under the sponsorship of the Office of Naval Research.

How was it possible to design and construct a steerable radio telescope

nearly six times the size of the Jodrell Bank installation? The unit must have a very accurate antenna surface and be driven and controlled to precise aiming tolerances. The structural-steel frame is required to support an antenna with a diameter greater than the height of the Washington Monument and an area exposed to wind of more than seven acres, greater than that of the Empire State Building.

The Naval Research Laboratory and the Bureau of Yards and Docks, U.S. Navy, developed the technical specifications for the telescope and its appurtenances, and the latter was given responsibility for engineering and construction. To conduct feasibility studies, the architect-engineer firms of Frank Grad & Sons of Newark, N. J.; Urbahn, Brayton & Burrows of New York, N.Y.; and Seelye, Stevenson, Value & Knecht of New York, N. Y., were selected. This joint venture engaged the services of Battelle Memorial Institute of Columbus, Ohio, and numerous consultants for the project.

Work was started in September, 1956. The architect-engineer contractor concluded that construction was feasible and recommended an alt-azimuth mount, with independent support and independent motions for the altitude and azimuth movements of the antenna. The solid-surface antenna originally planned resulted in high wind and ice loads. Two-wheel flotation, two-wheel nonflotation and trunnion concepts were evaluated. Preliminary designs were developed in sufficient detail to permit comparison of such factors as the weight of the structural steel, various erection



Artist's conception of radio telescope.

—Official United States Navy Photograph

schemes, methods of control and movement, and total cost. As the result of these studies the two-wheel non-flotation design was selected.

The technical specifications for preliminary engineering and final design include specific live-load criteria, as follows:

Operating conditions:

1. Wind at 20 mph plus ice at $2\frac{1}{2}$ psf
2. Wind at 30 mph and no ice

Non-operating conditions:

1. Wind at 50 mph plus ice at 5 psf
2. Wind at 90 mph and no ice.

All wind loads include a 50-percent gust factor applied on any 10 percent of the total area of the antenna.

The Velocity pressure of wind was taken as $q = 0.00256V^2$, where q = velocity pressure, in psf
 V = velocity of wind, in mph
 h = height above ground level in ft.

For heights above 50 ft., velocity pressures are increased in accordance with the formula, $q_h = (h/50)^{2/7} q$.

Allowable stresses for designing and detailing are in accordance with current specifications of the AISC, except that the non-operating allowable stresses are determined as follows:

1. For members governed by flexure or axial tension, 80 percent of the yield strength of the material.
2. For members governed by axial compression where elastic stability does not govern, 75 percent of the yield strength of the material.
3. For members governed by elastic stability, 70 percent of the critical strength.
4. For stresses such as shear, bearing, etc., the values used in design follow AISC specifications.

From the inception of the project the feasibility of providing a structural framework to support the antenna was one of the major problems. The method of framing the superstructure was not determined until comparative studies of the following systems had been completed: one-way truss, two-way truss, radial truss, ring girder, and space frame. The two-way truss system (Fig. 1) was finally selected as it provides greater stiffness and better distribution of loads.

The problem of designing a bracing system adequate to transfer a maximum horizontal wind-shear force of 12,700,000 lb. through the structure to the pintle with a minimum lateral displacement was solved by providing a V-shaped fixed portal attached to the altitude wheels at the plane of the bottom chord of the superstructure truss system. The rotation of the wheels at the plane about the fixed portal and the transfer of horizontal load is through massive thrust bearings.

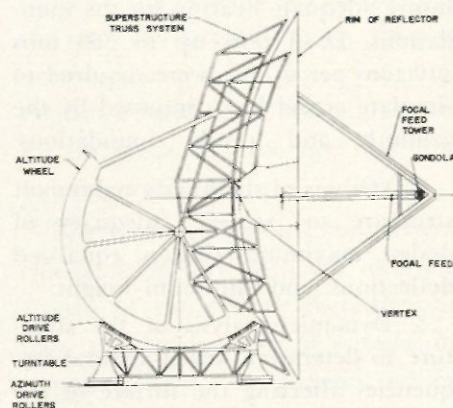


FIGURE 1
TELESCOPE STRUCTURE

The two-way main-truss framing system and intricate bracing of the superstructure resulted in a high degree of redundancy which had to be analyzed so that the design would be adequate and economical. The IBM 704 computer has sufficient capacity to solve the problem; it is reported that this is the most complex single task attempted to date with this equipment. The two-way truss system has as many as thirteen major members meeting at a joint. The transfer of stress at these joints or weldments is through pairs of heavy gusset plates reinforced by diaphragms and stiffeners. Structural steel is shop welded, and high-strength bolts are used for all field connections.

The surface of the antenna is expanded aluminum mesh supported by aluminum purlins spaced at 10-in. centers. The purlins are welded to tubular aluminum welded trusses forming panel units about 55 ft. on a side and 10 ft. deep. Since deflection of the structural-steel supporting frame caused by wind, ice and tem-

perature changes will far exceed the allowable deviation of the antenna surface from a true parabolic shape, a system designated as "configuration control" was devised to support the antenna so that the true parabolic shape can be maintained.

The antenna panels are designed to be supported by the corners on reversible screw jacks. As the steel frame deflects under various loading conditions, the corner jacks are automatically adjusted to compensate for the deflection, thus permitting the antenna to maintain its true parabolic shape about its axis.

The superstructure is supported by two altitude wheels of 190-ft. radius. Each altitude wheel consists of two dual-web box girders spaced 50 ft. apart. Each box girder or rim, 3 ft. 6 in. wide and 30 ft. deep, supports two rectangular steel billets, 10 in. wide and $4\frac{1}{2}$ in. thick, which serve as tires. Each tire, in turn, bears against 16 support-drive rollers of the altitude-drive system. Thus eight steel tires bearing against a total of 128 rollers support the total dead and live load of the antenna above the turntable, and at the same time provide for the 90-degree rotation of the antenna about the horizontal axis.

Two drive-support rollers are paired side by side in a total of 64 drive modules. The drive modules are designed to allow several degrees of movement to accommodate irregularities in the tires and rims of the altitude wheels. Since the design will not permit backlash in the fore and aft direction, the drive assembly has a very high spring constant. To insure full bearing, the drive rollers are centered on the tire by means of idler rollers.

The 16 modules in a quadrant are interconnected through a hydraulic system to insure equalization of the load among all the rollers in a quadrant. This hydraulic system also permits lowering of the antenna structure onto stowing pads to relieve the drive rollers from possible overload from high winds, and to permit removal of rollers for repair and maintenance.

Loads from the altitude drive units are carried by the turntable, a rec-

tangular framework of structural-steel trusses. The truss system transmits the vertical loads to the azimuth-drive rollers located at the corners of the turntable. The azimuth rollers bare on steel rails 10 in. wide and 4 in. deep. These rails in turn are supported on two circular foundations, 13 ft. wide and 6 ft. deep, which bear on shale. The turntable rotates about the pintle, a large bearing set in a mass of reinforced concrete 95 ft. in diameter and 20 ft. deep, Fig. 2.

The azimuth drive system (in the horizontal plane) is similar to the altitude system except that the antenna is designed to operate through 450 degrees in azimuth. The total live and dead load of the antenna is transmitted to the two azimuth tracks through clusters of wheels located at the corners of the turntable truss; however, only the outer wheels are driven.

The altitude and azimuth drive rollers are powered by a system composed of an induction motor, two opposed eddy-current clutches, and a gear box. The overall gear reduction is 516:1, and the gear train is designed so that the clutches are always connected to the train and oppose each other to eliminate backlash. The driving torque in either direction is controlled by varying the exciting current of the eddy-current clutch.

The control signal to the drives is received from the Input Command Converter. This special digital equipment converts programs from sidereal to altitude-azimuth coordinates. Another control is the Inertial Reference

system, which incorporates as its basic element an inertial platform. The platform provides information on where the axis of the telescope is pointing in altitude-azimuth coordinates. The basic elements of the platform are gyroscopes.

Some of the technical problems that are being solved and the research and development programs generated in meeting the challenge of the Big Dish are:

1. Determination of the finished grade elevation of the main site to insure adequate bearing for the foundations. Load tests up to 360 tons (10 tons per sq. ft.) were required to simulate actual loads imposed by the azimuth and pintle foundations.

2. Analysis of the highly redundant structure to achieve adequacy of design, maximum stiffness, equalized deflections, and minimum weight.

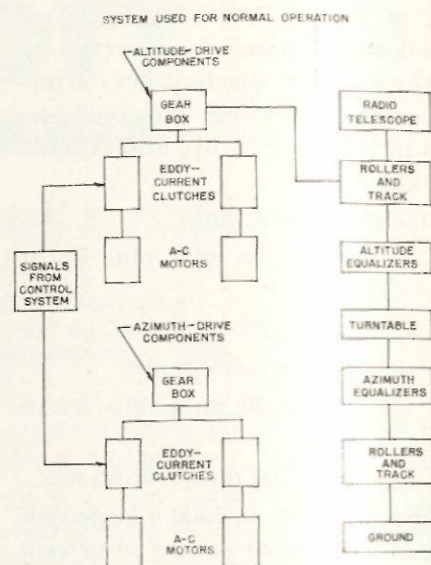
3. Dynamic analysis of the structure to determine lowest natural frequencies affecting the surface of the antenna.

4. Design of complex joints or weldments to provide distribution of shears and moments from two directions imposed by as many as thirteen main members intersecting at a panel point.

5. Design of the altitude wheels as curved box plate-girders 30 ft. in depth, subjected to normal stresses plus compressive stresses at right angles due to loads from spokes and moving roller loads.

6. Wind studies of scale models of the antenna panels to determine drag

FIGURE 3
BLOCK DIAGRAM OF DRIVE SYSTEM



factors. Studies to determine gust intensity and distribution.

7. Design of the aluminum panels to fine accuracy over the entire surface, supported to permit differential movement of the structural steel frame and aluminum panels and bonded to provide electricity continuity over the entire surface.

8. Erection of the structural steel and aluminum panels. Two movable towers, 90 ft. square and 420 ft. high, supporting cranes of 200-ft. boom length, are required to reach all points on the structure.

9. Drive systems (altitude and azimuth) are required to support a maximum load of 635 and 760 kips per roller, respectively, without overstress to roller or rail. The power train for the drives must be designed with zero backlash to produce maximum tracking torque at a rim speed varying from zero to 1 rpm. The conventional design formulas for allowable wheel loading based on diameter and Brinell hardness are not applicable. A comprehensive testing program to extend Jensen's formula was required. The eddy-current clutches have been tested for accuracy and response to varying load as a basis for the design of the control systems.

The development of control systems for the components of the device, to insure adequate performance and over-all system compatibility, was

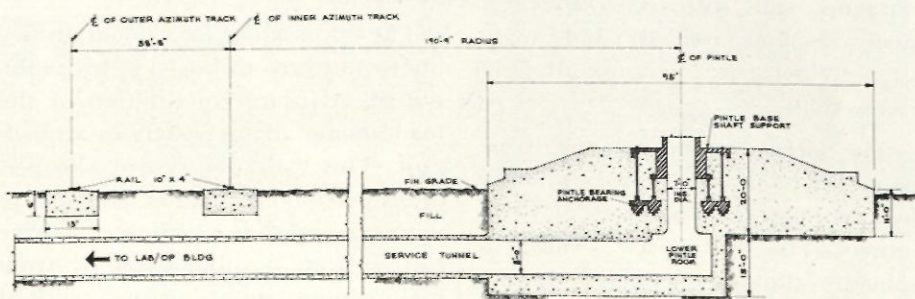


FIGURE 2
SECTION THRU PINTLE AND AZIMUTH TRACKS FOUNDATION

equally important in meeting the precise operational criteria.

The site was selected after an exhaustive study to find a location that would not be subject to hurricanes, heavy snow or ice, earthquakes, or extreme temperatures. A low level of man-made radio interference is also very important as industry, commerce and densely populated areas are the sources of electrical interference that reduces the efficiency of radio telescopes. The West Virginia Legislature recognized the importance of protecting the area by passing a bill that limits the electrical noise permitted adjacent to radio astronomy installations.

The project will occupy two separate areas to minimize the possibility of creating unacceptable radio interference at the antenna. The main site will accommodate the large telescope, operations building, 60-ft. radio telescope, and a small optical telescope. The support facilities site, which is four air miles from the main site, will include all personnel, administrative, shops and storage structures, and the power plant.

Construction Scheduled

By September 1958, construction funds had been appropriated, preliminary engineering completed, and contract plans and specifications advanced to the point where construction could be scheduled. A joint venture consisting of Tidewater Construction Corp., Norfolk, Va.; Peter Kiewit Sons Co., Omaha, Nebr.; and Patterson-Emerson-Comstock, Inc., Pittsburgh, Pa., was selected as the prime contractor. The contractor is subcontracting all major phases of the project on a competitive lump-sum basis. The grading and access road for the main site is being built by the Nello L. Teer Co., Durham, N. C. Excavation amounts to more than 1.5 million cu. yd. Blasting is not permitted.

