POPULAR RESEARCH NARRATIVES

TALES OF
DISCOVERY, INVENTION
AND RESEARCH

VOLUME II

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Sturgis H. Thorndike
to J. S. & T.
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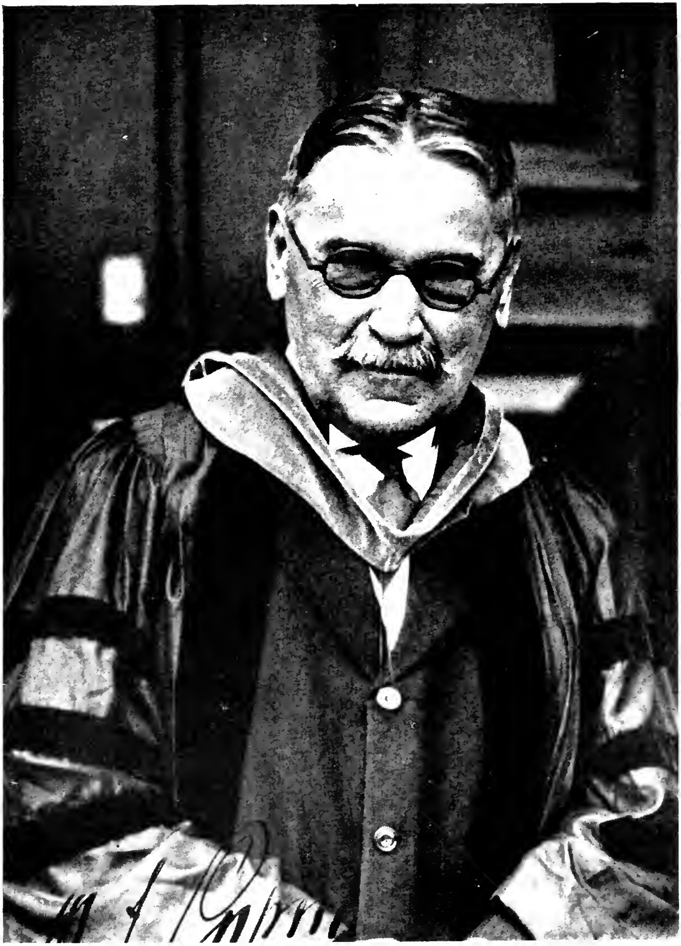

MICHAEL IDVORSKY PUPIN

Professor of Electro-Mechanics, Columbia University. Scientist and Inventor. President, American Institute of Electrical Engineers; President, American Association for the Advancement of Science; Chairman of Engineering Foundation 1917 to 1919; member, National Academy of Sciences, etc. Narrative 28.

Popular

RESEARCH NARRATIVES

VOLUME II

Fifty brief stories of research, invention, or discovery, directly from the "men who did it," pithily told in language for laymen, young and old

COLLECTED BY THE

ENGINEERING FOUNDATION

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TABLE OF NARRATIVES

THE BEE AND THE HONEY OF SCIENCE

BY M. I. PUPIN, PH.D., SC.D., LL.D., L.H.D., D.ENG.

President, American Association for the Advancement of Science, President, American Institute of Electrical Engineers

Railways, telephones, telegraphs and radio broadcasting; electric lights, automobiles, and labor-saving devices; electrical transmission of power for the purpose of lightening the burdens of man and beast; all these things are today the honey of our modern civilization. They make human life sweeter and more enjoyable; by eliminating drudgery they afford more leisure for the spiritual, the esthetic, and intellectual activity of the human soul. This activity is the real joy of life.

Whenever one contemplates these assets of modern civilization—this honey in the beehives of human life—he cannot help thinking of the busy bees whose toil gathered all this honey upon which human society is feeding today. Galileo, Newton, Franklin; Carnot, Faraday, and Maxwell; Kelvin, Helmholtz, Pasteur, and many other honey gatherers in the rich fields of human experience were the busy bees who have filled our beehives to overflowing. What a splendid spiritual lesson it is, in all activities of life, to watch the conscientious and intelligent toil of these bees! The fields in which their honey is gathered are inexhaustible, but the busy bees are not. Human society must take care of the honey gatherers, otherwise the stored up honey will soon be exhausted. It must also make their toil less arduous by enriching the fields of human experience. It must attend to the cultivation of those flowers which distill the honey-producing sap of human experience.

The "Popular Research Narratives" describe the honey, the bees, and the flowers in the fields of human experience. Each Narrative teaches the same lesson: Take care of the bee and of the honey; enrich the field of human experience. Scientific and engineering research is the honey gathering process; men trained and disciplined in this field of inquiry are the honey gathering bees. Research and the men conducting it contribute to the honey-hearted hive of our national life. We must cultivate both, otherwise the hive will soon be empty.

This was the aim of the Founder of the Engineering Foundation. This is the aim of those who are directing the noble work of this Foundation. We solicit your coöperation in this work. It is a national work, and its success will contribute its full share to the uplifting of the spiritual as well as of the material welfare of our nation. We must make every effort to keep the beehive of our national life full to overflowing.

ENGINEERING FOUNDATION

Why?

Very widely has the first volume of "Research Narratives" been dispersed. In Africa, Australia, China, Japan, isles of the seas, Europe, Canada, South America and all these forty-eight United States, persons have been reading the "remarkable little book," as Paul Brown dubbed it in "America at Work." Here is Volume 2.

"Research Narratives" have been published to spread knowledge of science, engineering and invention, and of their contributions to the welfare of men. These contributions do not just happen. For continuing progress new stores of knowledge must be always accumulating. Increasing of knowledge needs funds, facilities and trained men of ability.

To aid engineers in making their contributions to human welfare, the national societies of Civil, Mining, Mechanical and Electrical Engineers organized Engineering Foundation "for the furtherance of research in science and in engineering, or for the advancement in any other manner of the profession of engineering and the good of mankind."

The beginning of the Foundation was a gift from Ambrose Swasey, of Cleveland. He and others subsequently made additions. His gifts were intended as the nucleus of a great fund to be built up by numerous donors into an engineering "community trust." Engineering Foundation, then, is designed to be an instrumentality of the engineering societies to supplement their gifts of personal efforts and professional talents for the advancement of the good of mankind. It is well organized to receive and utilize funds for this purpose.

Engineering is interwoven with all activities which make up civilization. Engineering must advance unless Man's persistent elevation of his mode of living is to be halted. Engineering promotes peaceful communication among the peoples of the Earth. It aids in understanding and mastering Man's great environment.

One purpose of the Narratives is to lead persons to think on what is transpiring in the world to the end of adjusting their living, their working and their social and political organizing to the advance made by Science. Mankind must progress or regress, and either progression or regression will be rapid. Let us go forward, seeking truth and using it for the betterment of all mankind!

ALFRED D. FLINN,
Director.

THE HYDROPHONE OR HYDROPELORUS

An Underwater Direction Finder

H. C. HAYES

Through evolution the sound receiving sense in animals was placed in two ears. In the higher animals the ears are relatively widely spaced so that the difference of time in reception of the sensations may indicate direction from which the sound comes. An important natural faculty for finding a desired objective, or avoiding a danger, was thus created. Not until recent years, however, was the delicacy of this sense in humans appreciated and measured. In judging sound direction, average persons determine time differences between reception of sensation by the two ears to within a hundred-thousandth of a second; a trained listener, probably to within five-millionths.

Research Narrative Number 18, "Direction by Two Ears," told of the utilization of this faculty aided by special instruments aboard ship to detect submarines and of probable extension to peace uses of these principles and devices. Since the war, the United States Navy in its Engineering Experimental Laboratory at Annapolis, Maryland, has perfected the war instrument and named it, "M. V. Hydrophone," for use with underwater sounds. This hydrophone has a high degree of selectivity; which is to say, that it can be adjusted so as to be very sensitive to sounds from the desired direction and not sensitive to sounds from other directions. Furthermore, most of the local sounds about the vessel, such as those caused by waves and propellers, are of low pitch, and a filter has been devised which can eliminate all sounds below a certain chosen pitch. Consequently, signals and other sounds of higher pitch which the listener desires to detect can the more readily be heard. Fortunately the instruments are simple of manipulation and a person of ordinary intelligence can be instructed in their operation in an hour.

