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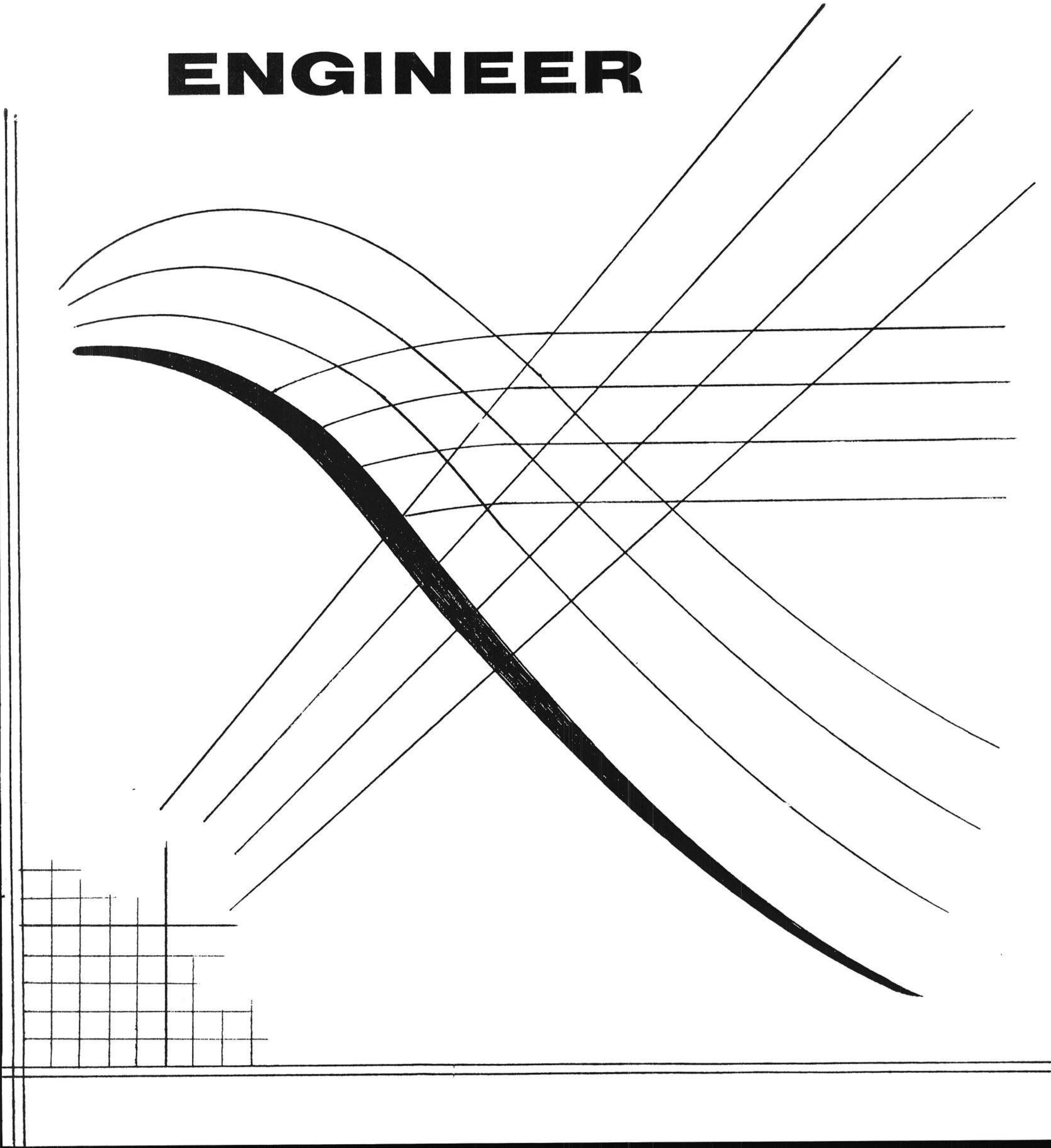

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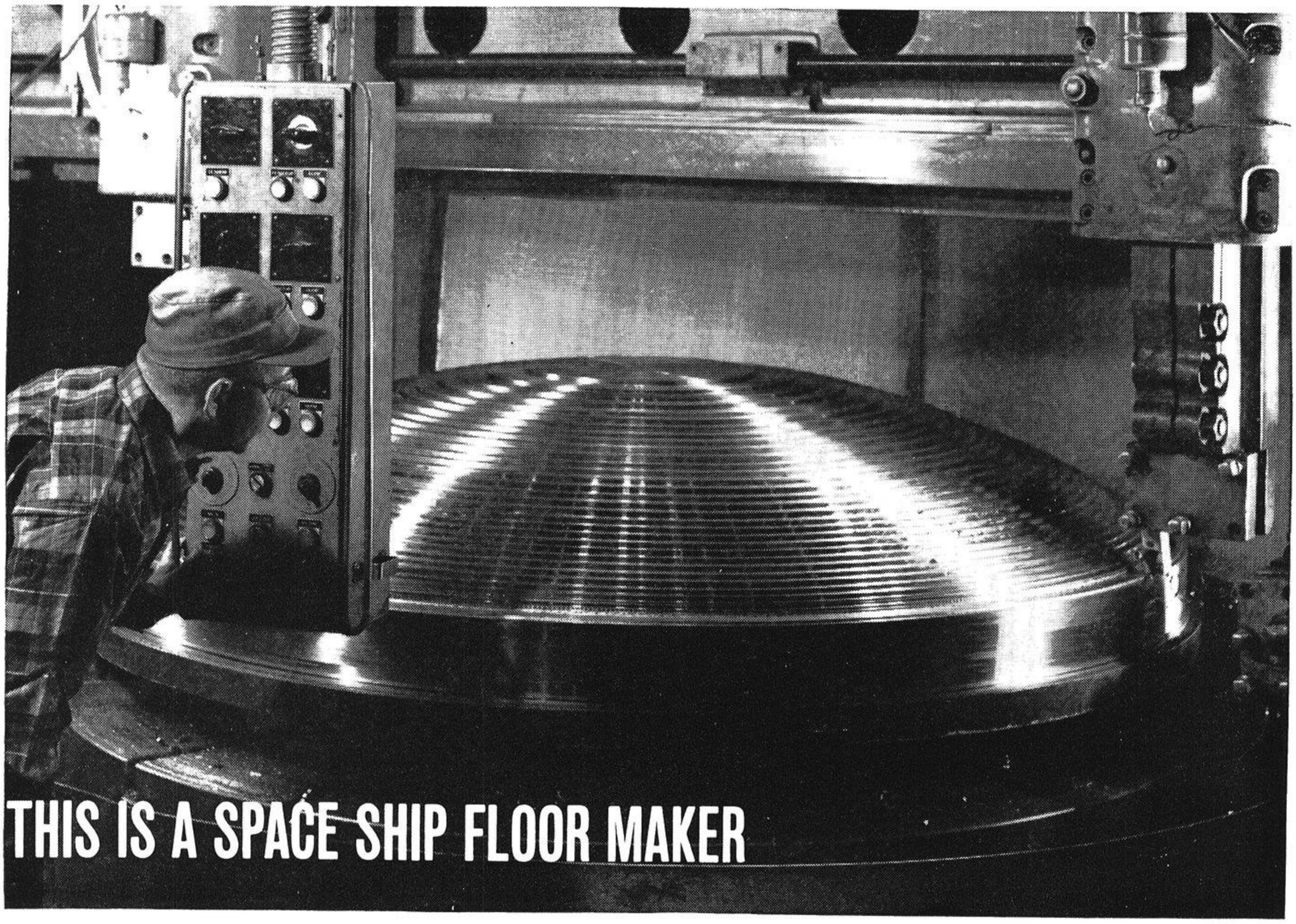

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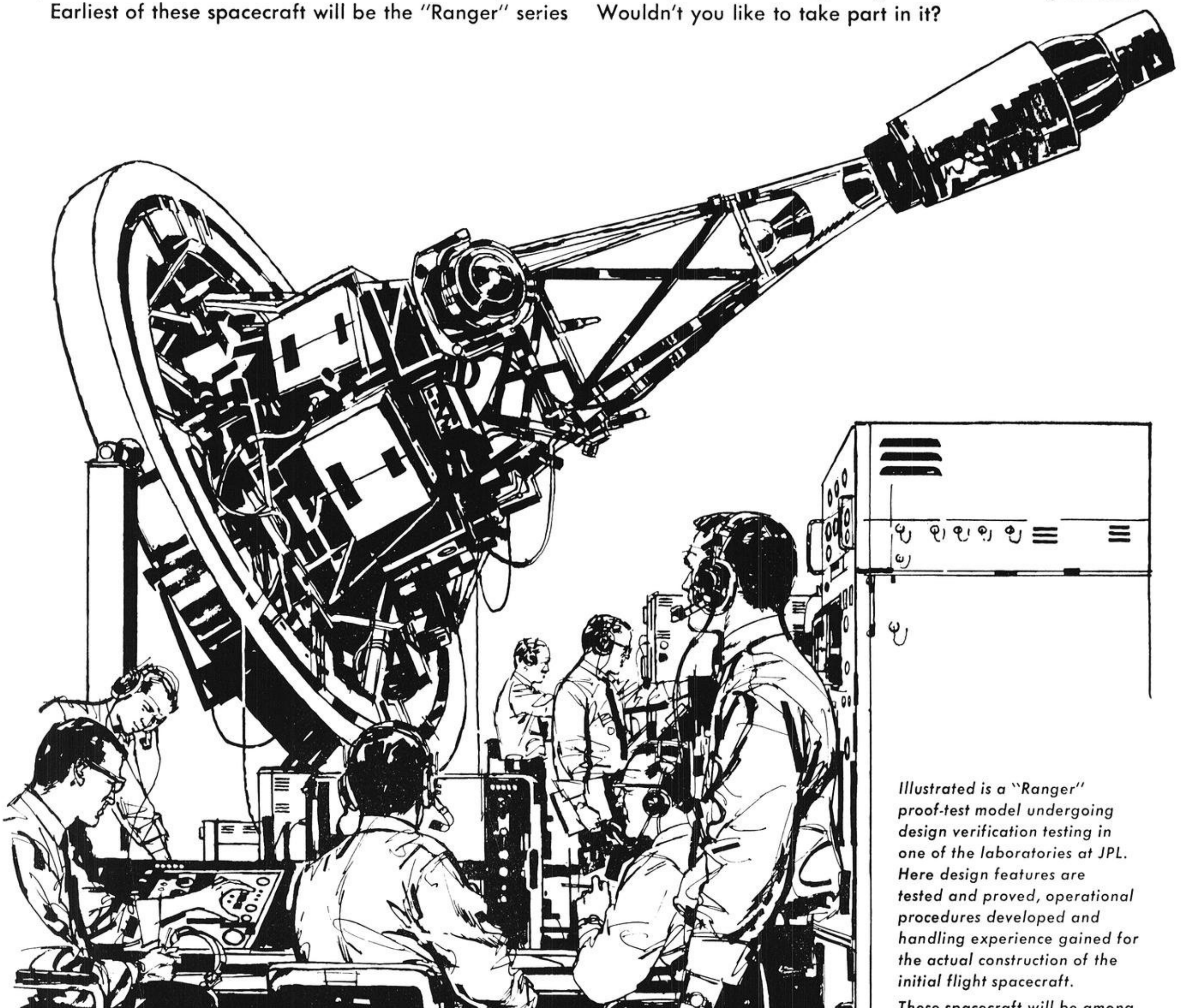

Illustrated is a "Ranger" proof-test model undergoing design verification testing in one of the laboratories at JPL. Here design features are tested and proved, operational procedures developed and handling experience gained for the actual construction of the initial flight spacecraft.

