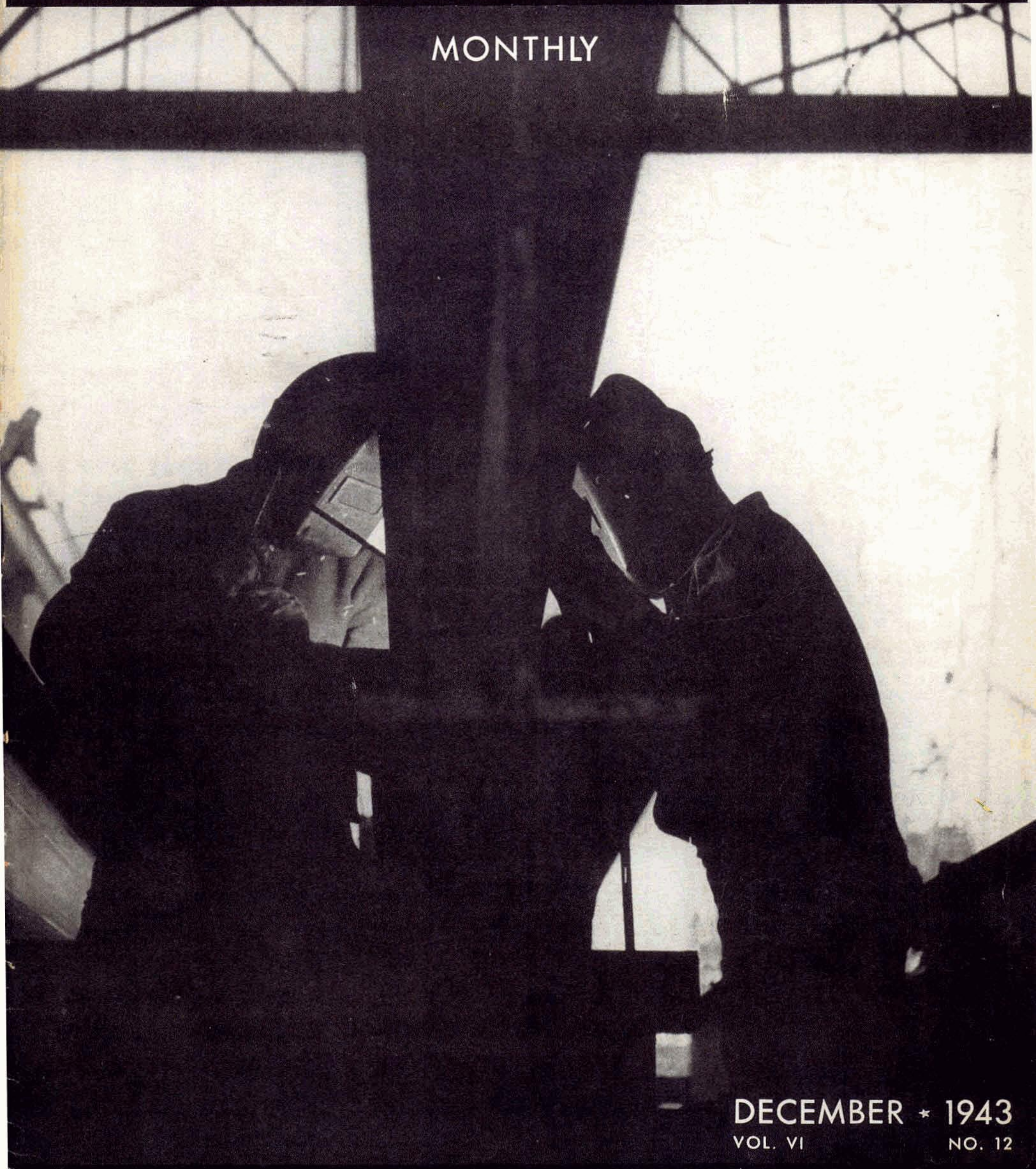
ENGINEERING AND SCIENCE



PUBLISHED BY CALIFORNIA INSTITUTE OF TECHNOLOGY ALUMNI ASSOCIATION

Never mind "who done it"—pitch in and help *get* it down!

THIS IS YOUR UNCLE SAM talking—but I'm going to talk to you like a DUTCH uncle, to keep all of us from going broke.

Ever since the Axis hauled off and hit us when we weren't looking, prices have been nudging upwards. Not rising awfully fast, but RISING.

Most folks, having an average share of common sense, know rising prices are BAD for them and BAD for the country. So there's been a lot of finger pointing and hollering for the OTHER FELLOW to do something—QUICK.

The government's been yelled at, too. "DOGGONNIT," folks have said, "WHY doesn't the government keep prices down?"

Well, the government's done a lot. That's what price ceilings and wage controls are for—to keep prices down. Rationing helps, too.

But let me tell you this—we're *never* going to keep prices down just by leaning on the government and yelling for the OTHER FELLOW to mend his ways.

We've ALL got to help—EVERY LAST ONE OF US.

Sit down for a minute and think things over. Why are most people making more money today? It's because of the SAME cussed war that's killing and maiming some of the finest young folks this country ever produced.

So if anyone uses his extra money to buy things he's in no particular need of . . . if he bids against his neighbor for stuff that's hard to get and pushes prices up . . . well, sir, he's a WAR PROFITEER. That's an ugly name—but there's just no other name for it.

Now, if I know Americans, we're not going to do that kind of thing, once we've got our FACTS straight.

All right, then. Here are the seven rules we've got to follow as GOSPEL from now until this war is over. Not some of them—ALL of them. Not some of us—ALL OF US, farmers, businessmen, laborers, white-collar workers!

Buy only what you need. A patch on your pants is a badge of honor these days.

Keep your OWN prices DOWN. Don't ask higher prices—for your own labor, your own services, or goods you sell. Resist all pressure to force YOUR prices up!

Never pay a penny more than the ceiling price for ANYTHING. Don't buy rationed goods without giving up the right amount of coupons.

Pay your taxes willingly, no matter how stiff they get. This war's got to be paid for and *taxes are the cheapest way to do it.*

Pay off your old debts. Don't make any new ones.

Start a savings account and make regular deposits. Buy and keep up life insurance.

Buy War Bonds and hold on to them. Buy them with dimes and dollars it HURTS like blazes to do without.

Start making these sacrifices now—keep them up for the duration—and this country of ours will be sitting pretty after the war . . . *and so will you.*

Uncle Sam

KEEP PRICES DOWN!

Use it up • Wear it out
Make it do • Or do without

This advertisement, prepared by the War Advertising Council, is contributed by this magazine in co-operation with the Magazine Publishers of America.

BY-LINES

ROBERT A. MILLIKAN

Dr. Millikan, Chairman of the Executive Council of the California Institute of Technology, and Director of the Norman Bridge Laboratory of Physics, has contributed extensively to advancements in the field of physics. He was awarded the Nobel Prize in Physics of the Swedish Royal Academy of Science in 1923.

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RUSSELL J. LOVE

Mr. Love received his B.S. degree in mechanical engineering from the California Institute of Technology in 1928. He served in the capacity of a research engineer with C. F. Braun and Company until 1932, and since that time he has been with the Southwest Welding and Manufacturing Company of Alhambra. Mr. Love has been chief engineer of that company since 1936.

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ROBERT JANES

Mr. Janes was graduated from California Institute of Technology in 1936 with a B.S. degree in civil engineering, following which he studied for a year at the University of Minnesota. Before coming to the Institute as an instructor, Mr. Janes was with the State of California Division of Highways, and was employed with that department during construction of the Santa Fe Dam.

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ENGINEERING AND SCIENCE

Monthly

The Truth Shall Make You Free

CONTENTS FOR DECEMBER, 1943

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ENGINEERING AND SCIENCE MONTHLY

Edited at California Institute of Technology

AMERICA'S DEBT TO GREECE

DR. John R. Macarthur, professor of languages at the California Institute of Technology, is the author of a comprehensive volume on Greek influence in America which recently has been published under the title, "Ancient Greece in Modern America."

As the author states in his preface, this book has a number of purposes. It makes easily available to the public the remains of the old classical education, shows how wide has been the influence of Greece upon our ways of life, and sets forth in large measure the classical background for students of English literature, or art and music. With its complete index, it may well serve both as a classical dictionary and as a textbook. The last third of the volume recounts in handy length the more important of the Greek myths. The text is illustrated.

JOHN R. MACARTHUR

We all know what we owe to the Greeks in the arts, but who, aside from the classical scholars, knows so well what we owe to them in the sciences, in mathematics, in medicine, in political science, and in economics? Yet, the Greeks laid the bases for all these and developed many to a high point, especially political science and mathematics. In medicine, the conduct of every physician is still guided by the Oath of Hippocrates. In the matter of religion, too, the Greek influence has been profound. For more than a thousand years Aristotle, though a pagan, was revered as an inspired authority by the early fathers of the church. In addition, Aristotle founded the bological sciences and gave system to the arts. The Greeks also developed such diverse sciences as horticulture and astronomy. Pythagoras accurately taught the sphericity of the earth and the movements of the planets, while Aristarchus taught the theory of the sun as center, doctrines which Ptolemy had done well to remember.

It may truthfully be said that as the genius of a nation approaches the ancient Greek genius, it rises in its civilization. All the great periods in world history were closely akin in spirit to the genius of the early Greeks. Is modern America in approach or in retreat? Nothing reflects change in a nation so quickly as its literature. Sadly, today, the study of the classics has gone out of fashion. Since the turn of the century, too, English poetry has been at low ebb. Is it significant that it has fallen off in a direct proportion to the neglect of classical learning? Nowadays, children are not encouraged to read the old myths and fairy tales. The myths, it is objected, do not deal with "a true state of affairs," neither does poetry; they deal with the imagination. Let it be remembered that Plato, the poetic dreamer, put the poets out of his republic because they did not tell the truth, and that Aristotle, the practical scientist, put them back again for the very same reason.

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Monthly

Vol. VI No. 12 December, 1943

The Month in Focus

Engineering Materials

IN the normal course of events during peacetime the engineer is prone to follow in the rut of his predecessors. A few individuals are farseeing enough to visualize the opportunities that lie in the development of new materials or the improvement of standard ones. During peace times we have seen some outstanding developments which have contributed to improved efficiency. But on the whole, there have probably been fewer changes in engineering materials during the period between World Wars I and II than within either of the war periods.

In time of war it becomes necessary to expend an unusual amount of energy on the development of new materials. Often it is not only improvement that motivates this development, but the unavailability of certain materials which are necessary in the construction of war materiel. When the enemy takes over territory which supplies essential materials, it is necessary to produce substitutes. Demand for these substitutes is immediate; and it is imperative to the war effort that these developments come rapidly so that they can be utilized in the construction of war goods.

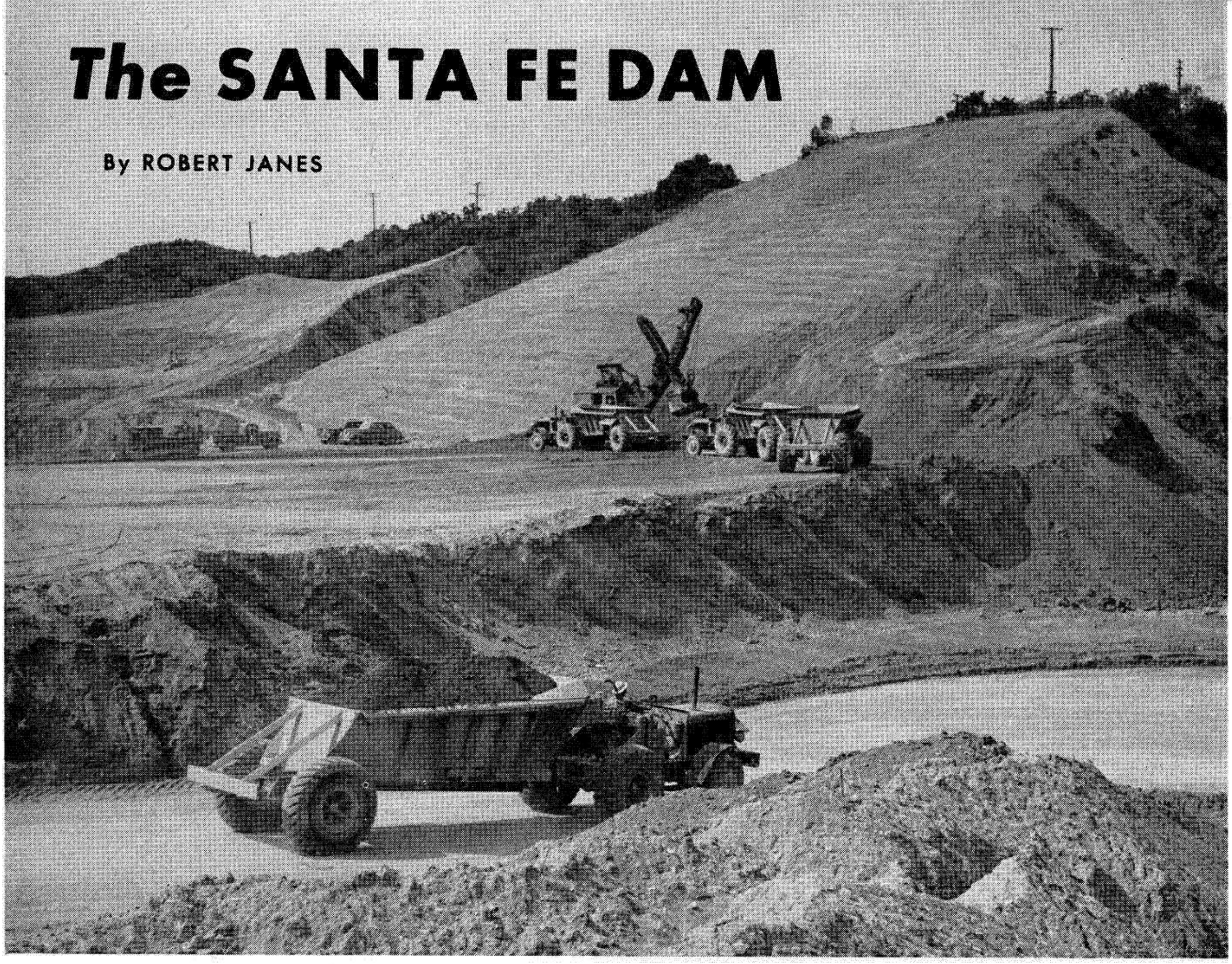
During the past two years we have been witnessing very marked developments in the application of such new materials. The tremendously increased requirement for aluminum and aluminum alloys in the aircraft industry has brought about great development and expansion in the aluminum industry, but apparently this has still not met the requirements of the aircraft industry for lightweight alloys. The situation has thus led to the development of magnesium resources in this country. However, the development of material production facilities alone is useless unless the engineer is provided with technical information concerning the properties of the new material. When one develops or finds a material which can be used as a substitute he has reached only the beginning point. Before industry is able to make use of this new material, much time, money, and the best technical brains must be utilized before the material can be employed for engineering applications. Take magnesium, for example. It has an entirely different structure from that of aluminum or iron or copper and thus it performs quite differently. It has many properties of which we would like to make use, but until we learn all of its characteristics its engineering application will be limited.