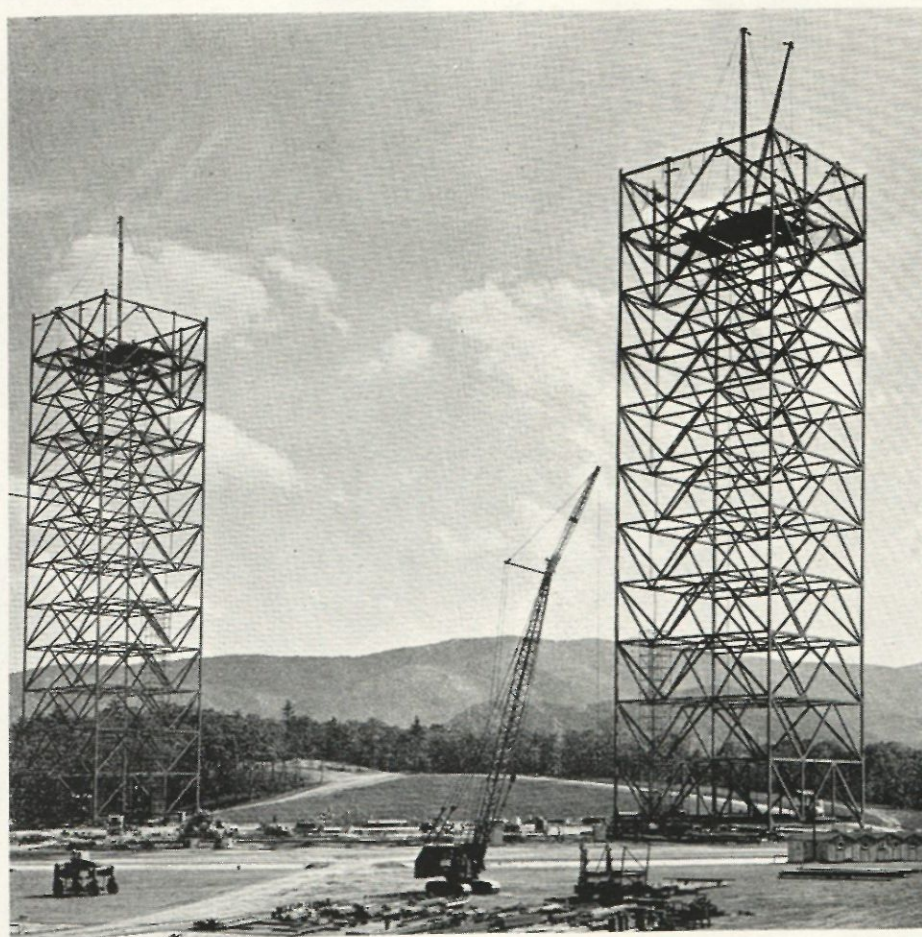
The American Bridge Division of the U.S. Steel Corp. was low bidder

for the fabrication and erection of the structural steel and the erection of the aluminum panels. Baker & Coombs, Inc. of Morgantown, W. Va. holds the contracts for the foundations and the reservoir for the water supply system. Additional increments of the work will be placed under contract as the plans and specifications are completed by the architect-engineer contractor. However, the design of certain electrical and mechanical components has approached the current limits of the art, thus requiring research or testing programs to insure feasibility. The target date for completion of the Big Dish and its supporting facilities is 1962.

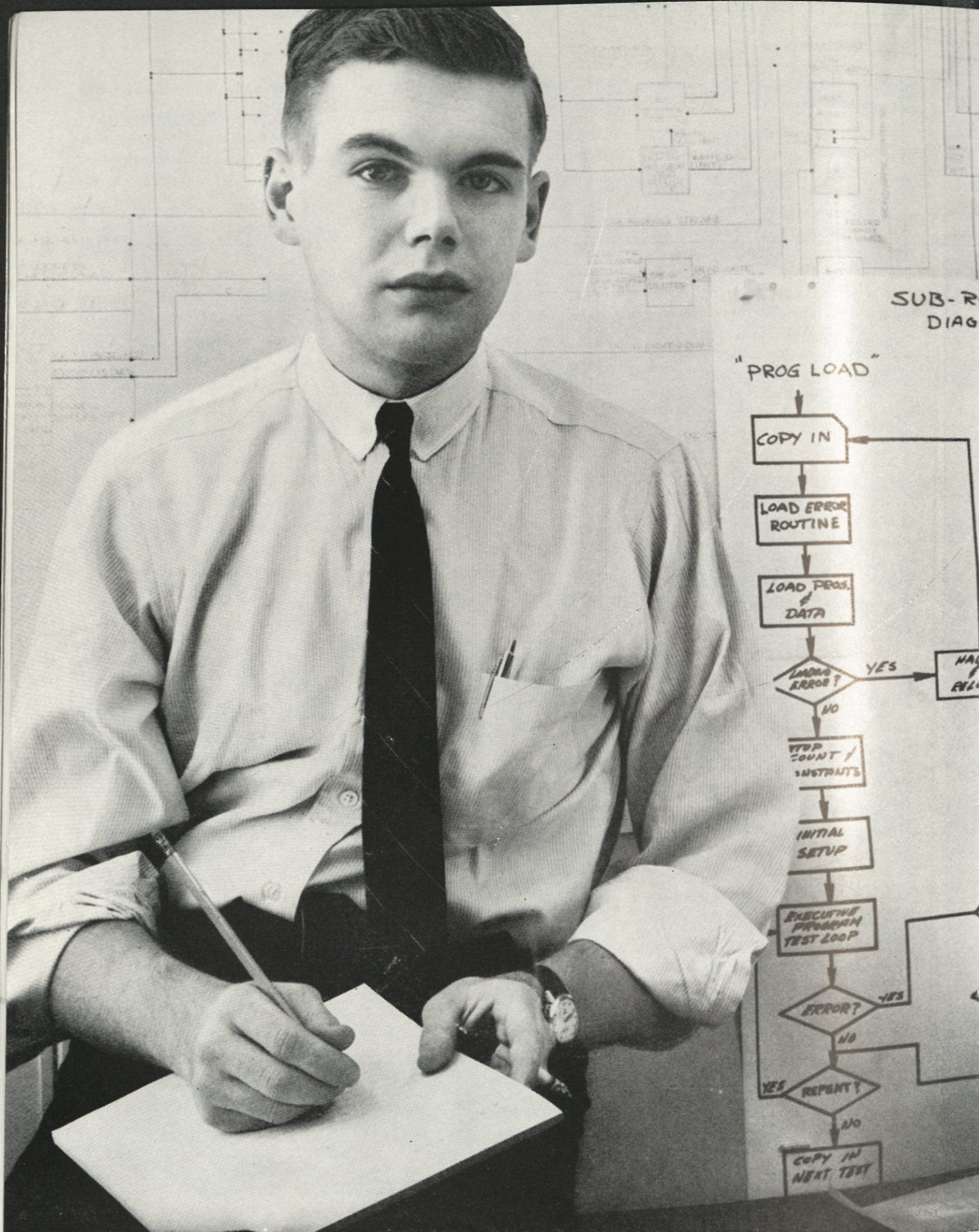
The Naval Research Laboratory is closely associated with all technical aspects of the project including, in part, the development of criteria, interpretation of requirements, review

of research and engineering programs that lead to the preparation of contract plans and specifications, shop and field tests of components, and the final operational checkout of the radio telescope. J. H. Trexler has been designated as Technical Director by the Naval Research Laboratory.

The Chief, Bureau of Yards and Docks, Department of the Navy, Rear Admiral E. J. Peltier, CEC, USN, F. ASCE, is responsible for the project as part of the Navy's Military Construction Program. The project is assigned to the Officer in Charge of Construction, Fifth Naval District, Rear Admiral H. B. Jones, CEC, USN. The writer has been assigned to the project since the start of feasibility studies and is the Resident Officer in Charge of Construction at the site.

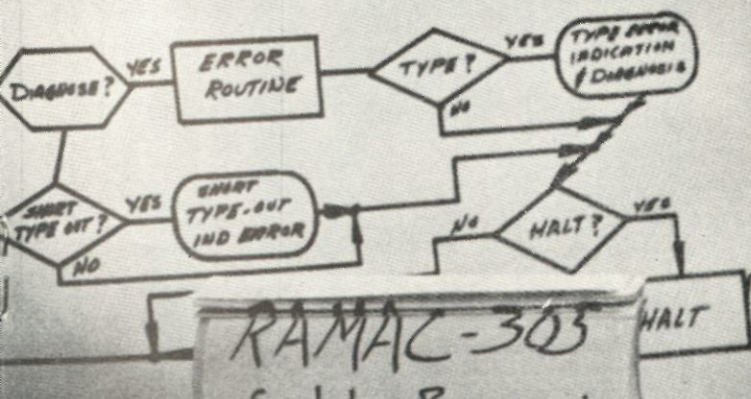


90 ft. square towers 420 ft. high, to support cranes of 200 ft. reach, are being provided by the American Bridge Division of the U. S. Steel Corporation for use in the erection of structural steel for the 600 ft. diameter radio telescope at the Naval Radio Research Station, Sugar Grove, West Virginia.



Robert M. King (B.S.E., Princeton '57, M.S., Carnegie Tech) is investigating applications of the electronic computer in advanced computer design. A skilled computer programmer, he has done original work in organizing programs that make possible computer self-diagnosis.

ROUTINE FLOW CHART
DIAGNOSTIC TEST BRACIA



HE GETS COMPUTERS TO DIAGNOSE THEIR OWN FAULTS

With the increasing size and complexity of modern computers, one of the most interesting problems that engineers face is the rapid and efficient location of failures within the system.

The method which they have found most practical is to use the speed and logical abilities of the computer itself to make the diagnosis. Programming computers to perform this function is the job of Robert M. King.

The Diagnostic Technique

He prepares programs for the computer which actually simulate the deductive processes of a man investigating the faults of the machine. Each program instructs the computer to exercise various segments of its circuitry in a logical order.

The result of each test is checked against the correct result, stored in the computer memory, of previous tests of the same circuitry when in proper working order. If the results do not agree, a message is automatically typed which indicates the failure and which component caused it.

A computer is particularly adept at this job. It can take into consideration simultaneously a large number of factors. It can also work at very high speeds. Once a program is properly written, the computer makes no errors. Appropriately enough, diagnostic programming often aids in designing better computers.

A Programmer's Background

Computer programs are the result of ingenious applications of many intellectual qualities. Computer design and language are based on sound laws of logic. Therefore an important prerequisite is the ability to analyze complex problems and to deduce from them useful methods of solution consistent with machine requirements.

If you think you might be interested in working in one of the many fascinating areas of computer programming, you are invited to talk it over with an IBM representative. The future can be as unlimited as the future of the computer itself.

IBM®

INTERNATIONAL BUSINESS MACHINES CORPORATION

Your Placement Officer can tell you when an IBM representative will visit your campus. Or write, outlining briefly your background and interests, to: *Manager of Technical Employment, IBM Corporation, Dept. 845, 590 Madison Avenue, New York 22, N. Y.*



Above—E. Days convocation speaker, Mr. J. A. Haddad.

Right—Miss St. Pat, Mary Papageorge.



ENGINEERS DAYS

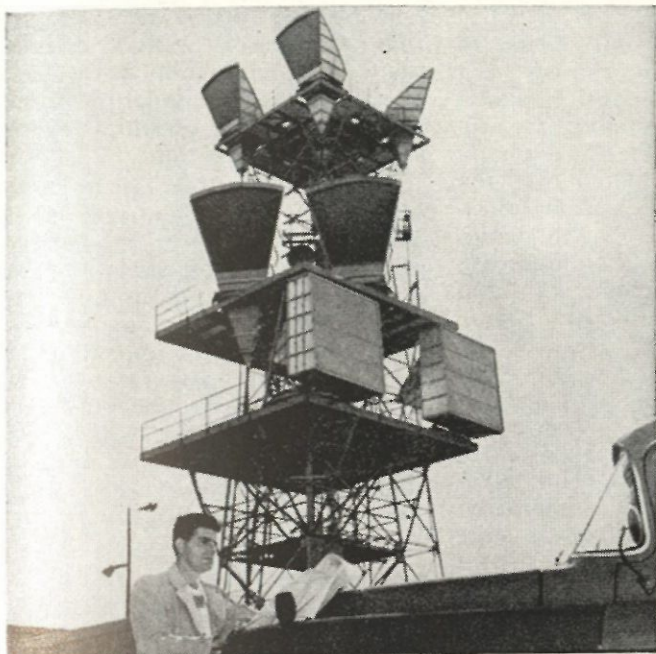
Finale to Engineers Days was the Annual E. Days Ball.

Below—Pull—Tug-of-War at Saturday's picnic.



1960





Dick Ernsdorff studies a microwave site-layout chart atop a mountain near Orting, in western Washington state. On assignments like this, he often carries \$25,000 worth of equipment with him.



Here, Dick checks line-of-sight with a distant repeater station by mirror-flashing and confirms reception by portable radio. Using this technique, reflections of the sun's rays can be seen as far as 50 miles.

He wears two kinds of work togs

For engineer Richard A. Ernsdorff, the "uniform of the day" changes frequently. A Monday might find him in a checkered wool shirt on a Washington or Idaho mountain top. Wednesday could be a collar-and-tie day.

Dick is a transmission engineer with the Pacific Telephone and Telegraph Company in Seattle, Washington. He joined the company in June, 1956, after getting his B.S.E.E. degree from Washington State University. "I wanted to work in Washington," he says, "with an established, growing company where I could find a variety of engineering opportunities and could use some imagination in my work."

Dick spent 2½ years in rotational, on-the-job training, doing power and equipment engineering and "learning the business." Since April, 1959, he has worked with microwave radio relay systems in the Washington-Idaho area.