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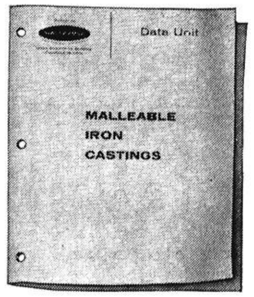

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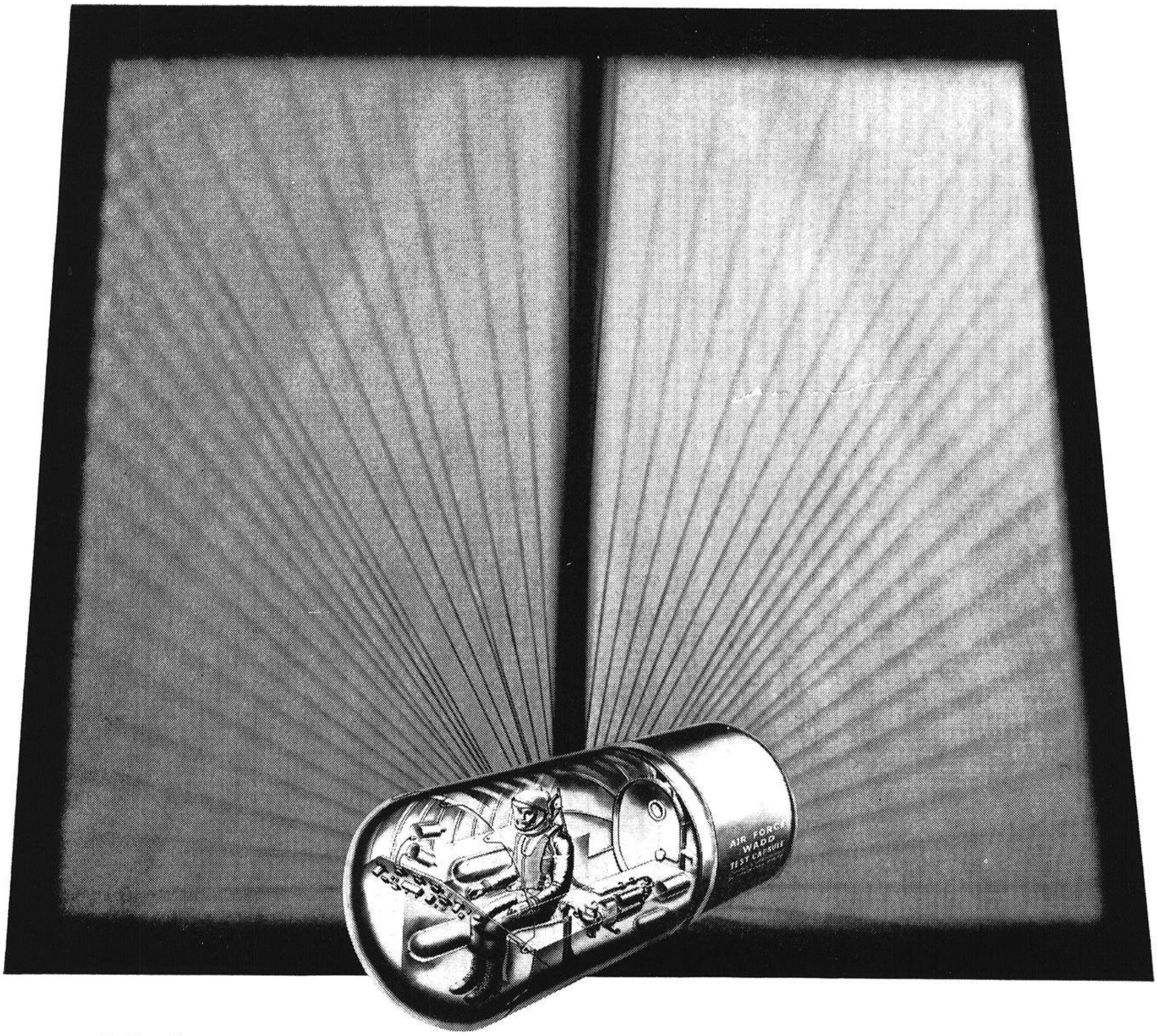
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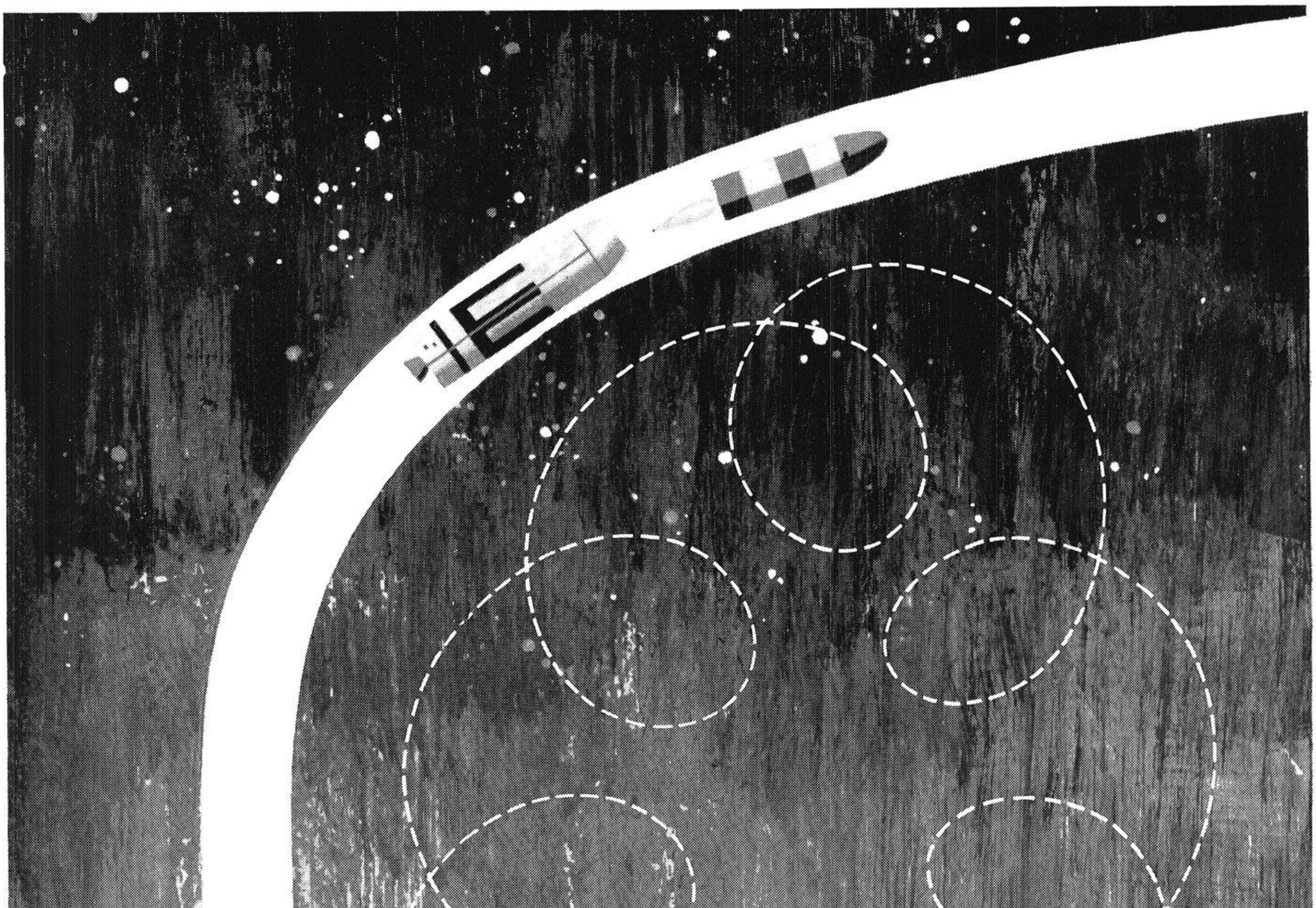
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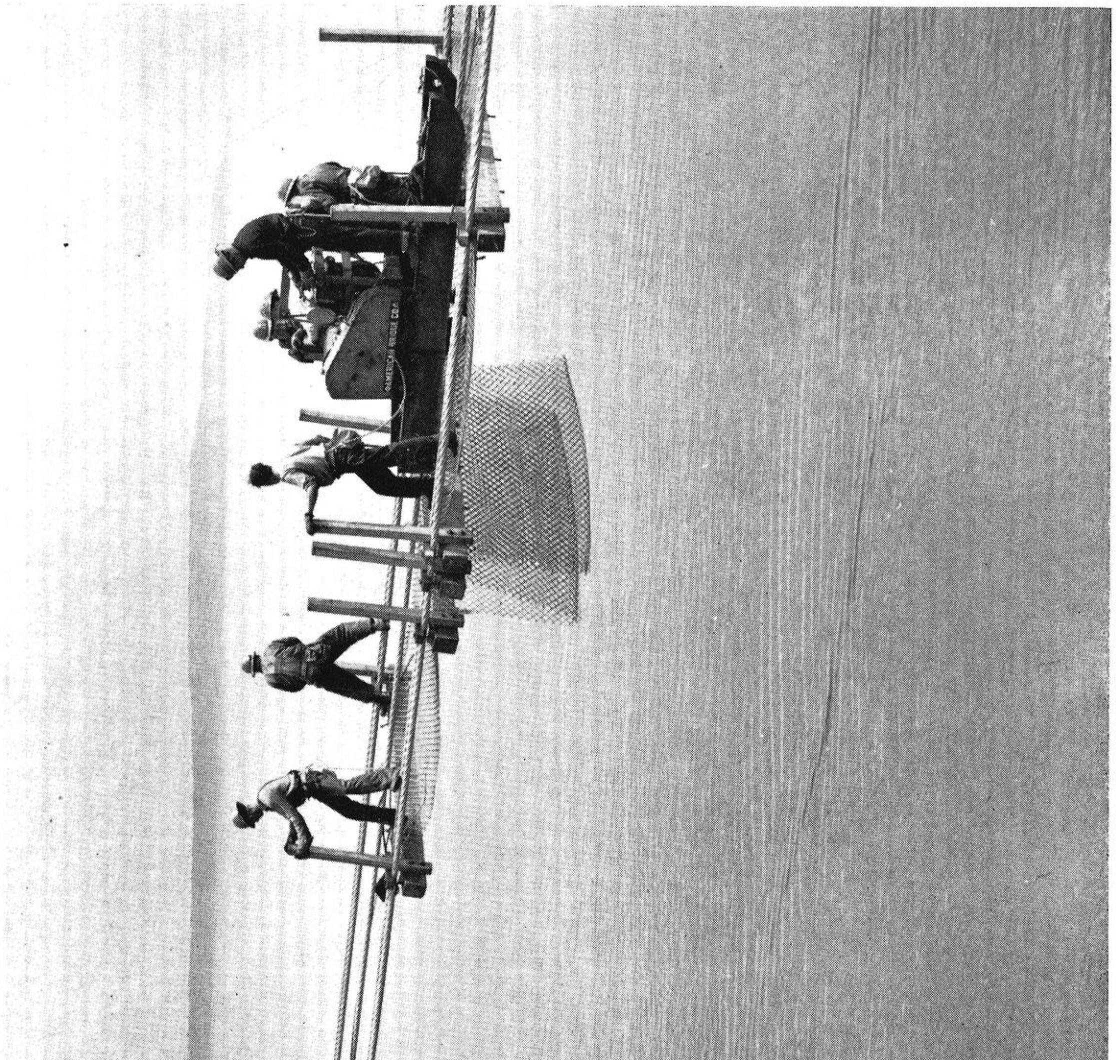

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Rambling With The Editor

What is being done in developing the most important part of our retaliatory weapon system, the bomb? Certainly we are researching and developing advanced H. bombs and various other super weapons, but how far can they be developed without actual testing?

For the past two years we have unilaterally suspended nuclear weapons testing. What has this accomplished? We haven't reached any agreement in disarmament. The Russians undoubtedly have continued testing. Our lead in development has certainly been shortened.

We admit we are months behind in development of missiles. In fact we have told the world of our supreme efforts to regain the lead. Nevertheless, we let our bomb development slide while the Russians race to surpass us in this field, too.

When President Kennedy proposed in his campaign that we insist that the Russians start something constructive at Geneva within two months or we would begin testing again, I wholeheartedly agreed with him. He has been in office for over three months and the Geneva fiasco still goes on.

Certainly disarmament or ending the cold war will hardly be attainable if the Russians are holding all the aces.—R.G.N.

◀ **This photograph, of men working on the Mackinac Straights Bridge, points out the fact that an engineer must think of how the final product will be made when designing it.**

Technical Barriers to Nuclear Disarmament

by Bob Halverson me'61

INTRODUCTION

THIS report sets forth the basic problems, particularly technical problems, affecting nuclear disarmament, a vital question of our time. The future course of action which the United States adopts on this question may well be the determining factor of national survival. The general background and history of disarmament, as well as the detailed technical considerations affecting the future course of action on this question, are discussed in the report to effect a more complete understanding of these problems.

THE PROBLEM OF NUCLEAR DISARMAMENT

One of the greatest problems facing the world today, and the most profoundly difficult to solve, is nuclear disarmament. Since the first use of an atomic bomb at Hiroshima on August 6, 1945 the prohibition of this type of weapon and its larger relative, the hydrogen bomb, has been the subject of hundreds of disarmament conferences and millions of written words—seemingly to no avail. The position of the United States in all the disarmament debates since the problem's first formal discussion in the United Nations in January 1946 has been reiterated many times. The United States asserted that disarmament and prohibition of atomic weapons are impossible without effective safeguards and controls enforced by inspection. Though effective control and inspection has been a stumbling block in all disarmament discussions to date, few people realize what effective control consists of, and fewer still comprehend the myriads of complex problems that effective control occasions. The purpose of this report is to summarize the more important technical considerations inherent in effective control—the indicated barriers that have halted progress in conference after conference. The political motives underlying the failure of these conferences are given only token treatment herein, as these are sufficiently detailed to constitute a complete report in themselves. To effectively examine the rather complex technical barriers to nuclear disarmament, a general knowledge of disarmament and the history of disarmament, particularly in the period immediately following World War II, is necessary.

Disarmament Defined

Webster's dictionary defines disarmament as, "the reduction of a military establishment to a minimum set by some authority," this to be done presumably in accordance with the terms of some agreement. A major problem is inherent within the definition—who or what will comprise the authority and by whom will its powers be defined?

Authority. In the period between the two World Wars the League of Nations served, though quite ineffectively, as the "authority" in the disarmament negotiations conducted prior to the Second World War. The United Nations has, in the period since World War II, acquired the role of international authority and has made numerous attempts through the International Atomic Energy Commission and the U.N. Disarmament Commission to reconcile the differences between East and West and produce a workable agreement. All attempts to date have been unsuccessful. The pertinent consideration is the existence or past existence of an organization capable of assuming the role of authority in accordance with the definition of disarmament.

Inspection and Control. Not as explicit in the definition as the authority, but equally necessary to the success of any disarmament venture is the provision, within the terms of any agreement, for thorough and effective controls and inspection to insure that the terms of the agreement will be kept by all the participating nations. Disagreement over this seemingly basic provision has completely blocked settlement of the problem to date. A workable disarmament agreement then, is predicated on the following assumptions:

1. That an international organization or authority exists, such as the United Nations or subsidiaries thereof, with the power to enforce the terms of an agreement.
2. That a workable system of inspection and control acceptable to all parties be devised which will prevent "cheating" on the terms of the contracted agreement.