Other interesting developments have occurred in the field of alloy steels. Prior to the war the engineer was accustomed to the utilization of steels with quite high alloy content. With the advent of war many of our alloying elements became very scarce, and some could be obtained only in very small quantities. Careful study and the utilization of residual elements present in scrap steel showed that proper combinations of alloying elements in much smaller quantities produced steel of very satisfactory characteristics. It is barely possible that by virtue of this wartime shortage of alloying elements, we shall have alloy steels of lower alloy content, but with as satisfactory engineering characteristics. In wartime it is definitely true that "necessity is the mother of invention."

Plastics, whose accelerated development has been another result of wartime needs, are believd by some people to be capable of replacing metals in a great many cases. Careful thought, however, will show that plastics cannot supplant the metals in every respect and that undoubtedly, our metals will continue to be used in about the same tonnage as heretofore. Some very important advancements have been made in the engineering application of plastics. Other developments have led to the production of plumbing parts, sprinkler nozzles for the garden hose, and other common items formerly made of metal. If war produces any benefits other than the winning of peace, it certainly can be stated that war is a tremendous stimulus to the development and improvement of materials and to pioneering in their uses.

Production Processes

What has been said for the development of engineering materials in time of war may also in certain degrees be said of the development and improvement of production processes. War necessitates a great increase in the rate of production. From this it does not follow that the efficiency of production is increased. In these times when unskilled labor must be trained to take the place of the younger men who are called upon to enter military service, and when women who have never done production work before enter industry by the hundreds of thousands, it is difficult to increase production rates unless improved methods are developed. These process developments naturally will carry over into peacetime production methods.



The SANTA FE DAM

By ROBERT JANES

Clay borrow pit four miles north of the Santa Fe Dam.

HUGE dams in the past eight or 10 years have become familiar sights to millions of people in the United States. Notable among those constructed in the last decade are Boulder Dam in Nevada, Norris Dam in the Tennessee Valley system, Dennison Dam in Texas, Fort Peck in Montana, Bonneville in Oregon, Grand Coulee in Washington, and Shasta in California. The more spectacular among these dams have been constructed of mass concrete, so that we are accustomed to think of this type of dam as being the most modern, the ultimate—till now at least—in dam design. Progress in design and construction methods, however, has not been confined to dams made of concrete. It has, in fact, been particularly noteworthy in the field of earth dams, which, because of greatly improved compaction equipment and soil analysis, could now replace many a dam constructed earlier from more costly materials.

Santa Fe Dam is an earth-fill dam. Located on the San Gabriel River just below the mouth of the canyon east of Pasadena, it forms a horseshoe four and one-half miles in length around the many branches of the San Gabriel, which at this point meanders over a thick blanket of alluvium brought down during the centuries. Since it is without the benefit of supporting canyon walls, it is necessarily three sided—open only at the upper end to allow the water to enter. Fifteen million yards of earth, three times the volume in Boulder Dam, was excavated to make this gigantic barrier, yet its maximum height of 92 feet appears insignificant alongside Boulder's 752 feet.

In cross-section the dam consists of five zones. Zone I is composed of approximately 1,000,000 yards of impervious clay-sand material, imported from a borrow pit north of the dam, necessitating an average haul of four miles. This core is keyed into the native alluvial deposit by excavating the latter to a depth of 10 to 15 feet, and then backfilling the resultant trench with the clay. The clay core has a maximum width of 40 feet at the base, narrowing to 10 feet at the top. Due to the difficulty of securing sufficient excavating equipment, most of the material for the core was excavated in a rather novel fashion. As the borrow pit was in a foothill location with fairly steep slopes, advantage was taken of the difference in elevation by constructing a timber loading trap, or tunnel, through which trucks to be loaded could pass. In the roof of the structure were gated openings, air operated. With the gates closed, material was dozed into position above the gates by bull-dozers and carryalls. Upon arrival of a truck, the gates were opened, allowing this material to drop into the truck. Since the material was always pushed downgrade, the task was simple for this type of equipment. Besides eliminating the necessity of maintaining a shovel at the location, which, because of the nature of the operation, was limited to a one-shift basis, this system allowed each truck to be loaded in a very few seconds instead of the two minutes or more required for a shovel to load the same truck.

The trucks used on the operation were of the bottom-dump type, carrying an average of 15 cubic yards, or 26 tons of earth. Upon arrival at the dam embankment, the material was dumped in Zone I in a long windrow while the truck was in motion, the length of the windrow being predetermined to give the correct depth of material when spread out by the grader, which followed the dumping operation and spread the material in a uniformly thick blanket of six inches. Then followed the compacting operation upon which the imperviousness of the dam depends. Spreading was followed by thorough harrowing of the earth, removal of any rocks larger than four inches, and watering. Harrowing and watering processes were repeated until it was determined that the optimum moisture content (that percentage of moisture at which maximum compaction could be obtained) was reached. This was followed by eight passes of the sheepsfoot roller, at which time full compaction was obtained. Daily tests of compacted material showed an average density of 144 pounds per cubic foot. When this figure is compared with the 150 pounds per cubic foot usually associated with reinforced concrete, or more aptly with the 140 pounds per cubic foot accepted for unreinforced concrete, the excellence of this method of compaction is clearly evident.

On either side of Zone I was placed a narrow layer of transition material, forming Zone II, and composed of about 30 per cent clay and 70 per cent pervious material. The purpose of this zone was to eliminate planes of sudden changes from pervious to impervious material which would tend to become seepage channels over a period of time.

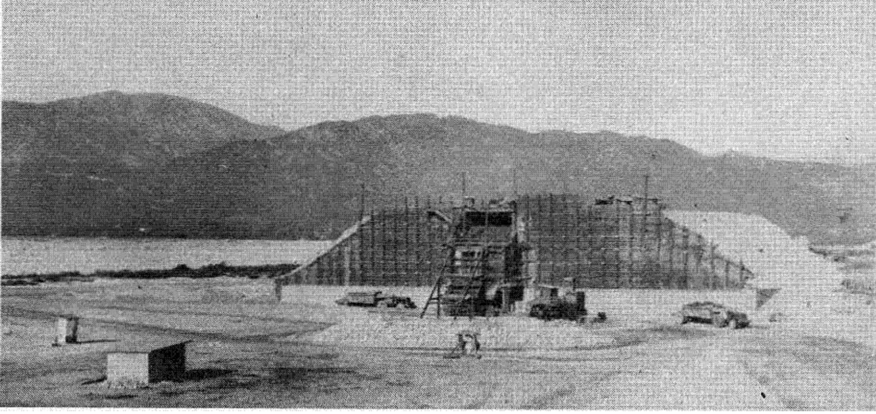
Beyond Zone II on either side is Zone III, making up the bulk of the dam volume. This material was excavated from the center of the horseshoe which makes up the dam, thereby adding to the reservoir capacity. It is strictly native alluvium except that boulders over five inches in size were first removed. Joining Zone II, which has a slope of 1:4, Zone III has a slope, both on the upstream and downstream sides, of 3:1. On the upstream face of Zone III there was placed a four-foot-thick layer of coarse rock from five inches to two feet in diameter, which serves the purpose of protecting the slope from wind and wave erosion. This was termed Zone IV. On the downstream face there was placed a much larger rock zone, comprising Zone V. Only two feet in thickness at the crest of the dam, it has a slope varying from 3:1 at the top to 5.5:1 at the toe, making the thickness of the dam at the toe line a maximum of about 700 feet. Materials for Zones III, IV, and V, comprising 90 per cent of the embankment fill, were obtained from the reservoir area. This material was excavated by three, two and one-half cubic yard Diesel-powered shovels and two electric machines, one four-yard and one six-yard. It was then loaded into trucks and hauled to the screening plants, or "grizzlies." After separation into two sizes, the material less than five inches in diameter was transported to the fill by additional trucks, where it was dumped, spread in 12-inch layers, and thoroughly flushed with water. No compaction other than that obtained from the pneumatic-tired truck equipment was required.

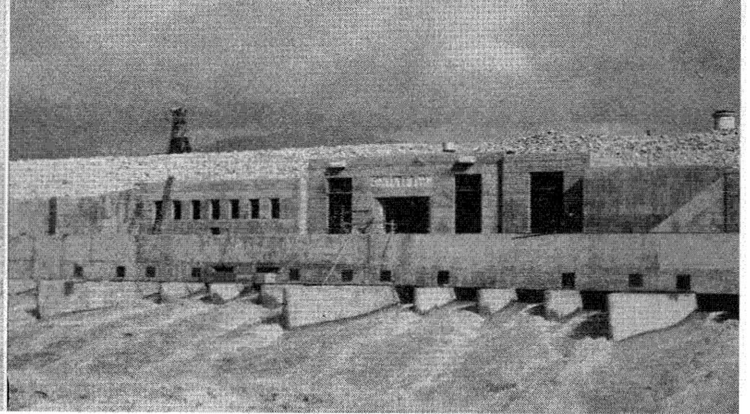
It will readily be seen that the separation of 11,000,000 cubic yards of material into two sizes presented a difficult problem, simply because of the large volume handled. For the purpose, four separate grizzly plants, two of which are illustrated, were constructed during the 24-month life of the job. The first plant was a conveyor type. Excavated rock was dumped into a hopper placed below normal ground level. From the hopper a six-foot-square hole in the floor of the hopper allowed the material to drop onto an apron feeder constructed with manganese steel wearing plates. In essence this was a conveyor with a length of but nine feet, and served to transfer the material from the hopper to the rubber conveyor belt with a minimum of shock and with a constant feed. After delivery to the conveyor, the material was transported to an elevation of some 40 feet above ground and dropped upon a series of inclined rails spaced very closely together at the head and flaring outward down the slope. The material flowing over the bars thus separated itself, that under five inches in size dropping through, while that over five inches was carried on over the bars and was received by a separate bin. The receiving bins were elevated sufficiently to allow trucks to drive beneath the bins and obtain their loads through the use of roller gates operated by compressed air.

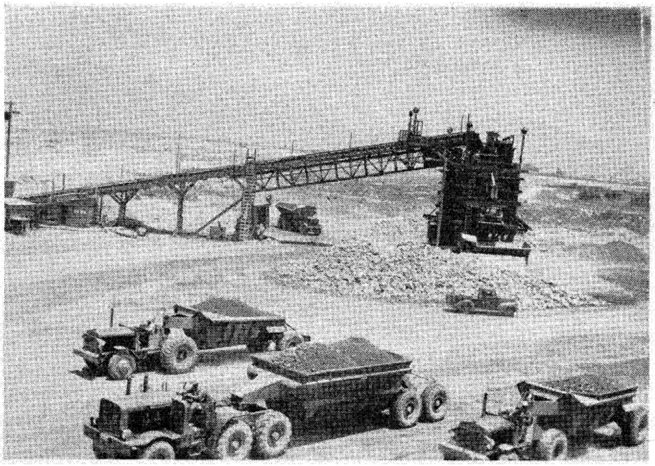
The final design of the inclined stationary bar grizzly involved a considerable amount of experimentation. The initial design used a patented type of movable bar grizzly, consisting of a series of parallel bars on a very flat slope of only four or five degrees. The bars were hinged at the upper end and fastened to an eccentric at the lower end, imparting vertical reciprocating motion with an amplitude of two inches to the lower end of the bars, and so arranged that while one bar was at the maximum height, the adjacent bars were at their minimum elevation. The design did not function satisfactorily for two reasons:

1. The material was of such a nature (rounded and very hard) that rocks tended to be wedged between the bars. Attempts were made to improve the operation, with meager success, and after two weeks of operation, an experimental stationary bar grizzly was constructed, which, after considerable evolution proved to be of satisfactory design. It was found that a slope of 26 degrees was best suited to the material. Less than this slope gave rise to sticking of material, while with a larger angle undesirable amounts of fine material were carried down with the coarse. Considerable flaring of the bars also was found necessary to prevent wedging of rocks, and in order to obtain maximum flare the bars

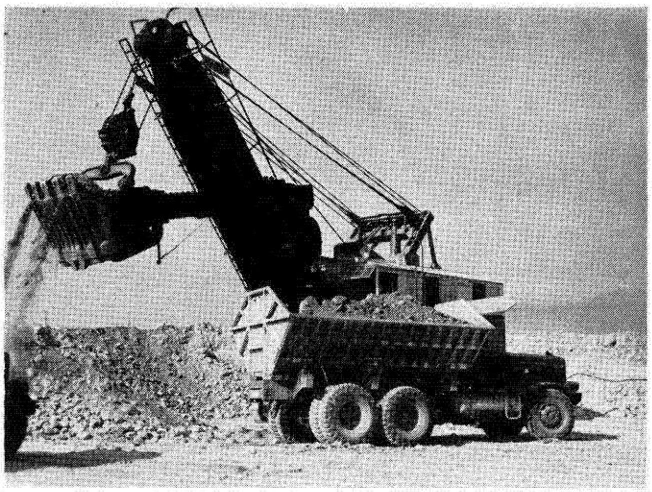
AT LEFT: Ramp-type "grizzly" or screening plant. AT RIGHT: Flood water leaving outlet works conduit. Dam under construction in background.