When Dick breaks out his checkered shirt, he's headed for the mountains. He makes field studies involving micro-

Dick stops by the East Central Office building in Seattle to look at some microwave terminating equipment. It's involved in a 4000 megacycle radio relay system between Seattle and Portland, Oregon.



wave systems and SAGE radars and trouble-shoots any problem that arises. He also engineers "radar remoting" facilities which provide a vital communications link between radar sites and Air Force Operations.

A current assignment is a new 11,000 mc radio route from central Washington into Canada, utilizing reflectors on mountains and repeaters (amplifiers) in valleys. It's a million-dollar-plus project.

"I don't know where an engineer could find more interesting work," says Dick.

* * *

You might also find an interesting, rewarding career with the Bell Telephone Companies. See the Bell interviewer when he visits your campus.

BELL TELEPHONE COMPANIES



In the Engineering Lab in downtown Seattle, Dick calibrates and aligns transmitting and receiving equipment prior to making a path-loss test of microwave circuits between Orting and Seattle.



THIS TODAY

By JOE LISCHKA, E. Physics '61

BIGGER AND BETTER WIND TUNNELS

The world's largest blower is now operating at the U.S. Air Force's Arnold Engineering Development Center at Tullahoma, Tenn. The machine, built by Westinghouse, consists of four good-sized air compressors coupled to four giant motors. Two of the motors develop 83,000 horsepower each, and the other two are rated at 25,000 horsepower. The 122-ton rotors of the motors spin at a rate of 600 revolutions per minute. Part of the machine is now being used to power a transonic wind tunnel which has been used for about three years in testing the Armed Forces' missiles. Nearing completion is a supersonic wind tunnel which will produce air speeds of about 3,000 miles per hour at simulated altitudes of over 100,000 feet. It will use the full capacity of the compressors. The diameter of the supersonic tunnel varies from 42 to 62 feet.

PLASTIC PRINTING PLATES

In 1949 it was discovered that printing plates for illustrations and text could be made from a plastic that hardens when exposed to light instead of using acid-etched metal plates. In 1957 the plates were introduced to the printing trade and have been successful. Now, after ten years of research and an expenditure of \$6 million, Du Pont is building a new unit at its Parlin photoproducts plant

to produce the plastic printing plates on a commercial scale.

An unexposed "Dycril" plate, as supplied by Du Pont, consists of a thin layer of light-sensitive plastic bonded to a metal support. To produce a printing surface, a photographic negative is placed over the plastic and exposed to a strong ultraviolet light. Where light passes through the negative, the photosensitive plastic quickly becomes hard and relatively insoluble. The plastic shielded by the dark areas of the negative is unaffected and is washed away easily, leaving the hardened, exposed areas in relief. The entire operation, from original exposure to finished plate ready to print, takes only 15 to 20 minutes as compared to a matter of hours for conventional engravings.

One characteristic of the photopolymer process is that the plate reproduces exactly what is in the negative, and any number of plates made from the same negative will be exactly alike.

THE SUN WILL SHINE AGAIN

There is hope that Los Angeles can once again be made fit for human habitation. Research conducted by the Air Pollution Control District of Los Angeles indicates that oxides of nitrogen, a major contaminant present in auto exhausts, can be reduced 80 to 90 per cent by introducing a small amount of cooled exhaust gas into the intake system of the engine. The UCLA Engineering Department, also conducting research on the problem, has designed a device using the principle. It consists of a narrow tube to carry the exhaust gas forward from the tailpipe to the carburetor, and a valve to meter the flow. Its estimated cost is given as less than \$15.

In addition to reducing nitrogen oxides, the innovation reduces the tendency of the engine to knock, thus improving the effective octane number of the fuel-air mixture. This would permit the high-compression engines to operate on gasoline of lower octane rating. The need for special anti-knock additives would be reduced also.

The discovery makes available for the first time a principle of control for all of the major contaminants in auto exhaust. The others, hydrocarbons and carbon monoxide, can be controlled by afterburners.

AN APPLICATION OF THE TUNNEL DIODE

A new broad-band microwave amplifier using all solid-state devices has been developed by scientists of the

Bell Telephone Laboratories. The new amplifier makes use of the negative resistance of the Esaki or tunnel diode in combination with non-reciprocal ferrite attenuation in order to achieve a high amplification ratio without self-oscillation.

The new amplifier can be used to increase the strength of radio signals over a broad range of frequencies in the microwave range above 1000 megacycles and is expected to have applications in radar, microwave, radio relay, satellite communications, and waveguide transmission systems. Power requirements are low and it is expected that the device will be lower in cost and have greater reliability than other methods of achieving comparable signal amplification.

The device is built on a traveling wave concept with a row of Esaki diodes along the center of a strip-line waveguide. The negative resistance of the diodes causes the power in a signal wave to increase progressively as it travels along the waveguide. By including non-reciprocal ferrite attenuation in the structure, the device is made to absorb waves traveling in the undesired reverse direction and to amplify waves traveling in the desired direction. This feature allows a large total amplification to be obtained with complete stability by eliminating internal "feedback" which has previously caused oscillations and other difficulties in amplifiers of this type.

The active diode used in this amplifier was the discovery of Dr. Leo Esaki of the Sony Corporation in Japan. It has aroused considerable interest in the electronics industry because it is a simple semiconductor device which can convert direct current into useful alternating current signals in communications and computed circuits. It has only two terminals and is easier to construct than triode transistors or vacuum tubes, yet can do many of the same jobs. The Esaki diode is useful because it is a negative-resistance element in which the current decreases as the voltage is increased. This causes it to add to the power of signal waves instead of absorbing the power as a positive resistance does.

The new amplifier opens a large field of useful applications for the Esaki diode by eliminating one of the major difficulties in applying it as a signal amplifier.

NEW OPTICAL RESEARCH FACILITY

To help them in their never-ceasing endeavor to build a better

Brownie camera, Kodak Company is building a new 8-story physics building at Kodak Research Laboratories in Rochester, N. Y. One of the unique features of the building is a 160-foot lens tunnel.

The tunnel will be used in research on lenses and optical systems. Its length is essential because in testing a new lens design, an observer or instruments must be far enough from the light source to have it appear as a single point of light.

J. Clay Turk, supervising engineer of the project, said the tunnel is insulated and covered with three feet of earth to keep interfering heat waves to a minimum. He said the tunnel is located at basement level, outside the building proper, so it will be free of vibrations from street traffic that might affect delicate measuring instruments.

An "optical penthouse" on the roof of the building will provide for study of such subjects as long-distance photography and the physical characteristics of sunlight. A railed, tiled area for outdoor experiments will also be located on the roof, Turk reported.

Especially important for electronics studies is a series of perfect electrical grounds, Turk said. Already installed, the grounds consist of 3-inch copper

pipes sunk into bedrock outside the concrete footings. Low resistance ground cable extends to the electronics laboratories from the ground pipes. The tubes may be filled with treated water for a perfect connection to ground.

Office areas will lie along the perimeter of the building, with laboratories in the interior. Each group of laboratories will have one wall facing on a 6-foot shaft running from basement to roof the length of the building. All utilities will be supplied through this shaft to eliminate piping on the walls and ceilings.

Inside laboratory areas will be completely air-conditioned. Office areas will have comfort-cooling and heating.

Turk outlined other construction features such as lightweight concrete aggregate floors, interior removable steel partitions, and high-speed personnel elevators.

The first floor will contain a reception area and a special physics library, plus building staff offices and a cafeteria, he said.

BETTER LIGHTING FOR SAFER DRIVING

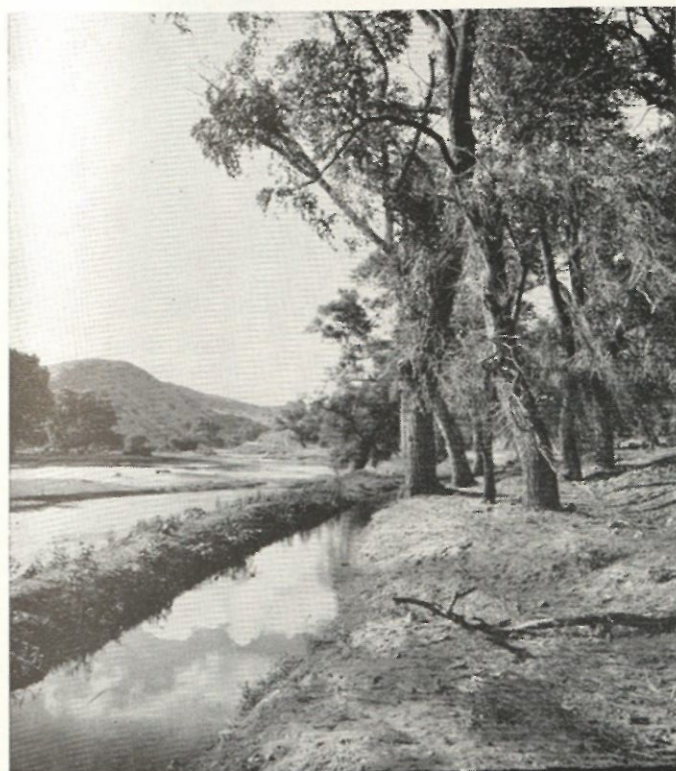
A fluorescent lighting system with

three times the brightness of any commercially available fluorescent unit has been demonstrated by Sylvania Electric Products, Inc.

The new system, which combines a newly-developed aperture lamp and an optically-controlled fixture, throws a narrow band of light for a considerable distance with a minimum amount of glare. These features will make the system useful for low-mounted highway lighting, expressway turn-offs, service stations, building facade floodlighting, and edge lighting for signs.

One of its more interesting application is its use as a linear fluorescent automobile headlight. The experimental headlight of a demonstration model extends across the grill of a car between conventional headlamps. The headlight distributes light uniformly in front of, and to the sides of a car with a vertical cut-off to keep glare from blinding oncoming drivers.

When used in highway lighting, the system has two distinct advantages: reduction of glare to a minimum, and uniform distribution of light over the highway surface.



The COCKS-CLARK ENGRAVING CO.



Photoengravers Illustrators

2200 ARAPAHOE ST.

TABOR 5-6244

DENVER 5, COLORADO

the
BOULDER
DAILY
CAMERA

COMMERCIAL
PRINTING
DEPARTMENT

FOR ALL YOUR PRINTING NEEDS
PHONE HI 2-1202

St. Patricia, 1960



MARY PAPAGEORGE
Freshman
Chi Omega



DIANNA RICHARDSON
Kappa Kappa Gamma



ANNE GIERE
Delta Gamma



DOTTIE HOWARD
Kappa Pledge

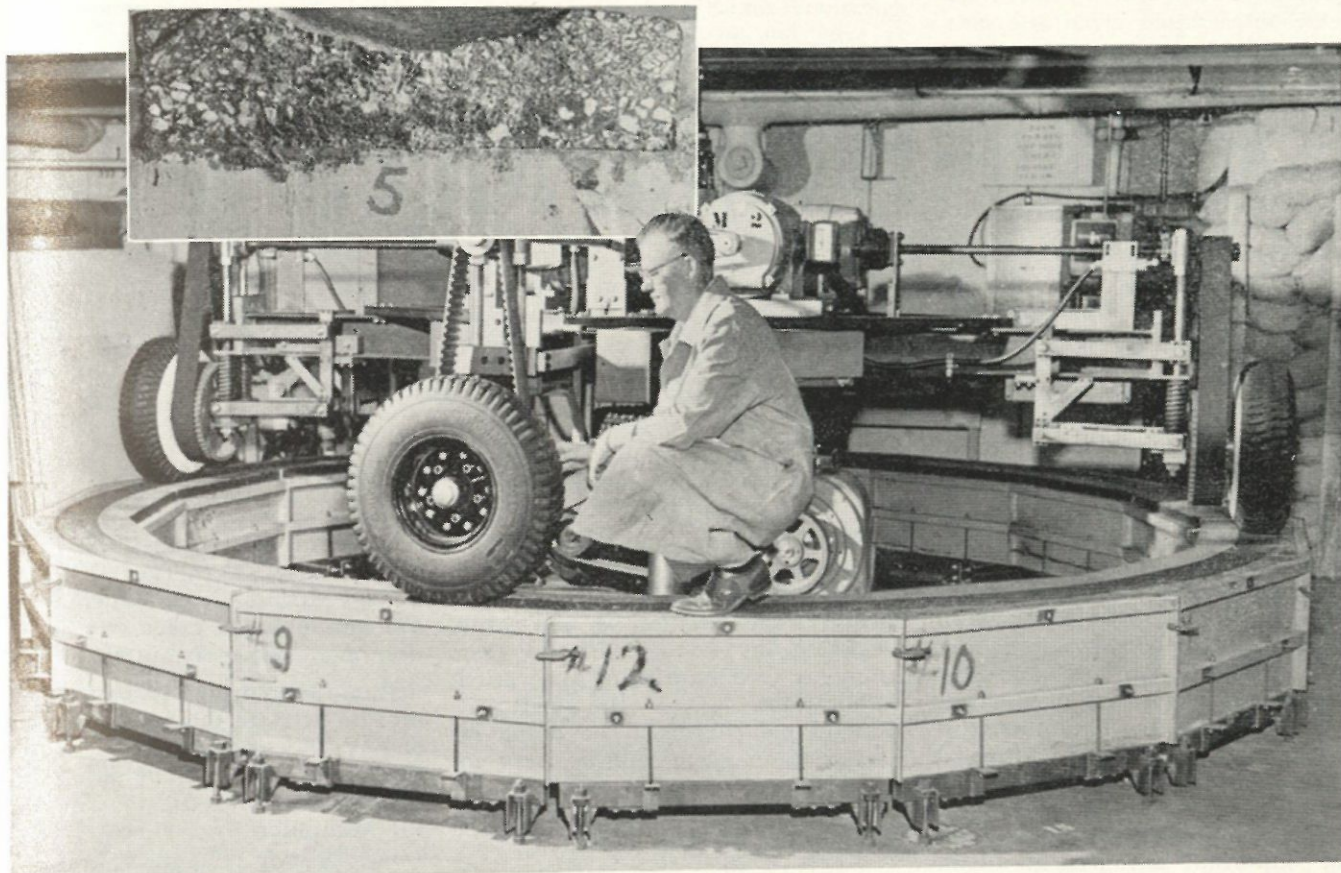


HONEY WEINSTOCK
Phi Sigma Delta

*A
t
t
e
n
d
a
n
t
s*



ONLY 12 INCHES WIDE...