The following brief history of disarmament work immediately after World War II will illustrate the above definition and aid in relating the technical considerations—the major subject of this report—to the whole of the disarmament problem.

HISTORY OF NUCLEAR DISARMAMENT

Conference and Political Problems 1946–1950. The forerunner of the hundreds of discussions on atomic weapons in recent years was held in the United Nations General Assembly in 1946. The General Assembly at that time established the International Atomic Energy Commission, consisting primarily of scientists, which presented three reports to the Security Council during the period 1946–1948. These reports are considered to be the first significant steps toward defining the disarmament problem.

The First Report, submitted in December of 1946, indicated that satisfactory control of atomic weapons was possible from a technical standpoint, but expressed doubt as to the political feasibility of control and inspection.

The Second Report, submitted in September of 1947, advanced a plan named after the U.S. delegate to the U.N. AEC, known as the Baruch Plan, which required that all fissionable materials, mines, and means of production should be owned by an international syndicate supervised by the U.N. However, the delegate from the Soviet Union, Mr. A. Vyshinski, rejected the proposal as a violation of the sovereign property rights of the U. S. S. R. (Russia had not at that time developed a workable atomic bomb.)

The Third Report, filed in May 1948 as Russia took over Czechoslovakia and blockaded West Berlin, stressed quite appropriately, the necessity for political harmony if concrete disarmament results were to be obtained.

Soviet Russia during this period advocated prohibition, and then control, of atomic weapons, in that order. The United States would not accept this particular sequence, correctly insisting that prohibition of atomic weapons was safe only after suitable controls were established. In December of 1949 the UNAEC declared continuance of discussion impractical due to increased political tension, and further work was ceased. At this time the Chinese Communists were busily driving Chiang Kai-Shek and his Nationalist forces off the mainland to Formosa. The first era had ended without success. The problems, however, had come into focus.

Conference and Political Problems 1950 – Present. At the end of 1950 the Russians exploded their first air-dropped atomic bomb—the world then had two atomic powers. In the same year Dr. E. Teller in the United States discovered a relatively inexpensive method of producing a new and more powerful weapon—the hydrogen bomb. Outbreak of the Korean war in June of the same year with resultant rapid rearmament made reduction in World tensions impossible, and no efforts at disarmament were conducted until the newly formed U. N. Disarmament Commission convened in 1952.

At the sessions of the Disarmament Commission the Western Powers continued to insist on the controls of the Baruch Plan previously rejected by the USSR. Compromise efforts were also defeated by the USSR. The United States exploded the first hydrogen bomb in November of 1952—the hydrogen era had begun. By 1953 the American system of rigid maximum controls lost favor, while a system of relaxed control became popular in the hope that an agreement could be reached. Stalin's death raised hopes that an agreement might now be attained. But as the Western Powers eased their terms, the USSR tightened its position by demanding unconditional prohibition of nuclear weapons. This proposal was promptly rejected by the West, which still insisted on policing the terms of any agreement. During the years from 1953 to 1957, control and inspection continued to be the focal point of the disagreements on disarmament.

In 1857 a new dimension and a new note of urgency was added to the problem with the advent of the intercontinental ballistic missile. Crises in Lebanon, Hungary, Suez, Viet Nam, Tibet, the Belgian Congo, and Cuba, kept international tensions high. Nuclear disarmament conferences continued to fail over the same bargaining question—effective inspection and control.

THE PROBLEM OF INSPECTION

General Considerations

A practical inspection system would make evasion of the terms of a disarmament agreement exceedingly difficult. Workable systems do not require flawless reliability—impossible in any event—but do require that a certain minimal security be maintained. Many alternative types of inspection and control are available to encompass the areas of nuclear testing, inspection of production facilities, and weapons manufacture. The technical features of an inspection system must consider the possibilities of inspection at strategic points in the mining, processing, manufacturing, storage and deployment of nuclear weapons and their delivery means. The possibility of evasion of the inspection processes by imaginative technology at the various stages must be considered. Once the technical possibilities for inspection and evasion are defined, the legal and administrative details and powers of the administering authority may be established. The definition of technical problems affecting the question of nuclear disarmament is the primary concern of this report.

Types of Inspection

If the major powers of the world were to join into a disarmament agreement including a plan of inspection to prevent clandestine weapons production and deployment, at least six major methods of inspection could be used:

1) Aerial inspection.

2) Inspection of government budgets and appropriations.

3) Detection of nuclear bomb testing and manufacture.

4) Detection of missile testing and manufacture.

5) Radiation inspection.

6) Checks on scientific personnel.

Aerial Reconnaissance. The full usefulness and capabilities of aerial inspection was revealed by the exposure of a high-flying camera-carrying aircraft belonging to the United States—the U-2. Published photographs taken by the cameras aboard the plane are remarkably accurate though taken from altitudes exceeding 70,000 feet. Clearly such cameras are capable of locating large military installations, industrial plants, areas of construction activity and transportation systems. They would, however, have great difficulty detecting missiles already emplaced in "silo" type underground launching areas and could not possibly locate missiles on submarines, merchant vessels or satellites. Aerial inspection, then, would be of very limited effectiveness in detecting many forms of illegal activity.

Analysis of Government Budgets and Appropriations. Analysis of budgets type of control contains a number of major intrinsic difficulties. Funds for secret armament production could be transferred between accounts, or spread out among a number of innocent appearing accounts, Estimates indicate that amounts up to $100,000,000 could be easily concealed annually within the budget of the United States. Greater amounts would be more difficult to conceal though not at all impossible. Standardized accounting systems for all national governments would increase the reliability of this type of control but would be very difficult to institute initially.

Detection of Bomb Testing. At the present time the feasibility of effective monitoring of nuclear weapons testing is being rather heatedly discussed by certain members of the United States scientific community. Dr. E. Teller, inventor of the practical hydrogen bomb, insists that tests cannot be effectively monitored by existing equipment and organizations, with their widely scattered stations, Under the terms of an international agreement, however, monitoring stations, perhaps automatic, would presumably be located in all countries to attempt the detection of illegal nuclear testing.

Scientific Personnel. Significant illegal production of any types of weapons in violation of an agreement within a country would require large numbers of scientists and engineers. The presence of large numbers of technically trained personnel such as radiologists in a certain locality could indicate illegal weapons production going on in that area.

Radiation Inspection. Industrial plants producing fissionable materials also produce large amounts of dangerous radioactivity and radioactive wastes. Close control must be kept over all operations involving radioactive materials, as substances which might be used for peaceful energy production or experimentation purposes can also be used with modification in the production of nuclear weapons.

Guided and Ballistic Missiles. Missiles will soon be the primary means of delivery for all nuclear weapons but the smallest tactical types. As such, they would necessarily fall under the provisions of a disarmament agreement. Adequate inspection of strategic points in missile production facilities would be necessary to prevent illegal manufacture of these delivery means for nuclear weapons. Rigid control is necessary to prevent missiles or missile components, used for scientific exploration and study, from being diverted into illegal channels and converted into weapons systems. At least five critical inspection points could be used in controlling missile production:

(1) Complex electronic equipment necessary for missile guidance could be controlled at production locations. However, as increasingly complex and compact electronic equipment comes into common use, the possibilities of differentiating between standard computors and airborne guidance systems for inspection purposes becomes increasingly difficult.

(2) Precision gyroscopes and accelarometers which form the basic components of inertial guidance offer good prospects for inspection purposes. To achieve the accuracy necessary in missile guidance, certain components of the guidance system must be produced to accuracies of one-millionth of an inch. The manufacturing equipment necessary for realizing this kind of accuracy can be produced only in limited quantities. The possibility exists, however, that in due time conventional equipment such as commercial aircraft systems will require accuracy of this degree, thus reducing the effectiveness of this control.

(3) Military missile frames require certain design accomodation to kinetic heating, atmospheric exit and reentry, and vibration and stability. Careful examination of structural design of scientific missiles would indicate the possibilities of converting the missile to military use.

(4) Production systems, notably the currently popular liquid fuel type, offer likely possibilities for inspection control. Specific areas include the monitoring of the manufacture of special light-weight pumps and turbines capable of handling extremely low temperature or highly corrosive fuels, special valves with similar characteristics, heat resistant materials used in engines such as ceramic oxides, graphite, cermets, processes involving heat resistant chromium-nickle coatings or other special equipment such as light-weight refrigeration units. Ram jet and solid fuel propulsion units, because of their greater simplicity, would be very difficult to detect during manufacturing operations.

(5) The United States has been very successful in detecting the high altitude missile tests that are a necessary and basic phase in the development of reliable missiles. High powered radar installations scattered around the world could make illegal testing of missiles impossible without detection.

Inventory Validation. The greatest threat to effective disarmament is the possibility that a nation anticipating a disarmament agreement might establish secret stores of arms before the agreement is consummated and prior to the inauguration of an inspection program. Each participating country would, under an atomic weapons disarmament plan, be required to declare its inventory of nuclear weapons and their delivery means. Inspecting teams would have to verify the correctness of the declared statements. A number of methods, none of which are particularly reliable, could be used to validate inventory declarations. Production, receipt and transfer records of weapons might be utilized as well as statistically estimating previous industrial output. However, the available knowledge of production systems does not permit accurate analysis of past output of manufacturing plants, particularly when estimates are based on current input-output relationships. Previous records are unreliable because of possibilities of forgery or unrecorded withdrawals.

POSSIBILITIES OF EVASION

A workable disarmament agreement, to be acceptable to the rational world powers, must provide relatively foolproof inspection of the terms of disarmament. Effective inspection must be able to cope with any of the various methods which might be used to evade an agreement. Significant evasion possibilities exist within the following particularly acceptable areas:

(1) Development of new weapons

(2) Falsification of inventories

Development of New Weapons. The production of new nuclear weapons and delivery means within a country under an inspection system would be a difficult but not altogether impossible achievement. The task would require significant numbers of trained personnel. Many of the specialists required could be obtained quite readily from unemployed workers of the world's immobilized weapons industries. Materials for weapons could be obtained from hijacked surplus weapons and parts. Nuclear materials could be stolen from reactors engaged in peaceful power or scientific applications. The creation of a significant number of weapons would require a large organization which would be difficult to operate under the constant surveillance of inspection teams within the country.

The most practical opportunity for a country to develop new weapons would be the interim period of successive steps which would necessarily precede total disarmament. Based on the very realistic assumption that disarmament would have to come in a series of progressive steps leading to total disarmament, a number of years would certainly elapse between the preliminary phases of disarmament such as suspension of nuclear tests and the final total prohibition of weapons. During the intervening years, parties to the agreement would have sufficient time to develop new weapons to meet the military requirements of the disarmament era. For instance, missiles with nuclear warheads could be developed that could be concealed in underwater launching sites in the oceans of the world. The operational Polaris solid fuel missile, now launched from submarines, could be inclosed in individual water tight containers which, fastened to the bottoms of passenger ships or warships, could be distributed to hidden locations beneath the oceans of the world, to be sent to their predetermined targets by remote radio signal. Weapons systems of this type are within the realm of contemporary technology and could be constructed in large numbers prior to the establishment of effective control organizations. This type of weapon would pose a most serious threat to the effectiveness of international controls, since they would be particularly difficult to locate once emplaced. After the total disarmament phase of the agreement was realized, the hidden weapons would become part of the problem of inventory validation by the inspection organization.

Inventory Validation. While development and manufacture of new weapons under an inspection system would be difficult, a significant portion of a nation's weapons could be retained by the age-old expedient of merely hiding them. Falsified inventories and records could be turned over to the inspection organization along with the identical supplies of weapons. The uncounted portion of weapons could simply be hidden from the inspecting group and would be very difficult to uncover.

Varied types of weapons could be concealed by falsifying inventories. The disclosure of one type to the inspection organization to reduce suspicion could be undertaken while the remaining types could still be retained in readiness.

CONCLUSION

Past actions by the Soviet Union and other Communist countries afford little assurance that disarmament is possible. The United States has bargained with the Communists for the past 14 years in an effort to halt nuclear weapons tests, cease the manufacture of nuclear weapons, and ultimately to prohibit nuclear weapons altogether. These attempts have been repeatedly thwarted by the Union of Soviet Socialist Republics as previously mentioned. Demonstrating its good faith and desire for world peace, the United States has unilaterally suspended nuclear weapons testing for the last two years, even though this was, in fact, detrimental to the national security of the United States. The U.S.S.R. has to the present time given no indications that it seeks an agreement in good faith. Reciprocal good faith at the bargaining table must be assured before any country can afford to relinquish its sovereignty to an international disarmament authority. An agreement based on distrust could be much worse than none at all if one of the participating nations decided to hedge on the agreement as did Hitler prior to World War II.

Current Inspection and control methods—even combinations of the systems outlined in this report—cannot guarantee the keeping of the disarmament terms by the par-

(Continued on page 27)

Bob Halverson is a senior in Mechanical Engineering and from Wauwatosa, Wisconsin. He plans on continuing his education by obtaining a Law or Commerce degree in addition to his ME degree. Bob is active on campus, being a member of Chi Psi fraternity, Phi Eta Sigma, MACE, Young Republicans, and Central Committee of Wisconsin Previews.

Principles of Corrosion

by Tom Ramsey

"With sharpen'd sight pale Antiquaries pore
Th' inscription value, but the rust adore.
This the blue varnish, that the green endears;
The sacred rust of twice ten hundred years."

—Alexander Pope

THE artistic value of the corrosion products on ancient plaques is small reward for the large economic loss caused by corrosion. Corrosion causes millions of dollars worth of damage each year in the United States. It has been estimated that as much as 2 per cent of the total tonnage of metal in use has to be replaced or preserved each year. An understanding of corrosion and methods of limiting its effects are therefore necessary to engineering.