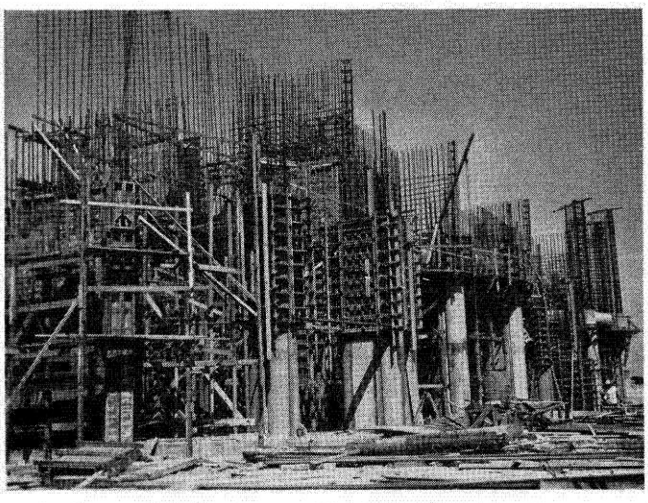




Conveyor-type "grizzly" or screening plant.



Loading a 25-cubic-yard side dump truck with a six-cubic-yard electric shovel.



Outlet works under construction, showing the upstream end, intake gate structure.

were constructed in two lifts. Spaces between bars approximated two inches at the top and seven inches at the bottom of the bars.

2. The large rocks moved the length of the bars so slowly that a thick mat of rock covered the bars at all times. Thus fines that should have gone through the bars were carried along with the rock and dropped into the wrong bin.

The second grizzly, and subsequently grizzlies three and four, were constructed with the benefit of the experience gained from the first unit. They differed, however, in one major respect. Instead of the conveyor system for elevating material, succeeding plants were of the ramp type, in which trucks delivered material direct from the excavation to the grizzly bars by driving up a two-degree ramp, eliminating the need for costly elevating equipment with its attendant maintenance.

The major operating problem was in scheduling operations for the most efficient use of equipment, and the maintenance of equipment to minimize the lost time due to idle units. Tire maintenance and inspection was a problem large enough to warrant a separate tire department, since the total mileage rolled up in one day of operation was equivalent to one tire being driven 80,000 miles. Forty-eight trucks were used, of three types. Best all-around unit was the bottom-dump type, previously described, which had two distinct advantages: it could dump on the embankment while still in motion, leaving its load spread out over a large area, and when dumping at the grizzly plant it required only two or three seconds to release the catch and allow the load to drop out, while the other types of truck used hydraulic jacks to tilt the dump body, an operation requiring 20 to 30 seconds. Of this type there were nine end-dump units of 10-cubic-yard capacity, and 13 side-dump units rated at 25 cubic yards that were used.

In addition to the dam embankment itself, a reinforced concrete outlet works and a mass-concrete spillway in the west leg of the dam were constructed. The outlet of 16 gated openings seven feet square in cross-section, with steel trash racks at the reservoir end, empty into a stilling basin at the downstream side. This stilling basin reduces the velocity of the water before it is allowed to continue down the San Gabriel channel. The conduits, about 500 feet in length, allow the stream flow to be controlled from zero to a maximum of 17,000 cubic feet per second. An access gallery located above the conduits permits passage between the gate chamber at the upstream end and a service building housing power and lighting units for the hydraulically-operated gates at the outlet end.

The spillway consists of a concrete weir, 1,200 feet in length, with an elevation 21 feet lower than the crest of the dam. Its maximum discharge capacity is 200,000 cubic feet per second. As in the outlet works, the water going over the spillway crest plunges into a stilling basin in which the velocity is reduced before it is allowed to proceed downstream. Together the two concrete structures required the use of 200,000 cubic yards of concrete and 6,000,000 pounds of steel reinforcing.

Bids for the construction of Santa Fe Dam were taken by the United States Engineering Department, under whose direction the dam was built, in June, 1941. Low bid of slightly less than $9,000,000 was entered by a combination of contractors consisting of the Morrison-Knudsen Company, Winston Bros. Company, J. F. Shea, and Ford J. Twaits. Construction began in August of the same year, and the structure was essentially completed in July of 1943. Lack of steel for the gates has delayed the 100 per cent completion for the duration. Except for delays due to difficulty in obtaining reinforcing steel, construction proceeded smoothly and according to schedule until the week of January 20,

(Continued on Page 18)

BENJAMIN FRANKLIN
As a Scientist

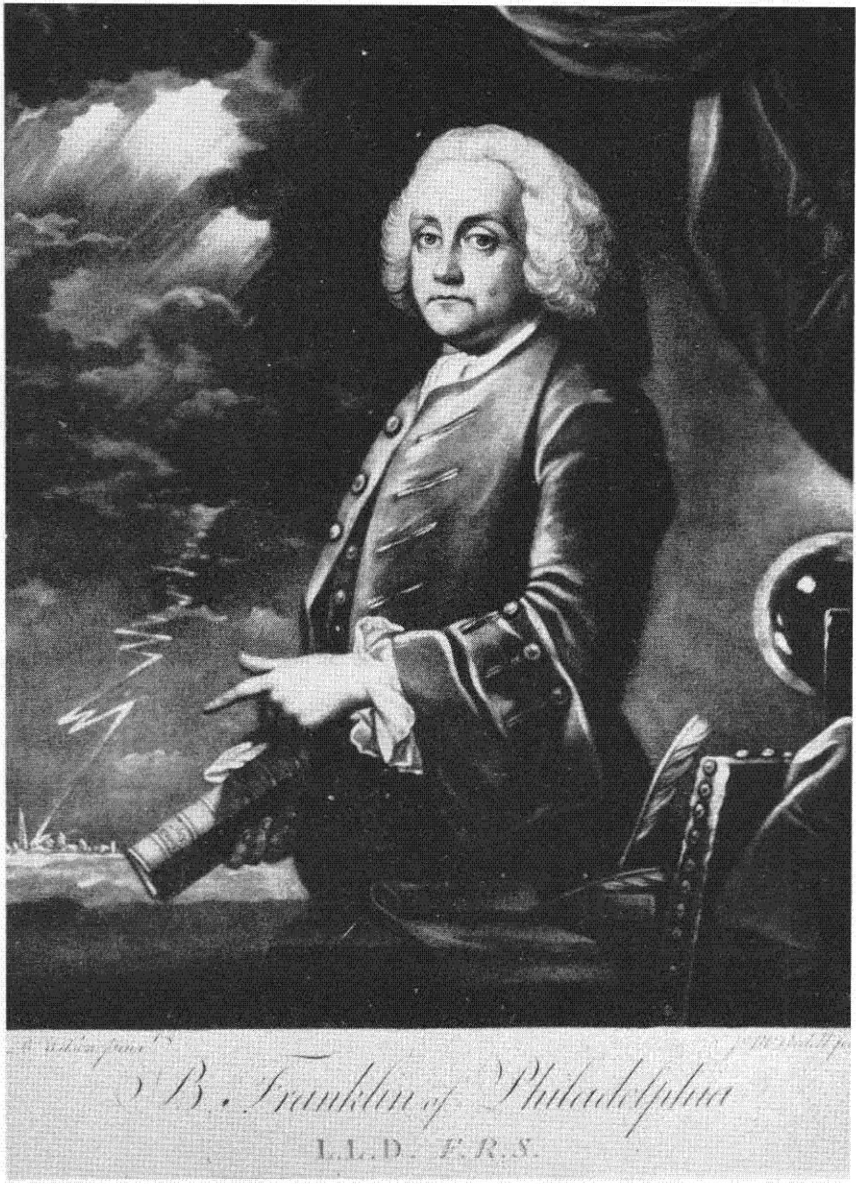
By ROBERT A. MILLIKAN

BENJAMIN Franklin is perhaps the only American in that relatively small group of men of any time or country who, without having been either the head of a state or a military hero, have yet gained so conspicuous a place in history that their names and sayings are known the world over. Although he lived 200 years ago in what was then a remote corner of the earth, far from any of the centers of world influence, yet his name and traits are still widely known. May I quote a paragraph from a short biography of Michelson which I published in the Scientific Monthly for January, 1939:

"It will probably be generally agreed that the three American physicists whose work has been most epoch-making and whose names are most certain to be frequently heard wherever and whenever in future years the story of physics is told are Benjamin Franklin, Josiah Willard Gibbs, and Albert A. Michelson. And yet the three have almost no characteristics in common. Franklin lives as a physicist because, dilettante though he is sometimes called, mere qualitative interpreter though he actually was, yet it was he who with altogether amazing insight laid the real foundations on which the whole superstructure of electrical theory and interpretation has been erected. Gibbs lives because, profound scholar, matchless analyst that he was, he did for statistical mechanics and for thermodynamics what Laplace did for celestial mechanics and Maxwell did for electrodynamics, namely, made his field a well-nigh finished theoretical structure. Michelson, pure experimentalist, designer of instruments, refiner of techniques, lives because in the field of optics he drove the refinement of measurement to its limits and by so doing showed a skeptical world what far-reaching consequences can follow from that sort of a process and what new vistas of knowledge can be opened up by it. It was a lesson the world had to learn. The results of learning it are reflected today in the extraordinary recent discoveries in the field of electronics, of radioactivity, of vitamins, or hormones, of nuclear structure, etc. All these fields owe a large debt to Michelson, the pioneer in the art of measurement of extraordinarily minute quantities and effects."

In that paragraph I have tried to appraise Franklin's place among American scientists. Let me now express my personal judgment as to his place in world science. If I were asked to list by centuries the 14 most influential scientists who have lived since Copernicus was born in 1473, I should include the name of Franklin.

There will doubtless be those, especially among Europeans, who will say, "Why do you give Franklin so high a place when there were but seven of his 84

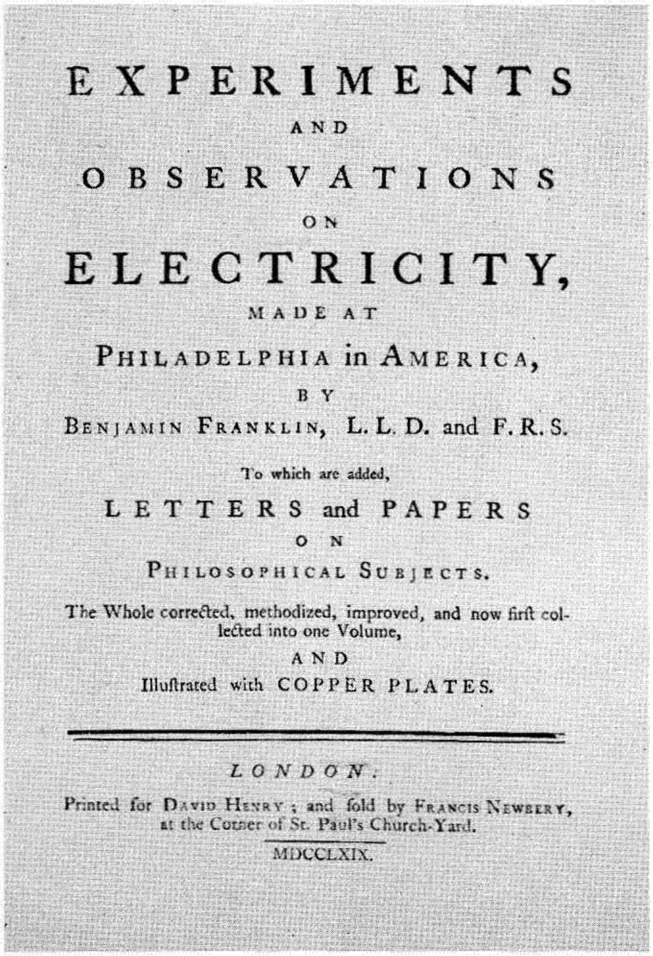


"B. Franklin of Philadelphia"—reproduction of artist's portrait showing Franklin holding a copy of the book published in 1769 describing the Franklin electrical experiments and observations.

years, namely, from 1746 to 1753, in which he pursued science at all, also when he wrote, so far as I can discover, not a single scientific paper designed for publication in a scientific journal?" His private letters to his friend Peter Collinson, which he never expected to be published at all, are practically the sole source of our knowledge of his scientific work. Even his own estimate of his scientific achievement was so small that in his autobiography he makes but casual reference to it.

The answer to the foregoing inquiry is that I have been guided in the placing of Franklin on such a list primarily by the significance of his contributions as measured by the influence they exerted in the development of our modern world. I have not been concerned at all with the erudition of the man, the profundity or extent of his scholarship, nor even by the magnitude and difficulty of the problems which he solved.

No one, however, can read these letters to Peter Collinson, published in 1774, without being amazed by the fact that Franklin without any previous training whatever in either the technique or the history of physics and with almost no contact with what others were doing or had done, within two years of the time of his first experiment had acquired a keener insight



EXPERIMENTS

AND

OBSERVATIONS

ON

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MADE AT

PHILADELPHIA in AMERICA,

BY

BENJAMIN FRANKLIN, L. L. D. and F. R. S.

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Title page of the same book—one of the first volumes to be illustrated by the copperplate engraving process.

into the fundamental nature of electrical phenomena, not merely than any one had acquired up to his time, but even than any of his successors acquired for the next 150 years, when, about 1900, the scientific world returned essentially to Franklin's views.

To justify this statement and to bring to light the extraordinary quality both of Franklin's physical insight and of his power of induction I shall make most of the remainder of this article consist of a few direct quotations from Peter Collinson letters which the editor informs us were being printed "without waiting for the ingenious author's permission to do so."

The first letter, dated March 28, 1747, reads:

"To Peter Collinson, Esq.; F. R. S. London

Philadelphia, March 28, 1747

"Sir,

"Your kind present of an electric tube*, with directions for using it, has put several of us on making electrical experiments, in which we have observed some particular phaenomena that we look upon to be new. I shall therefore communicate them to you in my next, though possibly they may not be new to you, as among the numbers daily employed in those experiments on your side the water, 'tis probable some one or other has hit on the same observations. For my own part, I never was before engaged in any study that so totally engrossed my attention and my time as this has lately done; for what with making experiments when I can be alone, and repeating them to my Friends and Acquaintance, who, from the novelty of the thing, come continually in crouds to see them, I have, during some months past, had little leisure for any thing else.

"I am, etc.

"B. Franklin."

*A straight three-foot glass tube as big as your wrist.