Tom Speer, Senior Engineering Research Supervisor at Standard Oil, inspects one of the 12 sections in a new miniature road tester. Under simulated weather conditions, four wheels

whirl around to reveal wear patterns and other vital information. (INSET) Ruler shows wear pattern after strip has taken pounding from tires during rain, freeze, thaw and heat.

...THIS 'ROAD' CARRIES WORLD'S HEAVIEST TRAFFIC!

Say good-bye to washboard pavements and chuck holes—their doom may be sealed!

Key weapon in the war on costly road damage is a new miniature highway developed in the Standard Oil research laboratories in Whiting, Indiana. It is only 12 inches wide and 44 feet in circumference, but it carries heavier loads than any highway in the world. This Tom Thumb turnpike will eventually lead to methods of building longer-lasting, smoother, safer highways...at far less cost to taxpayers.

Four wheels whirling around hour after hour can give it any degree of traffic intensity desired. Pressure that corresponds to the weight of the heaviest trucks can be applied to the wheels. To simulate actual traffic, the wheels are placed on braking and acceleration 90 per cent of the time. Automated electronic equipment can quickly change "road conditions"

from desert dry to cloudburst drenched. "Road conditions", too, can be changed from freezing to thawing.

Within weeks, the new test-tube roadway can determine what happens to roads during years of use in all kinds of weather. It can pre-test paving formulas and techniques, and may show how to eliminate washboard pavement and chuck holes. Savings in highway research alone may run into millions of dollars. Even larger savings in auto and road repairs and possibly in gasoline taxes are in sight.

This test-tube roadway is just one of the many exciting developments at Standard. Every day, scientific research, pure and applied, points the way to new or improved products. This work holds great challenge and satisfaction for young men who are interested in scientific and technical careers.

STANDARD OIL COMPANY

910 SOUTH MICHIGAN AVENUE, CHICAGO 80, ILLINOIS



THE SIGN OF PROGRESS...
THROUGH RESEARCH

Ramo-Wooldridge, Inc.

By LOWELL BROOKS, E.Physics '62

In this age of rockets and missiles, one of the most important industries of today is that of electronics. And a leader in this field is Ramo-Wooldridge. This company was organized in 1953 by Drs. Simon Ramo and Dean E. Wooldridge, with major financial underwriting by the Thompson Products Company. In 1954 it formed a Missile Research Division which was later incorporated as the Space Technology Laboratories which have made some important advances in missile research. In that same year Ramo-Wooldridge formed Pacific Semi-Conductors Inc. which today is one of the leading producers in that field. By 1955 the company had grown so that it had to move to larger quarters on Abor Vitae Street in Los Angeles. Then, still expanding in 1957 they began construction on the Denver plant, which was to do most of the manufacturing. In 1958 Ramo-Wooldridge merged with the company that had been its major financial backer in the beginning, Thompson Products, to make one of the 150 largest corporations in the United States today. Then in 1959 they opened their Research and Development Center in Canoga Park, California.

Since its beginning in 1953, Ramo-Wooldridge has been primarily concerned with developing products that are the result of relatively new scientific advances. Consequently, one is not surprised to learn of the large amount of training members of the scientific and engineering staff have had. On the average, members of this group have had 9½ years of experience since graduation; and of the 450 people in this group, 140 hold their master's degree, while another 55 hold doctorates. Many of these peo-

ple have national and international reputations for work that they have done in their fields. What are these fields? That question is not easily answered one-two-three, because electronics systems have many and varied applications. What the staff at Ramo-Wooldridge will be doing in the years to come will be hard to say. However, one can divide the work done by Ramo-Wooldridge into several different categories.

Digital Computers, Controls, and Information Processing

The main product in this category is the RW-300, which is a process control computer. As well as many industrial uses, it can be applied to making a last minute check on a rocket during its count down. Another important use for this computer is for testing rocket motors. Being a closed loop computer it can collect data in analog form from several hundred different instruments, convert it to digital language, process it, analyze it, and if need be change the test so that more important data can be obtained—all while the test is going on. This, of course, is a great advantage to the scientists, since before using the RW-300 they would have to run a test, analyze the data, and then devise a new test to answer questions not covered previously. But with the RW-300 they just have to run one test while the computer can process the data on the spot, change the test if need be, and end up with data that is two or three times more effective than that obtained previously. In industry this computer is used to automatically control such processes as chemical manufacture and

oil refining. The most striking instance of this is at the Texas Company in Port Arthur, Texas, where a RW-300 computer has taken over production on a completely automated basis.

Ramo-Wooldridge is now beginning to activate the prototype model of RW-400 computer. In the *RW-400 Preliminary Manual of Information* there is the following description of this computer:

The RW-400 is an integrated data processing system specifically designed for high speed data handling and simultaneous execution of multiple problems. The RW-400 design features a form of modularity which permits the rapid shift of equipment to handle multiple problems, new problems, or a varying workload. This modularity also provides a capability for growth, so that as the tasks increase and greater capacity is needed, the data processing system can grow in suitable increments with minimum cost and disruption.

Capability for growth has been extended through the use of several identical computers working simultaneously in the system. These Computer Modules operate in an extremely flexible manner with the various modules in the system. Different configurations of equipment can automatically be connected together through an electronic switching system to service many independent problems at the same time or to concentrate upon urgent or massive tasks. Thus the computing capacity can be allocated in a highly flexible manner to meet the specific data processing needs of the user.

Although each module used in the RW-400 Data processing system has built into it the highest reliability consistent with the "State of the Art," multiplicity of modules also has important reliability implications. For example, continuous operation is possible even in the event of a computer malfunction since one computer failure does not render the entire system inoperative. Instead another computer module takes over the assignment and the system continues

operation at a slightly reduced capacity during the maintenance interval. The use of identical modules also facilitates maintenance since the parts are identical and easily changed.

... The RW-400 Master Slave concept enables any single computer module to perform the role of master computer, and automatically monitor, schedule, and control the other computer modules which are designated "slave" computers. This affords an efficiency in operations and equipment utilization never realized previously. These special techniques are achieved in the RW-400 because the Computer Modules are able to communicate with one another in a rapid and automatic fashion. The unique organization of modules provides advantages in higher speed operation, more efficient equipment utilization, and greater flexibility and reliability, even though the system cost is much lower than existing large-scale computing systems. Further, data processing capability can be added as required in the form of additional modules rather than entire systems, and thus added capability is obtained in the RW-400 with minimum cost. The RW-400 is the first data processing system to simultaneously employ a number of computer modules for executing single or multiple applications and, therefore represents the first truly modular data processing system. . . .

Communication and Navigation Systems

New discoveries and a better understanding of the basic problems of communications indicate that our present system can be substantially improved. At Ramo-Wooldridge scientists have studied some new techniques to find ways to combat unfavorable signal propagation, ways to transmit signals with greater security, and ways to get larger information capacity per channel. Similar developments applied to navigation systems have resulted in new equipment for the guidance of aircraft at long ranges from their bases. Along this same line though not exactly a communication or navigation system is their AN/DRW-11 which is a command-destruct receiver. This is the device that receives the signal for a missile to destroy itself. Though it has been on the market for only about five months it has found wide acceptance among missile makers because of its compactness and its reliability. What makes this instrument almost foolproof is the fact that it is a three channel tone modulated receiver. That is, in order for it to be activated it must receive three separate signals simultaneously at exactly the right frequencies. The odds that this could happen accidentally or even by programmed jamming are very large; therefore one can be quite sure that the missile will be destroyed only upon the command of the Range Safety Officer.

Infrared Systems

Some unique properties of infrared light make it ideal for solving certain kinds of target discrimination problems. Studies along these lines have been carried on by Ramo-Wooldridge for several years now and have resulted in systems being developed for guidance, aircraft defense, aerial mapping, and anti-aircraft control.

Electronics Instrumentation and Test Equipment

In the past, many new electronic systems have failed to live up to expectations simply because adequate tests had not been worked out for them; consequently all the bugs had not been worked out of them by the time they were put on the market. Therefore, Ramo-Wooldridge devotes much time to developing tests and test equipment for their products. In addition, they also develop and build test equipment for systems developed elsewhere. The Denver facilities of Ramo-Wooldridge devote much of their technical effort to the development of this type of equipment.

This then, is a short summary of the different fields of endeavor at Ramo-Wooldridge. Excluding one quite large field, that of basic research. However, to go into that topic could be an article in itself, so let us just say that there is a terrific amount of basic research being done at Ramo-Wooldridge.

Now that we have had a look at Ramo-Wooldridge as a whole, let us come a little closer to home and examine the Denver plant. This large, modern building, located about 10 miles south of Denver, Colorado, performs three main functions for Ramo-Wooldridge. First, it develops test equipment as mentioned above; second it is the center of the Ramo-Wooldridge manufacturing, and third it is the center of the Data Systems Laboratories.

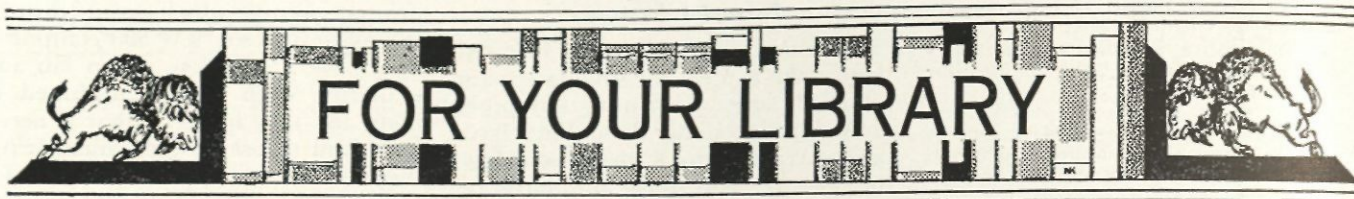
Of the 350 people employed in this plant, approximately one third of them are directly engaged in production and one third in production-support. The rest are involved directly or indirectly with the Data Systems Laboratory. Production at Ramo-Wooldridge is on a semi-production line basis. That is, they can't use many automatic machines because the nature of the work requires that many of the jobs be done by hand. So Ramo-Wooldridge proceeds with the work from station to station as in a production line, but most of the work is done by hand by skilled workmen. In this manner they produce about one RW-300 per month. For making

printed circuits, which are used quite extensively in the RW-300 computer, they have a complete photo lab and a plating shop that is equipped to plate any type of metal that is necessary. And to keep their standards up, they also have complete facilities for testing the equipment that is used to check their products. In fact, it amounts to a small bureau of standards.

So much for a very brief picture of the production. The processes used here are very similar to those used by most electronics firms, and therefore are nothing unusual and exciting. Now let's proceed to something that is not only unusual and exciting, but something that may very well play an important role in the future of our country, the Data Systems Laboratories.

The function of the Data Systems Laboratories is to conduct research in the field of "intellectronics." Intellectronics is a word that was coined to describe the technology of extending the human intellect by the use of electronics. For it is a well known fact that the human mind is very inefficient when it comes to "crank-grinding," i.e., mechanical computation and so forth; whereas, machine can sort, integrate, condense, and catalogue information; make logical deductions; information retrievals; and memory work very efficiently. But a machine can't think, so it has been the dream of man for a long time now to combine these two outstanding characteristics. Intellectronics may achieve this by making a man and a machine work together in such a way that the machine does all the "crank-grinding" and leaves the human mind free to make the real decisions. This idea is not just to train a person to work a machine better, but rather the objective is to make the machine an extension of the human. At the Data Systems Laboratories at Ramo-Wooldridge, they have a RW-400 and say, 10 or 15 operators (this is NOT the correct number as that information is classified) in a room with a completely controlled environment. They then give problems to these people and have them work the problems out while scientists and engineers make observations to see where the man-machine system can be improved. It may be a major change such as devising a completely new language for the man and the ma-

(Continued on page 47)



By JOHN C. WOOLUM, Physics '60

Radioisotope Techniques

By Ralph T. Overman and Herbert M. Clark. 476 pp. McGraw-Hill Book Co., New York, 1960. \$10.00.

Many engineers are now faced with a problem involving radioactive isotopes. It is for these people that this book is written. This laboratory manual deals with the problems associated with handling radioactive materials safely, performing proper and significant measurements of radioactivity, and interpreting the data obtained from such measurements. The book could be used as a text on the advanced undergraduate to graduate level.

Each chapter begins with the theory and discussion and ends with a group of experiments concerning a specific topic. The first two chapters deal with nuclear radiations, their interactions with matter, and their detection. The next chapter covers the needed material on the subject of errors and statistics. Chapter four is a discussion of the practice of radiological safety. The last six chapters are concerned with preparation, separation, and utilization of radioactive sources. Many good graphs, diagrams, and illustrations are included in this book.