The lower pitched sounds cannot be heard if the water depth much exceeds 100 fathoms, but high pitched underwater sounds of good intensity can be heard in water of any depth so as to locate accurately a vessel, or other source of sound, 10 to 30 miles distant, depending upon a number of conditions. Efficient high-pitched sound signaling apparatus is not expensive. If vessels generally, and lighthouses and buoy stations along the coasts and channels were equipped, the use of such signals in fog and other conditions of low visibility, combined with hydrophones on the vessels, would almost eliminate possibility of collision and running on to rocks or shoals. Not only the distances, but also the courses of vessels within range can be determined. Distances to submerged ledges, precipitous shores and other underwater objects capable of reflecting sound can be estimated with precision. Possibly even icebergs and derelicts may be detected at sufficient distance to avoid encountering them. With such equipment, underwater signals could be detected at much greater distances than lights could be seen, or bells or fog horns heard, and all the while the vessel can be safely proceeding at full speed. In event of breakdown of radio equipment, the hydrophone within limited ranges, for safety purposes, could take its place, especially if high-pitched signals are also used.

The pelorus, a nautical instrument for correcting errors of the magnetic compass, is said to have been named for the pilot of the ancient Carthaginian general, Hannibal, in his expeditions against Rome. Because of the hydrophone's possibility for determining accurately the ranges of beacons and other objects as an aid to navigation, it has been proposed that it should be called also the "Hydropelorus."

For more than two years, the hydrophone has been in use on certain vessels of the United States Navy and has indisputably proved its worth to those familiar with its performance. Science is thus making another contribution to the safety of lives and property on the seas. Other applications of the hydrophone will be described in a later Narrative.

Based upon information supplied by Dr. H. C. Hayes, Physicist and Sound Aide, U. S. Navy.

MARINE SOUNDING BY SOUND

The Sonic Depth Finder

H. C. HAYES

At the U. S. Navy Engineering Experiment Station, Annapolis, Maryland, there has recently been developed a practical instrument for quickly and accurately measuring both small and great depths in water by reflection of sound. Its use is coupled with the hydrophone, which was the subject of Research Narrative Number 51, and it is known as the Sonic Depth Finder.

For many purposes, Man has needed knowledge of the depth of great and small bodies of water. For untold centuries, he has "heaved the lead" or lowered other weights at the ends of cords or wires. Some refinements in method and equipment and corresponding improvements in results have been achieved, but high accuracy, or great speed, could never be attained because of inherent, insurmountable difficulties. Use of the hydrophone, a world war invention for detecting submarines, coupled with certain physical laws, led to the development of methods for sounding in water of all depths which have amazing possibilities. Great precision may now be combined with speed of observation. It would seem feasible to chart the bottom of an ocean, a lake, or a river, to any practically needed accuracy with a celerity and facility comparable to that of land topography. With the hydrophone properly installed in the forward part of a vessel, an operator can determine depths to bottom rapidly and continuously, while proceeding at full speed, utilizing the reflection of the sound of the vessel's propeller. Such soundings have been made successfully on "destroyers" traveling at 36 knots. But with this equipment alone, depths greater than three times the length of the vessel cannot be measured with satisfactory precision. If a high-pitched underwater sound signaling apparatus be added, any depths exceeding 80 fathoms can be measured with acceptable accuracy.

Sound travels through water (and through all liquids and many solids) with great velocity. If, however, the substance through which the sound is traveling is interrupted by one of very different density, the sound is at least partially reflected from the surface at which the density changes, for example, the surface of rock, or earth under water, or of mineral deposits in the earth. By utilizing well established mathematical and physical laws, the new instrument makes reflected-sound distance measurements possible with great precision. Many mechanical difficulties had to be overcome in designing the instrument. Simplicity and accuracy were obtained by basing the design upon the measurement of a time interval which could be controlled and whose relation to the sound reflection interval of time could be mathematically known. Measurements can be made from a vessel traveling at any speed or from a stationary base.

Possessed of the sonic depth finder, Man can now determine with ease, precision and speed, the configuration of land under any depth of water. Harbors and their approaches, "sea lanes," routes of existing or proposed deep-sea cable or submarine pipe lines, and anchorage grounds can be charted with a completeness of detail heretofore beyond the realm of engineering. Underwater topography can be mapped as an aid to studying reasons for the courses of ocean currents, for earthquakes and many another scientific problem. Bottoms of streams and lakes can be investigated in a manner never before practicable. Indeed, it may be possible to study the shifting bed of a river during flood, thus gaining knowledge that will facilitate flood control. The engineering-economic possibilities of this instrument as well as its contributions to pure science, cannot be grasped at once. The vista is fascinating. The mariner may have maps of his course and means for checking his position by "landmarks" anywhere in the wide sea, just as roads and trails on terra firma may be followed.

Based upon information supplied by Dr. H. C. Hayes, Physicist and Sound Aide, U. S. Navy.

A NEW METHOD OF MEASURING THE FLOW OF WATER

Applicable to Pipes under Pressure

NORMAN R. GIBSON

About the end of the first century, Hero of Alexandria first described the volumetric, or bulk, method of measuring the flow of water. He pointed out that it was not necessary to measure the area of the orifice through which the water was flowing but that a pit might be dug and the water allowed to flow into it for an hour by the sun dial, and the volume of the pit filled in that time determined. This method, refined by the use of instruments of precision, remains today the standard.

During the past 3 years,* an entirely new method has been invented by the author, using three fundamental principles developed within the last 250 years: that force is equal to the product of the mass and acceleration of bodies; that the momentary change of pressure in an enclosed column of water is equal to a "constant" multiplied by the momentary change in velocity, when due allowance is made for the compressibility of water and the elasticity of pipe walls, and when the speed of propagation of pressure waves in water is taken into consideration; and that the spouting velocity of water is equal to the square-root of the head or fall under which the water is discharged, multiplied by the square-root of twice the gravitational unit. Velocity heads and friction losses are proportional to the square of the velocity.

* 1920 to 1923.

Two essential conditions for the new method are: First, the water must flow through a pressure pipe or other closed conduit, and, second, means must be available for controlling the flow, such as a valve or the gates of a turbine at the end of the conduit. In a typical hydro-electric power plant these conditions are fulfilled when water flows out of a forebay into a penstock at the lower end of which is a turbine and generator equipped with hydraulic governor to operate the turbine gates. The new method is particularly applicable to measurement of water for testing efficiencies of hydraulic turbines in hydro-electric power plants.

The principal operation is to obtain a record of the changes of pressure that occur in the conduit when the water therein is brought to rest. Steady conditions of load on the turbine are maintained for several minutes until the flow has become as uniform as possible. When the usual observations of head, power, etc., have been made, the turbine gates are gradually and gently closed so as to shut off the supply of water to the turbine. Immediately preceding and during the closure of the gates and for a short time afterward, there is obtained a record of time intervals and of the changes of pressure that occur in the conduit. This record is obtained by means of the Gibson Apparatus which is connected through the wall of the conduit by a ¼-inch piezometer opening at any convenient point upstream from the turbine casing. After the closure, when the disturbance in the penstock has subsided, the same apparatus is used to record the static pressure then existing in the conduit. The complete record is called the pressure-time diagram and when properly interpreted is a precise measure of the mean velocity of the water in the conduit at the moment the gates began to close.

In addition to usual equipment for efficiency tests there is required the apparatus for obtaining pressure-time diagrams. It combines mercury U-tube gage, pendulum, camera box, photographic lens and motor-driven revolving drum enclosed in a light-proof cylinder. The U-tube is made with a short leg of glass tubing and a riser of steel tubing, the ratio of the areas of the two legs being such as to limit within the length of the glass tube the displacement of the mercury under changes of pressure. Calibration of this ratio is readily made.