Now as to some of the experiments themselves. The very first one of them, done within a few months of the time he first heard of electricity, contains the key to his invention of the lightning rod. Note from the following how skillfully and strikingly he arranges his electrostatic experiments by making the length of the suspension of the cork ball very long. After 200 years of the development of electrostatics these experiments cannot be made more tellingly today than by setting them up and performing them exactly as Franklin directed nearly 200 years ago. He writes:

"The first is the wonderful effect of pointed bodies, both in *drawing off* and *throwing off* the electrical fire. For example,

"Place an iron shot of three or four inches diameter on the mouth of a clean dry glass bottle. By a fine silken thread from the ceiling, right over the mouth of the bottle, suspend a small cork-ball about the bigness of a marble; the thread of such a length, as that the cork-ball may rest against the side of the shot. Electrify the shot, and the ball will be repelled to the distance of four or five inches, more or less, according to the quantity of Electricity.—— When in this state, if you present to the shot the point of a long, slender, sharp bodkin, at six or eight inches distance, the repellency is instantly destroyed, and the cork flies to the shot. A blunt body must be brought within an inch, and draw a spark, to produce the same effect. To prove that the electrical fire is *drawn off* by the point, if you take the blade of the bodkin out of the wooden handle, and fix it in a stick of sealing-wax, and then present it at the distance aforesaid, or if you bring it very near, no such effect follows; but sliding one finger along the wax till you touch the blade, and the ball flies to the shot immediately."

Here is where he learned that his lightning rod had to have a good ground in order to work at all. He continues:

"To show that points will *throw off* as well as *draw off* the electrical fire, lay a long sharp needle upon the shot, and you cannot electrise the shot so as to make it repel the cork-ball. . . . Or fix a needle to the end of a suspended gun-barrel, or iron-rod, so as to point beyond it like a little bayonet; and while it remains there, the gun-barrel, or rod, cannot by applying the tube to the other end be electrised so as to give a spark, the fire continually running out silently at the point."

I can find no evidence that prior to Franklin the electrical properties of points had been discovered at all. He continues:

"The repellency between the cork-ball and the shot is likewise destroyed, (1) by sifting fine sand on it; this does it gradually; (2) by breathing on it; (3) by making a smoke about it from burning wood; (4) by candle-light, even though the candle is at a foot distance: these do it suddenly. . . . The light of a bright coal from a wood fire; and the light of a red-hot iron do it likewise; but not at so great a distance.

"The light of the sun thrown strongly on both cork and shot by a looking-glass for a long time together, does not impair the repellency in the least. This difference between fire-light and sun-light is another thing that seems new and extraordinary to us.*"

The insight shown in the last three lines, in which he correctly makes particle carriers (ions, we now call them) from the match do the discharging while sunlight produces no ions and therefore does not discharge, is unbelievably penetrating for a date 200 years back, though the conception of neutral particles being first attracted and then repelled is of course definitely wrong.

The next experiment, with its interpretation, is probably the most fundamental thing ever done in the field of electricity. Get it exactly in Franklin's words:

"1. A person standing on wax, and rubbing the tube, and another person on wax drawing the fire, they will both of them (provided they do not stand so as to touch one another) appear to be electrised, to a person standing on the floor; that is, he will receive a spark on approaching each of them with his knuckle.

"2. But if the persons on wax touch one another during the exciting of the tube, neither of them will appear to be electrised.

"3. If they touch one another after exciting the tube, and drawing the fire as aforesaid, there will be a stronger spark between them than was between either of them and the person on the floor.

"4. After such strong spark, neither of them discover any electricity.

"These appearances we attempt to account for thus: We suppose, as aforesaid, that electrical fire is a common element [we now call "electrical fire" electrons], of which every one of the three persons above mentioned has his equal share, before any operation is begun with the tube. *A*, who stands on wax and rubs the tube, collects the electrical fire from himself into the glass; and his communication with the common stock being cut off by the wax, his body is not again immediately supply'd. *B*, (who stands on wax likewise) passing his knuckle along near the tube, receives the fire which was collected by the glass from *A*; and his communication with the common stock being likewise cut off, he retains the additional quantity received.—To *C*, standing on the floor, both appear to be electrised; for he, having only the middle quantity of electrical fire, receives a spark upon approaching *B*, who has an over quantity; but gives one to *A*, who has an under quantity. If *A* and *B* approach to touch each other, the spark is stronger, because the difference between them is greater; after such touch there is no spark between either of them and *C*, because the electrical fire in all is reduced to the original equality. If they touch while electrising, the equality is never destroy'd, the fire only circulating. Hence have arisen some new terms among us: we say *B* (and bodies like circumstanced) is electrised *positively*; *A*, *negatively*. Or rather, *B* is electrised *plus*; *A*, *Minus*. And we daily in our experiments electrise bodies *plus* or *minus*, as we think proper.—To electrise *plus* or *minus*, no more needs to be known than this, that the parts of the tube or sphere that are rubbed, do, in the instant of the friction, attract the electrical fire, and therefore take it from the thing rubbing; the same parts immediately, as the friction upon them ceases, are disposed to give the fire they have received, to any body that has less."

The next two long letters are taken up largely with what he calls "M. Muschenbroek's wonderful bottle," accidentally discovered in Leyden one year earlier, 1746, now known as the Leyden jar, and with explaining all such effects just as we do today in terms of the opposite charges or the inner and outer coats. Thus, to use his exact words:

"At the same time that the wire and top (inside coat) of the bottle is electrified positively or plus the bottom (outside coat) of the bottle is electrified negatively or minus, in exact proportion: i.e., whatever quantity of electrical fire is thrown in at the top an equal quantity goes out at the bottom." And "Again, when the bottle is electrised, but little of the electrical fire can be drawn out from the top by touching the wire unless an equal quantity can at the same time *get in* at the bottom. Thus, place an electrised bottle in clean glass or dry wax and you will not, by touching the wire get out the fire from the top."

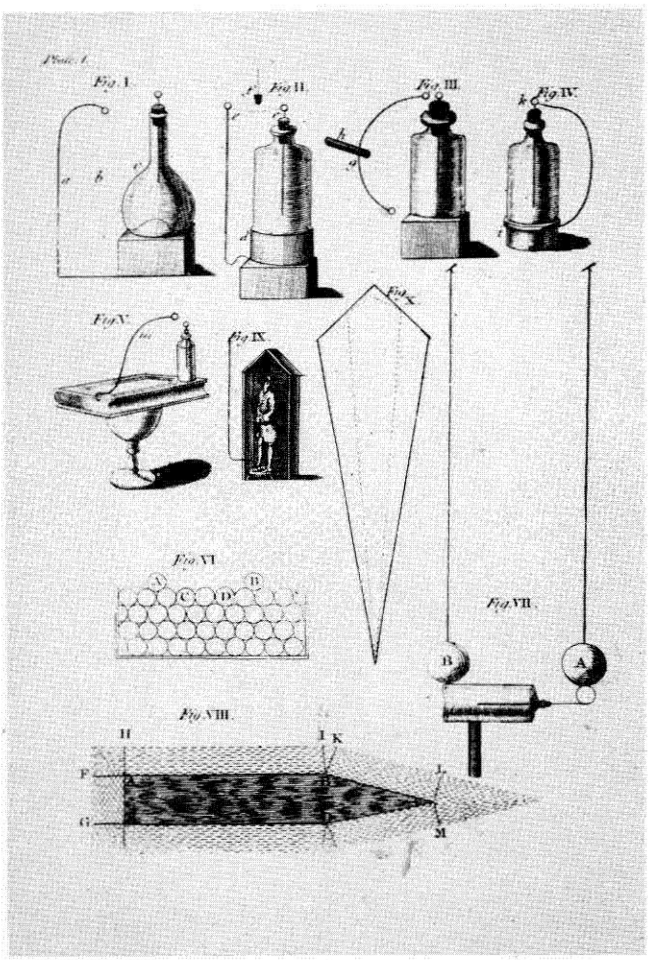
These chapters, too, contain the uncannily clever experiment of showing, just as we do today, that the charge resides in or on the dielectric. How many of us realize that the familiar classroom experiment of removing the coats of a Leyden jar and touching each of them, then putting them back again, and after that getting a strong spark by connecting the replaced coatings with a wire was devised by Benjamin Franklin in 1749? Again, he says:

"There is one experiment more which surprises us, and is not hitherto satisfactorily accounted for; it is this: Place an iron shot on a glass stand, and let a ball of damp cork, suspended by a silk thread, hang in contact with the shot. Take a bottle in each hand, one that is electrified through the hook, the other through the coating: Apply the giving wire to the shot, which will electrify it *positively*, and the cork shall be repelled; then apply the requiring wire, which will take out the spark given by the other; when the cork will return to the shot: Apply the same again, and take out another spark, so will the shot be electrified *negatively*, and the cork in that shall be repelled equally as before. Then apply the giving wire to the shot, and give the spark it wanted, so will the cork return: Give it another, which will be an addition to its natural quantity, so will the cork be repelled again: And so may the experiment be repeated as long as there is any charge in the bottles. Which shows that bodies having less than the common quantity of electricity, repel each other, as well as those that have more."

In that last sentence Franklin states clearly that matter which had lost its normal amount of electricity was self repellent. In modern terms the atom is neutral when it has its full complement of electrons. When any of these are removed the nuclei repel one another.

In some of his letters, notably the fifth, Franklin goes off into long and incorrect speculations as to the difference between the terms "electric bodies per se" and "non electric bodies." But this adds to, rather than subtracts from my own appreciation of him, for no human being could possibly have seen correctly all the ele-

(*Continued on Page* 16)



Copperplate line cut appearing as "Plate I" of the book, illustrating the experiments described in the Franklin letters to Collinson.

*"This different effect probably did not arise from any difference in the light, but rather from the particles separated from the candle, being first attracted and then repelled, carrying off the electric matter with them."

Recent Developments in
WELDED REFINERY EQUIPMENT

By RUSSELL J. LOVE

THE field of petroleum refining used to be a series of simple physical processes, but, in recent times and increasingly today, it has become a series of complex chemical processes. Recent developments require the petro-chemist to use not only extraction methods other than absorption and distillation, but also chemical and catalytic reactions involving many reagents other than the natural hydrocarbons.

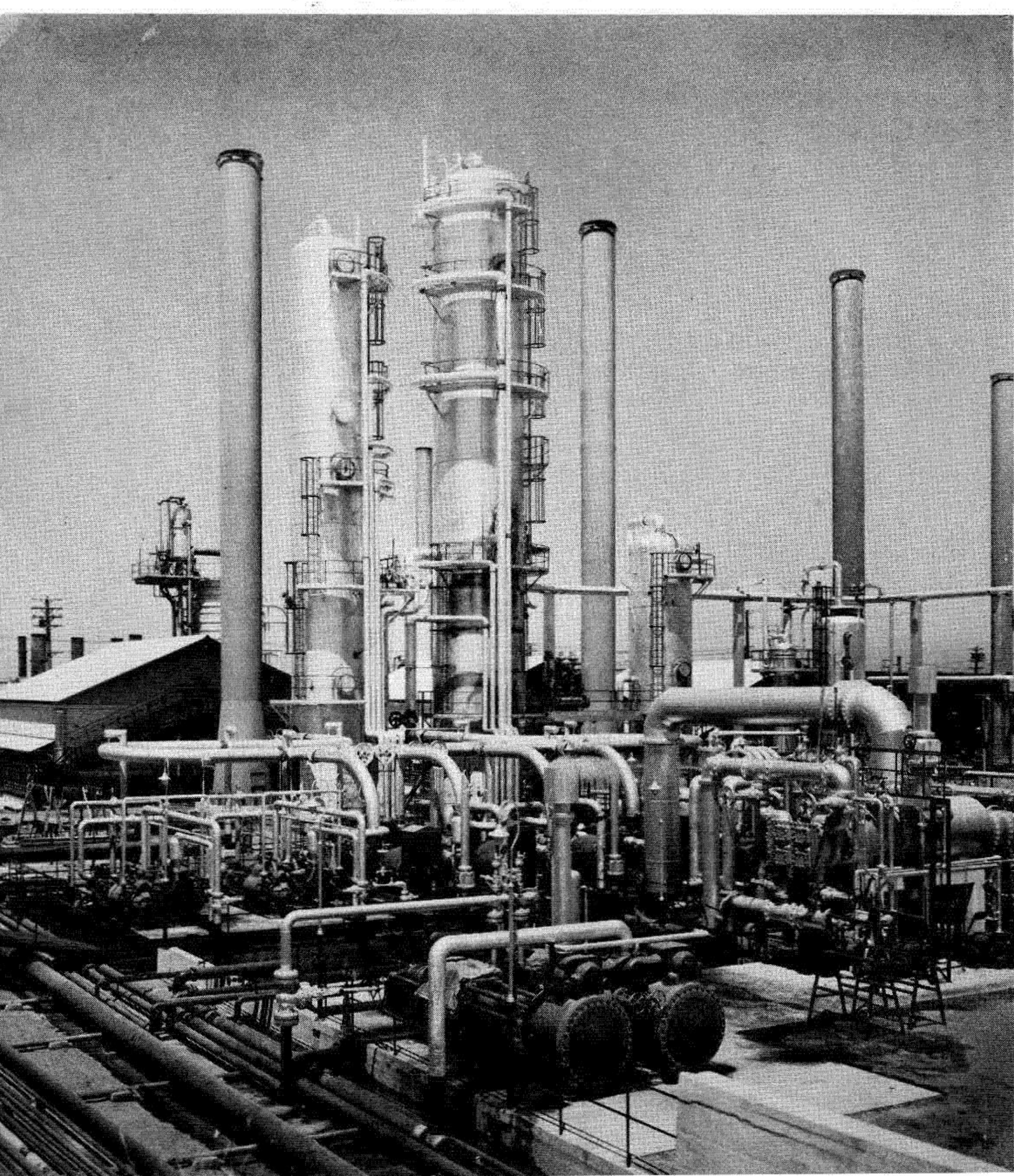
New equipment has had to be developed for this new petroleum technology. This paper* will describe some of the recently developed equipment. There will also be presented some of the details of construction, with particular reference to the materials used and the various welding processes for joining these materials.

The separate types of equipment in a modern refinery are too numerous to treat individually. Furthermore, much repetition would occur were we to consider refinery equipment in terms of refinery processes, such as alkylation, polymerization, thermal and catalytic cracking, and so on. The most interesting aspects of recently developed equipment may be summarized as due to the increasing demands for:

1. Higher operating temperatures.
2. Higher operating pressures.
3. Larger pressure vessels.
4. Better resistance to corrosion and abrasion.

These four topics will be discussed separately, although all the conditions represented often occur together.

*Presented at the October 7, 1943, meeting of the California Natural Gasoline Association.