Elementary Analysis: A Modern Approach

By H. C. Trimble and F. W. Lott, Jr. 621 pp. Prentice-Hall Inc., Englewood Cliffs, N. J. 1960. \$6.95

This text is designed to prepare entering freshmen for a course in calculus. It is a full year text but could be used for one semester for more advanced students.

The authors introduce set theory in the first chapter and use set theory notation throughout the rest of the

book. All the usual topics of such a book such as complex numbers, roots and powers, trigonometry, and functions of one and several variables besides many in the modern realm are included. Some of the modern topics include an introduction to groups, fields, matrices, and linear transformations. The analytic geometry needed for a course in calculus is integrated into several of the chapters. The authors have included a great many interesting and instructive examples and exercises on many applications.

We feel the more advanced subjects in this book have not hurt the readability but actually aid in understanding the mathematics. If the student has mastered this text, he should be far ahead in future mathematics courses.

Thermodynamics: Second Edition

By Franklin P. Durham. 349 pp. Prentice-Hall Inc., New York, 1960. \$8.35.

Undergraduate courses in thermodynamics have obtained an almost universal reputation for being among the most difficult to understand. The author of this text believes that this is partly due to the thermo books which, though they seem quite suitable to the instructor who already knows the subject, are unsatisfactory from the student's point of view. He has written this book for the engineering student. He has tried to keep the text reasonably simple so that the material is readily understandable through home study and thus more class time can be devoted to more advanced topics of interest to the different classes.

The basic theory is developed in terms of a minimum number of simple equations in order to eliminate

memorizing of specialized equations and to focus the reader's attention on the important relations. The concept of entropy is introduced early in the book to integrate the ideas into later developments. The concept of stagnation conditions in steady flow systems is treated because of its importance in measurement of high speed flows and to simplify the general energy equation. Each chapter contains many good examples and problems. An excellent illustrated glossary of thermodynamic terms is included in the appendix.

Petroleum Engineering: Drilling and Well Completions

By Carl Gatlin. 341 pp. Prentice-Hall Inc., New York, 1960. \$13.00

Written especially for engineering students, this book covers the factors involved in the successful drilling, testing, evaluating, and completing of an oil well. The author assumes no prior knowledge in the field so begins with a number of general topics as the nature of petroleum, reservoir rock properties, core analysis, well logging, and formation damage. Some of the more advanced topics covered include factors affecting penetration rate; special drilling techniques such as crooked hole problems, directional drilling, and fishing; and well completion elements such as casing and cementing procedures, perforating, stimulation, sand exclusion, permanent-type completions, and water or gas coning. For generality most of the equipment descriptions are only schematic.

The reader will appreciate the numerous examples which are worked and the comprehensive problems and extensive bibliography which accompany each chapter.

what is magnetism?



An orientation to home?
Domain orientation?
The secret of a lodestone?
The cosmic ray accelerator?
An aspect of a unified field?

Fundamental to Allison's business — energy conversion — is a complete familiarity with magnetism in all its forms. This knowledge is essential to our conversion work.

Thus we search for a usable definition of magnetism—not only what it is, but why it is. And to aid us in our search, we call upon the capabilities within General Motors Corporation and its Divisions, as well as the specialized talents of other organizations and individuals. By applying this systems engineering concept to new research projects, we increase the effectiveness with which we accomplish our mission—exploring the needs of advanced propulsion and weapons systems.

Energy conversion is our business



Want to know about YOUR opportunities on the Allison Engineering Team? Write: Mr. R. C. Smith, College Relations, Personnel Dept.

ALLISON

Division of General Motors,
Indianapolis, Indiana

WE HONOR...

By **THOMAS A. CLARK**

After a total of 129 years of service to the University of Colorado, to its College of Engineering, and especially to its students, four well-known professors are retiring this year from the staff of the school.

These persons are Clarence Lewis Eckel, Dean of the College of Engineering; Roderick Lyle Downing, professor of civil engineering; Harold W. Sibert, professor of aeronautical engineering; and W. Otto Birk, professor of English in engineering.

In respect to these educators, we submit brief sketches of their lives in the hope that their devotion will continue to inspire all those who have known them.

CLARENCE LEWIS ECKEL

Dean Eckel was born in Illinois in March, 1892. The University of Colorado knew him first as an engineering student and football player. After

a short period in industry, he returned to the University as an instructor in the Department of Civil Engineering.

In 1918, when the United States was readying for war, Dean Eckel enlisted in Company B Engineers, Colorado National Guard, and was discharged after he war as a captain, 115th Engineers, U.S. Army.

After four years at the University of Pennsylvania as assistant professor of civil engineering, he returned in 1923 to his alma mater as professor of civil engineering. He became head of that department in 1926, and in 1943 he was made Dean of the College of Engineering.

The Dean has been a consultant on many of the buildings on the University campus, including the Library, Fieldhouse, and Ketchum. He is a licensed professional engineer in Pennsylvania and Colorado, and has been for 18 years a member of the

Colorado State Board of Registration for Professional Engineers and Land Surveyors. He belongs to many professional engineering societies and has held national offices in nearly all of them.

After retirement? Dean Eckel does not plan just to "rest" after a life so dedicated to students; he has accepted a post as visiting professor of civil engineering at San Diego State College. He will also continue as an active professional engineer. His devotion is reflected in his answer to our question about hobbies: "The College of Engineering and keeping track of alumni."

RODERICK LYLE DOWNING

Professor Downing was born in Lamar, Colorado, in June, 1892. All of his schooling was in this state, including a degree in engineering from the University of Colorado. From 1914 to 1917, he worked for the railroads; then for six years he was with



DEAN ECKEL



PROF. DOWNING

the U.S. Bureau of Public Roads as a highway engineer.

In 1923 Professor Downing took up private practice. In 1926 he too returned to his alma mater as instructor in civil engineering. He is a member of several honoraries and professional societies, including the A.S.C.E. and A.A.S.H.O.

Prof. Downing has been very active in the planning and construction of state roads and highways. He will be long remembered as "Father of the Denver-Boulder Turnpike." Until this March he was chairman of the engineering section of the Colorado Highway Long-range Planning Committee.

He has been active in civic affairs, too, having served for 16 years on the Boulder Planning Commission.

After retirement? Professor Downing will stay in Boulder and devote some time to his hobbies, golf and fishing.

HAROLD W. SIBERT

Professor Sibert was born in Kentucky in May, 1892. He received his M.E., M.A., and Ph.D. degrees from Cornell and Cincinnati Universities. He was a chemist until 1916, when he joined the army. He was discharged with the rank of major in the Corps of Engineers.

In 1922, after three years as an industrial designer in Illinois, Professor Sibert began his career in education at the University of Cincinnati as professor of mathematics and aeronautical engineering. He was on the staff for 22 years.

During World War II he served as a major and then lieutenant colonel. After the war he joined the staff of the University of Colorado as professor of aeronautical engineering. He has published a number of books and papers. He is a member of Tau Beta Pi and Sigma Xi and is an Associate Fellow in the I.A.S.

In retrospect, Professor Sibert notes that aeronautical engineering has come a long way as an academic subject. Its importance at the University of Colorado is indicated by the fact that it is second in enrollment only to the Department of Electrical Engineering.

After retirement? Professor Sibert is so vitally interested in education that he plans to find another teaching position. His spare time will still be devoted to his hobby, bridge—or to his favorite exercise, walking.

W. OTTO BIRK

Professor Birk was born in Ohio in July, 1891. He graduated in 1914 from Wabash College and received

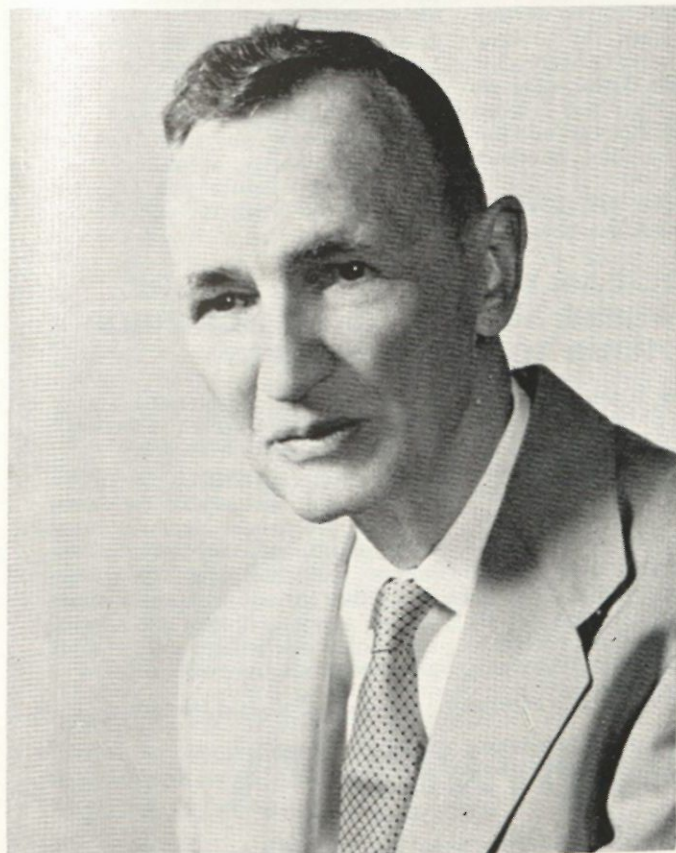
his M.A. in 1917 from the University of Cincinnati, where he taught for two years.

He came to the University of Colorado in 1919 as head of the Department of English in the College of Engineering. Professor Birk's professional affiliations include the American Society for Engineering Education, in which he served 15 years on the English committee, and the National Council of Teachers of English. He is well-known for his English texts.

In his 41 years at the University of Colorado, he has seen a tremendous growth in enrollment. His department first consisted of two full-time members and a student assistant. It now has 13 members. He has also seen much improvement in educational standards.

After retirement? Professor Birk hopes to travel and to continue to enjoy reading and all the other pleasures provided by the humanities, such as the theater, music, and other fine arts.

We at the University of Colorado hope that these educators enjoy the coming years and that the records left by them will forever serve as a guiding light to their successors and all those who aim for success in engineering fields.



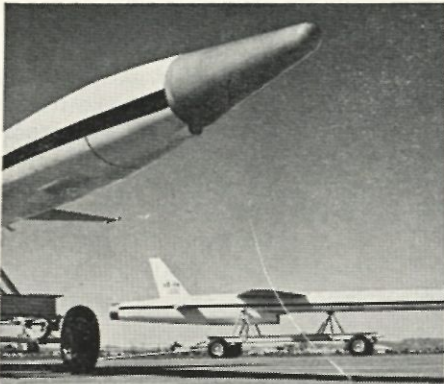
PROF. SIBERT



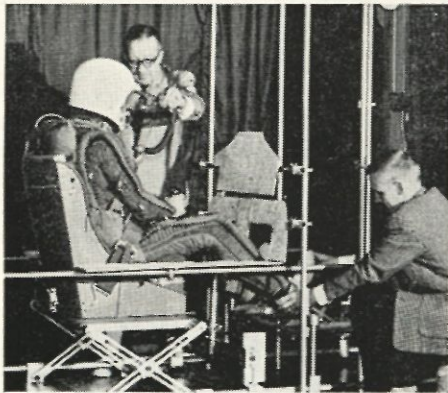
PROF. BIRK

...**NEWS IS HAPPENING AT NORTHROP** \

Take this 3-Minute Quiz to help you determine your future



1. What part of the country has the best future for your type of work?
2. What part of the country offers an outstanding opportunity to enjoy your leisure?
3. Where can you work and still earn advanced degrees?
4. How important to you is the challenge of opportunity — and salary that matches your achievements?
5. Where can you work with outstanding men in your field?



FIVE IMPORTANT QUESTIONS... NOW CONSIDER THESE ANSWERS:

1. If your interests are in the fields of electronics or the aircraft/missile industry, you will want to join the outstanding scientists and engineers in the space age center of the world — Southern California.

2. If you work at Northrop you will live in Southern California — famous for its year-round vacation climate. Here you're close to the beaches, mountains and desert where you can enjoy an active life in the sunshine.

3. Northrop encourages you to work for advanced degrees and to keep current with the latest developments in your chosen field. With Northrop's program, you will continue to learn while you earn with no-cost and low-cost education at leading Southern California institutions.

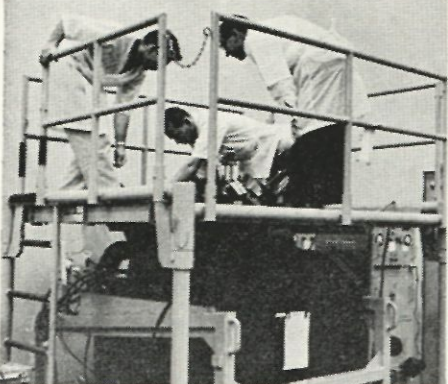
4. At Northrop you will work with the newest, most-advanced research

and test equipment. And with over 30 operational fields from which to choose you can apply your talents to the work you enjoy—in the fields best suited to your inclinations.

At Northrop you will earn what you are worth. With this growing company you receive increases as often as you earn them. And these increases in salary are based on your own individual achievements.

Northrop's vacation and fringe benefits are extra liberal.

5. Men you work with at Northrop are acknowledged leaders in their fields. They are selected because they have the skill to guide younger men. These are men who know how to delegate authority, encourage your progress, and assure you of your fair share of credit for engineering achievements.