The making of a pressure-time diagram is simple, each diagram being made on a photographic film 11 inches wide by 18 inches long, from which blue-prints are obtained. On the blue-prints lines are delineated, first to determine the end of the diagram, which is readily accomplished by reference to the uniform periodicity of the pressure oscillations which occur after closure of the gates, and, second, to eliminate from the diagram that portion of its area which has been created simply by the recovery of the combined friction and velocity heads of the water flowing in the conduit. The remainder of the area is then used as a measure of the mean velocity in the conduit. In this method only the flow actually shut off is measured. Usually the turbine gates are not perfectly tight. This leakage is readily determined and added to the discharge calculated from the diagram.

Measurements at the hydraulic laboratory of Cornell University, in 1920, showed the mean variation from volumetric measurement was less than 0.2 of 1 per cent, and the maximum variation of any one measurement was 1.6 per cent. Advantages, in addition to accuracy, are brief interruption in operation of power plant, and low cost.

Contributed by Norman R. Gibson, Hydraulic Engineer, The Niagara Falls Power Co., Niagara Falls, New York.

A NEW RADIO ANTENNA

An Experiment with Lightning-Rod Material

JAMES ASHTON GREIG

The large capacity and low resistance of lightning-rod conductor, when used as a radio antenna, have been found to increase audibility nearly 40 per cent. Radio improvements come so rapidly that it is unsafe to designate anything as "new" for more than a week; nevertheless, the following narration may be of interest. About a year ago, while making some laboratory tests on lightning-rod conductor for a large manufacturer of this kind of apparatus, it occurred to the writer that the braided copper cable commonly employed for this purpose would make a very fine antenna for the reception of the component electro-static and electro-magnetic waves of radio frequency sent out by the big radio transmitting stations.

Engineering calculations indicated that this type of conductor would increase the antenna current resulting from the intercepted wave of a given potential about 10.8 per cent over a single copper cable of the usual type and of the same physical length, so the experiment was deemed of sufficient worth to carry out.

The result of the first experiment was impressive, an audibility meter recording the fact that the signal strength was increased 39.7 per cent as compared with circular twisted copper cable of $\frac{1}{4}$-inch diameter. Also transmitting stations which were never before detected on the usual type of antenna were brought in loud and clear.

The lightning-rod conductor used in these experiments resembles in shape a flat ribbon about $\frac{1}{2}$ inch wide and $\frac{1}{8}$ inch thick. Actually, however, it is composed of ten strands of No. 18 bare copper wire braided closely together on a special machine to give it its ribbon like appearance. On account of its use to ground heavy potentials during an electrical storm its copper content is unusually high.

Several reasons have been ascribed by the writer to account for the results obtained. In the first place, it is well known that high-frequency currents exhibit the characteristic often called "skin effect"; that is, they have a tendency to collect and move on the outside of a conductor, and as this type of conductor presents a much larger surface area to radio waves, it is reasonable to suppose that a great number of electro-static and electro-magnetic lines will cut it and therefore induce a larger current therein.

Another factor is that because of its flat surface it builds up a greater electro-static field with relation to the earth and acting thus as a condenser stores up a greater amount of energy than the usual type of antenna.

Neither one of these factors could be accurately calculated in advance of the experiments because of the lack of authoritative data on the measurement of high-frequency resistance and capacitances.

With an antenna 30 feet long of this type, strung in a basement at a level about 1 foot below the surface of the earth, better results were obtained than with an antenna of the usual type, of 100-foot length, strung between two poles out of doors at an elevation of about 40 feet.

These and other similar experiments conducted by the writer would seem to indicate that while we have been spending most of our efforts in designing efficient internal circuits for radio reception, the exterior, or antenna, circuit offers a field well worth intensive research.

The writer's experiments on this subject have been presented to the American Institute of Radio Engineers and have been described in technical journals as well as the November, 1922, issue of "Radio News." Those who wish details can find them in these sources of information at Engineering Societies Library, New York.

Contributed by James Ashton Greig, B.S.E.E., Associate Editor, "Electric Traction"; formerly radio engineer, Marconi Wireless Telegraph Company of America and 1st Lieutenant, Radio Co. A., 331 F. A. 89 Inf. Div., U. S. A.

CONVERSION OF ELECTROMAGNETIC ENERGY INTO USEFUL HEAT

A High Temperature Electric Furnace

E. F. NORTHRUP

Advancement in several arts demands means for creating, controlling and using extremely high temperatures. In some applications of such temperatures, it is necessary to avoid mechanical contamination from products of combustion contingent upon the production of heat directly by fuel. Discoveries and inventions in the electric and magnetic areas of science have been yielding the means sought.

The laws of electromagnetic induction were first unravelled by Faraday. They were rigidly defined and quantitatively expressed by Maxwell. Then Hertz showed that if the frequency of the current in the primary circuit is high, electromagnetic energy flows into space in the form of a radiation, differing in no respect from luminous radiation except as to wave-length. He showed that such portion of this radiation as becomes intercepted by a closed conducting circuit, sets up currents in the circuit. These secondary currents die out because of the resistance of the secondary circuit, and the original energy of the current appears as heat developed in the secondary. The closer the secondary lies to the primary, the greater is the proportion of energy which the primary radiates that is intercepted and converted into heat.

If the primary is a solenoid and the secondary a mass of conducting material in the solenoid, 50 to 80 per cent of the electromagnetic energy radiated by the primary may become intercepted by the secondary. If the conductivity of the secondary is favorable, all the electromagnetic energy intercepted is transformed within the secondary into heat energy. If the secondary is covered with a layer of refractory heat insulation to retain the heat generated, then the temperature of the secondary may mount, under specially arranged conditions, to near that of the carbon arc.

To secure these results the solenoid, or primary, must carry a current of 3000 to 30,000 cycles a second. If the electromagnetic energy developed at each alternation of this current were allowed to radiate, it would do so with a wave length of from 100 kilometers to 10 kilometers. In radio practice, currents having a frequency of this order of magnitude are being generated and the electromagnetic energy associated with them is radiated into space for the purpose of sending messages half round the world.

It is quite recently, however (since about 1916) that electromagnetic energy of like character has been absorbed before it escapes from its source and used for producing heat free from the contaminating carbon of the arc furnace.

A high-frequency induction furnace was invented by the author and developed with the financial assistance of G. H. Clamer. It is an ironless induction furnace that embodies the basic conceptions outlined above. In its smaller sizes it is used to melt the precious metals, gold, platinum, iridium, and their alloys; also samples of carbonless iron, and its alloys with various metals of the tungsten group. In its larger sizes, silver and the base non-ferrous metals and their alloys are melted; also nickel and iron alloys which must be maintained extremely pure.

The heating and melting of these materials results from the direct transformation of electromagnetic energy into heat energy within the substance itself or within the walls of a conducting crucible used to hold the product heated. If the substance to be heated does not conduct electrically, Pyrex glass for example, it is nevertheless heated and melted by the same process by placing it in a crucible which is made of conducting material.

These ironless induction furnaces, depending as they do upon the passing of a high-frequency current through an inductor coil, require for their operation a source of current of much higher frequency than the current supplied by commercial circuits. So-called "high-frequency" converters of new design have been developed especially to meet this requirement. It is but a short step, however, to adapt the high-frequency, high-power converters which have been developed for transoceanic radio transmission to the service of inductive heating. Thus again, the electron vacuum tube raises as the genie to do things useful, things wonderful. It sends voices to other continents and it generates the electromagnetic energy which, changed into heat, will give the highest of temperatures and the highest efficiencies in electric heating. It gives us the one most perfect method for developing excessive temperatures free from chemical contamination.

Contributed by E. F. Northrup, Vice President and Technical Adviser, the Ajax Electrothermic Corporation, Trenton, New Jersey.