Typical view of refinery. Note large amount of welded equipment.

HIGHER OPERATING TEMPERATURES

Operating temperatures of 750 degrees F., and upward to 1100 degrees F., are more and more frequently encountered. Thermal cracking, for quite a few years past, has employed temperatures from 850 to 1000 degrees F. But some catalytic cracking processes now require operation at over 1000 degrees F. At these temperatures metals are actually red hot. And for operation at red heat, the selection of materials and the design of equipment must take into account the following factors:

A. The high temperature strength of the material (resistance to creep).
B. The possibility of temperature embrittlement.
C. The accelerated corrosion rates at high temperatures.

In meeting the three conditions *A*, *B* and *C*, present when high temperature is encountered, the materials used greatly influence design of the equipment. Following are a few examples of design and fabrication considerations, as related to the material selected.

Straight carbon molybdenum steel (A.S.T.M. A-204) may be selected for creep strength (factor *A*), but it may not satisfy factors *B* or *C*. In other words, although the creep strength of carbon-Molybdenum is about twice that of carbon steel at 1000 degrees F., operating conditions at this temperature may induce temperature embrittlement, or the carbon-molybdenum steel may offer inadequate resistance to corrosion.

It has been found that the addition of chromium, even in relatively small amounts, to carbon-molybdenum steel materially reduces the risk of temperature embrittlement, and may add to the creep strength. As little as 1.25 per cent chromium with 0.3 per cent molybdenum may be used to satisfy factor *A* and factor *B*. But this small amount of chromium usually is not sufficient to improve the corrosion resistance very much.

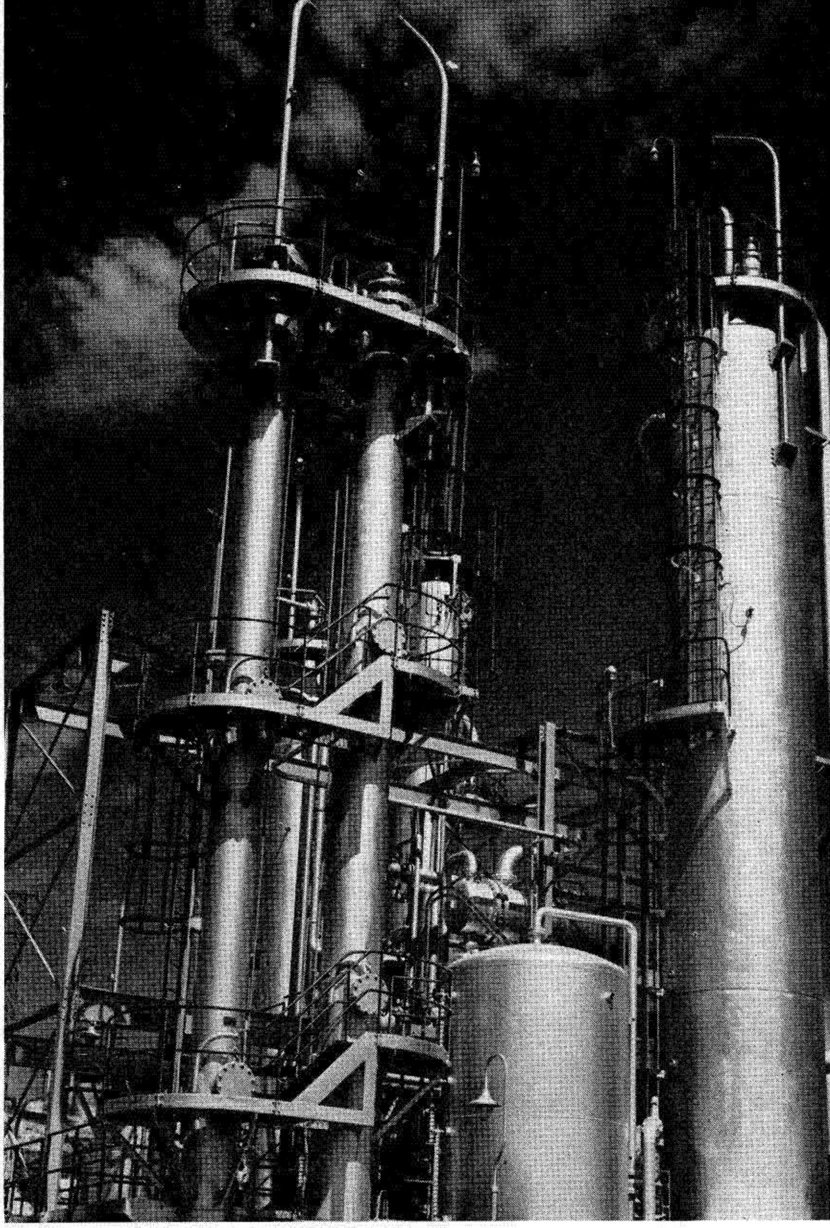
The high temperature corrosion problem alone has three distinct elements: First, atmospheric corrosion, which at lower temperatures is almost no problem at all; second, the special type of heat corrosion encountered in those cases where equipment is direct-fired or in contact with hot furnace gases; and third, the corrosion due to the process fluids. A further discussion of the corrosion problem is included in the latter part of this paper.

When creep and embrittlement and corrosion are all expected, the economic solution is sometimes found in the use of plain carbon-molybdenum steel for the pipe or vessel wall, to provide the necessary creep-strength, plus the use of a liner of high-alloy material to resist the corrosion or embrittlement that the process fluid would otherwise cause. The various forms that the liner may take, such as cladding, plating, or separately attached lining, will be discussed more in detail.

It is indeed fortunate that welding processes and techniques have been well developed for materials other than plain carbon steel. It is by virtue of the versatility of welding that the alloy or composite materials so often necessary for high operating temperatures can be fabricated in the size and shape necessary for almost anything from a simple pipe to a complicated heat exchanger. Moreover, welded attachmnet of alloy linings, whether by fusion plug welding or by resistance spot welding, is often the most economical method of providing such linings. And when clad material is used, though it may be costly, the cost is minimized if fabricated by proper welding methods.

Equipment for high operating temperature frequently involves complex combinations of low and high alloy materials. Accordingly, at this point we will temporarily postpone discussion of topic No. 2, high pressures, and topic No. 3, large vessels, and will mention some of the methods of welding alloy materials and composite materials.

It has been found that electric fusion welding is entirely satisfactory for most of the low-alloy steels, if proper welding rods are selected, and the special preheating precautions necessary in some cases are observed. There is one low-chrome alloy, however, that has been quite troublesome. It is the type 501 or type 502 stainless commonly called 4-6 per cent chrome. This alloy has a marked tendency to air-harden in the temperature range around 500 degrees F., and any weld-



Welded fractionating towers.

ing process employed is bound to create a temperature gradient extending into this air hardening range, unless something is done about it. What usually has to be done is to maintain a preheat temperature above the air hardening range and to conduct all welding operations at or above, say, 500 degrees F. Furthermore, the anneal necessary to stabilize the properties of this alloy must follow the welding without loss of the preheat temperature. In other words, to avoid the air hardening effect which may cause embrittlement or actual cracking of the material or the welds, a very elaborate setup is required, and much discomfort is involved for the welding operator. Because of these conditions, it is sometimes more practical to use the more expensive but easier to weld higher-chrome alloys, such as 11-13 per cent chrome, even though a lower chromium content would satisfy the operating temperature or corrosion problem.

The welding complications just described are often alleviated by the use of good old-fashioned acetylene welding, with its wider heated zone in the vicinity of the joint, but this process does not provide much of a protective envelope while the weld is being made. The atomic-hydrogen process is often superior, because it combines the ability to create a broad heating band, with an almost perfect reducing atmosphere (the hydro-

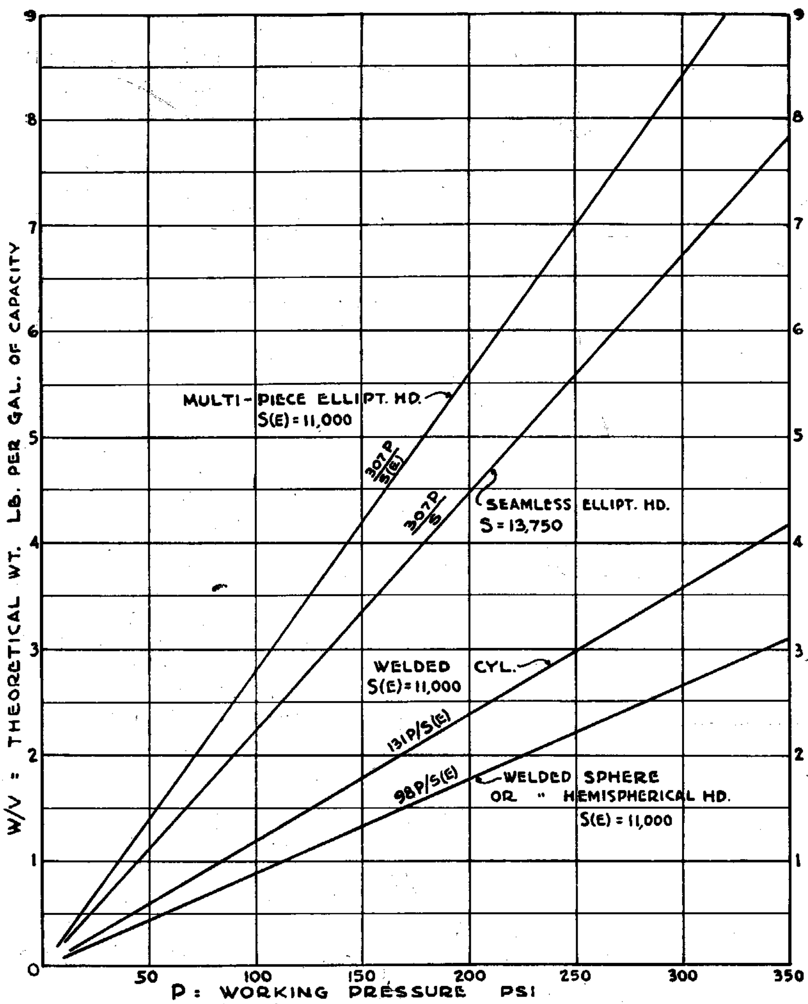


FIG. 1. Containers: Weight per unit volume for various pressures.

gen envelope). Another welding process, the very recently developed Heliarc or heliom-envelope weld, has not yet been applied to welding of the alloys encountered in modern refinery practice.

In connection with the fabrication of apparatus by welding, the details of the shaping and preparing of the edges to be welded are very important. The design of welded joints will vary according to:

1. Whether the joint is to be made in the shop or in the field;
2. The size of the part being welded—which may determine whether both inside and outside welding can be done, or whether all welding must be from the outside only;
3. The thickness of the main wall; and
4. Whether the wall is clad or lined.

Space does not permit a complete discussion of the many types of welded joints for composite materials, but it should be mentioned that whenever there is a considerable difference between the composition of the main wall (the "parent metal") and the composition of the cladding or lining, contamination is a serious problem. Contamination, sometimes called dilution, means either:

a. Detrimental dissolving of excess carbon from the carbon steel (or the dissolving of carbon steel itself) into the higher-alloy steel, or
b. The contaminating effect of some of the alloying constituents migrating into the weld joining adjacent portions of the parent metal.

In case (*b*), the effect is usually bad because of the formation of an imperfect alloy in the weld itself, which may seriously weaken the joint. It is obvious that the strength of the vessel or pipe is dependent upon the joint because the strength of lining or cladding is seldom, if ever, taken into account in the design. The pressure-vessel codes allow no credit for liners or the alloy portion of clad plates, in computing the strength of the vessel.

In case (*a*), the detrimental effect is primarily due to carbon pick-up spoiling the anti-corrosion properties of the alloy, or secondary effects such as checking.

LOW-TEMPERATURE OPERATIONS

While on the subject of temperature-effects, and before proceeding to discuss high operating pressures, we should mention the present status of low operating temperatures in today's refineries. Although alkylation processes, and cold acid treating, and solvent extraction, all commonly use refrigeration, the low operating temperatures have not become materially worse, from a design standpoint, than those low temperatures encountered some 10 years ago in solvent dewaxing. At that time, investigations were made of the special design problems incidental to low operating temperatures (around 100 degrees below zero Fahrenheit) where the main problem was that of impact strength, and where the generally acknowledged solution was the use of nickel steel, contain-

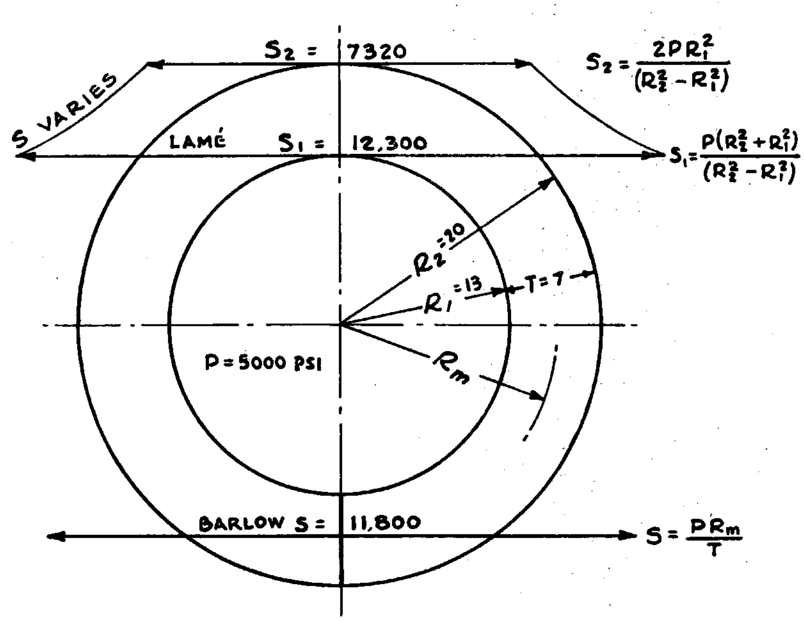


FIG. 2. Stresses in a thick-walled cylinder.

ing from two and one-half to four per cent nickel. Such steel was found to be weldable, and is still commonly used for low temperature applications. Now, still speaking of cold temperatures, we can only go down 460 degrees below zero F. and no lower. Up toward the other end of the thermometer, however, even 1000 degres F. may not be the limit. According to one authority, thermal polymerization may require over 1100 degrees F., and tomorrow the industry may need to go still higher.