Corrosion is a very complex problem, and much research is being conducted to solve the many problems which still exist. Although much is already known about corrosion, engineers must rely on the results from service tests, since actual performance may differ from predictions of laboratory investigations.

Although corrosion theory can not be applied strictly to all problems, in many cases its basic principles offer a guide to corrosion control.

TYPES OF CORROSIVE ATTACK

The corrosion of common metals in usual surroundings is an electrochemical process. That is, it has to do with the chemical effects of electrical action. It has been found that the amount corrosion occuring is directly proportional to the amount of electric current which passed.

Contact between a metal and a liquid solution results in corrosive attack. The corrosion may proceed unnoticeably slow or at a fast rate. The degree of attack depends upon the metal and the environment. No metal can avoid corrosive attack in all environments.

Direct Attack

Direct attack occurs if the immediate products of the corrosion are deposited on the metal. If these corrosion products happen to be insoluble in the solution, their deposit provides a protective insulating film. The corrosion rate diminishes as the deposited film gets thicker. The corrosion products may also be soluble in the solution. In this case, the corrosion products will form and then dissolve, thus leaving the metal exposed for continued attack.

Two-Stage Attack

When the first corrosion products to form further react with the solution to form a second corrosion product, we have a process known as two-stage attack. The second stage products are usually less soluble than the first stage corrosion products. They may be of value in slowing down corrosion if they are deposited on the metal surface. They are sometimes deposited a small distance away from the metal surface, and when this happens they are nonprotective.

Electrochemical Attack

The term electrochemical attack is applied to those reactions in which electric currents flow. This condition occurs when corrosion products are deposited at some distance from the area under attack. It also comes about when dissimilar metals come in contact with each other.

Factors Which Affect Corrosion Rate

A whole report could be written on factors which affect corrosion rate. Therefore, I will have to be brief and mention only the main causes of corrosion. Factors such as erosion, abrasion, and cavitation will not be mentioned, but the engineer should realize that these are also a cause of corrosion in some situations.

Moisture

The presence of liquid or gaseous water is the factor which is most important in causing normal types of corrosion. This is because moisture usually increases the electrical conductivity of the environment surrounding the metal surfaces. Since corrosion is commonly electrochemical in nature, an increase in electrical conductivity of the environment will permit larger currents to flow which will result in higher corrosion rates. Unalloyed steels will remain uncorroded if they are exposed to air with a relative humidity less than 30 per cent. At higher humidities, however, corrosion will rise in proportion with the rise in humidity.

Salts, Acids, and Alkalis

Salts, acids and alkalis all form electrolytes. An electrolyte consists of positive and negative ions and is capable of transmitting electric currents.

Salts may stimulate corrosion in the presence of moisture in two ways:

1. They increase the electrical conductivity of the solution and thus increase corrosion currents.
2. In some cases, corrosion products which are formed adhere to the surface of the metal and prevent further attack. In the presence of salts, however, these corrosion products may be dissolved leaving the metal open for further attack.

There are two types of acids which cause corrosion:

1. Oxidizing acids such as concentrated nitric acid
2. Non-oxidizing acids such as hydrochloric acid

Group (2) acids cause direct corrosion, which is nothing more than ordinary chemical attack. These acids are used as pickling solutions. They dissolve the metal surfaces uniformly without the formation of protective layers and without selective attack on certain phases or components of the metal. The attack continues at an almost constant rate that can be measured in standard units such as inches penetration per year. A typical direct corrosion reaction is $Fe + 2H^{+} \longrightarrow Fe^{++} + H_2\,(gas)$, which describes the direct attack a non-oxidizing acid has on iron.

Oxidizing acids may or may not be corrosive. If they form a thin protective film on the metal surface they are non-corrosive. Steel in concentrated nitric acid will not corrode because of the thin insoluble film that is formed on the surface of the steel. Very concentrated sulphuric acid also forms such a protective film on steel. Most generally, however, an increase in the acidity of a solution will increase its corrosiveness.

An increase in the alkalinity of a solution generally will tend to reduce the total amount of corrosion in ferrous materials. Very strong caustic solutions, however, especially at high temperatures, may be corrosive to a serious extent.

Oxygen and Oxidizing Compounds

Oxygen and oxidizing compounds have a complex effect on the corrosion of metals. In water solutions they tend to increase the total amount of corrosion but restrict the area under attack.

When oxygen is present at elevated temperatures, steels will exhibit an increased rate of oxidation. Scaling will take place and will flake off exposing new areas of metal to attack.

Sulphur Compounds

Sulphur compounds, either in solutions or gas, stimulate the corrosion of iron and steel. Sulphur at high temperatures seems to cause the most damage. It has been estimated that in the petroleum industry alone, corrosion resulting from the presence of sulphur compounds causes millions of dollars worth of damage. Sulphur compounds tend to render iron scale less protective, thus permitting increased rates of attack.

High Temperature

In most cases of corrosion, the higher the temperature, the faster corrosion will proceed. There are cases where this is not true, however. Raising the temperature of a solution will drive out any dissolved oxygen which may be present. It may also cause more continuous protective films to be formed on anodic areas. Both of these factors will reduce corrosion rates. As a general rule, when the temperature of solutions which are exposed to the air is increased, corrosion will increase until the temperature gets to be 180 F. Past this point, the corrosion rate may decrease until the boiling point is reached.

Galvanic Action

When dissimilar metals are placed in contact with each other, and exposed to an electrolyte, corrosion of one of the metals is increased while corrosion in the other metal is decreased.

The metal which happens to be the most active sends currents through the solution to the cathodic metal. The direction of the current flow determines which metal will suffer accelerated corrosion. Galvanic action can also be caused by contact between two different alloys of the same metal.

Stray Currents

Stray direct-current electricity is a common cause of corrosion to underground steel pipes. It also causes problems in ship hulls when the vessels are tied up at docks. Stray current causes more rapid corrosion attack than almost all other causes of corrosion. Whenever there is very rapid corrosion attack to some metallic structure which is underground or in water, stray currents should be investigated.

Concentration Cells

If one portion of a metal surface is exposed to one electrolyte and another portion of the same metal surface is exposed to another electrolyte, corrosion will take place. Suppose a steel tank is filled with salt water. If the concentration of the salt is different at the top than at the bottom, corrosion will take place at either the top or the bottom. An easy way to solve this problem would be to mix the salt

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solution so it would have a uniform concentration. Corrosion can very often take place on the outside of chemical tanks if the surface is wet. The reason for this is that a concentration cell has been set up.

Surface Effects

Almost any local difference at the metal surface can cause corrosion under suitable conditions. Scratches in the metal surface, local differences in temperature, degree of surface roughness, and even the amount of illumination can all cause localized corrosion in specific cases.

Metallurgical Factors

Any discontinuities in a metal can give rise to localized corrosion. This is not a serious problem, however. Environmental factors are of much greater importance, and only in rare cases will metallurgical factors be important.

Corrosion Tests

Since corrosion usually takes place over a long period of time, it is impractical to test metals under service conditions. Therefore "accelerated" tests are used. The results of these tests are not always true, however. The intensification of corrosion conditions to cause severe corrosion in a short period of time seems to give a completely changed nature to the test environment. It becomes difficult to interpret test results for the normal range of service conditions.

Laboratory tests serve as control tests to assure uniformity of product and as property tests to determine susceptibility to special types of corrosion.

The typical laboratory tests are:

Total Immersion Test

For most of these tests, the parts to be tested are dipped into an acid bath. Velocity in the bath, temperature, aeration, and concentration are some of the important variables that must be controlled to standardize the test results.

Intermittent Immersion Test

This test is useful for comparing corrosion resistance in a wide variety of media. It is also a useful test for controlling quality in production lots.

Salt Spray Test

For this test the parts to be tested are inclined in a chamber and subjected to a fine spray of salt solution at a specified temperature. Things such as the effectiveness of plating are determined in this test. It is possible to determine the porosity of the plating by counting the number of rust spots formed per unit time. It is also possible to determine the time it takes for rusting to begin. With this information the thickness of the desired coating can be calculated.

Humidity Chamber Test

Parts are subjected to high humidity at a specified temperature. This test is useful in comparing paint and primer coatings.

Special Purpose Tests

These include a number of tests which are used for determining such things as dezincification, impingement corrosion, intergranular corrosion, and stress-corrosion cracking. There are also field tests which consist of subjecting panels to exposure under various atmospheres, in different soils or in different types of water.

METHODS OF PREVENTING CORROSION

It is important to know about the factors which speed up corrosion bcause it helps one to guard against corrosion failures. A knowledge of the proper methods of preventing corrosion is important for the same reason. Corrosion control measures can be considered under three general headings:

1. Improving the characteristics of the metal
2. Protecting the metal with a coating substance
3. Treating the corroding medium to reduce its corrosive action

These three general headings can be further divided into the *six subheadings* which follow.

Material Selection

An obvious way of preventing corrosion is to build the structure from some material which is unaffected by the service. This is not always possible, however. The material which would stand up against corrosion may be too expensive or otherwise unsuited for the article to be built, so a compromise must usually be made. The engineer must select a material which has the lowest combined initial cost and maintenance costs. In order to do this, an engineer must have a thorough knowledge of the corrosion behaviors or the various materials from which he must make his selection. Previous service tests provide him with the most accurate knowledge on the subject. It should be stressed, however, that results from these tests are not always true. Small variations in service conditions can sometimes affect corrosion rates greatly.

If the engineer wishes to select material which will be used for some new process or will come in contact with a new chemical, there may not be any previous knowledge on the subject. In these cases, it is oftentimes helpful to build scale models and test these models in a laboratory. It should be kept in mind that the closer these tests can be designed to the actual situation the more accurate the results will be.

If a suitable material has been selected it may be unnecessary to use any other form of corrosion prevention. The most resistant material will in most cases cost more, however, so it is frequently more economical to use some less resistant and cheaper material and to employ some protective measure.

Appropriate Design

Design changes may make it possible to use cheaper materials for construction. For example, stainless steel pipe might have been suggested by the engineer for some particular application. Instead of using this, it might be possible to use a carbon-steel pipe and insulate it against condensation and eventual corrosion.

It has been found that in tanks which contain liquids, corrosion is most likely to occur in crevices, pockets, joints or other dead spaces. By eliminating these regions it may be possible to use the same material with greatly reduced corrosion damage. It is interesting to note that in tanks or processing vessels for chemicals, the most severe corrosion often occurs on the outside of the tank and not on the inside. If this is the case, the vessel should be so designed that moisture cannot accumulate anywhere on the vessel. Even condensed moisture or tap water can cause severe damage. The design may be as important as the material in construction of vessels.

Protective Coatings

There are many types of protective coatings. Based on their means of preventing corrosion, they are classified as follows:

Anodic Coatings. If there are pores in a coating covering a metal article and the article is exposed to an electrolyte, several things can happen. A positive electric current may flow from the coating through the electrolyte to the base metal. When this happens, the coating is anodic to the base metal. Anodic reactions are always oxidation reactions and tend to destroy the anode metal by causing it to dissolve as an ion or to form an oxide. Cathodic reactions, on the other hand, do not affect the cathode metal. Thus, anodic coatings prevent corrosion by forming corrosion products which may plug up the pores in the coating or by causing the corrosion to take place in the coating, leaving the base metal unaffected.

Cathodic Coatings. These coatings are just the opposite of anodic coatings. They tend to stimulate corrosion at the exposed areas of base metal. It should be pointed out that this does not always mean that increased attack will occur in these areas. If the coating is thick and the exposed areas of base metal are small, attack may be stopped by plugging of the small pores in the coating with corrosion products.

The same metallic coating on the same base metal can act as an anodic coating under one set of conditions, as a cathodic coating under other conditions, and as an inert or even as an inhibitive coating under still different conditions.

A coating of tin on steel serves as a good example for this varied behavior under different conditions. When exposed outdoors, in most waters, or even to most food products in the presence of air, tin is cathodic to the exposed areas of the steel base. When exposed to nearly air free food, tin is anodic to steel. If exposed to food in an oxygen free atmosphere the tin would be inert.

Inert Coatings. Inorganic coatings can be inert, cathodic or inhibitive. Organic coatings are usually inert or inhibitive. Inert coatings are self defined. They are coatings which are unaffected by the service conditions which prevail.

Inhibitive Coatings. These coatings slow down the process of corrosion. For example, some organic coatings serve as semi-permeable membranes on the surface of the base metal. That is, liquid, by the process of osmosis, is transferred through the coating to the base metal. This liquid which passes through the coating may or may not be of the same composition as the liquid outside the coating. Also, it may be either more or less corrosive to the base metal the parent liquid is.

Treatment of Environment

It is sometimes possible to prevent corrosion either by adding something to the corrosive medium or by removing some corrosive agent from the medium. Sodium chromate may be added to tap water to prevent corrosion in steel tanks. Corrosion will be reduced in like manner by removing dissolved oxygen from the water.

These treatments to the environment are normally used when there is a limited amount of the corrosive material. It wouldn't be practical to treat water which is flowing continuously from the source without recirculation.

Cathodic Proteciton

It was earlier mentioned that some coatings act so as to send an electric current through an electrolyte to exposed areas of the base metal. Such current flow tends to prevent corrosion of the base metal. This type of protection by current flow from any source is called cathodic protection. Instead of using a coating, it is possible to connect the base metal to a storage battery and achieve the same protecting effect. As long as the current is maintained at the proper level the base metal will be protected.