THE HAUNTED RESTAURANT

The Humorous Aspect of an Annoying Magnetic Situation

ANONYMOUS

The wisest men that e'er you ken
Have never deemed it treason,
To rest a bit, and jest a bit,
And balance up their reason;
To laugh a bit, and chaff a bit,
And joke a bit in season.
—*From an old calendar.*

"Once upon a time," on Manhattan Island, a restaurateur leased a building hard by a sub-station of the local electric light company, from which electric current for light and power was dispensed to the district round about. In due course the premises were equipped for appeasing human hunger and were opened for business. Patrons came "from far and near."

Not long thereafter, the manager of the light and power company found in his morning mail a letter from the restaurant keeper complaining that "electricity" from the adjoining sub-station was cutting up such pranks in his restaurant that his business was being seriously interfered with, and would the lighting company please take steps to confine their loose current within their own station walls. Indeed, he could do no business. No "help" would stay, nor patrons come, because of the strange happenings in his establishment. His silver and plated ware were all blackened and his utensils of iron and steel were magnetized; customers' watches were stopped, and table knives would not stay where they were put.

The manager called one of his electrical engineers and showed him the letter. "The man has queer ideas, very queer; but let's make an investigation and have an eye open as to the man's truthfulness. Don't let him suspect, however, that you think he may be unbalanced." Soon the investigator returned. "Our friend 'has the goods on us.' Conditions are as stated in his letter." "How can that be? I'll see for myself!" And to the restaurant they went.

"Mr. Restaurateur, please be good enough to show us the evidence on which you base your remarkable charge against the electric light company." "Kindly come with me. See! Here is my silver, black, as stated. And, now, please watch!" Some knives and forks were placed upon a table as if it were being set for a patron. Instantly they shifted and pointed toward the wall between the restaurant and the electric station. "Remarkable! Mr. Restaurateur, this is a dangerous state of affairs. Suppose one of your guests should attempt to eat his peas with his knife! The knife might switch around and cut his mouth from ear to ear!" "Oh, Mr. Manager, this is nothing! Come to the kitchen." An iron pot was taken to the stove; when near its place, it suddenly went down with a bang, as if seized by a mighty unseen hand. And then the pot was held so strongly to the stove that it seemed almost necessary to have the aid of a crane to lift it off. Other weird demonstrations were given.

The explanation was easy and the remedy, too, thanks to

Science. On the sub-station side of the party-wall were many large electrical conductors, leading heavy currents into and from the converters. These conductors created and maintained a powerful magnetic "field." For the "lines of force" of this field, the brick wall was no barrier. But magnetic screens could be simply made. In this case it sufficed to cover the restaurant side of the wall with heavy steel plates, just as the lighter stamped steel plates are often used on ceilings and walls in lieu of plaster. For the blackening of the silver, however, the manager refused to accept responsibility, but suggested that a little more liberal use of elbow grease and metal polish might take care of that condition. Of course, another obvious solution would be the equipment of the tables with nonmagnetic knives and forks and the kitchen with aluminum or copper pots and frying pans.

Contributor anonymous, but credible and respectable.

DISCOVERY OF $26,000,000 WORTH OF PLATINUM DREDGING GROUND IN THE URAL MOUNTAINS

American Mining Methods Applied in Russia

R. S. BOTSFORD

Before it was impossible to operate in Russia, when it was vitally necessary to obtain adequate quantities of this precious metal for sulphuric acid manufacture, electric contact points and other purposes, every effort was put forth to increase production. Great advance in price was a stimulus to studying peculiarities of occurrence with the object of enlarging reserves and cheapening and hastening production.

Platinum occurs in the Ural Mountains in those small localities where the ultra-basic rocks are exposed. It has not been successfully worked in situ, nor are there veins capable of economic exploitation. It is sparsely distributed in the olivine rock associated with chromite. Disintegration of the olivine liberates the fine round grains of platinum through erosion and it finds its way into the beds of the streams which flow off these olivine bosses. A stream flowing over such rock might also contain platinum down stream. Irregularities may be discovered for in certain instances reconcentration has occurred. Further, since the deposition of platinum, the stream may have changed its course, and it is a problem to determine where the platinum is at this time.

Besides fifteen dredges of construction too light for the purpose most of the work was done by hand. A group of seven or eight men would be allocated a plot of ground 70 x 70 feet. Then they would sink a shaft through the gravel and clay to bedrock, pumping out the water and wherever possible joining their workings with others, should there be a bedrock drainage tunnel. The sandy clay paystreak six inches to one foot above bedrock in favorable localities, contained the platinum richly concentrated, sometimes so that it could be picked up with a spoon. Kytlim river on the Nicolo Pavda estate was such a locality, within a few miles of the divide between Europe and Asia, with 5000 men so employed, each group washing out its own platinum and turning it over to the company office, at a reduced price, to compensate for facilities furnished, and in some parts for a central washing plant operated by hand. The ground remaining was fast becoming unprofitable. Steep creek grade, old timbers, abundance of clay of the worst kind, and many big bowlders seemed to make dredging hazardous.

The two miles of Kytlim river flowed into the Lobva. Many shafts had been sunk in the latter, across the streambed, with negative results, by local operators and by exploring parties from other countries. Apparently not realizing the source of the platinum, previously described, the upper extension had been missed. A series of shafts at sufficiently close equal intervals, at right angles to the probable direction of bedrock flow of the platinum paystreak, disclosed that there had been three streams which had united to produce the deposit. This fact discovered, lines of shafts determined the limits, average value, depth and conditions to be encountered in exploitation.

The assumption before this discovery was that the much larger Lobva river had brought in so much gravel and had been so swift that much of the platinum had flowed away and had been so diluted as to yield only the traces hitherto found. It was further assumed that the platinum, being heavy, round and easily concentrated when freed from the clay, had not been carried in large quantities far beyond the junction, which their prospecting seemed to confirm.

Lines of shafts extending across the valley, sunk to investigate previous results, only confirmed those results. However, continuing to extend a line of shafts to the bedrock rim, which seemed to be close, at a point beyond other prospecting shafts and below what appeared and is now known to be a bench, the bedrock receded,—and then we came into the platinum a few shafts farther on. It was a glorious feeling, especially as there is fully five miles of it over 750 feet wide tucked in under the bench, averaging from top to bottom over 80 cents per cubic yard at present prices. The upper end was much richer.

We were not quite out of the woods yet, but the stuff was there. Other problems were solved. Four dredges have been operating and two others under construction, three of them modern American dredges, electrically driven from a wood-fired power plant in the forest. The product was about a quarter of a ton of platinum annually, and when all the dredges are in operation, will be about two-thirds of a ton, at a trivial working cost. Shares went from 67 to 450 during this period, and dividends increased continuously.

Contributed by R. S. Botsford, Member American Institute of Mining and Metallurgical Engineers, Engineer in Charge.

CONCRETE-BORING MOLLUSCS

A Cousin of the Shipworm

C. A. KOFOID AND R. C. MILLER

Molluscs that bore wood have been extensively known for centuries. Some of them are familiar by name even outside the circles of zoology; for example, Teredo navalis and Xylotria, or Bankia,—in common English, pileworms or shipworms. A number of species that bore into rocks along the sea coast have also long been known to Science. In quite recent years, a very few specimens have been found in marine concrete structures, but were regarded as curiosities only.

But no longer can rock-boring molluscs be treated wholly with disdain by "practical" men. A representative of the family, Pholadidea penita by name, has quite recently been found on mischief bent to an extent that demands attention, in some places. In San Pedro, the harbor of Los Angeles, the wooden piles of certain wharves were jacketed with mortar of Portland cement and fine gravel to protect them from destruction by teredos or other marine wood-boring animals. This protection appeared to be effective until November, 1922, when it was discovered that Pholads had bored into and through the jackets on some of these piles. Examination showed that the attack had been extensive, the jackets of fifty per cent or more of the piles examined being found infested with these little shell fishes. But that was not all,—in the irony of zoology, other molluscan borers were reported to have found their way through the passages made by the pholads and entered the wood inside the jacket.