HIGH PRESSURE AND SUPER-PRESSURE

To apply the term "high pressures" to working pressures near 400 p.s.i. is almost obsolete. Nowadays, one thinks of pressures from 750 to 1500 p.s.i. as high pressure, although the limits are very indefinite. Where high pressure ends and super-pressure begins is an open question. One authority considers pressures over 100 atmospheres, roughly 1500 p.s.i., and up to 50,000 p.s.i., to be super-pressures. Another states that the best definition is that we are dealing with super-pressure if the cylinder wall thickness exceeds 10 per cent of the diameter. Suffice it to say that pressures from 500 to 1500 p.s.i. are becoming quite common, and that full scale refinery operations at 3000 p.s.i. are not unheard of, and that there is at least one well-developed line of laboratory and pilot plant equipment for up to 50,000 p.s.i.

Even for the moderately high pressures around 1000 p.s.i., the design of equipment must take into account many more factors than when dealing with only 100 p.s.i. The designer of high-pressure equipment must consider:

1. Alternate materials; carbon steel or high strength alloys.
2. Size and shape factors; see Fig. No. 1 and below.
3. Type of construction:
   a. Rolled and welded; single-plate wall or multiple layers.
   b. Seamless: forged, drawn, or case, or bored from solid.
   c. Combinations of *a* and *b*, such as welded attachments on a seamless shell.

These factors will be considered in the order presented above.

Selection of material for high-pressure construction is almost always determined by making an economic balance between massive carbon steel and expensive alloy steel. This economic balance, however, involves more than simply material costs and fabrication costs; the availability and suitability of the material must be considered also. As in high-temperature design, the action or reaction of the process fluid on the material is often of supreme importance. If high pressure is accompanied by high temperature, all of the factors under each of these headings must be considered fully. Fortunately, the alloy materials outlined under the preceding discussion of high temperature have higher-than-ordinary tensile strength, and hence, are advantageous in meeting the requirements of high pressure. For example, carbon-molybdenum steel, often selected for high temperatures because of its better creep strength, is available in three grades—*A*, *B* and *C*, and has minimum (cold) tensile strengths respectively of 65,000, 70,000 and 75,000 p.s.i. One method of treating the

View of large towers under construction for butadiene plant, showing method of erection.

problem is to make the main wall of the vessel of the strongest suitable inexpensive material, and employ a liner to meet the heat or chemical corrosion problem. For instance, a fusion welding piping assembly for pressure at high temperature (the pipe being fabricated by rolling and welding clad plates) has carbon-molybdenum base metal with 18-8 stainless cladding, the carbon-molybdenum to provide strength at high temperatures, and the stainless to provide resistance to corrosion by the flowing catalyst.

When high pressure alone is being considered, uncomplicated by high temperature or severe corrosion, the lowest cost high-strength steels are carbon-silicon (A.S.T.M. A-94, A-201 and A-212) or carbon-manganese (A-225). Until sidetracked by the advent of the present war, the low alloy steels known as Corten and Mayari-R also provided low cost high strength materials, both easily workable and easily weldable.

In high-pressure vessels, shape and size are not mere factors of convenience. The process requirements for size may have to be modified to permit selection of an economic design. The cost per cubic foot of capacity becomes a matter of much money when pressures of 500 p.s.i. and upward are encountered. Small diameters minimize the cost, but some reactions, particularly catalysis, may require as large an area or volume as possible; hence the factors of size, shape, material, construction, and operation must be balanced.

The type of construction to be employed in a vessel for high pressure will determine to some extent what materials may be employed. For instance, in seamless forged, or bored-from-the-solid, or cast vessels, high strength may be provided by high-carbon content alone. The use of high carbon, however, may preclude the possibility of making any attachment by welding. As has already been pointed out, carbon-molybdenum steel, carbon-silicon steel, the low-chrome steels, and the stainless steels, whether used as the main vessel-walls or as liners, can readily be welded.

Welding also has made possible some very interesting combination designs for high pressures, such as long-stroke pumps made by welding two or more forged steel parts together; the welding of the outer barrels for Hydropress pumps; and the familiar examples of welding pressed heads onto seamless bored or forged cylinders, or of welding forged or cast steel nozzle flanges onto seamless necks.

Welding has made possible the recent development of multiple layer pressure vessels, an example being a vessel in hydrogenation service at high temperature; it is 36 inches inside diameter, built of 20 layers, for a working pressure of 3000 p.s.i. Whenever possible all connections leading into multiple-layer vessels are made through the head, inasmuch as nozzle attachment to the laminated shell is something of a problem.

Since the high pressures and super-pressures being discussed very often involve thickness-to-diameter ratios of over 10 per cent, and since when this relation exists, specialized formulas should be used, Fig. No. 2 has been prepared to show the difference between the usual Barlow formula for computing ordinary pressure vessels, and the Lamé formulas for thick walled vessels.

SUPERSIZE EQUIPMENT

Among the most outstanding, *literally outstanding*, features of the newer refineries, particularly those producing synthetic rubber ingredients and toluene, are the supersize of some of the vessels and the structures for them. This is not only because of large throughputs or large outputs, but because of the process requirements. Superfractionation involves more and more trays, which *means higher and higher towers. Semi-batch processes* require very large volumes to maintain some semblance of continuous flow with reasonable off-stream, on-stream cycles. Catalytic reactions often require catalyst beds with large areas or volumes.

The recently-developed equipment and apparatus exemplifying supersize can best be described by citing a few case histories, as follows:

Case I:

A deisopentanizer tower now being built is 96 inches diameter by 175 feet high overall, contains 70 bubble trays and weighs 150,000 pounds without the trays. It is designed to be self-supporting, having an extended base heavily reinforced. Although the topmost part of the shell is only three-eighths-inch thick, such factors as resistance to earthquake, hydrostatic loads and wind loads, require that the shell be thicker and thicker toward the base, and we find the thickness of the lowest course to be one and three-sixteenths inches. In fact, the thickness-to-diameter ratio of the lower 68 feet of the shell height is such that *that portion must be stress relieved to comply with the* A.P.I.—A.S.M.E. Code. This is truly a super fractionator.

Case II:

Very tall bubble towers, even though nominally self-supporting by virtue of properly designed bases, may suffer troublesome vibration if they are very slender. Typical of the modern treatment of this problem is the case of a fractionating column only four feet in diameter but over 90 high, which required bracing. Instead of a multiplicity of guy wires attached at various elevations, which would have formed a network overhead, it was decided to use harmonics sway bracing, consisting of three trusses equally spaced around the circumference of the tower. Each truss consisted of a steel cable attached at the top and bottom of the tower by welded clips, and each cable was spread at the center by a three-foot strut. Singing, or vibration of the truss wires themselves, is avoided by using vibration dampeners between the turnbuckles and the attachment at the bottom of the column.

Case III:

A typical reactor for a fluid catalyst cracking unit is 27 feet diameter by 87 feet high, having 50 of this height the full 27-foot diameter. The top head is a 90-degree cone; the bottom head is similar except that it has a 10-foot diameter by 13-foot deep sump appended. The main support ring is at the bottom of the 27-foot shell, where the vessel rests on a special elevated structural support. The main shell is one and one-half inches thick, the cone heads two inches thick, and the entire vessel is made of Plurameld (a clad plate, in this case with 20 per cent type 347 stainless on the inside, the remaining 80 per cent of the thickness being carbon-silicon high tensile plate.) Although the operating pressure is low, the operating temperature is about 1000 degrees F. The required stress relief was the subject of debate: whether to stress relieve in the field by building a fire inside, or to let the 1000 degree operating temperature accomplish the relief of locked-in stresses. Stress relief at temperatures somewhat lower than the 1100-1200 degree range generally recommended is feasible, but a much longer time is required—at 1000 degrees F., about 10 times as long as at 1100 degrees F.

Case IV:

A typical catalyst regenerator operates at 1100 degrees F., is 42 inches in diameter by 35 feet shell height, and has a 90-degree cone bottom. The top is a practical combination of cone and dome, having about two-thirds composed of a 90-degree cone, and the upper one-third bridged over with a portion of a sphere. Just a chamber, having no internal parts, but being constructed of one-inch plate for the shell and one and one-fourth-inch plate for the cones, it weighs over 200 tons empty. Because the catalyst flow from this regenerator is by gravity, this whole vessel is mounted at the topmost part of a structure built like a 20-story building. The operating temperature, 1100 degrees F., will do the stress relieving in a little over one hour.

Case V:

Typical catalyst hoppers are 30 or 32 feet in diameter by about 80 feet high overall, and have conical bottoms and full hemispherical top heads. Design is for five p.s.i., working temperature is 650 degrees F. As in the case of very tall fractionating towers, the shell thickness varies from top to bottom. These hoppers are about one-half inch thick at the top and each course of shell plate, proceeding downward, is one-sixteenth- to one-eighth-inch thicker, making the bottom course about one inch. One hopper weighs over 250,000 pounds when empty.

Case VI:

Although standard A.P.I. storage tanks continue to be generally used, with cone roofs or floating roofs, for storage of low vapor pressure fluids, there has been an interesting development of containers for high vapor pressure fluids. Large spheres and spheroids are suitable for pressures from 10 to 100 p.s.i., and volumes up to tens of thousands of barrels. Large diameter vertical pressure containers have been used, and supersize horizontal cylindrical tanks are now being constructed for pressure storage of liquids. An example of a recently developed special design of horizontal pressure tank of large capacity is located in southern California. It is 38 feet in diameter by 114 feet long, for a working pressure of 60 p.s.i. The novel feature is the method of support. Instead of two piers or cradles, which would require two ring girders to maintain the tank round at the points of support, and would involve sliding bearings or rockers at one end to allow for expansion, a transverse central support is used. The ring girder at this point is inside of the tank shell, and so the whole thing looks like a blimp almost floating in mid-air. The advantages, of course, are freedom to expand and contract, or to curve under the differential heating of the sun's rays, and, it is claimed, ease of field erection resulting in low cost per gallon of contents. In comparison with spherical containers, the cylindrical type is not at such a disadvantage as many believe. The mere fact that for a given pressure and diameter a sphere needs to be only half as thick as the cylinder does not mean that the weight or cost of a sphere will be half that of a cylindrical tank for a given capacity. (See Fig. No. 1.)

The transportation and construction problems in building supersize vessels are many. Super-fractionators often require shipment in two or more sections, to be joined by welding in the field, usually before erection. The gargantuan catalyst equipment described in case-histories III, IV and V obviously cannot be shipped even partly assembled. Erection becomes a matter of assembling, plate by plate, the individual pieces after prefabrication and transporting to the site. Even so, rather heavy lifts are involved in building those vessels with plate thickness over one inch. For example, a one-and-one-half-inch plate eight feet wide by 30 feet long weighs 15,000 pounds, and such plates must be lifted to fantastic heights to assemble a catalytic reactor, say, on the 14th floor of the building. Field welding of these vessels, as is evident from the construction details given in the case histories, may involve all of the problems connected with welding of composite materials as previously discussed under the topic of high temperature. Doing such welding in the field means that every precaution must be taken to insure not only the safety of the men and materials during construction, but also safety of operation of the finished vessel.

CORROSION AND ABRASION

All of the "old" corrosion problems are still with us, and a host of new ones are at hand. As has already been mentioned, any or all corrosion is aggravated by the higher temperatures of operation. Many of the old corrosion problems were adequately solved by simply providing extra metal for corrosion allowance. Most of the new corrosion problems are not solved that easily. The prevention of chemical attack, of heat or stress corrosion, of embrittlement, and of hydrogen-penetration, may require the most expensive materials and the best fabrication knowledge available. Do not exepect this brief study of equipment to answer all the new corrosion questions. Just a few of the things that are being done will be reviewed; and some of these things are only trial attempts to find out the answers.

The use of substances heretofore foreign to refinery operations is compelling the careful adaptation of materials equally foreign to the usual refinery experience. Here are a few examples:

Hydrochloric acid may occur in such form and such concentrations that only a very high alloy like Hastelloy will endure. In one such case, a liner of Hastelloy is installed in the lower section and bottom cone of a tower, and also within the necks of certain nozzles. Attachment is by plug welding, except that small diameter nozzles are of solid Hastelloy. Because this alloy costs several times as much as 18-8 stainless steel, its use is generally limited to zones of expected corrosion, where nothing else will do. In welding Hastelloy the welds tend to be porous; remelting of the weld in a carefully controlled atmosphere boils out the porosity and gives a smooth bead. The atomic-hydrogen arc is especially well suited to this "sealing" operation, but the acetylene flame also can be used successfully.

Hydrofluoric acid is another of the newcomers. When most of us were first introduced to hydrofluoric, we learned that its salient property was that it couldn't be kept in glass bottles, and this property has earned for HF an undeservedly bad reputation for supercorrosion. Just like concentrated H_2SO_4, and anhydrous HCL, according to C. M. Fehr, anhydrous HF can be tolerated by any good steel. By contrast, at concentrations over 65 per cent it attacks lead rapidly. Welded or cast steel equipment, therefore, may be used when the acid is known to be anhydrous, or nearly so.

Ammonia is not only a refrigerant but also a reagent or catalyst, as in modern toluene plants. Some designers or users may need the reminder not to use brass or copper in ammonia's presence, not even to braze a cracked compressor head, if the ammonia is to be held.

Hydrogen sulfide, no newcomer to the group of corrosion problems, nevertheless brings new headaches when it appears in some of the new processes. In one case where H_2S was present at a temperature of 900 degrees F., the piping and accessories had to be stainless steel, 18-8 with three per cent Molybdenum. In another case, this insidious compound H_2S had to be removed because it acted as a "poison" spoiling the action of phosphoric acid as the catalyst in making polymer gasoline. In absorbing or otherwise separating H_2S from a gas stream, a weak acid may be formed and lead lining (if temperature permits) may be needed to avoid this corrosion.

The non-ferrous materials, notably copper and Everdur, Monel, Inconel, and nickel, are becoming increasingly useful in meeting new conditions of corrosion, or in some cases conditions requiring non contamination of the products by iron. Fortunately, the chemical process and food industries in solving similar problems caused the development of dependable methods of working these non-ferrous materials into exchanges, pressure vessels, etc. This "know how" will be very useful to the new petro-chemical industry. Some examples of non-ferrous equipment are: copper or Everdur reaction-chambers, nickel salt-handling equipment, Monel or Inconel evaporators, and solid Hastelloy (nearly non-ferrous) for plastic-compounding.