Determining the strength of the current to be used is probably the most difficult problem. Variables such as size of base metal, type of environment and type of base metal make it difficult to predict with accuracy the most economical current to use. Fortunately, with ferrous materials this problem is not so great. Any current will reduce corrosion to some extent. Too much current will not hurt anything. It will simply mean that some of the current is being wasted.

At the present time, this type of protection has many uses. It is applied to the steel hulls of ships, to the interiors of water tanks, to the exteriors of buried steel pipes and to many types of chemical equipment.

Caution should be used when planning a use for cathodic protection. For while it is easy to apply cathodic protection to small geometrically simple structures, experienced electrochemical engineers are needed to design effective protection for large structures.

Periodic Cleaning

A last but sometimes important method of preventing corrosion is periodic cleaning. Cleaning is important because it removes moist layers of material from the metal surface. Many corrosion products are hygroscopic or water absorbing. They tend to "pull" water out of the air and deposit it on the metal surface. Under such conditions, the metal surface will be wet for a greater proportion of the time than will a similar clean surface. Layers of soot or dust will also stimulate corrosion. It is only in rare cases that surface debris are protective.

Because of the complex nature of corrosion and the lack of definite information on the subject, few rules can be stated for application

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Fabrication of Transistors

by Peter Schneider

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Introduction

BECAUSE of the relative ease with which it may be purified, germanium is the most widely used semiconductor at the present time. The second major semiconductor material, silicon, has the more promising future due to its ability to withstand high operating temperatures and its relative abundance. Regardless of the type, semiconductors represent both the present and the future of the electronics industry. For the engineer who desires to remain proficient in his field and expand upon his general knowledge of semiconductors, this paper will provide an excellent discussion of transistor fabrication that will well serve the reader in future, more advanced, study.

Mining techniques and initial refining operations for germanium and silicon differ widely, but all further steps in the production of quality transistors are about the same for both elements. Thus, the first two steps in the construction process will be discussed independently for the two materials, while all succeeding operations will be covered concurrently with minor variations noted as they occur.

The materials travel from the mine to an initial refining stage and then on to the zone refiner. The product obtained from the zone refiner may be used to produce alloyed or diffused transistors or be sent to a crystal pulling furnace. The crystals obtained by pulling may be used to fabricate either grown, alloyed, or diffused transistors. This flow diagram will provide a general outline for the discussion.

Transistor Fabrication

The only source of germanium in the United States is the Illinois-Kentucky fluorspar district where the ore is found in zinc as a by-product. The concentration is too low (.03–.07%) to mine the germanium competitively. The two ores, Argyrodite ($Ag_8\ Ge\ S_6$) and Germanite ($7CuS\ FeS\ Ge\ S_2$), contain six to eight percent germanium but occur very rarely. At present the world relies primarily on the zinc mines of the Belgian Congo for its raw germanium. Because of the extremely low concentration of the ore it must be treated and enriched at the mine before being shipped out.

Reinerite, a form of germanium found in the Belgian Congo ores, follows the zinc during floatation and so is present during smelting. The dust from the smelting process contains a large amount of germanium that may be claimed by baking, leaching, and precipitating. The product shipped from the mine usually contains 30 milligrams of germanium per liter.

At the refining plant the germanium dioxide that is the main constituent of the processed ore is reduced to pure germanium at a temperature of 650° to 1100°C. in a clean quartz tube. The reduction is followed by a segregation procedure and directional cooling from a temperature of around 1030°C. The rather crude ingot formed at this stage is ready for the next step in transistor production–zone refining.

Before going on to zone refining techniques, a few words will be said about the production of crude silicon crystals. Since silicon is a most abundant solid, sources present no problem. Silicon is usually obtained from silica (SIO_2) by reduction with carbon at temperatures above 1000°C. To eliminate the majority of the impurities the silicon is reacted with chlorine to form $SiCl_4$ which is then placed in contact with zinc at a temperature above the boiling point of $ZnCl_2$ to yield silicon metal. A further purification is obtained by forming SiI_4, distilling, and decomposing in a quartz tube at 900° C. to form silicon that is 99.999999% pure—but not pure enough.

The crude crystals produced by the previous processes have an impurity concentration of about one part per ten million. In order to obtain the necessary purity of one part per ten billion a rather exotic zone refining technique is applied. Zone refining is based on the well founded metallurgical principle of rate cooling in which a solute tends to remain in solution as the solvent solidifies. In zone refining of semiconductors a molten zone is swept down a boat shaped quartz container 1" in diameter and 15" to 18" long which is filled with the crude crystals. As the molten region sweeps down the boat it will gather impurities and carry them to the end of the boat where they will be sawed off after cooling. There are actually two basic methods of producing the sweep down the boat, with each possessing its advantages and disadvantages.

One makes use of a mechanical sweep of the crystal charged boat past fixed narrow heat zones. The heat zones are formed by radio frequency (rf) induction heating coils wrapped around the quartz tubular enclosure. The hollow rf coils are energized by a 10 kilowatt 450 kilocycle generator and cooled by distilled water circulating through the tubes. Besides providing heat, the rf field circulates the metal in order to provide a more uniform product. The atmosphere inside the tube is primarily nitrogen under a slight pressure, which prevents impurities from entering the crystal.

A normal rate of sweep for the boat is five inches per hour. Because there are an average of six coil zones on the tube, one passage of the boat amounts to six zone sweeps through the crystal. Although more passes produce a more pure product, diminishing returns set in and it is economically unfeasible to use more than one mechanical sweep.

A second method of achieving zone refining is obtained with no mechanical motion of the boat by the use of a switched zone furnace. A switched zone furnace is composed of an average of thirty Globar heated cells. The first two cells contain two Globar heating elements in order to provide the heat necesary for the initial melting. Each cell is separated by a quarter inch thick fire wall to prevent the heat of one cell from melting the load in another and to support the silica housing tube. As in the previous case, the tube is filled with an inert gas.

The molten zone is moved across the stationary boat by switching in the various cells in a continuous manner. Switching of the cells is carried out by transistor switches coupled to a mechanical timer of relatively small size. Since the boat is about 40 inches long, several sweeps may be occurring simultaneously if they are separated by several cell spacings. The efficiency of this system is low so that 18 passes must be made to obtain acceptable results. The main advantage of this device is the high degree of precision with which the zones may be moved by electrical means and the low maintenance rate.

The zone refined crystal produced by either of the previous methods may be doped in one of two possible ways. The first method of doping, called zone leveling, is carried out in the same apparatus that was used for the zone refining operation. By controlling the rate of sweep down the boat a set impurity concentration may be developed in the crystal. Thus, by adding either antimony or indium to the refined charge and adjusting the sweep rate a p type or n type crystal is obtained. The first part of the charge will have a low concentration and the last part to freeze will have a high concentration due to starting and stopping transients.

The normal charge for a 12 inch boat weighs about 500 grams. This weight includes a seed crystal that is placed in the end of the boat where solidification is to begin in order to yield the optimum crystal orientation. The ingot that is formed would be diced with a diamond saw and the pellets used for the production of alloyed or diffusion transistors.

The second method of doping crystals is based on the famous Czocharlski technique. In this process a seed crystal is placed in contact with the molten, doped semiconductor and slowly withdrawn as new lattice layers freeze out from the melt. The only problem with this technique is that the doping solute will tend to remain in solution as was noted when zone refining was discussed. The result is a nonuniform crystal with excessive impurity concentration at the bottom of the crystal.

A highly improved crystal growing furnace has been developed by the RCA laboratories. In order to alleviate the problem of solute concentration in the melt, a rod of polycrystalline germanium is fed into the melt at the same rate as the doped crystal is withdrawn. The composition of the rod is used to control the degree of doping.

The melt, which is held in a carbon crucible, is heated by induction coils wrapped around the furnace and powered by an rf generator of the type used in zone refining. The working range of temperatures is from 1100°C. to 900°C. with the actual temperature of the melt controlling the diameter of the crystal. In practice, the diameter of the crystal is chosen to be two centimeters. An inert gas atmosphere is maintained and all drive rods placed in bushings to prevent leakage. In order to obtain a more uniform crystal, the pull rod is rotated at one revolution per second thereby stirring the melt.

Undesirable properties are eliminated from the crystal by several refinements of the basic process. It is found that the slight amounts of oxygen contained in the crucible will drastically change the properties of the crystal. To minimize this effect the crucible is rotated in the same direction and at the same speed as the seed crystal, giving what is termed a nonrotated crystal. This reduces the oxygen impurities from one part per ten million to one part per one hundred million. Dislocations are reduced by necking down the crystal at the start.

With either the zone leveling or crystal pulling techniques a high quality single doped crystal may be obtained. These single doped crystals are used to form either alloyed or diffused junctions. For the production of grown junctions, the crystal pulling technique is the only usable method.

In order to change the doping in various regions of a single crystal, as is required in the manufacture of grown junction transistors, two distinct methods may be employed. In the first method a series of n type and p type layers may be formed by the alternate addition of impurities of the opposite type, such as indium and antimony, in higher and higher concentrations to the melt. The resulting crystal may be sliced into n-p junctions for diode use, or it may be used to form npn transistors. This process does not allow for exact control of the resistivity of the crystal.

The second method employs two separate crucibles of oppositely doped melt in a common furnace. To obtain a grown junction, the crystal is alternately placed in one crucible and then the other by moving the crucibles under a fixed pulling shaft. The use of movable components complicates the operation and requires greater care to maintain the seal. The reason why this technique has gained wide popularity is that it is possible to exercise control over the resistivity of each layer.

After the crystal is formed it is cut axially into rods and then transversely into single junction transistors. These grown junctions have

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Methods and Problems of Recovering Sunken Ships

by Morris Coffman

INTRODUCTION

SHIP collisions occur at a rate of three a day. Not all of these result in a ship being sunk, but many of them do. Usually when a ship of any value is sunk, divers are sent down to determine the possibility of the ship being refloated. The world they find, far from the one imagined by the layman, is a cold, dark, current-swept maze of mud and seaweed. The dangers they face are seldom as exotic as eels or squids, but far more real and terrifying. The most fearsome of them is the invisible but ever-present phenomenon called water pressure.

PRACTICALITY OF REFLOATING

Value of a Refloated Ship

Refloating a sunken ship is at best an expensive operation. In some cases, it is impossible. In times of war, a ship may be refloated at a tremendous expense because materials are in short supply and the demand for the ship is immediate. In peacetime and in a commercial operation, refloating is never attempted unless the expected profit is very large. All conconsiderations, therefore, are economic. The first thing considered is the value of the refloated ship and the cost of repairs to make it ready for return to service. It would be absurd to start a salvage operation on a ship which has been sunk for more than ten years since the ship would be in an advanced stage of rusting. The hull would be weakened, the engines would be ruined, and all wooden fittings would be waterlogged.

The value of some ships at the time of their sinking can be readily determined. The *Andrea Doria*, the Italian liner which sank after a collision in 1956, was only three years old. One of the newest liners on the seas, she was powered by turbines, equipped with three swimming pools, three ballrooms, and every piece of navigational equipment available. She was valued at about $30,000,000 when delivered to the line. Repairs to the ship if she were refloated would run about $2,000,000. If it were possible to refloat this ship by regular methods, obviously it could be done with a great profit. The Cunard line's *Lusitania*, which was sunk by a German torpedo in 1915 is an example of the other extreme where a refloat would have been ridiculous. The *Lusitania* lay in 240 feet of water on her side, watersoaked, and heavily damaged by a torpedo. Her sister ship, the *Mauretania*, afloat and in excellent condition, had been scrapped several years before just because she was such a poor ship.

An example of an operation which needs more consideration is the refloating of the *Prince Wilhelm*, a cargo vessel which is sunk in shallow water outside the Milwaukee harbor. Though not a large or expensive ship, she did her job efficiently and profitably. If she could be refloated by some inexpensive means, which might be possible in her case, it might be a practical undertaking.

Feasibility of Refloating

A refloating operation is a complete deficit if the ship is not recovered. Regardless of possible profit, an operation will never be undertaken unless there is a very good chance that it will be successful. Salvage operations are always a gamble, but the risk is reduced by careful analysis of the problem and careful formulation of a solution. If it is decided that a ship is worth salvaging, divers are sent down to determine the position in which the ship came to rest after sinking and, as nearly as possible, the extent of damage caused by the collision and sinking. A ship gathers considerable speed while sinking and many times incurs more damage when striking the bottom than it did in the collision which sank it. If the ship is not too badly damaged and if it is in a position to be refloated, a method is decided upon, an approximate cost is computed, the chance of success is determined and then the decision is made as to whether refloating is a worthwhile operation.

Before any positive steps are taken, the salvage company must acquire ownership of the vessel. Contrary to popular belief, a ship still belongs to the owner or usually to the owner's insurance company even though it is sunk. If the insurance company has no intention of salvaging, it will usually give public notice that it has abandoned the ship. The ship then belongs to anyone who can recover it.