A full grown Pholadidea, as found in the mortar jackets at San Pedro, is about two and three-quarters inches long and one and one-quarter inches in greatest diameter, near its forward end. His shape resembles a flattened pear. He is a bivalve. He starts operation as a youngster and so his hole at first is only about one-sixteenth inch or less in diameter at the surface of the rock, concrete, or mortar, but expands as the animal grows and penetrates. The forward, rounded portion of the shells has a surface resembling a rasp or file. Whether, however, the cutting of the concrete or rock is due wholly to attrition with the rough shell, or whether it is aided by some secretion which softens the material, has not been surely determined. These molluscs have been found in some hard rocks, but are generally found in shales.

Reports from Los Angeles state that at every point in the inner harbor where mortar-jacketed piles exist, about 50 per cent had been more or less attacked, of which more than one-fifth were badly bored, and of those not attacked a number were so far inshore as to be but little exposed. To allay unnecessary alarm, it should be said that the mortar was below average in quality, from two to five inches in thickness, some being decidedly poor. That these jackets had escaped attack for fourteen years is attributed to the fact that the wooden forms used in depositing the mortar had been left in place. They were gradually destroyed by marine wood borers, thus exposing the mortar to the Pholadidea. The probabilities of attack upon well-made precast piles and other high-grade concrete depend upon whether the action of these molluscs is mechanical, or chemical, or both.

Another species, Platyodon cancellata, more clamlike in shape, has also been found in disintegrating concrete. The first species is found on the Pacific Coast from Alaska southward even to Ecuador. One species of rock-boring mollusc has also been reported on the Gulf and South Atlantic and at Panama. Since these pholads have shown capabilities for damage of commercial significance, they received attention from the Committee on Marine Piling Investigation, of National Research Council, with which Engineering Foundation coöperated. These investigations comprised studies of damage to wooden piles and means of prevention or protection, substitutes for wood in piles and other parts of marine structures, and deterioration of concrete structures in and near seawater.

Based on information supplied by Professor C. A. Kofoid and R. C. Miller, University of California, of the San Francisco Bay Marine Piling Committee.

Sir Robert A. Hadfield

Scientist and steelmaster. Fellow of the Royal Society and the Physical Society, of England, etc. Inventor of manganese steel and silicon (low hysteresis) steel. Chairman and Managing Director of Hadfields, Limited. Narratives 35 and 91.

L. O. X.

Safe Explosives

GALEN H. CLEVENGER

Liquid Oxygen Explosives are a fine example of the dependence of engineering and industry upon scientific research. They are a type of Sprengel explosive. The novel feature is that the oxidizing agent (liquid oxygen) and the combustible substance (carbonaceous matter alone or in combination with liquid hydrocarbons or even metallic powders, and, at times, inert absorbents) are brought together immediately before use. The components separately are non-explosive. Before L. O. X. could be seriously considered for commercial work, it was necessary to produce liquid oxygen economically in large quantity and to have satisfactory containers.

Liquefaction of so-called permanent gases, air, nitrogen, oxygen and others, long baffled those who attempted it, and yet required no unusual equipment once fundamental laws were known. Repeated endeavors to liquefy these gases by pressure alone, despite development of elaborate equipment for producing pressures up to 60,000 pounds per square inch, failed; one law had been overlooked, that all gases have not only a critical pressure, but also a critical temperature. Thomas Andrews, in 1869, was first to show that there is a temperature for every gas at and below which it can be liquefied and above which it cannot be liquefied by pressure; further, that when gases heretofore regarded as permanent were at their critical temperatures, they could be liquefied by comparatively moderate pressure.

Louis Cailletet, in 1877, produced the first liquid air by allowing the pressure on previously compressed air to fall 4500 pounds per square inch, thus lowering the temperature. In 1895, or somewhat earlier, Linde in Germany, Hampson in England and Tripler in America, demonstrated that liquid air could be produced upon a large scale. Later Claude found it more economical to cause the air to do work in expanding by passing it through an engine instead of expanding it through a nozzle.

Not until 1902 did Linde demonstrate that liquid air could be separated into its constituents by passing through a special still, similar in principle to that used for separating alcohol-water mixtures. This rendered possible the production of liquid oxygen on a large scale. To-day it is practicable to produce it upon any scale desired, employing air pressures of 900 to 3000 pounds per square inch. Liquid oxygen boils at −182.93 degrees Centigrade; to be used without excessive evaporation loss, satisfactory storage and transport containers were necessary. Dulong and Petit were probably first to discover that passage of heat through glass by conduction could be greatly reduced by a vacuum wall; d'Arsonval, in 1887, was first to make practical use of glass-walled vacuum containers, reducing evaporation loss to 1/10 that in plain glass. It was soon discovered that a vacuum did not prevent passage of radiant heat. Dewar, in 1892, found that silvering the inner walls of vacuum chambers of containers reduced evaporation loss to 1/200 of a plain glass container's loss. These containers were admirable for laboratory use, but fragile. There was needed a metallic container with low evaporation loss. Dewar discovered that properly treated charcoal, at the temperature of liquid oxygen, had the property of adsorbing large quantities of gases, including air, so perfectly as to produce a very high vacuum. He secured a British patent in 1904, and in 1906 pointed out that a high vacuum could be maintained between metallic walls by this means. Modern metallic containers for liquid oxygen are rugged, highly efficient devices.

These scientific developments and actual trial of L. O. X. had been made before the world war. When Germany was cut off and it became necessary to find a substitute for large quantities of explosives used for civilian purposes, incentive came for rapid development of these new explosives.

L. O. X. under certain conditions, have distinct advantages: substantial saving in cost, greater safety, freedom from noxious gases, no possibility of explosive in ore or waste rock, which may occasion trouble; elimination of danger from drilling into unexploded charges. In cities, where large quantities of explosives are used in excavating, there is ever present danger attendant upon transportation through the streets and risk of their falling into the hands of miscreants. These hazards can be eliminated through use of L. O. X. L. O. X. have certain disadvantages. They are not so convenient in inaccessible parts of a mine, nor have they been used successfully for shaft-sinking, or under water. Under no circumstances should they be used in gaseous or dusty coal mines. We may still look forward to important improvements through research in this interesting development of a valuable commercial use for one of the constituents of the air which surrounds us.

Based upon information supplied by Galen H. Clevenger, Consulting Metallurgist, U. S. Smelting, Refining & Mining Co., Boston, Mass. Details can be found in a paper by Michael H. Kuryla and Galen H. Clevenger, presented to February, 1923, meeting of American Institute of Mining and Metallurgical Engineers.

COMBATING MOSQUITOES BY MEANS OF FISHES

Minnows, et al. vs. Wrigglers

J. PERCY MOORE

Measures aiming at abatement of mosquito nuisances have generally been directed at the aquatic stages of the insect's life as being the more vulnerable and concentrated. Such measures may be roughly contrasted as extermination and control. Under the former fall land drainage and filling. They aim at complete destruction of the aquatic habitat and permanent prevention of breeding. Exterminative methods are effective but crude, inasmuch as along with the mosquitoes they destroy all associated animals and plants. Methods of control employ a variety of mechanical, chemical, and especially biological agencies. They introduce or strengthen factors detrimental to mosquitoes, or remove or weaken favorable factors, and thus prevent or limit production without destroying the habitat. They are modifying and corrective and their ideal is to reduce the maturation of mosquitoes to a minimum with least damage to associated life.

Methods of extermination are well suited to conditions in centers of human population but their application is limited. Wherever it is desirable to preserve natural conditions, control is indicated. Extension of antimosquito campaigns into suburban and rural districts calls for methods both inexpensive and effective. The rising conviction that swamps and other minor inland waters are present and prospective assets demands that a limit be placed upon indiscriminate drainage.