IT'S NOT TOO EARLY TO PLAN YOUR FUTURE. WHICH OF THESE 3 DIVISIONS OF NORTHROP ARE BEST FITTED TO YOUR TALENTS?

NORAIR DIVISION is the creator of the USAF Snark SM-62 missile now operational with SAC. Norair is currently active in programs of space research, flight-testing the USAF Northrop T-38 Talon trainer and Northrop's N-156F Freedom Fighter.

RADIOPLANE DIVISION, creator of the world's first family of drones, produces and delivers pilotless aircraft for all the U.S. Armed Forces to train men, evaluate weapon systems,

and fly surveillance missions. Today Radioplane is readying the recovery system for Project Mercury.

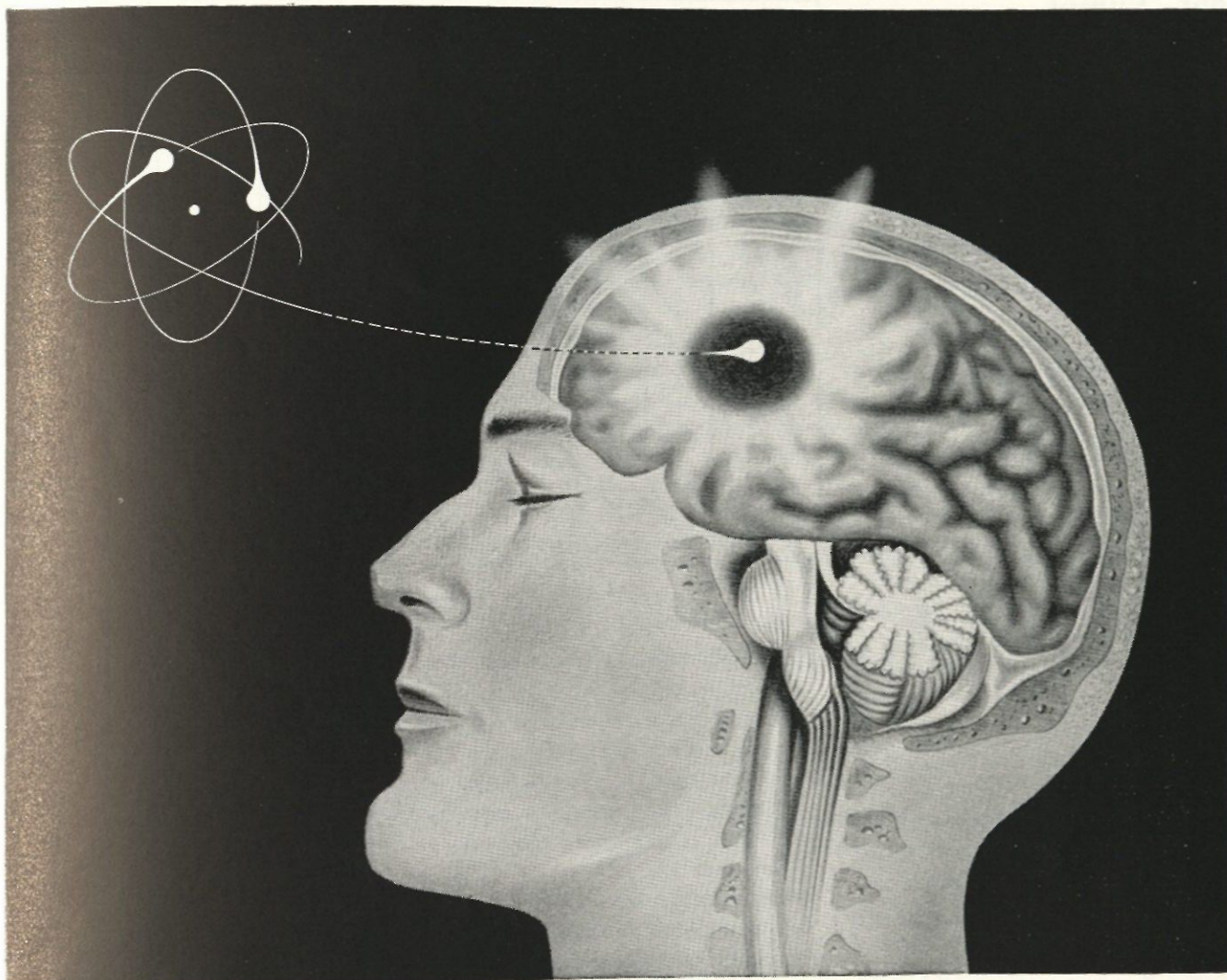
NORTRONICS DIVISION is a leader in inertial and astronertial guidance systems. Nortronics explores infrared applications, airborne digital computers, and interplanetary navigation. Other current programs include ground support, optical and electro-mechanical equipment, and the most advanced data-processing devices.

Write today for complete information about your future at Northrop.

NORTHROP \
CORPORATION

Engineering & Scientific Personnel Placement Office
Northrop, P.O. Box 1525, Beverly Hills, California





Boron-10 vs. brain tumors

Physicians and scientists working in cancer research at Brookhaven National Laboratory, Upton, N. Y., are probing the use of Boron-10 isotope in treating a common type of brain tumor (glioblastoma multiforme).

Results of this therapy are so encouraging that Brookhaven and at least two other institutions are constructing additional nuclear reactors used in this therapeutic venture.

The method. In a technique known as Neutron Capture Therapy, the patient receives an injection of a Boron-10 compound. Cancerous tissue absorbs most of the neutrons.

In the split second that the Boron-10 becomes radioactive, it produces short-ranged alpha particles which destroy cancerous tissue with a minimum of damage to healthy tissue.

Producing the isotope. The plant furnishing Boron-10 to Brookhaven ordi-

narily turns out about three pounds during a 24-hour work day. Separation of the isotope takes place in what is described as "the world's most efficient fractionating system." In 350 feet of total height, six series-connected Monel* nickel-copper alloy columns enrich a complex containing 18.8% Boron-10 isotope to one containing 92% Boron-10.

Purification. To purify the 92% concentrate, a whole series of complicated processing steps are needed . . . including deep freeze. Columns, reboilers, condensers, vessels, pumps, and piping abound—each a constant challenge . . . both to the metal and to those concerned with equipment design and operation.

How would you meet such challenges? Some problems, of course, were unique and demanded ingenuity of a high order. But answers to most, 90% or more, could be found in the vast "experience bank" maintained by Inco . . . some 300,000 indexed and cross-referenced reports of metal performance under all manner of conditions.

Make a mental note: (1) that The International Nickel Company is a rich source of information on high-temperature and corrosion-resisting alloys; (2) that Inco makes this experience available to you.

©1960, Inco

The International Nickel Company, Inc.
New York 5, N. Y.



International Nickel

The International Nickel Company, Inc., is the U. S. Affiliate of the International Nickel Company of Canada, Limited—producer of Inco Nickel, Copper, Cobalt, Iron Ore, Tellurium, Selenium, Sulfur, and Platinum, Palladium and Other Precious Metals.

Heat, Pumps

(Continued from page 11)

pump operating with 45°F outdoor temperature during the heating function and a 95°F outdoor temperature during the cooling function:

Heating function performance factor = 2.5

Cooling function performance factor = 2.0

Sources and Sinks

Harnish⁴ lists (1) outdoor air, (2) ground, and (3) well water as possible heat sources and sinks.

The outdoor air is the most widely used heat source and sink because it is so freely available and easy to handle. Air does have one serious drawback; the temperature variation is very large from season to season.

The ground is probably the least used heat source and sink because of the expense involved in installing the underground heat exchanger. Ground temperature does, however, show less seasonal variation than does the air temperature.

Well water is used wherever it is available. This source and sink shows the least seasonal temperature variation of the three mentioned. The disadvantages are the pumping cost and the infrequent availability of the quantity of water necessary for the cycle.

Air Temperature Influence on the Cycle Performance

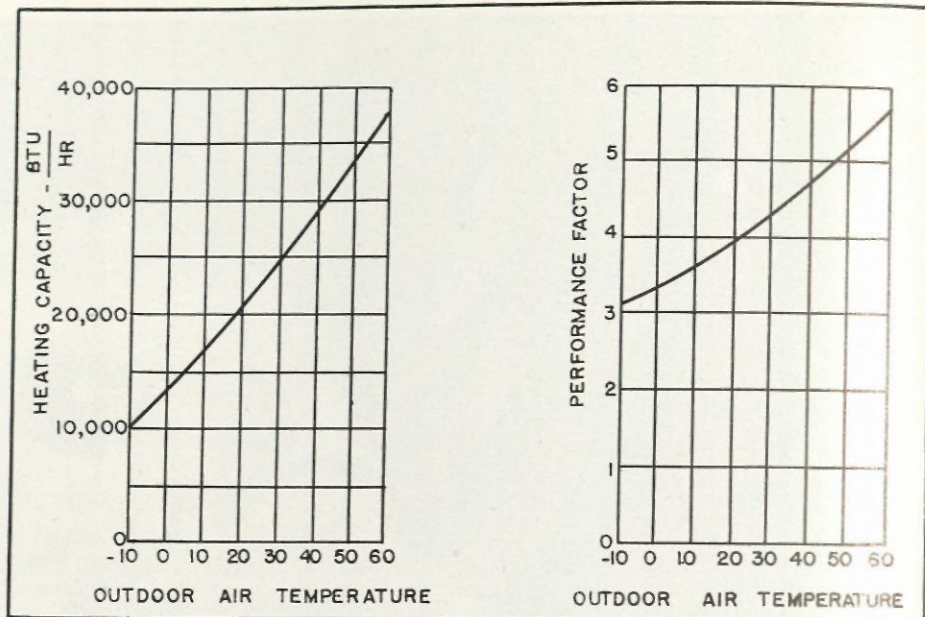
Since outdoor air is by far the most widely used source and sink, the influence of the air temperature on the cycle needs special description.

Stoecker¹ reports the following data for a typical air-source heat pump during the heating function. (See figures 4 and 5.)

The charts show that both the performance factor and the heating capacity decrease as the outdoor temperature decreases. This is the main disadvantage of the heat pump.

Since the unit size is usually based on the summer cooling load³, the unit may not be able to meet the peak heating loads. Stoecker¹ suggests the following methods of overcoming this problem:

1. Size the unit for the heating load. (Unit will then be oversized for the cooling function.)



Figures 4 and 5.

2. Incorporate supplementary electric resistance heating. (This method is considered uneconomical if it has to be used over 10% of the time.)
3. Increase the compressor capacity. (This is essentially the same as method 1.)
4. Provide a method of heat storage during high outdoor temperature conditions. (No efficient storage method has yet been demonstrated but this method offers possibilities.)

Building Internal Heatloads

Werden⁵ reports that internal heatloads such as people, lights, and appliances are important factors. Lights and appliances are being used to such an extent that the gap between summer cooling loads and winter heating is rapidly closing. This fact helps justify the installation of units where a few years ago they would have been impracticable.

D. PRESENT APPLICATIONS AND THE FUTURE PROSPECTS

Present Conditions and Applications

Versagi² reports the following figures on the present uses of the heat pump: At present, November, 1959, there are about 40,000 central units and 250,000 window and wall units in operation in homes in this country. The majority of these units are in use in the southern part of the coun-

try, although their utilization is gradually creeping northward. Southern utility companies are expecting a 70% increase in heat pump use during 1960.

The increased use of the heat pump depends, of course, on both the original unit cost and the operating cost.

Unit Costs

Versagi² quotes the installed cost of typical pumps at \$1000 to \$3000 for the complete unit. These figures amount to about \$200 dollars more per unit than a conventional fossil-fuel heating system for a house in the \$15,000 class.

Operating Costs

Most authorities consulted agree that an electrical energy charge of 1.7¢ kwhr is the borderline cost for economical heat pump operation. This figure is based on an average fossil-fuel price. The fuel cost comparison between electrical energy and fossil type fuels is thus the critical factor in determining the economical use of the heat pumps in any given location.

*Electric World*⁷ quotes a southern utility company slogan: "Two cents competes, 1.5 cents converts." This statement dramatizes the interest of utility companies in the increased use of heat pumps.

Advantages

Although fuel costs are seen to be the critical test of economical use,

there are several distinct advantages over conventional heating systems which should not be overlooked.

1. The same unit provides both heating and cooling functions.
2. The space requirements are small compared to conventional systems.
3. No Chimneys are required.
4. The units are extremely clean since no combustion occurs.
5. Humidity control and air filtering are easily accomplished.
6. The operation is automatic for all outdoor conditions. The unit cools and heats as needed without adjustments.

Future Outlook

The future looks good for the increased use of heat pumps. Public utility companies are predicting and encouraging increased use.

Harnish⁴ brings out the fact that over the years fossil-fuel costs are steadily increasing while the cost of electric power has remained essentially constant. Nuclear energy for electric power production may further reduce this fuel-cost difference. This fuel-cost convergence greatly enhances the competitive position of the heat pump.

Werden⁵ and Harnish⁴ both see increased use of multi-stage compression for colder climates. Following is a table from Werden⁵ which demonstrates the advantages of multi-stage compression for winter heating:

Outdoor Temperature	-30°F	-20°F	-10°F	0°F
Single Stage Compressor	Not Practical	1.65	2.20	2.4
Two Stage Compressor	2.42	2.65	2.92	3.18

Table 1—Performance factors

The unit, for summer cooling, could use one stage of compression which in effect reduces the size of the system.