METHODS OF REFLOATING

Tank and Pontoon Method

The Tank and Pontoon method of raising a ship is the simplest, fastest, and most economical method if it can practically be employed. Briefly, it consists of towing large steel tanks to the sunken ship, sinking them by blowing the water out of them with compressed air, thus giving the sunken ship the bouyancy needed to refloat it. Sometimes the ship is towed to port with only the bouyancy of the tanks keeping it afloat. Where practical, it is safer to put a temporary patch over the damaged portion of the ship after refloating it, pump it out and remove the pontoons; the ship may then be towed to dry dock much faster than if it were being supported by pontoons. The pontoons are usually towed back by another ship. Speed is important if a long distance tow is involved. A storm or high seas can cause heavy damage to the ship if it is being supported by pontoons because of the violent contact between the ship and the pontoons as the ship rolls in the waves. If it has been pumped out and is supplying its own bouyancy, it will still have a large amount of water in its hold; in a storm, this water will surge from one side of the ship to the other and may cause the ship to capsize and sink. The flotation tanks are long and cylindrical for ease of handling and maximum capacity. They have thick steel bands around them with eyes at the bottom of the band to which chains can be attached. The chains are run under the ship through small tunnels which are usually blown out by compressed air. Both ends of the chain are hooked to pontoons and the chain is hooked to the ship to prevent slipping. Great care must be taken when sinking the pontoon to make sure it settles next to the ship in a predetermined location. This is accomplished by running guide lines from the salvage vessel through the eyes of the bands to the point on the sunken ship where the pontoon is to be attached. The pontoon is then filled with water and allowed to sink guided by the guide lines.

The tanks are usually chained together when being towed to prevent damage.

The Tank and Pontoon method has some obvious limitations. It would be out of the question to try to refloat a 40,000 ton vessel by this means. It is effective for harbor vessels, small seagoing vessels, submarines, and highly compartmented warships which can be sealed and blown but still need an additional lift. For larger ships the Seal and Blow method is employed.

Seal and Blow Method

The seal and Blow method, as the name implies, is a process by which the compartments of a ship are sealed off from the rest of the ship and the water blown from them by compressed air. After enough compartments are blown to give sufficient bouyancy, the ship will rise if it is not stuck in the mud. If it is stuck, other steps, explained below, must be taken.

The Seal and Blow method is used extensively on warships. These ships are built to withstand heavy damage and still remain afloat. They have many watertight bulkheads and are extensively compartmented. If the ship was scuttled (deliberately sunk) and there is no damage to the hull, refloating is relatively easy. During the second world war, the Germans scuttled several ships to prevent their destruction or capture. These ships were always top heavy due to guns and excessive superstructure. Because of this, they would always capsize before sinking and settle to the bottom upside down. Recovery was affected by opening all watertight doors in the hull, sealing the main deck against the sea, and blowing air into the ship. The hull effectively formed an airtight diving bell and the ship would rise to the surface upside down. Due to the heavy superstructure on the bottom, it was more seaworthy then than in its upright position and was towed to port that way. If the ship is damaged, repairs may have to be made underwater to make the ship sufficiently airtight for blowing. This was the process used to refloat our sunken battleships at Pearl Harbor. Oil tankers and submarines have a great many built-in tanks. These tanks can be blown and will usually give sufficient bouyancy to raise the ship. If not, a few pontoons are used to give added bouyancy.

Large commercial passenger liners are the most difficult ships to refloat. Unlike warships, they are built for comfort and convenience. These vessels usually have no more than three watertight bulkheads and compartmentization is at a minimum. These watertight bulkheads extend across the ship and from the bottom to about three or four decks above water level. The stairways which lead down into these separate compartments cannot be sealed off. This gives an effect comparable to welding four square washtubs together in a row. They can prevent the ship from sinking sometimes, but if the ship does sink, it is very difficult to seal up the top of the compartments for blowing. Due to the many stairways, passageways, and port holes, trying to refloat a liner is like trying to refloat a 25,000 ton sieve. To further complicate this problem, the hole in the hull which sank the ship originally would have to be repaired underwater. The ship usually settles on the bottom on the damaged side because of the list in this direction when the ship begins to sink. The *Andrea Doria* came to rest on her damaged starboard side. This is one of the major reasons no attempt has been made to refloat it. If ships in this position are to be refloated, a new method will have to be devised.

A New Method

I have given this problem some thought and have come up with an idea which I do not guarantee to be either foolproof or even workable but which I believe at least merits consideration. Moreover, it is not completely new in its essence. It is rather a refinement of a method which was to be tried by the salvors attempting to refloat the *Prince Wilhelm.* Unfortunately, the man in charge of the operation was killed in an automobile accident before the system was tried and refloating operations were abandoned. He had proposed to refloat the ship by inflating rubber life rafts inside the ship until it had sufficient bouyancy to float. Though I doubt the workability of that plan, a similar idea seems more realistic. I propose to prefabricate a series of inflateable rubber cubicles approximately the size of the compartments in which they will be used. They would have nylon threads imbedded in the side to help withstand the stress caused by the pressure gradient between the top and bottom of the cubicle. Completely deflated and folded, they could be easily carried by a diver to the compartment, unfolded, and inflated; thus effectively blowing the compartment. If the ship were raised by blowing enough compartments by this method, it would eliminate the need for repairing the damage to the ship underwater and for damaging the ship by weldments used during normal sealing. Also the ship could be towed immediately upon refloating with little danger of it capsizing.

I believe this method is not only workable but practical. It would involve a great deal of expense in prefabricating the cubicles but this expense would be negligible compared to the value of a large ocean liner. This method is presented not as a cure-all but as a possible aid in refloating. There are other problems to be considered such as diver's personal problems, adverse working conditions, and problems involving the suction on the ship caused by mud and quicksand.

PROBLEMS INVOLVED IN REFLOATING

The Diver's Problems

The deep sea diver is confronted by a series of problems on the bottom, all of which are due either directly or indirectly to the extreme water pressure which surrounds him. The pressure on a diver at even a nominal depth of 132 feet is four and one half tons per square foot or a total of about sixty tons on his entire body. The diver is able to withstand this pressure because he breathes compressed air as he descends. The pressure is distributed to his body through his blood stream. The pressure in his helmet is maintained at a pressure slightly greater than the surrounding sea. The diver then becomes, in effect, a human balloon whose orifice is inside the diving helmet.

The "squeeze" is the term applied to the situation where a diver lets the outside pressure become greater than his helmet pressure. If the difference is slight, the diver experiences a firm hug warning him to increase his pressure. If it becomes suddenly large because he falls off the side of a sunken ship into deeper water or if his helmet pressure fails he is immediately squeezed bodily into his helmet like a collapsing balloon. This, of course, is certain death. When falling into deeper water, a diver may save himself by increasing his helmet pressure. Since he doesn't have much time he will usually open his air valve wide open. This causes him to "blow up".

"Blowing up" is caused by the pressure in a diver's helmet becoming much larger than the surrounding water pressure. It will cause his rubber diving suit to inflate, making him bouyant. If the diver doesn't correct this before he has risen about six feet, he can no longer reach his air control valve because his arms are held straight out by the pressure in his suit. He will then continue to rise with increasing velocity. If his suit bursts due to the constantly increasing pressure difference, he will drown. If he hits the bottom of the salvage ship at that velocity, it will crush his skull. If his suit does not burst and he does not hit the bottom of the ship, he will come fiying out of the water like a leaping tarpon. If he has been down only a short time, he may be okay but if he has been down more than a few min--utes, he will probably get the "bends".

The "bends" is an affliction caused by the air bubbles forming in the blood stream and in the heart. As a diver breathes compressed air, nitrogen is absorbed into the blood stream. If this pressure is released too suddenly, bubbles form much the same as when the top is pulled off a bottle of charged water. This can cause death or permanent disability. It can be prevented by rising slowly, giving the nitrogen a chance to come out of solution slowly.

There are other problems of a less dangerous nature the diver must face. Oxygen drunkenness is one. When a diver's breathing air is compressed to five atmospheres of pressure, he gets five times as much oxygen in each breath as he gets in a normal breath. This excess oxygen can cause a reaction very similar to alcoholic intoxication.

Under this extreme pressure, the larnyx, which is used to using air at normal pressure, cannot form words which are very understandable. Over the diver's phone, he sounds like a voice on a 45 rpm phonograph record being played at 33 rpm. This is not normally a great problem but in an emergency it can be quite serious. The operator at the other phone may not be able to understand a sudden call for more air or less air or a request to be pulled up immediately if his suit should get ripped. This sometimes results in injury or death.

Another common problem is exhaustion. Because of the excess oxygen mentioned before, a diver becomes much stronger than he normally is. He may overwork himself without realizing it and suffer serious consequences later. Besides his personal problems, a diver's working conditions are some of the worst in the world.

Conditions on the Bottom

Lighting is a problem under water. On a sunny day and in about fifty feet of water, a diver may be able to see a distance of a city block. On an overcast day in two hundred feet of muddy water, he literally cannot see his hand in front of his face. These are extremes and the lighting is usually somewhere between these two conditions. The diver will have to carry a searchlight to see his work and in an extreme case he may have to work by feel.

Currents make movement difficult and dangerous and in rare cases may cause the ship to make a sudden shift causing the diver to fall over the side or pinching his lifeline.

The diver must work in extreme cold. The temperature of deep water is very close to freezing. The rubber diving suit and even the heavy woolens the diver wears do not help much if he is down more than a few minutes.

The bottom in most cases is mud or quicksand. Walking becomes a tedious and tiring chore. Sometimes he will get stuck in the mud. Usually he can free himself by increasing his air pressure and giving himself a little more bouyancy. Sometimes he may need help. It is very easy for him to accidentally stumble into a piece of fallen debris and injure himself or tear his suit. These and many other difficulties abound in the diver's world so he must work slowly and cautiously; and to make matters worse, he must contend with "normal" ship conditions.

Ship Conditions

When a ship sinks, it very rarely comes to rest on an even keel. It will usually come to rest at an angle or completely on its side. This makes walking and working on the ship very difficult and dangerous since a slip into deep water can mean sudden death.

Debris is a serious problem to the diver. A sunken ship is littered everywhere with bunks, tables, luggage, stores, personal effects, and innumerable other objects. Around the point of collision, fragments of steel and sharp edges are everywhere and the diver must be careful not to cut his suit or lifeline. The accompanying photographs of the *Stockholm* after collision give a vivid picture of the conditions a diver must work with.

Another problem a diver is faced with occasionally is a ship which has been blown but will not rise. To be bouyed up, the ship must have the water pressure acting on a large section of the under side. If it settles deep in the mud and if the mud is too solid to transmit the pressure, a diver may have to blow out some of the mud with compressed air. This is a dangerous practice with the ship ready to rise as soon as it gets free of the suction. A preferred alternate method is to drop pontoons to add bouyancy to the ship and thus pull it from the mud.

CONCLUSION

This is a great simplification of the actual flotation of a sunken ship. Ship salvage is a complex and dangerous operation and not one to be attempted by the ambitious amateur. It takes months of planning, preparation, and research to even begin the operation. If things do not go well, the operation may end in death and disillusionment, but if luck holds a large profit may be realized in a short time.

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Fabrication of Transistors

(Continued from page 19)

gradual transition regions and are classified as graded junctions. It is easier to produce npn transistors since resistivity control is not as great a problem as in the pnp type.

As previously noted, alloyed junctions may be made from crystals produced by either zone leveling or crystal pulling. In a typical formation process a crystal of a single doped type is selected and diced into small wafers or "blanks" with a thickness of .5 mils and a surface diameter of several mils. The emitter and collector regions are formed by alloying the doped germanium wafer with an impurity metal of the opposite type. A spot of this impurity element is placed on the surface of the wafer and the combination heated to 500°C. for a minute. The metal will melt and dissolve the germanium in contact with it to form a solid solution. When the heating cycle is completed the melted germanium solution solidifies, forming a continuous crystal composed of the base doped wafer and the newly created region of oppositely doped germanium. This oppositely doped region occurs because of the high concentration of alloying metal in the section of the crystal that was dissolved.

If this type of process is carried out on both sides of the blank a transistor junction will be formed. In practice the collector junction will be made somewhat larger than the emitter in order to increase the collectors efficiency.

Usually the surface of the blank is cut parallel to the (111) plane so that the end of the alloyed region is almost perfectly flat. The reason that this occurs is that the alloying process must remove a whole plane before it is energetically possible to penetrate the next layer. Because of this sharp separation of the layers and the corresponding narrow transition regions the alloyed transistors are termed "abrupt junctions".

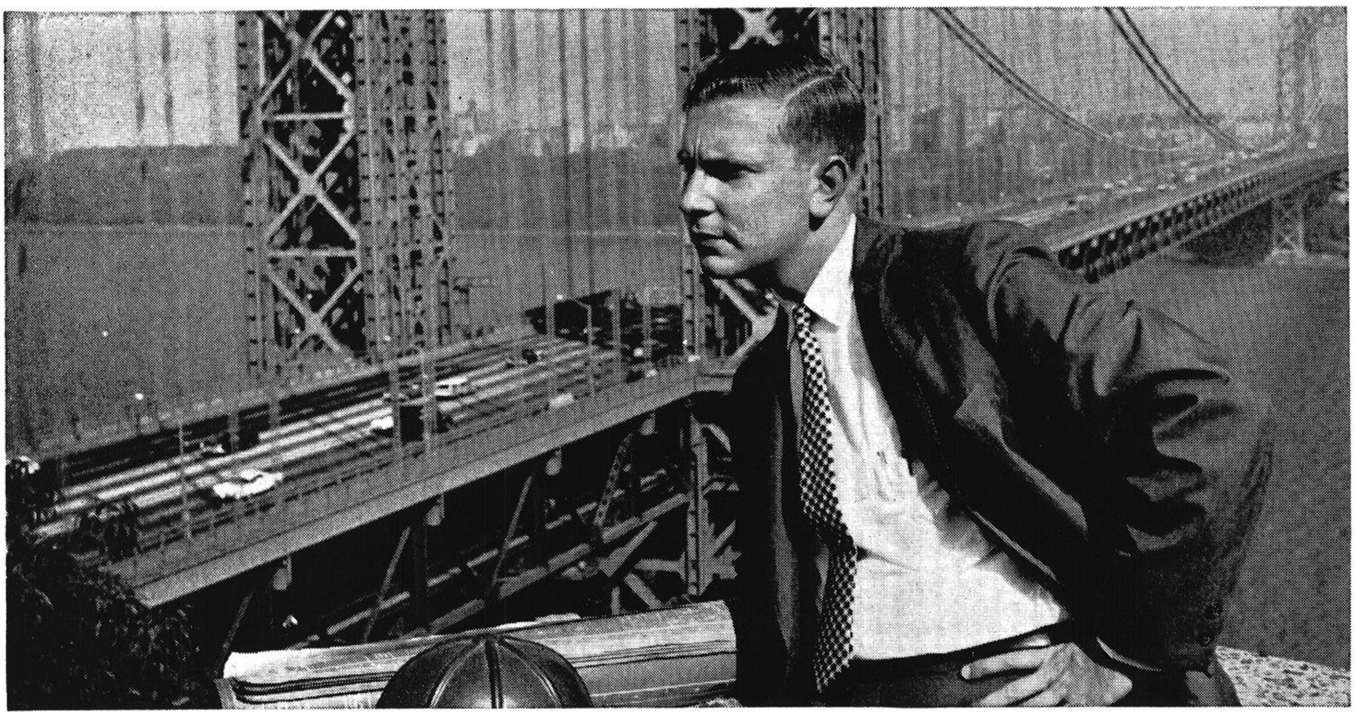
The third type of transistor fabrication process, double diffusion, is also carried out on the single doped wafer obtained from zone leveling or crystal pulling. The basic principle involves allowing an impurity to diffuse into a preheated oppositely doped blank in a temperature range between the melting point of the crystal and about 200°C. below this point. While in the oven, the crystal is placed in a quartz rack to prevent contamination. If a gaseous diffusant is used, the vessel may be evacuated or a carrier gas may be present. A second way to introduce the diffusant is to spray a solid form of it on the wafer before the wafer is placed in the oven.