Under this urge the U. S. Bureau of Fisheries investigated the biological control of mosquitoes. It was known that certain small fishes were mosquito-eaters and some advantage had been taken of this knowledge. In the South the conditions of utilization of the top minnow (Gambusia) were worked out especially by S. F. Hildebrand and this little fish is now used extensively and satisfactorily in the anti-malaria crusade. In the North practically nothing was known of the actual value of freshwater fishes as mosquito repressors and opinions differed greatly. Here the investigation was organized on a broad observational and experimental basis covering a variety of conditions and particularly 29 species of fishes.

Among the most significant experiments were those which admitted fishes to areas from which they had been debarred, or excluded them from areas to which they had had access. In the former case the aquatic stages of mosquitoes quickly diminished in numbers or disappeared and simultaneously were found in the stomachs of the fishes. In the latter case wrigglers usually appeared in large numbers where none had been before. As an index to the comparative rate of breeding at different points or on successive days 10 samples of water of 3 to 4 ounces each were taken at each observation, the mosquito egg-boats, larvae and pupae in each counted and the whole averaged. Thus in one area in which the breeding rate was 32 on July 10, when young sunfishes were admitted, it had fallen steadily to less than 4 on July 24, while in the areas from which fishes were still debarred it was 28.

Were it not for the check by fishes in most ponds and similar waters, mosquitoes would become everywhere intolerable nuisances. This control varies from complete suppression, along clean open shores, through diminishing control under less favorable conditions, to shore lines lost in plant-grown swamps, where it may cease altogether. Imperfect suppression is due chiefly to barriers which prevent the fishes from reaching the mosquitoes, or to a superabundance of food so that mosquitoes are sought less eagerly by the satiated fishes. The most prevalent barriers are dense shallow-water and marginal vegetation, flotsam which lodges along the shores, and pollution of the waters, chiefly of human origin. If these are removed or corrected, the control immediately increases in effectiveness. A simple method of reducing marginal vegetation in ponds controlled by dams is to lower and raise the water level, thus alternately drying and drowning the plants. Reduction of the per capita food supply is best accomplished by overstocking with small fishes. As young fishes are by far the most effective, rapid multiplication should be encouraged. The most useful species for New England and Middle States are the common sunfish for ponds and lakes generally, the mud minnow for swampy areas with much decaying vegetation, and the common killifish for marshes. Other species may be combined with these or employed for special purposes. Use of fishes is much less expensive than draining or oiling, may be made nearly as effective and under most conditions is preferable.

Prepared by Prof. J. Percy Moore, Department of Zoology, University of Pennsylvania. (For further information consult Public Health Bulletin No. 114 of the U. S. Public Health Service and Bureau of Fisheries Document No. 923.)

THE GEOPHONE

Hearing Through Rock and Earth

ALAN LEIGHTON

The geophone is a sound-ranging instrument invented by the French during the war. The form of the instrument was developed by the U. S. Army Engineers and the U. S. Bureau of Standards. Later the sensitiveness of the instrument was increased by engineers of the U. S. Bureau of Mines. The instrument is, in principle, a seismograph and is entirely mechanical in its action. The geophone consists of a flat iron ring about 3½ inches in diameter and ½ inch in thickness, in the center of which is suspended a lead weight fastened with a single bolt through two metal discs, or diaphragms; one of these diaphragms covers the top, the other the bottom of the iron ring. There are two brass cap pieces, the top one having an opening in the center to which is fastened a rubber tube leading to a stethoscopic earpiece.

If the instrument is placed firmly upon the ground and there is any pounding or digging in the vicinity, the case of the instrument will vibrate with the earth. The lead weight, because of its mass, will, however, remain comparatively motionless, since it is suspended between the elastic diaphragms. There is thus produced a relative motion between the diaphragms and the case. This motion alternately compresses and rarefies the air in the spaces between the cap pieces and the diaphragms. The air waves thus set up within the instrument are then transmitted to the observer's ears by means of the rubber tubing and the ear-pieces. The small enclosed air-space in the bottom of the instrument, between case and diaphragm, serves to dampen the vibrations of the diaphragms. It is customary to use the geophones in pairs, connecting one instrument to each ear. The direction of a sound from an observer can in this way be determined with considerable accuracy on the bi-naural principle of direction determination, as has already been outlined in Research Narratives No. 18 and No. 51.

The diaphragms in the original instrument were mica. It has been shown, however, that metal diaphragms are more sensitive and more durable. A nickle diaphragm 0.025 inch in thickness is perhaps best. The thickness of the diaphragm is apparently limited by the ability of the enclosed bottom air pocket to prevent undue vibration.

To give some idea of the sensitiveness of the instrument, it may be said that under suitable conditions sledge pounding has been detected over three thousand feet through solid rock in a western metal mine, that the same pounding has been detected two thousand or more feet through coal, five hundred feet through mine "cover," and about three hundred feet through clay. External noises, such as those caused by light winds, or machinery running nearby, greatly interfere with the successful operation of the instrument. The characteristics of the sounds are transmitted very accurately through the geophone. This means that one can easily judge the nature of the machine or instrument making the sound. Talking can be heard through an ordinary 50-foot coal pillar with about the clearness of the old-fashioned phonograph.

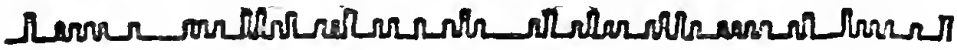
While the geophone was first used to detect the under-ground mining operations of the Germans, it has been successfully applied to many peace-time purposes. The instruments may frequently be of value in locating and rescuing miners who have been entombed in a mine disaster. They have also been used successfully in establishing roughly the relative positions of approaching tunnel headings, and may thus serve to prevent accidents incident to blasting through unexpectedly. They can frequently be employed in determining the drift of churn-drill holes, and experiments with diamond drilling seem to indicate that under certain conditions they would serve the same purpose with such drills. While it might not always be possible to follow the drill from the surface, it is certain that if the hole were being put down ahead of accessible workings the geophones might be useful. Under exceptional conditions they have served in locating mine fire areas. Usually the sounds from such a fire are too weak to be transmitted any great distance. Most satisfactory results have been obtained in locating water-pipe leaks, and one mining company reports success in locating leaks in compressed air lines buried along their entries. They report, however, that they were unable to detect the very smallest leaks.

Contributed by Alan Leighton, Physicist, Bureau of Mines. Full details regarding the geophone and its operation are given in Technical Paper 277, U. S. Bureau of Mines, "Application of the Geophone to Mining Operations."

EXPEDITING ELECTRICAL TRANSMISSION OF MESSAGES

A Universal Telegraphic Alphabet

GEORGE O. SQUIER



T H E S Q U I E R A L P H A B E T

Messages are conveyed electrically by land wires, submarine cables and the ether (wireless). Ever growing demands upon the wires led to multiplex and machine telegraphy, multiplying capacity. Ocean cables are costly; doubling the rate of sending messages is equivalent to saving a cable. There are ship lanes in the northern Atlantic. Crowding automobiles in city streets have necessitated traffic lanes. Aviation is establishing lanes in the air. Allotting of lanes in the ether has become urgent. Broadcasting messages and music is an every day practice. Wireless power has been a limited possibility for several years. Use of radio for range-finding, navigation, and other purposes, demands additional ether channels. Scientists believe we are on the threshold of photo-broadcasting. Collisions in the ether have become annoying, if not so disastrous as those on sea and land and in the air.

Transmission in the ether is by forms of motion likened to waves. In length ether waves vary from distances too minute for ordinary conception to thousands of feet each. Wave-length is a familiar term in wireless. Due to rapid expansion of radio telephony and telegraphy, problems of interference press for solution. Among artificial disturbances the chief offender is the radio telegraph; it is impossible to tune out a high-power station, especially when one's receiving station is nearby. Morse signals are emitted from transmitting antennae as sudden interruptions or variations in antenna current, producing disturbances among the worst possible, because having no regularity.