Several other investigators have proposed new methods of heat pump operation. Lindenblad⁷ proposed a system using thermoelectric principles and Versagi² mentioned that work was being done on a heat pump which utilized the principles of absorption refrigeration. This latter method would eliminate the disadvantage of high electric rates found in some areas since the energy input in this

last system would be heat energy from the combustion of a fossil-type fuel.

Greatly increased use is thus seen for the heat pump in the future. Perhaps within this century the heat pump will become the general meth-

od of residential heating.

References

1. Stoeker, W. F. 1958. *Refrigeration and Air Conditioning*. New York: McGraw-Hill Book Company, Inc.
2. Versagi, F. J. 1959. "Meet the Heat Pump." *House Beautiful*, 101 (November, 1959), 248.
3. Spofford, W. A. 1959. "Heat Pump Performance for Package Air Source Units." *ASHRAE* (April, 1959), 59-63.
4. Harnish, J. R. 1947. "Heat Pump Bids for Colder Climate Jobs." *Power*, 101 (June, 1957), 73-76.
5. Werden, R. G. 1957. "At Last: A Practical Heat Pump." *Refrigeration Engineer*, 64 (May, 1956), 48.
6. *Electric World*, "Heat Pump Growth in Line with Predictions — South Still Ahead." *Electric World*, 149 (December, 1957), 103.
7. Lindenblad, N. E. "Thermo Electric Heat Pumping." *Electrical Engineering*, 77 (September, 1958), 802, 806.

Dean's Page

(Continued from page 9)

needs an outstanding College of Engineering at the University of Colorado.

Although basically a sound institution, the present College of Engineering is beginning to show evidence of falling behind the advance of technical knowledge. Especially necessary is improvement in the qualifications of the faculty, the program of research and graduate study, as well as in the several engineering curricula.

Program of Excellence

In addition to providing the graduate with the rudiments of a strong general education which will stimulate his pursuit of intellectual interests outside the engineering profession, a high-quality program in engineering education should provide him with basic scientific and technical knowledge and insight necessary to the professional practice of engineering. At present, as in the past, an appreciable part of engineering education is directed toward rather spec-

ific training for fairly definite types of employment. Because our technology is progressing so fast that specific "know-how" abilities are virtually out-of-date by the time the graduate takes his place in industry, this is no longer compatible with quality education, nor is it even really practical. What is now needed is an understanding of basic principles and the "why" of engineering which can be used in a wide range of specific applications. The Committee report indicates that three requirements must be met: (a) the faculty must be strengthened, both by the addition of outstanding new members and by providing opportunity and incentive for the profession development of present faculty members, especially the younger ones; (b) the program of graduate study and research must be expanded and strengthened; and (c) all curricula must be critically examined and revised where revision is necessary. While these requirements are closely related, the most critical in terms of space needs is the emphasis on graduate study and research.

Finis

On June 30, I shall retire as Dean of the College of Engineering. Most of my adult life has been devoted to the College of Engineering, first as a student and then as an instructor, Assistant Professor, Professor, Head of the Department, and finally as Dean of the College of Engineering. Working with young people and noting their progress, both as undergraduates and as members of the engineering profession, have provided a tremendously satisfying career. Likewise, working with the Faculty of the College of Engineering has been a source of gratification for me.

I expect to continue to live in Boulder, and I shall hope to see the College of Engineering accomplish the goals which the Study Committee has set. Mrs. Eckel says that my heart has always been in the University. I expect it to remain here. My best wishes go with every student and graduate of the College of Engineering as well as every member of the Engineering Faculty.

C. L. Eckel
Dean

point of production . . .

When the design, the engineering and the construction work are completed, Stearns-Roger delivers a complete project. The plant is at the point of production to run far into the future, efficiently, economically.

Engineers, Constructors . . .
Manufacturers
to industry

Stearns-Roger

THE STEARNS-ROGER MFG. CO. - DENVER, COLORADO

DENVER • HOUSTON EL PASO
SALT LAKE CITY
Stearns-Roger Engineering Co. Ltd. Calgary

Design for your future!

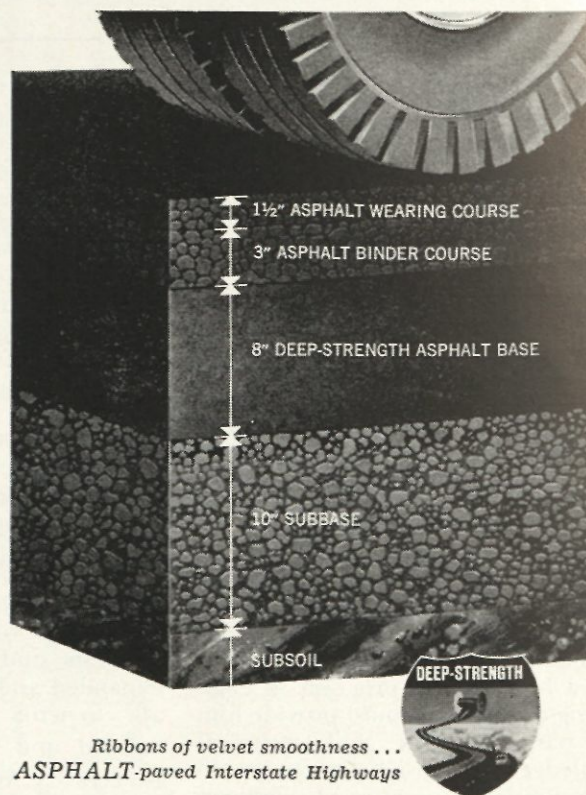
Learn how to build the new **DEEP-STRENGTH** Asphalt pavements

If you're going into Civil Engineering, it will pay you to keep a close eye on Asphalt design developments.

Here, for example, is the latest from Oklahoma . . . one of the new, DEEP-STRENGTH Asphalt pavements the state is using on Interstate 40. This one is outstanding because its base is 8 inches of hot-mixed—hot-laid sand-Asphalt . . . no coarse aggregate.

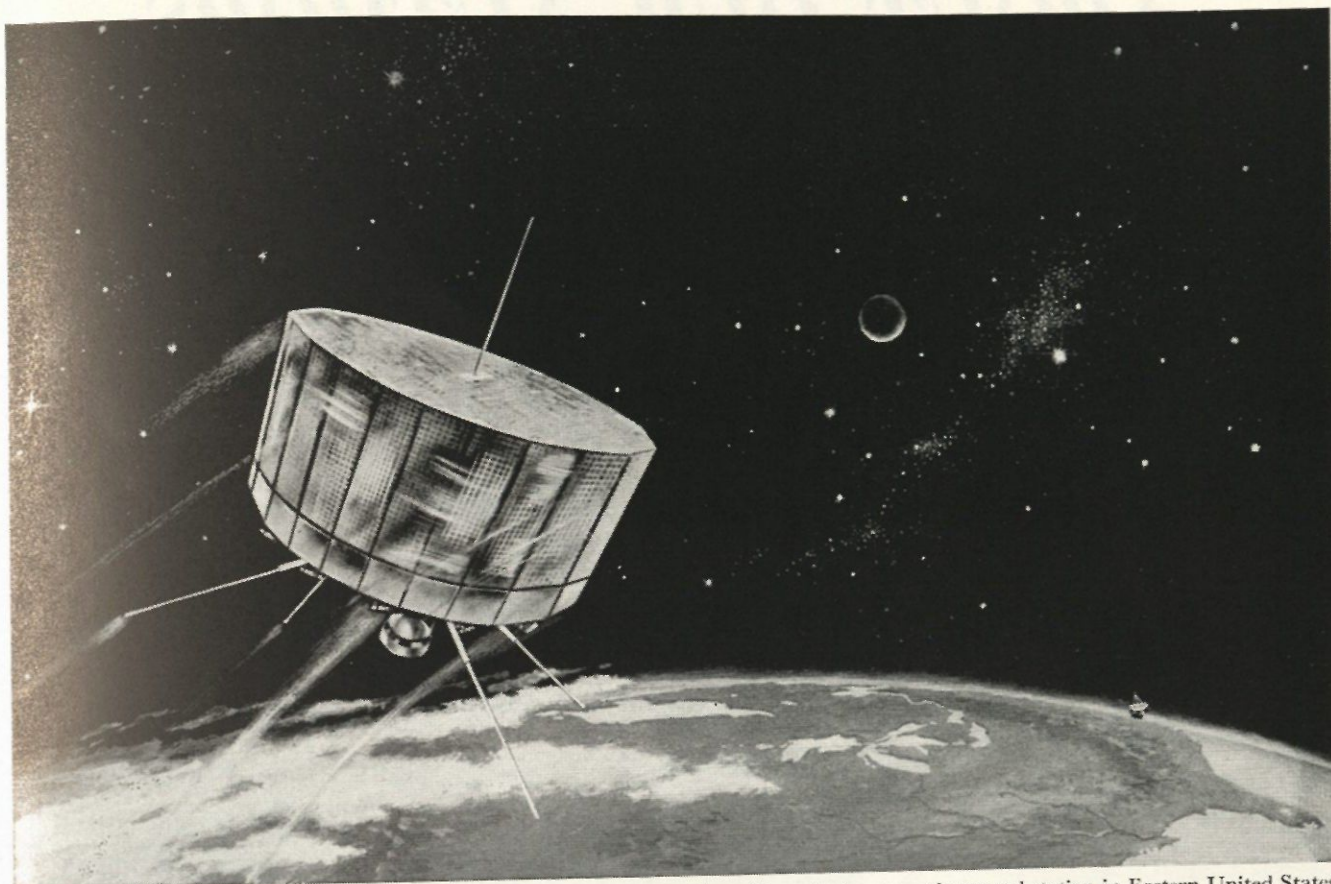
Why 8 inches? Why not 6 or 10? What did engineers do to insure good drainage? What factors set the design?

The Asphalt Institute answers questions like these . . . keeps you abreast of all the latest in the design of Asphalt Highways, the most durable and economical pavements known. Would you like our new booklet, "Advanced Design Criteria for Asphalt Pavements", or our "Thickness Design Manual"? Write us.



Ribbons of velvet smoothness . . .
ASPHALT-paved Interstate Highways

THE ASPHALT INSTITUTE
Asphalt Institute Building, College Park, Maryland



TIROS satellite orbiting towards ground station in Eastern United States.

RCA-BUILT "TIROS" SATELLITE REPORTS WORLD'S WEATHER FROM OUTER SPACE

As you read these lines, the most remarkable "weather reporter" the world has ever known hurtles around our globe many times a day, hundreds of miles up in outer space.

The TIROS satellite is an orbiting television system. Its mission is to televise cloud formations within a belt several thousand miles wide around the earth and transmit a series of pictures back to special ground stations. Weather forecasters can then locate storms in the making . . . to help make tomorrow's weather forecast more accurate than ever.

The success of experimental Project TIROS opens the door to a new era in weather forecasting—with benefits to people of all lands. This experiment may lead to advanced weather satellites which can provide weathermen with hour-by-hour reports of cloud cover prevailing over the entire world. Weather forecasts, based on these observations, may then give ample time to prepare for floods, hurricanes, tornadoes, typhoons and blizzards—time which can be used to minimize damage and save lives.

Many extremely "sophisticated" techniques and devices were required to make *Project TIROS* a success—two lightweight satellite television cameras, an infra-red

horizon-locating system, complex receiving and transmitting equipment, and a solar power supply that collects its energy from the sun itself. In addition to the design and development of the actual satellite, scientists and engineers at RCA's "Space Center" were responsible for the development and construction of a vast array of equipment for the earth-based data processing and command stations.

Project TIROS was sponsored by the National Aeronautics and Space Administration. The satellite payload and ground station equipment were developed and built by the Astro-Electronic Products Division of RCA, under the technical direction of the U. S. Army Signal Research and Development Laboratory.

The same electronic skills which made possible the success of man's most advanced weather satellite are embodied in all RCA products—RCA Victor black & white and color television sets, radio and high-fidelity systems enjoyed in millions of American homes.



**THE MOST TRUSTED
NAME IN ELECTRONICS**
RADIO CORPORATION OF AMERICA

ABOUT OUR AUTHORS



Paul Johnson, who hails from Montrose, Colorado, is a senior in Mechanical Engineering. He is a member of Pi Tau Sigma, Sigma Tau, Tau Beta Pi, and the American Society of Mechanical Engineers. Paul is married; his wife, Dee, is employed by the News Service on campus.

For the past year, Paul has been working for the Office of Research Services in the Physics building. Prior to that he worked for the High Altitude Observatory and the University food services.

William Robbins, '63, of Rockland, Massachusetts, attended Brown University during 1953-54 and then enlisted in the U. S. Navy. After several duty stations and Navy schools, he spent nearly a year at the United States Naval War College, Newport, Rhode Island, assigned to the "NEWS". In April of 1959 he was selected, under the newly inaugurated "Naval Enlisted Scientific Education Program," to attend the University of Colorado where he is now studying for a degree in Electrical Engineering.



Captain Frank C. Tyrell, CEC, USN. B.S. in C.E., 1928, and M.S., 1937, from the University of Colorado. Four years experience with American Bridge and seven years with Bureau of Reclamation. Reported for active duty in the Navy in March, 1940. Duties have included: two tours at the Bureau of Yards and Docks, Washington, D. C., and field staff assignments, Public Works Officer for air station and shipyard, two tours with Construction Battalions (Seabees), and the first Commanding Officer of the Navy's Civil Engineering Laboratory at Port Hueneme, California. Assigned to the Naval Radio Research Station project continuously from the initial engineering studies in September, 1956, to date. Member of the A.S.C.E., Society of Military Engineers, and Naval Institute, and a registered engineer from the District of Columbia.