Many of the newer cracking and reforming operations involve dehydrogenation. In these, as well as in the direct hydrogenation process, the presence of free hydrogen may cause the phenomenon known as hydrogen-penetration. This causes progressive deterioration of the steel and to date, I am told, no fully satisfactory remedy has been found. Vessels have been made with walls twice as thick as would otherwise be required, but still the hydrogen seeps through.

Now a word about abrasion. Without referring too specifically to the mechanism of the several new catalytic processes, it may be said that at least two of them use finely divided solids as catalysts, and these fine solids are caused to flow in suspension in fluids. During this flow, and in subsequent separation (in one process), the solid particles act abrasively. Equipment handling this mixed flow condition may be either of abrasive-resistant material like the workable low-manganese alloy steels, or, the anti-corrosion claddings or liners, by virtue of their generally better physical properties, hardness and tensile strength, may offer long enough economic life. If temperature permits, one should not overlook the fact that rubber linings are often resistant to both abrasion and corrosion.

CONCLUSION

The development of the new applied science of petrochemistry is just beginning. As new processes, new reactions, new catalysts are discovered, and new products are developed from petroleum there will be more new equipment—perhaps unlike any we have yet seen. That is the only conclusion with which this article can end.

Photo on page 13 courtesy the Lummus Co.

Benjamin Franklin

(Continued from Page 9)

ments of a huge and thus far completely unexplored field, and his wrong steps give him opportunity to show his greatness by the way he goes to work to discover and to admit his error. Thus, he writes as follows:

> "*Query*, Wherein consists the difference between an *electric* and a *non-electric* body?
>
> "Answer, The terms electric *per se*, and non-electric, were first used to distinguish bodies, on a mistaken supposition that those called electrics *per se*, alone contained electric matter in their substance, which was capable of being excited by friction, and of being produced or drawn from them, and communicated to those called non-electrics, supposed to be destitute of it: For the glass, etc., being rubb'd, discover'd signs of having it, by snapping to the finger, attracting, repelling, etc. and could communicate those signs to metals and water.—Afterwards it was found, that rubbing of glass would not produce the electric matter, unless a communication was preserved between the rubber and the floor; and subsequent experiments proved that the electric matter was really drawn from those bodies that at first were thought to have none in them. Then it was doubted whether glass and other bodies called *electrics per se*, had really any electric matter in them, since they apparently afforded none but what they first extracted from those which had been called non-electrics. But some of my experiments show that glass contains it in great quantity, and I now suspect it to be pretty equally diffused in all the matter of this terraqueous globe. If so, the terms *electric per se*, and *non-electric*, should be laid aside as improper; and (the only difference being this, that some bodies will conduct electric matter, and others will not) the terms *conductor* and *non-conductor* may supply their place."

Without doubt the most profound paragraphs in all of Franklin's letters are the following, written in 1749:

> "1. The electrical matter consists of particles extremely subtile, since it can permeate common matter, even the densist metals, with such ease and freedom as not to receive any perceptible resistance.
>
> "2. If any one should doubt whether the electrical matter passes through the substance of bodies, or only over and along their surfaces, a shock from an electrified large glass jar, taken through his own body, will probably convince him.
>
> "3. Electrical matter differs from common matter in this, that the parts of the latter mutually attract, those of the former mutually repel each other. Hence the appearing divergency in the stream of electrified effluvia.
>
> "4. But though the particles of electrical matter do repel each other, they are strongly attracted by all other matter.
>
> "5. From these three things, the extreme subtility of the electrical matter, the mutual repulsion of its parts, and the strong attraction between them and other matter, arise this effect, that, when a quantity of electrical matter is applied to a mass of common matter, of any bigness or length, within our observation (which hath not already got its quantity) it is immediately and equally diffused through the whole.
>
> "6. Thus common matter is a kind of spunge to the electrical fluid. And as a spunge would receive no water if the parts of water were not smaller than the pores of the spunge; and even then but slowly, if there were not a mutual attraction between those parts and the parts of the spunge; and would still imbibe it faster, if the mutual attraction among the parts of the water did not impede, some force being required to separate them; and fastest, if, instead of attraction, there were a mutual repulsion among those parts, which would act in conjunction with the attraction of the spunge. So is the case between the electrical and common matter.
>
> "7. *But in common matter there is (generally) as much* of the electrical as it will contain within its substance. If more is added, it lies without upon the surface, and forms what we call an electrical atmosphere; and then the body is said to be electrified."

In these paragraphs Franklin states with great succinctness what later became known as the Franklin one-fluid theory, and after 1900 was known as the electron theory. In his day and for 150 years thereafter it received very scant consideration in the old world, and the so-called two-fluid theory of Aepinus, put forward a little later, was universally taught in textbooks the world over up to the triumph of the electron theory in 1897 under the active leadership of J. J. Thomson, who himself pointed out that this electron theory was in essential particulars a return to the theory put forth by Franklin in 1749. For Franklin's electrical matter consisted of extremely subtle mobile particles (now called negative electrons), which in order to make matter exhibit its common or neutral properties had to be present in each kind of matter (we now say in each kind of atom; but the atomic theory had not been formulated in 1749) in a particular number, an increase in which number made it exhibit electrification of one sign, a decrease, an electrification of the opposite sign. In Franklin's theory only one kind of electrical matter was mobile, the other sign of electrification appeared when the mobile kind was removed so that it could no longer neutralize the effect of the opposite kind which *inhered in the immobile part of the matter (i. e., in the* nucleus).

The Franklin theory was mathematically identical with the two-fluid theory, but while the former was a definite and profound physical theory the latter was a hold-over from medieval mysticism. It came from the age of the so-called "imponderables"—an imponderable or weightless heat theory, the caloric—and the imponderable electric fluids. Such vague, tenuous, contradictory ideas were ill at home in the highly realistic, practical mind of Franklin. They were justified, like Faraday's lines of magnetic force, as analytical conveniences but not as physical realities. Franklin introduced a definite physical theory which rendered unnecessary such fantastic conceptions as two weightless and hence non-existent fluids introduced for purely *ad hoc* purposes, and then told to destroy each other, also for *ad hoc* purposes.

Let us now return to Franklin's discussion of points and their properties of throwing off or drawing off the electrical fire. He says, very modestly and wisely:

> "These explanations of the power and operation of points, when they first occurred to me, and while they first floated in my mind, appeared perfectly satisfactory; but now I have written them, and considered them more closely, I must own I have some doubts about them; yet, as I have at present nothing better to offer in their stead, I do not cross them out; for even a bad solution read, and its faults discovered, has often given rise to a good one, in the mind of an ingenious reader."

Then in the next paragraph note how clearly he sees the necessity of eliminating unnecessary hypotheses, i. e., he adopts the scientific principle of "minimum hypothesis."

> "Nor is it of much importance to us, to know the manner in which nature executes her laws; it is enough if we know the laws themselves. It is of real use to know that china left in the air unsupported will fall and break; but *how* it comes to fall, and *why* it breaks, are matters of speculation. It is a pleasure indeed to know them, but we can preserve our china without it."

He then describes some discharging effects of points conducted on a larger scale than he had before attempted, and in a later paper dated November 7, 1749, he enumerates all the known points of resemblance between lightning and electricity, and concludes with the comment:

> "The electric fluid is attracted by points. We do not know whether this property be in lightning but since they agree in all points in which we can compare them, it is not improbable that they agree likewise in this. Let the experiment be made."

In June, 1752, he made it, carrying out in a shed with his son the experiment which he describes as follows in his letter of October 19, 1752, to Peter Collinson.

> "As frequent mention is made in public papers from Europe of the success of the Philadelphia experiment for drawing the electric fire from clouds by means of pointed rods of iron erected on high buildings, etc. It may be agreeable to the curious to be informed that the same experiment has succeeded in Philadelphia, though made in a different and more easy manner, which is as follows:
>
> "Make a small cross of two light strips of cedar, the arms so long as to reach to the four corners of a large thin silk handkerchief when extended; tie the corners of the handkerchief to the extremities of the cross, so you have the body of a kite; which being properly accommodated with a tail, loop, and string, will rise in the air, like those made of paper; but this being of silk is better to bear the wet and wind of a thunder gust without tearing. To the top of the upright stick of the cross is to be fixed a very sharp pointed wire, rising a foot more above the wood. To the end of the twine, next the hand, is to be tied a silk ribbon, and where the silk and twine join, a key may be fastened. This kite is to be raised when a thunder-gust appears to be coming on, and the person who holds the string must stand within a door or window, or under some cover, so that the silk ribbon may not be wet; and care must be taken that the twine does not touch the frame of the door or window. As soon as any of the thunder clouds come over the kite, the pointed wire will draw the electric fire from them, and the kite, with all the twine, will be electrified, and the loose filaments of the twine will stand out every way, and be attracted by an approaching

finger. And when the rain has wet the kite and twine, so that it can conduct the electric fire freely, you will find it stream out plentifully from the key on the approach of your knuckle. At this key the phial may be charged; and from electric fire thus obtained, spirits may be kindled, and all the other electric experiments be performed, which are usually done by the help of a rubbed glass globe or tube, and thereby the sameness of the electric matter with that of lightning completely demonstrated."

In a further letter written in September, 1753, he says: "In September 1752 I erected an iron rod to draw the lightning down into my house, in order to make some experiments on it." He carried on these experiments for some months to learn whether the clouds were positively or negatively electrified, and after many trials he says:

"I concluded that the clouds are *always* electrified *negatively*, or have always in them less than their natural quantity of the electric fluid.

"Yet notwithstanding so many experiments, it seems I concluded too soon; for at last, June the 6th, in a gust which continued from five o'clock P. M. to seven, I met with one cloud that was electrified positively, though several that passed over my rod before, during the same gust, were in the negative state."

The foregoing shows what most commendable scientific care he took in his experiments and what caution he used in drawing conclusions.

But he did not stop with making scientific experiments. His active and practical mind was not satisfied until he had applied it to the useful end of the invention of the lightning rod, as indicated in the first paragraph of the letter of October 19, 1752, quoted above.

After his definite proof of the identity of lightning and electricity he was recognized by the most distinguished English scientists by being elected to the Royal Society, and was presented for the year 1753 the Copley medal of the Society, the highest honor within the gift of the world's most illustrious scientific body.

Santa Fe Dam

(*Continued from Page* 6)

1943, at which time heavy and prolonged rains caused flood conditions of major proportions to develop along the river channel. During this week the highest rainfall intensity recorded to date in the United States was measured in the mountains a few miles east of the dam, where 25 inches of rain fell in 24 hours. Tremendous quantities of material were washed down into the reservoir area, and wide gullies were cut in the upper end of the reservoir borrow pit. Floating debris partially choked up the trash racks, causing the water to be backed up in the reservoir and threatening two of the grizzly plants with inundation, but quick work of removing trash with a dragline eliminated the hazard. Construction work was halted by this and succeeding storms for a total of five weeks and clean-up work continued for many weeks more; yet in spite of delays, construction was completed four months ahead of schedule.

Principal credit for maintaining the production schedule regardless of delays was due to the fine spirit of co-operation between the contractors, represented by Project Manager R. F. Rasey, and the U. S. Engineering Department. J. G. Morgan was resident engineer for the government.

C. I. T. NEWS

WARTIME CHANGES IN CAMPUS LIFE

WARTIME has brought many changes to the Caltech campus. Perhaps the most evident change is the presence of large numbers of students in uniform. There are 196 Army and Navy men studying meteorology and 531 undergraduate students in the Navy V-12 program. These undergraduates are quartered in the student houses, double-deck beds having been installed to accommodate them. The quadrangle in front of Throop Hall has been designated the quarter-deck and all Naval students and officers are required to salute upon entering this area.

The 300 undergraduate civilian students live off campus, and are organized through the Throop Club. Retiring presidents of the student houses, in an effort to perpetuate the traditions and spirit of student house life, have recorded their impressions to be reviewed when campus life again returns to normal.

The three-term system has been discontinued in favor of a two-semester basis and classes continue throughout the summer under an accelerated program. The first Commencement Day under this system will be on February 18, 1944. Undergraduate enrollment has increased by about 230. The graduate enrollment has decreased from the usual number of about 300 to only 94. Many of these men, however, are still on the campus engaged in war work or instructing. There has been a decided trend towards engineering study, there being 425 engineering undergraduates and only 92 science majors.

Returning alumni comment upon the large feminine contingent upon the campus. Visitors to the school are sometimes under the impression that the Institute is coeducational. The regular Institute secretarial staff has been greatly expanded, and many new jobs of a wartime nature have been opened to women. The Athletic office relinquished one of its offices for use as a ladies' lounge.

Many structural changes have been necessitated by the increased personnel. Apollo retreated to an obscure outdoor corridor to make room for an addition to the comptroller's office. The south hallway on the main floor of Throop Hall has been partitioned off for office space.

Each weekday night the Institute is alive with activity as business men and women gather to take advantage of the war training courses that are offered in various subjects. Guards are stationed throughout the campus at all times, and passes are required to enter restricted zones. Professors have taken on added duties in teaching and research work until many are carrying a double load.

When the war is over many remarkable discoveries and accomplishments undoubtedly will be revealed that have been developed during this period of intense work and research.

WASHINGTON ALUMNI TO MEET

An alumni meeting will be held in Washington, D. C., on Thursday, January 13. Any alumni interested in attending the meeting, or in contacting fellow alumni in that area should call one of the following men: Major J. E. Joujon-Roche, Ft. Belvoir, Virginia; F. D. Tellwright, Telephone: Ordway 4662; F. J. Groat, 5010 Fulton Street, N. W., Washington, D. C., Telephone: Emerson 0295; Major V. W. Rodgers, Telephone: Republic 0461.

ALUMNI NEWS

1918

In September, 1918, Dr. James A. B. Scherer was host to the graduating class at dinner at the Maryland Hotel. During the evening it was agreed to hold a class reunion every 10 years. However, it has since become a custom to meet every five years. On September 15, 1943, the 25-year reunion was held at the Pasadena Athletic Club. Twelve members of the class were present, including the following:

W. A. KROUSE, of Los Angeles, has been with the General Electric Company for 24 years. He has two sons.

FRITZ KARGE, of Eagle Rock, is again with Union Oil Company of California as chief engineer of the pipe line department after a lapse of 18 months durng which time he was connected with Fluor Corporation as project engineer. He has two daughters.