In 1913, Squier of the U. S. Army Signal Corps, commenced investigations for improving transmission of the telegraph alphabet. In the Morse alphabet, invented about 80 years ago (before telephone, alternating current, and radio), dots, dashes and spaces are made by permitting current to flow different lengths of time. Squier redesigned the telegraphic alphabet, having regard for these three new Arts. In the Morse code the current is interrupted between signals; with the new system, the current flows uninterruptedly. Establishment of a uniform alphabet for all branches of telegraphy would result in great economies.

Squier based his studies upon the conception of an ocean cable as a power transmission line. He selected apparatus, a form of current, and methods which would deliver power most efficiently. A single-phase, alternating current of convenient frequency (number of alternations per second) was chosen, one that would trace a sine curve on a paper tape (a sinuous line curving from side to side of a straight line). In cables it is important that the expensive insulation shall not be endangered, particularly in deep water, where repairs are slow and costly. By the new method, the higher the speed of transmitting at a given voltage, the safer the cable from electrical strain. For cables all signals should represent equal times; consecutive signals should not be of same sign (traced on same side of middle line of the tape); all letters should be equally legible; the total quantity of electricity put into the cable should be as nearly as possible equal to zero for any two consecutive signals (i. e.: first positive, then negative). The ideal solution for power transmission comprises each condition stated, has advantages in cable safety, and greatly increases message capacity. Dots, dashes and spaces (i. e., their equivalents) are transmitted by impulses of either sign, differing only in amplitude (distance of crest of curve from center line of tape). Taking advantage of the paradox of alternating current, that although flow is continuous, there are regularly recurring instants when the quantity of current is zero, at change of sign (when the sinuous line crosses the center line), operations can be performed when there is no current.

The new continuous-wave system can be applied to radio telegraphy. Variations for dots, dashes and spaces are reduced to the minimum, on the theory that the least practicable change of the fundamental wave should be made. For easier reading the waves have been made square-topped, as shown on page 34. By present methods a large flow of current is interrupted or changed in the same message at all values from zero to maximum, positive or negative. Operating upon a current ranging from zero to hundreds of amperes, veritable eruptions occur in the ether.

The modulating frequencies employed in the new method being of low order, it should be simple to devise instrumentalities to differentiate between them and the higher frequencies of "static" or other natural disturbances. A modulating frequency of 60 cycles per second (a normal electric power frequency) corresponds to a speed of 450 words a minute.

If this speed is too great, make the same perforations in the transmitting tape correspond to a suitable even multiple of a semi-cycle of current to reduce the speed as desired. Radio engineers have utilized the audio frequency range and several octaves of radio frequency. This new plan proposes to enter the unused infra-audio range, not only adding a useful band of frequencies, but one below the range of the human ear. If employed for telegraphy, this band could not interfere with radio telephony receiving. It is possible to modulate a single radio frequency by a number of modulating frequencies, and thus multiply the capacity of each radio frequency channel (increase traffic in each ether lane without collisions).

National legislation and international conferences are now in order to put into use these methods of relief, to establish this simple universal alphabet. Science and Commerce will not hesitate. Is Statecraft ready to perform its function? Radio engineering is leading the peoples of the Earth toward a common language, a mutual understanding.

Based upon information supplied by Major General George O. Squier, Chief Signal Officer, U. S. Army.

HUMUS FROM GARBAGE

Inoffensive Waste Disposal

JULES BREUCHAUD

For generations, men have sought to return to the soil some of the nutriment taken from it. In the main, Man's organic wastes have been lost, especially from communities. Indeed, they have been a nuisance or a menace unless destroyed. Often they have been removed long distances only to pollute streams, harbors or idle land. Science and engineering have offered many methods for disposal of sewage, garbage and other wastes. One of the problems has been to devise simple, inexpensive and safe means suitable for small communities, institutions or single families, yielding an inoffensive and useful product. High cost of fertilizers, caused by the war, gave new impetus to endeavors in some European countries.

A few years ago, an Italian scientist, who had worked on the problem for a long time, Giuseppe Beccari, discovered that in a properly constructed cell of cement concrete or other tight masonry, natural processes of fermentation could be so controlled and expedited as to reduce kitchen wastes, animal carcasses, grass clippings, fallen leaves, stable manure, and human fecal matter to humus without disagreeable odors or other offensive features. No fuel nor chemical is required. Aerobic bacteria do the work. All disease germs of man, beast and plant, all weed seeds and parasites are destroyed. Gustavo Gasparini and other scientists have confirmed by extensive tests the results gotten by Dr. Beccari. The zymothermic cells are in practical use in a number of places in Italy.

After a cell has been filled, the temperature begins to rise on the third day, and in a comparatively brief time attains 140 to 150 degrees Fahrenheit. Maximum temperature, between 150 and 160 degrees, is reached about the 10th day, holds nearly constant for 20 days and then falls slowly. Fermentation is complete in from 35 to 45 days, depending on atmospheric conditions and the nature of the wastes. By the 35th to the 45th day, the product is sufficiently cooled to be drawn out to a bin in front of the cell, or other convenient place, where, exposed to sunlight, the excess moisture dries out. The product then resembles loam. Bones, objects of metal and ceramic wares are not affected; they are removed by screening. Of course, it were better to keep them out of the garbage in the beginning, particularly tin cans and broken crockery. Carcasses of animals are reduced to skeletons (entirely free from flesh and cartilage) and a small humid mass. At no time during the process is there odor of putrid flesh.

The inoffensive black humus yielded by the cells may be used as an enricher of the soil, restoring some of the properties taken out by crops. It is a good fertilizer, containing nitrogen, phosphate and potash.

Each cell is an approximately cubical masonry box of from one to 25 cubic yards' capacity, according to requirements of each installation. Larger plants are made by grouping cells in series. Each cell has a double floor, the lower one water-tight, and the upper, a concrete grating. Through the outer wall, between the two floors, are air inlets. In the four interior corners are vertical air ducts with openings at regular intervals connected with horizontal air passages formed by ridges on each wall, projecting a few inches. All these air ways, and the space at the top of the cell, over the charge of wastes, connect with a specially constructed ventilation tower surmounting the cell and having opening to the atmosphere. Wastes are put in through an opening in the top of the cell. The product is removed through a large opening in the front wall controlled by a tight door. The liquor from the charge during fermentation is collected by drains from the lower floor into a pit. This liquor contains many of the bacteria of fermentation and is used for wetting new charges so as to assure and expedite the beginning of the process. The exact form and arrangement of the cell was determined by years of experimentation.

Although an outgrowth of the compost heap, common in gardens for centuries, the zymothermic cell is a product of scientific research and engineering design. Success appears to be due in large measure to the arrangement of air passages which distribute air to all parts of the contents of the cell.

Based on information supplied by Jules Breuchaud, J. Waldo Smith and E. Payson Cooke, of the American Beccari Corporation.

HUMAN MOTION STUDY

WITH SCALE CAGE AND CAMERA

FRANK B. GILBRETH AND L. M. GILBRETH

In work and sport there is a best way. It is that way by which the highest score can be made with least effort in shortest time. How can it be learned? The economic advantage of knowing in industry is greater production, with conservation of human energy. All operatives cannot attain the highest score, but knowledge of the best way should help everyone. Even the score of the best untutored "expert" may be improved by analytical study. The scientific method of improving an art is to gather facts by observation or experiment, make reasoned deductions and then test the deductions. Measurement of some sort is always involved. How shall one measure the motions of the bricklayer, the machine operative, the golf-player? For the purpose in mind, measuring must not even suggestively interfere with motion. Measurements must be in three dimensions. The camera has been used,—ordinary, stereoscopic, motion-picture. And how measure three dimensions on a flat plate? Floors and backgrounds with regularly spaced lines in two directions have been helpful in some situations, but are not practicable for others.