The transistor layers may be formed by separate diffusions of opposite impurities for different lengths of time or, more conveniently, by simultaneous diffusion. The diffusion coefficient of a group three, p type, acceptor is 10 to 100 times greater than that of the group four donor in the same row of the periodic table. This means that the n type donor surface concentration will be 10 to 100 times greater than that of the p type during simultaneous diffusion. npn transistor will result. The approximate width of the p type base shown in the diagram is 2×10^{-4} centimeters. To obtain a pnp diffused transistor, separate diffusions with opposite impurities must be made.

After the formation of the non-ohmic crystal junctions by either of the three processes mentioned above, (alloying, growing, or diffusing) ohmic contacts for the leads are made to the base, emitter, and collector. In order to prevent alloying and the resulting formation, the crystal area where the ohmic contact is to be made is damaged by sand blasting. This destroys the band structure and allows ohmic contacts to form. To procure durability and reliability of the electrical and structural properties, the ohmic contacts are gold bonded. A lead formed in this manner will stand a pull of 5000 dynes or .01 pounds of force.

The final step in the production of quality transistors is capsulation in a hermetically sealed glass or metal container. The area between the transistor body and the wall is filled with an insulating plastic material to guard against vibration and shock damage. For better collector heat dissipation the collector

(Continued on page 27)



THIS YOUNG ENGINEER IS ON THE ROAD TO MANAGEMENT

Dick Cotton knew he wanted to take the engineering route into management long before he joined New Jersey Bell Telephone Company. In fact it was his goal when he was working for his engineering degree at Rutgers.

When he graduated, he had his lines out to eleven other companies. He came to New Jersey Bell because: "I didn't feel I was just a number to these people. There was no doubt in my mind that this job would be the best for the long pull."

His first assignment was a tough one. A complex of major telephone cables lay in the path of the approach to the new traffic level of the George Washington Bridge on the Hudson. Dick's job was to find the most practical and economical way to reroute these cables, and at the same time to provide for future telephone growth in the area around the bridge approach.

Dick ironed that one out and got a crack at another tough job.

Next stop: New Jersey Bell Headquarters Engineering Staff, Special Studies Group. Here Dick was a member of a four-man team whose job was to find ways to eliminate some of the routine work of field engineers to give them "more time to think." Dick also helped plan and control a $100,000,000 annual telephone construction budget.

Presently, Dick is responsible for telephone equipment engineering projects in the Camden, New Jersey, area.

How does Dick look at it? "This is a growing business. I work with this growth every day. And growth means more room at the top. Of course, I don't figure I'll get there overnight—but on my jobs so far I've had a chance to take a good look at how this business is run. And I think the sky's the limit for a man who really wants to work for it."

If you're a guy who can tackle a tough job and deliver the goods—then you're the kind of man who should find out more about the Bell Companies. Visit your Placement Office for literature and additional information.

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FREDERICK R. KAPPEL, *President*
American Telephone & Telegraph Co.

BELL TELEPHONE COMPANIES

ENGINE EARS

by Larry Hyde ce'62

AMERICAN NUCLEAR SOCIETY

During the past month of March, a student chapter of the American Nuclear Society was formed on our campus. At the chapter's first meeting Mr. Octave DuTemple, Executive Secretary of the National American Nuclear Society, outlined the requirements for membership and the goals of a student chapter.

Membership is open to any student interested in the field of nuclear science. This is not a society for engineers exclusively; it is open to students in physics, chemistry, or any other associated field.

The goals of the chapter are: to acquaint students with people working in the different fields of nuclear science, to induce discussion of the different areas of nuclear science among the students, to introduce students to the technical publications available, and to promote interest in the field itself.

At the second meeting held April 18th, Leonard J. Koch, Deputy of Reactor Engineering at Argonne National Laboratory, spoke on the Experimental Breeder Reactor Program. During that meeting the chapter also elected its officers and ratified their constitution. Tom Plunkett, a senior in mechanical engineering and organizer of the society, was elected unanimously for president of the chapter for 1961–1962.

Tom has asked that we invite all students interested in nuclear science to attend the society's first meeting next fall.

THETA TAU

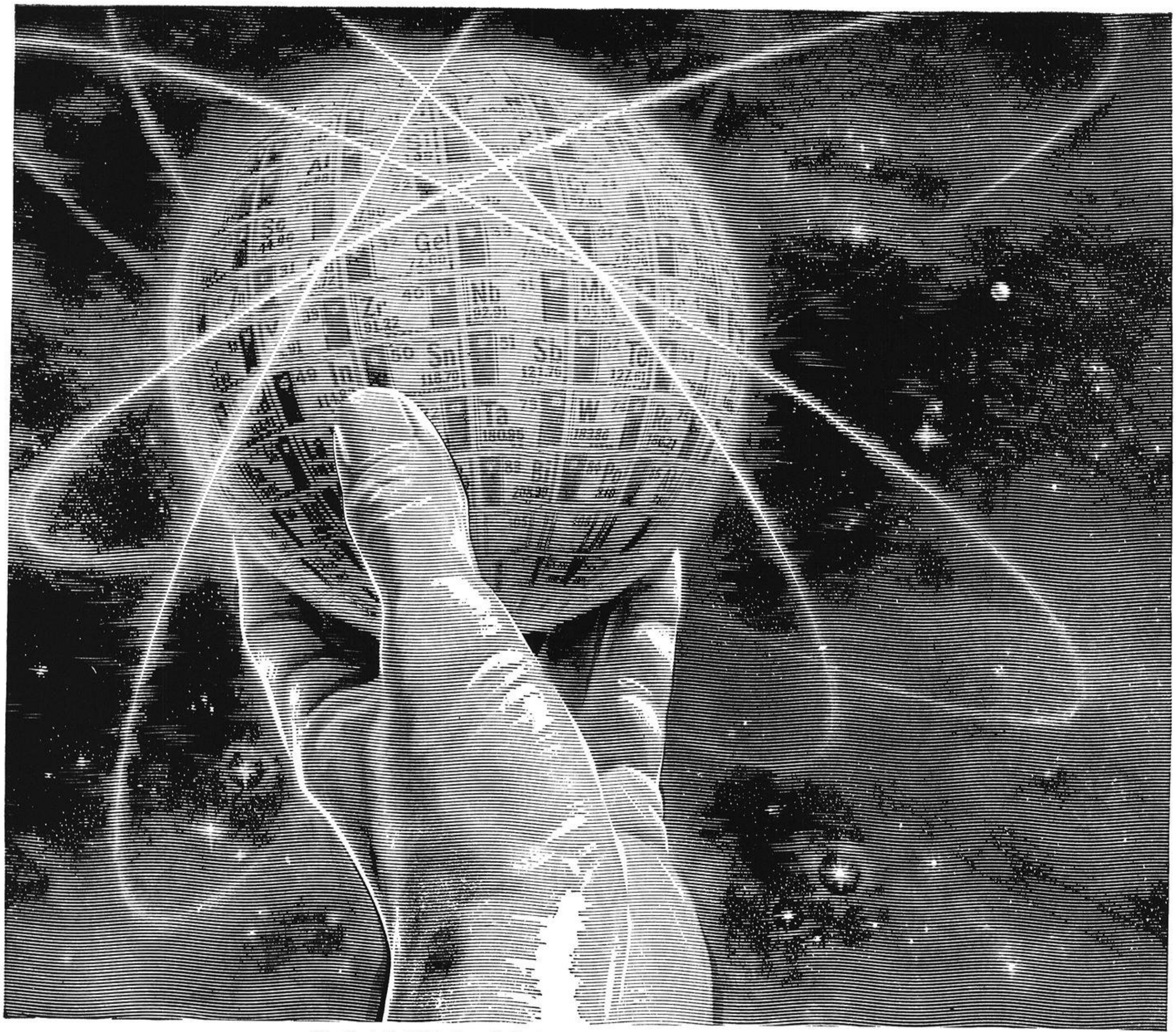
Theta Tau at Wisconsin, after a slow start this year is gaining momentum and will be very active during the coming semester. The Wisconsin chapter recently initiated 4 new members, Robert S. Burdick, ME 3, David J. Richter, ME 3, John R. Imhoff, ME 2, and Henry R. Hahn, Jr., CiE 4. The national Grand Regent and Grand Scribe participated in the ceremonies.

The Grand Regent, Charles Britzius, addressed the initiation banquet on "The Role of the Societies in the Engineering Profession". Mr. Britzius is the national director of the American Society of Civil Engineers, the Society of Professional Engineers, and the director of the Minnesota Society of Consulting Engineers, in addition to his post with Theta Tau.

Theta Tau is the oldest and largest national professional engineering fraternity and has recently expanded to 27 chapters on the leading engineering campuses in the United States, soon to again expand, to 28 chapters later this year. The national fraternity was founded in 1904 and the Wisconsin chapter in 1923. Dr. Gerald A. Rohlich, Professor of Civil Engineering, is the chapter advisor.

Among the projects anticipated for the second semester are the Outstanding Sophomore award and a Professional Education program for the fraternity members. The Outstanding Sophomore Award will be made at the St. Patrick's Day Engineering Dance to the student selected jointly by faculty and students. **THE END**

The secretary said she would do anything for a fur coat. When she got it she couldn't button it.



The Periodic Table lists all the known elements of the world we live in . . . more than half of them used by Union Carbide

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. . . bringing you a steady stream of better products from the basic elements of nature

You're probably one of the millions who have used such Union Carbide products as PRESTONE anti-freeze, EVEREADY flashlights and batteries, or PYROFAX bottled gas. But the major part of Union Carbide's output is in basic materials, employed by more than 50,000 industrial customers to fill your life with useful things.

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Periodic Chart ©Welch—Chicago

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UNION CARBIDE

. . . a hand in things to come

Fabrication of Transistors

(Continued from page 23)

junction is placed in direct thermal contact with the wall in high power transistors. Good job of capsulation results in a rugged, good looking final product that will protect all the previous care in the production process.

Referring back to the flow disorption it seen that we have followed the metals germanium and silicon from the mine, through an initial refining process, and on to a high level precision purification procedure known as zone refining. The zone refined crystal was doped in either a zone leveling process or by crystal pulling. It was found that grown junctions could be made only from the crystal pulling process while alloyed or diffused transistors could be produced from blanks obtained by either procedure. The final steps in either of the three cases were ohmic contact formation and hermetic capsulation. The progression from mine to engineering use involved much care and precision but the product that is obtained is well worth the effort. Transistors represent both the present and future of the electronics industry.

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Principles of Corrosion

(Continued from page 17)

to design problems. Instead, when a metal is being chosen for a particular service, the possible choices must be carefully evaluated. When it is necessary to use a particular metal, the design engineer may have to choose some type of protective coating for the metal. The same problems face him when he chooses a coating. He should secure the results from service tests whenever possible. Laboratory tests should be compared with service tests to make sure results obtained in the laboratory are valid.

Nuclear Disarmament

(Continued from page 13)

ticipating nations. Imagine, for instance, the political chaos that would result if Russia announced during a period of protracted disarmament reduction, that a large part of its inventory of nuclear weapons had been stolen!

The United States has no reason to believe that Russia seeks an agreement in good faith. Without this assurance the United States would be foolish to place its national security in the hands of an international authority, which must rely totally on an inherently weak system of controls and inspection. Perhaps some day the world powers will realize that nuclear weapons should be treated, as Bertrand Russell says, like a plague that dooms mankind to extinction unless it can be eradicated from the face of the earth. However, until the Communist nations subvert their own imperialistic desires for world conquest, and until technology can devise adequate protection through inspection, nuclear disarmament will continue to be nothing more than a myth—a false light held aloft by the Russians, blinding the world to the harsh realities of Communist conquest.

It was while they were crushed together in passionate embrace that Harry decided the psychological moment was at hand to tell Marge.