JAMES F. HARTLEY, of San Marino, is with the War Department, U. S. Engineering Department, Camouflage Maintenance. He has one son and one daughter.

RETLA ALTER owns his own business in Pasadena, where he manufactures orthodontic materials and equipment which he sells throughout the United States and in many foreign countries.

H. DARWIN KIRSCHMAN is consulting chemist with Pomeroy and Associates in Pasadena. He also teaches chemistry at U.C.L.A., and has one daughter.

The members of the class who were not present were FRANK CAPRA, who is with the Army in England; BOB SICHT, who is in Australia, his original home; C. E. Nelson, a professor at the University of New Hampshire; and J. P. STELE, who is doing construction work at Ely, Nevada. CORLISS A. BERCAW answered the roll call with a wire from Springfield, Ohio, where he is on a new assignment as Assistant General Manager of the Springfield Division of the Elliott Company. PROFESSOR HOWARD CLAPP, who retired this year from the staff at the Institute, was invited to the reunion and made an honorary member of the class.

1922

JOHN H. HOWARD, who received his B.S. degree in mechanical engineering from Caltech in 1922, passed away on September 20, 1943. He was employed by General Petroleum from 1923 to 1929, when he became chief engineer of Globe Oil Tools. At the time of his death, he was vice-president and general manager of that concern. While carrying heavy executive duties, he maintained an active interest in engineering problems, and was a serious student of mechanical and metallurgical engineering. He leaves a wife and three children. The older boy, Paul J. Howard, attended Caltech until this year when he entered the Army Air Corps. Jack will be missed not only by his family, but by his company to which he contributed capable leadership, many practical engineering advances, and high standards of integrity, and by his friends who loved him for his lively interest in many subjects and his genial friendship.

LIEUTENANT COLONEL DOUGLAS C. MacKENZIE has been transferred from Camp Stewart to Marietta, Georgia, where he will continue to serve as an area engineer. He had been area engineer at Camp Stewart for approximately one year, and during that period his office was responsible for a considerable expansion in building facilities at the camp. He also assisted in construction of Cochrane Field at Macon, Georgia, the first flying school in the country completed by the Corps of Engineers.

1924

HOWARD W. GOODHUE is the author of an article in the October issue of Civil Engineering. He is the project engineer of the Appalachian Project of the Tennessee Valley Authority, and describes the design of that 75,000 K.W. development.

ORVAL E. LIDDELL is chief engineer of the Wilshire Oil Company at Norwalk, California. He is now supervising construction of a new 100 octane aviation gasoline refinery in conjunction with the present plant. The new refinery will consist of hydrofluoric acid alkylation, isomerization, fluid catalytic cracking and all auxiliaries such as a 450-pound steam generating plant, turbo electric generation, etc.

1925

LIEUTENANT COLONEL O. S. LARABEE is in the Engineer Corps with the Headquarters Army Air Forces at Washington, D. C.

MICHAEL C. BRUNNER, C.E., is a lieutenant colonel at Engineer School, Ft. Belvoir, Virginia.

EDWIN THAYER, who was formerly manager of the New York office of Advertising Age and Industrial Marketing, is now president and publisher of the Tide Publishing Company, which publishes a news magazine of advertising and industrial marketing. He was recently a visitor on the campus.

1926

FIRST LIEUTENANT MANLEY W. EDWARDS has been transferred from Ft. Douglas, Utah, to Pasadena, where he is Assistant Vicinity Maintenance Engineer. He is in charge of maintenance work on all smaller ground stations in Southern California, which includes up to 800 different stations.

1927

LIEUTENANT COLONEL JAMES BOYD is located at Washington in the Headquarters of Services of Supply.

MAJOR DICK DARLING has been stationed at an Automatic Weapon School at Ft. Bliss, Texas.

1928

MAJOR ED JOUJON-ROCHE, C.E., has been with the Engineer School at Ft. Belvoir, Virginia, for two years as an instructor in antimechanized defense. The last of September he was made commanding officer of the Student Officers Training Regiment, consisting of about 1600 officers and 400 enlisted men (and Wacs). He sees many Caltech men who go there for officer courses.

CAPTAIN GUY CHILDBERG is with the Army Signal Corps at Ft. Monmouth, New Jersey.

1929

LIEUTENANT COLONEL WALTER B. GRIMES writes from Australia that the presence of alligators in the rivers does not give him much opportunity to engage in his favorite sport of swimming.

LIEUTENANT COMMANDER FRED WHEELER has been in active service since March, 1941, and is now a division officer in the engineering department on a battleship.

LIEUTENANT COLONEL BILL MOHR is with an engineer battalion and spent the early part of the summer in desert maneuvers in California.

1930

DONALD P. BARNES has been promoted from major to lieutenant colonel in the Corps of Engineers, U. S. Army. He is now on an assignment in the west, after having served as assistant executive officer and chief of the camouflage section at Ft. Belvoir, Virginia.

1932

BILL SHULER has recently been promoted to the rank of colonel and has been in the war zone for several months. He is one of the youngest men to hold this rank in the engineering corps of the Army.

1933

FERDINAND MENDENHALL, survivor of a torpedoing in the Atlantic, visited his parents in Van Nuys in September. He is a gun crew commander and has been overseas for eight months.

1935

ENSIGN WARREN T. POTTER received his commission at the Naval Training School at Cornell University and is now an instructor at the Department of Inspection of Navy Material in Chicago.

1936

DONALD FOLLAND is with the Blind Landing Equipment Department at the research laboratories of Sperry Gyroscope.

1937

LIEUTENANT (j.g.) DANIEL SCHUMAN is serving as gunnery officer on merchant and transport ships.

DANIEL L. GERLOUGH, of San Marino, is the father of a daughter, Constance Claire, born October 5.

1938

CHARLES F. ROBINSON and Miss Virginia Coke, of Flintridge, were married on September 11. He is employed as research associate, connected with N.D.R.C., at the Institute.

ROBERT H. OLDS and Miss Marion Picton, of South Pasadena, have announced their engagement. He is a research assistant in the chemical engineering department at the Institute. No date has been set for the wedding.

CAPTAIN CARTER LOWELL, U.S.M.C., is stationed at Pensacola, Florida.

CLAY SMITH has been exploring since June for Consolidated Mining and Smelting Company. Most of the time has been spent in Canada in the wilds of the Southern Yukon.

1939

LIEUTENANT MELVIN LEVET is in charge of the Weather Station at the Reading Army Air Field at Reading, Pennsylvania.

ENSIGN HERBERT STRONG has recently completed a three months course in aeronautical engineering at Caltech.

1940

ALEXANDER BREWER is employed by Sperry Gyroscope, where he is working on special electronic devices.

WILLIAM T. KLUGE and Miss Zora Shurtz, of Pasadena, were married October 17.

LIEUTENANT GERALD P. FOSTER, U.S.M.C., and Miss Betty Owen Talbot, of Glendale, were married on June 25 in St. Andrew's Chapel, U. S. Naval Academy, Annapolis, Maryland. The Academy chaplain officiated at the ceremony.

1941

WAYNE G. ABRAHAM is with the Blind Landing Equipment Department at the research laboratories of Sperry Gyroscope.

SUB-LIEUTENANT GLYN FRANK-JONES, Royal Navy, is a service engineering officer for special electronic equipment and is stationed at Staten Island, New York.

WILLIAM L. DENISTON and Miss Marjorie Fletcher, of South Pasadena, were married recently. They are living at Bellflower, California.

JOHN B. HIATT has resigned his position as assistant to the welding engineer at the California Shipbuilding Corporation and has accepted a commission as ensign in the United States Naval Reserve.

1942

MERLE SMALLBERG is working on aircraft armament at Sperry Gyroscope.

DICK HEAD and Miss Isabel Saunders were married early in October. He is employed as a research engineer at Caltech.

Mrs. Elizabeth Swingle, wife of STANLEY SWINGLE, died Thursday evening, September 23, as the result of an accident on the Caltech campus. Mrs. Swingle, a graduate bacteriologist, had been in charge of the stockroom in Crellin Chemistry Laboratory for the past year. She was carrying a bottle of Ethyl-chloro-carbonate from a storage vault in the sub-basement of Crellin to the elevator. The container apparently shattered, due to pressure caused by decomposition of the substance. Immediate treatment was given and the Fire Department Rescue Squad accompanied by an Emergency Hospital doctor arrived in a few minutes. Death was due to inhaling the fumes of the gas. All those who had worked with Mrs. Swingle deeply admired her and expressed their sympathy to Dr. Swingle, who is a member of the chemistry staff at the Institute.

BOB GREENWOOD has spent the past summer exploring in the Southern Yukon, five to 50 miles north of the Alcan Highway, for Consolidated Mining and Smelting Company.

LIEUTENANT (j.g.) WILLIAM CALLAWAY is in active service in the Southwest Pacific.

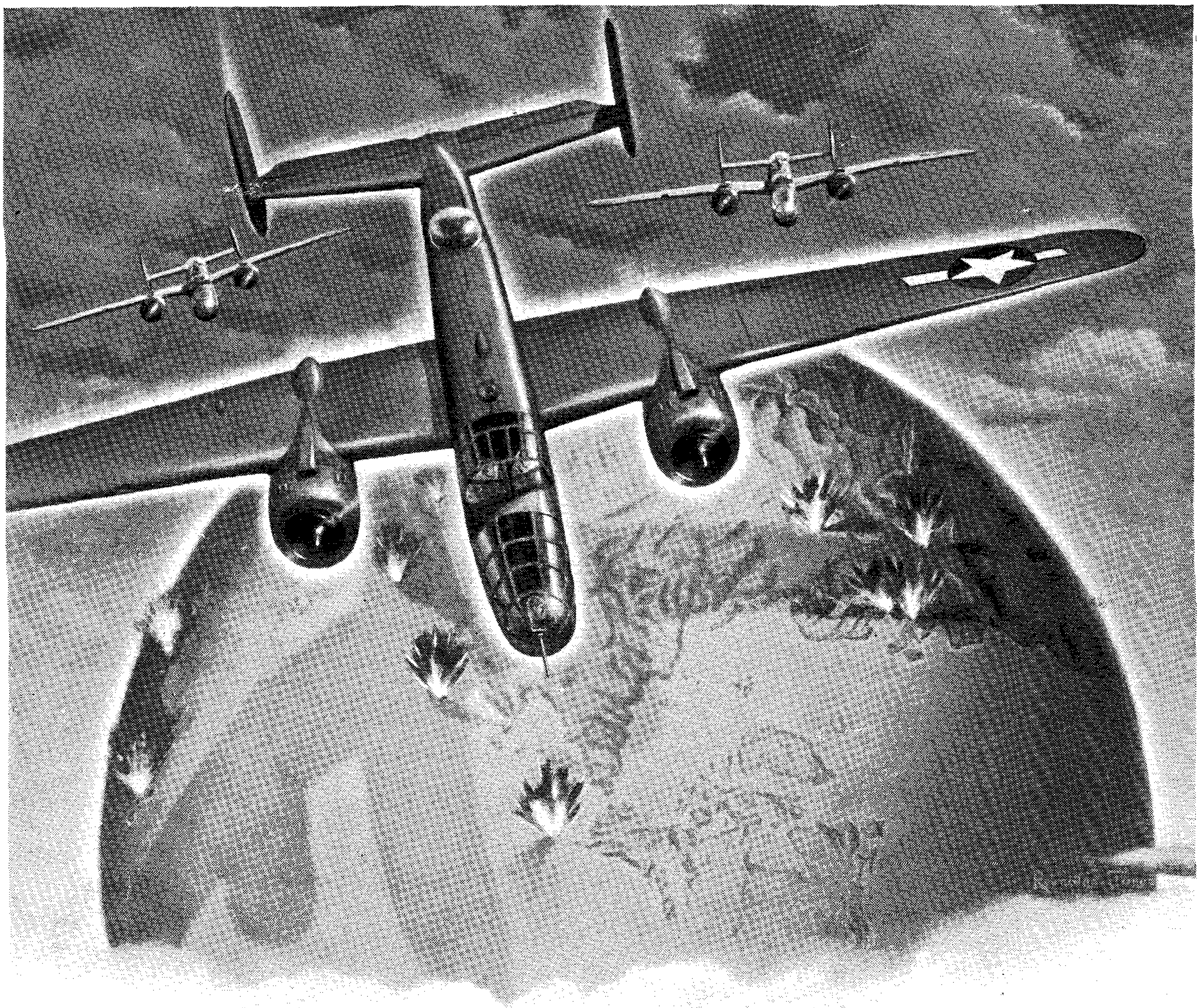
CLIFFORD C. HOAGLAND and Miss Louise Allen were married on September 18 at Willow Grove, Pennsylvania.

1943

BILL FAIR is preparing for field service assignments on special electronic equipment for Sperry Gyroscope.

OSCAR TERRELL and Miss Jean Hadley announced their engagement in October. No date has been set for the wedding. He has joined the U. S. Merchant Marine.

JOHN M. FRENCH and Miss Charlotte Rahn, of Pasadena, have announced their engagement and plan to be married in February. He is taking graduate work at Caltech.



Where there's a fight there's a Mitchell

...and behind every B-25 Mitchell bomber, from Sicily to New Guinea, is the North American engineering department.

Just designing good planes isn't enough. They must also be easy to build. That is why there is a project engineer in charge of any particular contract.

It is his responsibility to synchronize the work of all engineering groups involved, to work with designers and layout men in adapting designs for ease of production and to coordinate the work of engineering with the shop.

Because of the complexity of today's warplanes, highly specialized engineering groups are required for such work as experimental design, aero-dynamics, wind tunnel tests, stress analysis and weight control, the design and installation of hydraulic, power plant, electrical and radio equipment.

Engineering's job doesn't end when a plane gets its final OK. From field service representatives, stationed all over the world where North American planes are operating, come changes indicated by battle experience. These are carefully studied by design engineers for possible use, since only by constant improvement will we keep our planes better that the best the Axis has.

North American's engineers are helping to win this war sooner.

NORTH AMERICAN AVIATION, INC.
Inglewood, California · Dallas · Kansas City

Designers and builders of the B-25 Mitchell bomber, AT-6 Texan trainer and P-51 Mustang fighter (A-36 fighter-bomber). Member Aircraft War Production Council, Inc.

North American Aviation *Sets the Pace!*