ENVIRONMENTAL CONTROL SYSTEMS

- Shown above is a freon refrigeration system for the Boeing 707. Through its unique design, a 10-ton cooling capacity is provided at one-tenth the weight of commercial equipment. The leading supplier of manned flight environmental control systems, Garrett designs and produces equipment for air-breathing aircraft as well as the latest space vehicles such as Project Mercury and North American's X-15.

DIVERSIFICATION IS THE KEY TO YOUR FUTURE

Company diversification is vital to the graduate engineer's early development and personal advancement in his profession. The extraordinarily varied experience and world-wide reputation of The Garrett Corporation and its AiResearch divisions is supported by the most extensive design, development and production facilities of their kind in the industry.

This diversification of product and broad engineering scope from abstract idea to mass production, coupled with the company's orientation program for new engineers on a rotating assignment plan, assures you the finest opportunity of finding your most profitable area of interest.

Other major fields of interest include:

- Aircraft Flight and Electronic Systems—pioneer and

major supplier of centralized flight data systems and other electronic controls and instruments.

- **Missile Systems**—has delivered more accessory power units for missiles than any other company. AiResearch is also working with hydraulic and hot gas control systems for missiles.

- **Gas Turbine Engines**—world's largest producer of small gas turbine engines, with more than 8,500 delivered ranging from 30 to 850 horsepower.

See the magazine, "The Garrett Corporation and Career Opportunities," at your college placement office. For further information write to Mr. Gerald D. Bradley in Los Angeles...

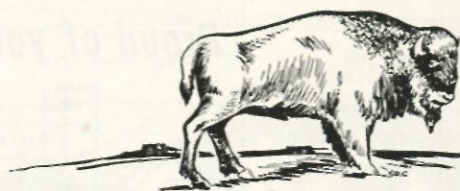


THE GARRETT CORPORATION

AiResearch Manufacturing Divisions

Los Angeles 45, California • Phoenix, Arizona

Systems, Packages and Components for: AIRCRAFT, MISSILE, NUCLEAR AND INDUSTRIAL APPLICATIONS



Chips

Into every life let there come humor.

Edited by JACK BISHOP, JR., Chem.E. '61

Overheard in Hellems: "He has a contagious smile . . . trench mouth."

★ ★ ★

I stood upon the ocean's moonlit beach
And with a fragile reed I traced upon the sand
"Sweetheart, I love thee!"

A Wave
Came rolling by and erased the fair impression.
Cruel wave!

Frail reed!
Treacherous sand!
I'll trust thee no more—but with a giant hand
I'll pluck from Norway's shore her tallest pine

Dip its tip into the crater of Vesuvius
And on the high and flaming sky I'll write

"Sweetheart! I LOVE THEE!"
And I'd like to see any goddamn wave wash THAT out!

★ ★ ★

Note: Flattery is the art of pretending you like the girl more than the kiss.

★ ★ ★

Definition: A bachelor is a man who doesn't want to play truth or consequences.

★ ★ ★

A young married lady was having her house painted. When she got up in the morning, she noticed there was a mark on the bedroom wall. She called downstairs to the painter, "would you please come upstairs, I want to show you where my husband put his hand last night."

"If it's all right with you lady," replied the painter, "I'd just as soon have a glass of beer."

★ ★ ★

In your spare moments note what motel spells backwards.

It seems one of the coeds at a recent wedding ceremony carried Four Roses—rather well.

★ ★ ★

Coed: "Have you heard the new game here?"

Ch.E.: "No, what is it?"

Coed: "Button, Button, here comes the house mother."

★ ★ ★

Noah, on his ark, had prepared for almost everything. The one item that he overlooked was the small matter of disposing of the great quantity of waste matter these animals produced. Finally he hit upon the plan of having them all go up to the poop deck (he originated the term) every morning.

Eventually this pile got so high that there was danger of the ark capsizing. So one morning Noah and his sons shoveled the whole thing into the water and watched it float away.

Believe it or not; it wasn't discovered again until 1492.

★ ★ ★

OXIDATION:

His love reached out for me
As rust reaches out for new steel.
His passion weakened the structure
Of my resistance, and . . .
I rusted.

★ ★ ★

Scene: A lonely corner in a dark night.

A Voice: Would the gentleman be so kind as to assist a poor hungry fellow who is out of work? I haven't a thing in the world besides this revolver.

You probably have heard of the girl who just broke up with her boy friend and then went to the Engineers' Ball. She wore her new evening gown, but her heart wasn't in it.

★ ★ ★

A traveling buyer had been on a trip for three months. Every few weeks he'd send a telegram home to his wife saying: "Can't come home. Still buying."

The wife stood it for awhile, but when the fourth month started, she decided to do something. She sent him a telegram. "Better come home. I'm selling what you're buying."

★ ★ ★

The automobile motor pounded and suddenly wheezed to a stop on a lonely road.

"I wonder," mused the Chemical, "what that knock is?"

"Maybe," suggested his blonde companion, "it's opportunity."

★ ★ ★

The judge looked down at the sweet young thing. "You claim that the defendant stole your money from your stocking?" he asked.

"That's right, your honor."

"Well, why didn't you resist?"

The girl blushed, lowered her eyes and answered, "I didn't know he was after my money, your honor."

★ ★ ★

OIL CAN

The final nomination to the oil can society goes this year to the professor who explained the "Honor System" to his students: "The professors have got the honor and the students have got the system."

If your sights are set



on outer space—

—you'll find
**Photography
at Work
with you.**

From the time a scientist's mind first sparks an idea for exploring space, photography gets to work with him. It saves countless hours in the drafting stage by reproducing engineers' plans and drawings. It probes the content and structure of metals needed by photomicrography, photospectrography or x-ray diffraction. It checks the operation of swift-moving parts with high-speed movies—records the flight of the device itself—and finally, pictures what it is in space the scientist went after in the first place.

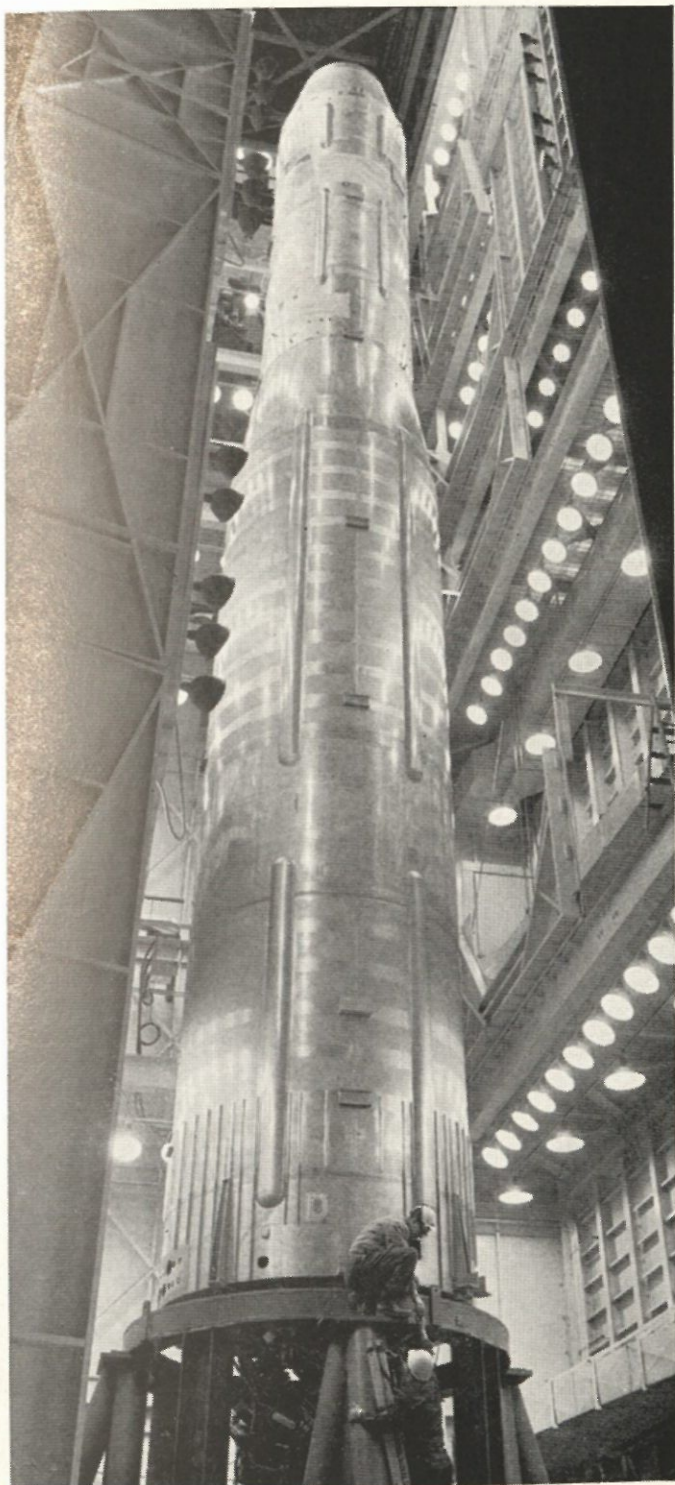
There's hardly a field on which you can set your sights where photography does not play a part in producing a better product or in simplifying work and routine. It saves time and costs in research, in production, in sales and in office routine.

So in whatever you plan to do, take full advantage of all of the ways photography can help.

CAREERS WITH KODAK:

With photography and photographic processes becoming increasingly important in the business and industry of tomorrow, there are new and challenging opportunities at Kodak in research, engineering, electronics, design, sales, and production.

If you are looking for such an interesting opportunity, write for information about careers with Kodak. Address: Business and Technical Personnel Department, Eastman Kodak Company, Rochester 4, N. Y.



U.S. Air Force I.C.B.M. "Titan" shown in the vertical test laboratory at the Martin Company, Denver, Colorado.

EASTMAN KODAK COMPANY
Rochester 4, N. Y.

Kodak
TRADE MARK

Interview with
General Electric's Byron A. Case
Manager—Employee Compensation Service

Your Salary at General Electric

Several surveys indicate that salary is not the primary contributor to job satisfaction. Nevertheless, salary considerations will certainly play a big part in your evaluation of career opportunities. Perhaps an insight into the salary policies of a large employer of engineers like General Electric will help you focus your personal salary objectives.

Salary—a most individual and personal aspect of your job—is difficult to discuss in general terms. While recognizing this, Mr. Case has tried answering as directly as possible some of your questions concerning salary:

Q Mr. Case, what starting salary does your company pay graduate engineers?

A Well, you know as well as I that graduates' starting salaries are greatly influenced by the current demand for engineering talent. This demand establishes a range of "going rates" for engineering graduates which is no doubt widely known on your campus. Because General Electric seeks outstanding men, G-E starting salaries for these candidates lie in the upper part of the range of "going rates." And within General Electric's range of starting salaries, each candidate's ability and potential are carefully evaluated to determine his individual starting salary.

Q How do you go about evaluating my ability and potential value to your company?

A We evaluate each individual in the light of information available to us: type of degree; demonstrated scholarship; extra-curricular contributions; work experience; and personal qualities as appraised by interviewers and faculty members. These considerations determine where within G.E.'s current salary range the engineer's starting salary will be established.

Q When could I expect my first salary increase from General Electric and how much would it be?

A Whether a man is recruited for a specific job or for one of the principal training programs for engineers—the Engineering and Science Program, the Manufacturing Training Program, or the Technical Marketing Program—his individual performance and salary are reviewed at least once a year.

For engineers one year out of college, our recent experience indicates a first-year salary increase between 6 and 15 percent. This percentage spread reflects the individual's job performance and his demonstrated capacity to do more difficult work. So you see, salary adjustments reflect individual performance even at the earliest stages of professional development. And this emphasis on performance increases as experience and general competence increase.

Q How much can I expect to be making after five years with General Electric?

A As I just mentioned, ability has a sharply increasing influence on your salary, so you have a great deal of personal control over the answer to your question.

It may be helpful to look at the current salaries of all General Electric technical-college graduates who received their bachelor's degrees in 1954 (and now have five years' experience). Their current median salary, reflecting both merit and economic changes, is about 70 percent above the 1954 median starting rate. Current salaries for outstanding engineers from this

class are more than double the 1954 median starting rates and, in some cases, are three or four times as great.

Q What kinds of benefit programs does your company offer, Mr. Case?

A Since I must be brief, I shall merely outline the many General Electric employee benefit programs. These include a liberal pension plan, insurance plans, an emergency aid plan, employee discounts, and educational assistance programs.

The General Electric Insurance Plan has been widely hailed as a "pace setter" in American industry. In addition to helping employees and their families meet ordinary medical expenses, the Plan also affords protection against the expenses of "catastrophic" accidents and illnesses which can wipe out personal savings and put a family deeply in debt. Additional coverages include life insurance, accidental death insurance, and maternity benefits.

Our newest plan is the Savings and Security Program which permits employees to invest up to six percent of their earnings in U.S. Savings Bonds or in combinations of Bonds and General Electric stock. These savings are supplemented by a Company Proportionate Payment equal to 50 percent of the employee's investment, subject to a prescribed holding period.

If you would like a reprint of an informative article entitled, "How to Evaluate Job Offers" by Dr. L. E. Saline, write to Section 959-14, General Electric Co., Schenectady 5, New York.

Progress Is Our Most Important Product

GENERAL  ELECTRIC