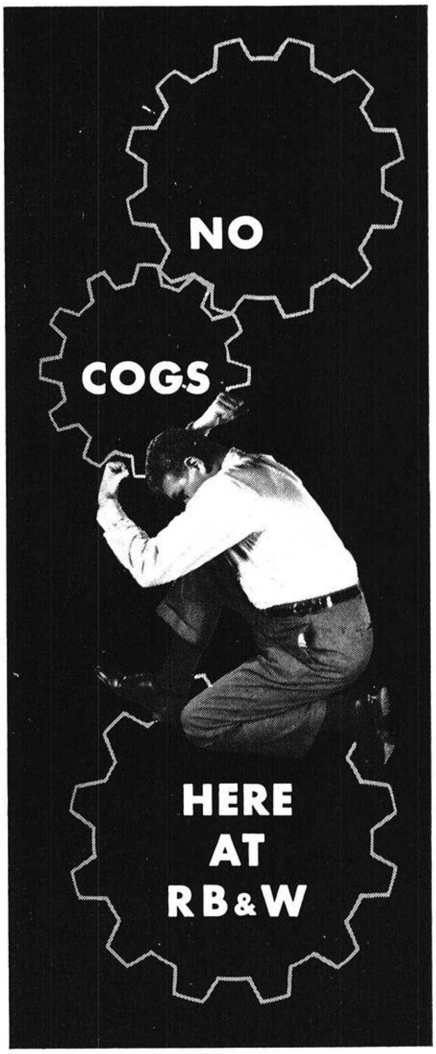
"Honey," he whispered, "I want you to know that I think you're a wonderful person, and that I certainly appreciate your—uh—company, but as far as I'm concerned, wedlock is nowhere."

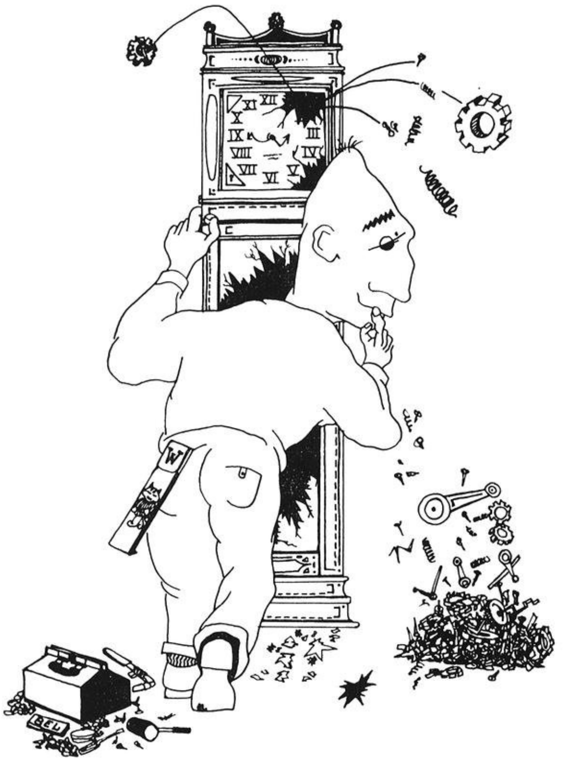
In reply, Marge uttered only a small sigh of pleasure.

"I mean," Harry went on doggedly, "you're more like a sister to me."

At that, Marge's lovely eyes opened, and her lips parted in surprise.

"My God," she murmured, "what a home life you must have!"





STRIPPED GEARS

edited by Glydewell Burdick

The big day was here. The wonderful gigantic bridge connecting two of the country's largest cities was being formally opened. At the height of the festivities, when thousands of people had thronged onto the bridge, the center span—with a crash heard for miles—fell into the bay, a mass of twisted girders and human bodies. The frenzied mayor seeing the engineer dashed up to him and wailed, "Look what you have done."

The engineer, scratching his ear, replied, "I told Joe that decimal point was a fly speck."

* * *

The Texan was unbending his argument. "I still say Texas is bigger than Alaska. Let's face it," he said, "if you compare highballs you don't count the ice."

* * *

Then there's the one about the new Beatnik Cookbook. One of the wild recipes calls for lettuce and tomatoes—then you add a dash of marijuana and the salad tosses itself!

Two shady businessmen with a reputation for doing almost anything for a buck were discussing their mutual financial problems. Said the first, "I understand the insurance company turned down your request for fire insurance." "Yeah," said the second ruefully. "They offered to give me earthquake insurance instead, but I turned it down." The first shady character shook his head understandingly. "I don't blame you," he said. "It's awfully hard to start a convincing earthquake."

* * *

The teacher was explaining to the grammar school students the merits of owning a yearbook and having one's picture in it.

"Just think," she said. "Thirty years from now you can look in this annual and say, 'There's Willie Jones; he's a judge now. And there's Sally White; she's a nurse. And there's . . .' "

"And there's teacher," came a voice from the back of the room. "She's dead."

Some of the girls were seated on the porch of the clubhouse at the golf course. Somehow, the locker room was partly open and the girls could not help but notice a nude man whose head and shoulders were covered by a bath towel.

After studying the body, so to speak, one of the girls reported that it was not her husband. A second girl gazed at the man and said, "No, it isn't my husband." The third girl, who was a life-of-the-party type, shifted her chair, peered intently at the masculine torso and blurted, "Why, he isn't even a member of the club!"

* * *

Parables to the Isms

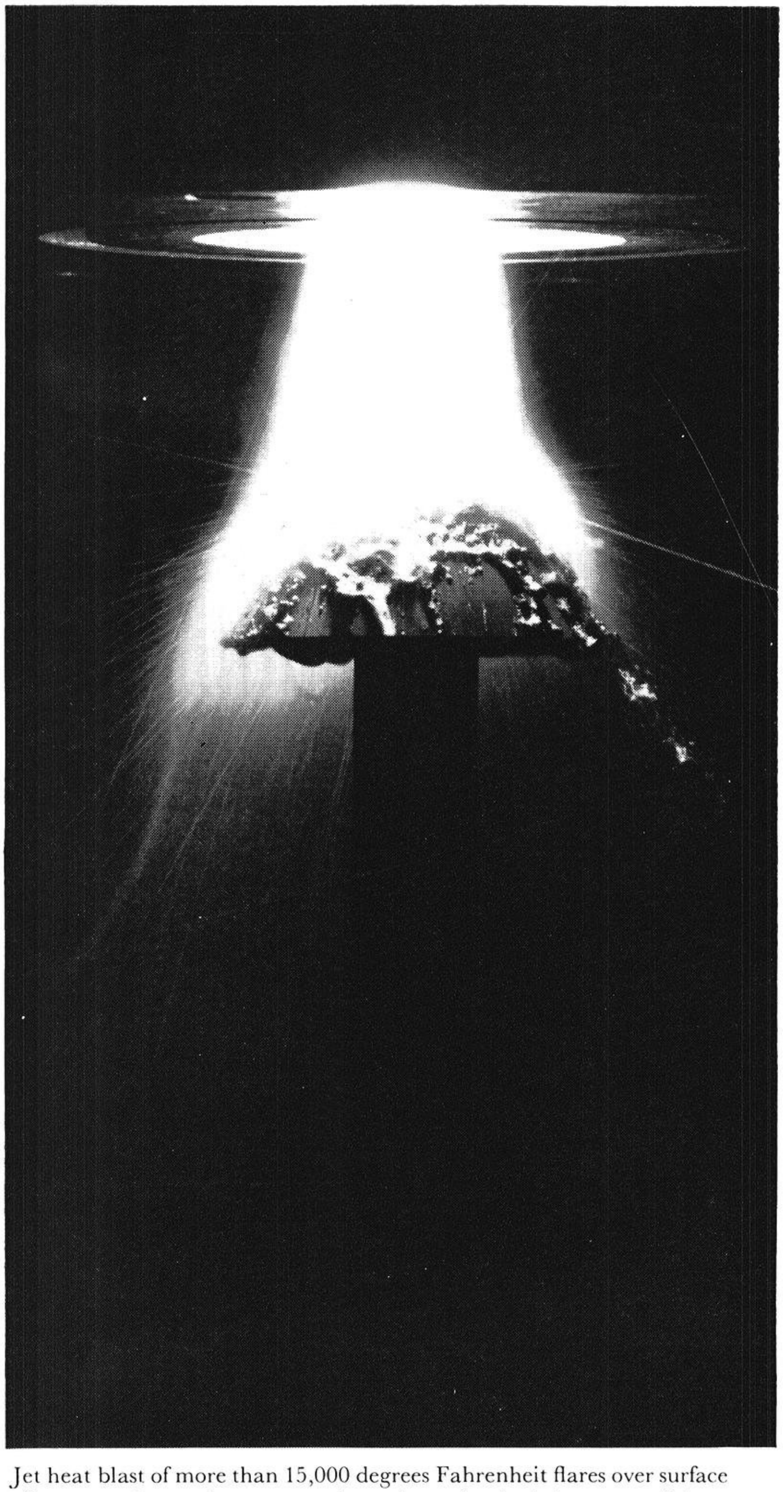
Communism: If you have two cows, you give them to the government and the government gives you some milk.

Nazism: If you have two cows, the government shoots you and keeps the cows.

Capitalism: If you have two cows, you sell one and buy a bull.

If your sights are set on

research and development-



Jet heat blast of more than 15,000 degrees Fahrenheit flares over surface of an experimental nose cone shape in a physics laboratory of Avco Research and Advanced Development Division, Wilmington, Mass.

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RESEARCH and development engineers find photography one of their most versatile tools. Camera and film can record the readings of instruments—can capture for study the fleeting transient on the oscilloscope face. The content and structure of metals can be studied by photospectrography or x-ray diffraction. And stresses in parts are visualized by photographing plastic models with transmitted polarized light.

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One of a series

Interview with General Electric's

Francis J. Boucher

Manager-Manufacturing Personnel Development Service

How Good Is Your Best Job Offer . . .

Q. Mr. Boucher, with all the job interviews a graduating engineer goes through, how can he be reasonably sure he has made the right choice?

A. This is a good question because few seniors have enough work experience in industry, government and educational institutions to allow them to make a fully reasoned choice. However, I think the first step is to be sure that short-term factors like starting salary and location don't outweigh long-range factors like opportunity and professional growth. All of these factors should be evaluated *before making a final commitment.*

Q. But you do feel that starting salary is important?

A. Very much so. If you are married—it may be an even greater consideration. But you should also look beyond starting salary. Find out, for example, if the company you are considering has a good salary administration plan. If there is no way of *formally* appraising your performance and determining your appropriate rewards, you run the risk of becoming dissatisfied or stalemated due to neglect of these important considerations.

Q. What considerations do you feel should be evaluated in reaching a job decision?

A. Let me refer you to a paper written by Dr. L. E. Saline, now Manager of Information Systems in our Defense Systems Department. It is titled "How to Evaluate Job Offers." (Incidentally, you may obtain a copy by writing as directed in the last paragraph.) In it, Dr. Saline proposes six questions—the answers to which should give you much of the information you'll need for an objective job-offer evaluation. He suggests you determine . . .

- to what degree will the work be challenging and satisfying?
- what opportunities are available to further develop abilities?
- what opportunities are there for advancing in the Company (and how dynamic the Company is in the marketplace is an important aspect of this question).
- what salary potentials are possible with respect to the future?
- what about geographical location —now and in the future?
- what effort does the Company make to establish and maintain a professional climate?

There is more to these questions than meets the eye and I think you would enjoy reading Dr. Saline's paper.

Q. What about the openings on defense projects that are listed in the various magazines and newspapers?

A. Presumably, there will always be a need for technical manpower in the defense business. But I want to point out to you that most of these opportunities are for experienced personnel, or personnel with specific additional training received at the graduate level.

Q. How do you feel about training programs? Do they offer any particular advantages over any other offer I might accept?

A. I feel training programs are particularly helpful in easing the transition from an academic to a business environment. Of course they provide formal training designed to add to the individual's basic fund of knowledge. They also provide working experience in a variety of fields and a broad knowledge of the company concerned and its scope of operations. Upon completion, the individual is generally better prepared to decide the direction in which he will pursue his professional career.

General Electric conducts a number of training programs. Those that attract the greatest number of engineers are the Engineering and Science, Manufacturing, and Technical Marketing Programs. Each combines a formal, graduate-level study curriculum, on-the-job experience, and rotating assignments. There is little question in my mind that when an engineer completes the Program of his choice, he is far better prepared to choose his field by interest and by capability. I might also add that because of this, he is more valuable to the Company as an employee.

Q. Then you feel that a training program is the best alternative for a graduating engineer?

A. Not always. Some seniors have already determined the specific field they are best suited for in terms of their own interests and capabilities. In such cases, direct placement into this specific field may be more advantageous. Professional self-development for these employees, as for all General Electric technical employees, is encouraged through a variety of programs including the Company's Tuition Refund Program for work toward advanced degrees, in-plant courses conducted at the graduate level, and others designed to meet individual needs.

Q. For the record, how would you rate a job offer from General Electric?

A. I've tried to get across the need for factual information and a long-range outlook as the keys to any good job evaluation. With respect to the General Electric Company, seniors and placement offices have access to a wide variety of information about the Company, its professional environment and its personnel practices. I think qualified seniors will also discover that General Electric offers professional opportunity second to none—and starting salaries that are competitive with the average offered throughout industry today. From the above, you can see that I would rate a job offer from General Electric very highly.

Want more information about General Electric's training programs? You can get it, together with a copy of Dr. Saline's paper "How to Evaluate Job Offers" by writing to "Personalized Career Planning," General Electric Company, Section 959-15, Schenectady 5, New York.

GENERAL ELECTRIC