Recently the scale cage has been devised. It is quite simply constructed of pieces of wood one inch square, hinged so as to be folded together for convenience in carrying. As set up for use the scale cage may be 6 feet long, 3 feet wide and 3 feet high. It can be placed so as to be included in the picture or it may be inserted on the foreground or background subsequently. After the pictures have been taken, they can be projected at any speed desired upon a screen with a rectangular system of lines (cross section paper) so that the lines of the scale will coincide, at any point desired, with the markings on the scale cage according to the distance and angle that the screen on which the pictures are projected is held to the line of light used for projecting. The possibilities of this device will be apparent at once, even to persons not familiar with motion study of human behavior.

A most interesting application of the scale cage has been made in the study of imbeciles. A practical industrial use of the knowledge gained grows out of the facts that many persons are absent minded and it has been learned that absent minded persons behave for the moment similarly to the motion behavior of imbeciles. Motions of epileptics in seizure are now known to be largely automaticity of habit formed during periods of consciousness. The motions of the normal man not trained in the best way to do work to a point of automaticity are also full of indications and registrations of indecision that are identical with those of the sub-normal.

Bricklayers of ordinary training have used the same methods probably for 7000 years. The berry picker, the most ancient of craftsmen, has followed simple natural methods for hundreds of thousands of years. Studies of these workers give no indication that the best way to do work is a matter of instinct, or is developed through successive generations by natural processes. By finding out the best way, as demonstrated by the most expert worker, the brick-layer can be trained to do more than three times as much work with the same effort. The amateur berry picker most highly educated in everything except berry picking and motion study, may be so trained as to increase his output fifteen fold.

During the present generation, a beginning has been made in recording exact data of the arts, trades and professions. Many mental processes too may now be recorded by photography. The fact that one's thoughts are constantly changing is the reason why no two photographic records are exactly alike. The fact that the moron makes cycles that are nearest alike furnishes interesting data on monotony.

The scale cage is offered by the inventor, Frank B. Gilbreth, without restriction, as one more device for recording the sequences of motions which make up the skill of the superlative workers and as a means for determining the great waste resulting from inefficient, ill-directed and unnecessary motions.

Based on information supplied by Frank B. Gilbreth, expert in motion study, and Dr. L. M. Gilbreth, industrial psychologist.

MEASURING WATER WITH SALT AND ELECTRICITY

A Simple Method for Pipes, Aqueducts, Canals and Streams

CHARLES M. ALLEN

Measurement of large quantities of flowing water is at last being reduced to the simplicity which the uninitiated would think obvious. To be sure, there have been, for many years, good meters and other measuring devices,* but in many situations these are impractical or too costly. Modern hydro-electric power plants use water in enormous quantities. For example, a water wheel was recently tested with a discharge of 3500 cubic feet per second, or three times the quantity of water used by the City of New York, with its population of six million persons. High efficiency in power development is most important, but the degree of realization can be known only through precise measurement of the quantity of water and its fall through the turbines or water wheels. Some of the methods of measurement have not been satisfactory in degree of accuracy. The most accurate method (almost perfect) is weighing in tanks on good scales. Manifestly, it is quite impracticable in many situations.

Professor C. M. Allen, of Worcester Polytechnic Institute, has recently added a method which is giving results of remarkable precision. Like other methods of modern science for measuring quantities of many kinds, it is indirect. It depends upon the fact that common salt increases the electri-

* See Research Narrative Number 53.

cal conductivity of water in proportion to the quantity of salt dissolved in the water. The salt velocity method consists in accurately timing between two known points the passage of a charge of brine which has been injected into the water at a point upstream. Dividing the volume of the conduit between the two points by the time of passage gives the rate of flow, or discharge.

For introducing the salt, a strong brine is injected under pressure at an upstream point through a system of small pipes so placed as to give approximately uniform distribution in the cross-section of the conduit. At one or more convenient places downstream, electrodes are inserted in the conduit and used to detect the changing conductivity of the water as the brine passes. The timing of the passing of the brine is done by means of a stop-watch or recording seconds clock and indicating or recording electrical instruments.

The instant of introducing the brine may be registered by a switch operated in conjunction with a quick-opening brine introduction valve, or by a pair of electrodes placed just below the brine distributing system. The times of passage by the downstream points or sections of the conduit are obtained by the use of one or more pairs of electrodes inserted in the conduit at each point.

The recording chart can be run at various predetermined speeds to suit the conditions of the test. All events can be registered mechanically or electrically on this chart, including time of introducing brine, passing of brine by one or more electrodes, and the elapsed time in seconds. From this chart, the actual time of the passing of the brine is obtained.

Comparative tests of the salt velocity method with the

Venturi meter, the weir, and the weighing tank, show it to be very accurate. It requires no unusual equipment for controlling the flowing water, no huge tanks and scales, no long interruption of the operation of the power plant in which the water is being used.

This method may be compared to the submerged float method of measuring the quantity of water flowing through canals of uniform cross-section, by which the mean time of passage of all the floats between two known points gives the mean velocity of flow.

With the salt velocity method there is almost an infinite number of truly submerged floats, and by timing the passage of the center of gravity of the salt solution charge, the true mean velocity of the water flowing is obtained.

Experiments were recently made on an 8-foot pipe line over 3 miles in length with four pairs of electrodes installed in the line. About fifty minutes were required for the charge to pass through this pipe. Time of passage was accurately recorded at each pair of electrodes, the last pair giving as distinct a curve as any of the others.

Although this method of measuring water has been used as yet only at power plants, it is equally applicable to pipes, flumes and conduits for water supply and irrigation, and even to the measurement of stream flow.

Based on information supplied by Prof. Charles M. Allen, of Worcester Polytechnic Institute, member of American Society of Civil Engineers and American Society of Mechanical Engineers.

SUPREMACY OF ARTIFICIAL LIGHT

Advantages Due to Ease of Control

M. LUCKIESH

For countless centuries man evolved under natural light which was adequate and to which he had become adapted through the natural processes of evolution. As long as man remained outdoors, daylight was free but he could not control it. Nature is whimsical and provides many kinds of lighting such as overcast sky, blue sky and direct sun. Furthermore, natural light is at best limited to certain hours of the day. As civilization advanced man came indoors and thereby introduced a degree of control over natural light during the hours that it was available. However, indoors daylight was no longer without cost and artificial light became necessary for extending the hours of activity.

For many centuries artificial light was obtained from feeble flickering flames so that from a lighting viewpoint we have just emerged from the dark ages. Further, the present age of adequate and completely controllable artificial light has come so suddenly and so recently that it has found mankind unprepared and fettered by habits to such an extent that he is not applying the possibilities of artificial light to their full extent. Artificial light can be completely controlled in intensity, color, distribution far beyond natural light, owing to marvelous scientific developments. Furthermore, in this struggle of civilization against Nature, artificial light costs only one or two per cent as much as it did a century ago. And while the cost of artificial light has steadily decreased and its controllability has rapidly increased, the growing complexity of our economic life has increased the cost of natural light indoors and has, to some extent, even decreased the meagre control we have enjoyed over it during its hours of availability.

Now artificial lighting, in general, costs less than natural lighting indoors and from the viewpoint of controllability it is very superior to natural lighting. We can now reproduce daylight artificially and can in most cases greatly improve upon daylight from the viewpoint of distribution and proper lighting in general. We must charge to natural lighting the additional cost of windows and skylights; their maintenance; the additional heat losses and the necessary additional capacity in heating plants. We can also charge to natural lighting some of the cost of artificial lighting where and when daylight is inadequate. In our congested cities certain wall areas, light-courts and ground area add greatly to the cost of daylight. Finally if we should also include the cost of fading and depreciation of interior decorations, furnishings and art treasures due to natural light the cost in many cases becomes stupendous.

We want daylight when we can obtain it adequately and at reasonable cost but we should recognize its cost and shortcomings. Our complex city life calls for compromises and also for much nightwork. Almost everywhere indoors we need artificial light at night and in many places by day. Those interested in building will do well to consider seriously the cost of daylight and its inadequacy in many places and to reflect upon the demands of the present age for good lighting. Artificial lighting has advanced far beyond natural lighting and has great possibilities in reducing the cost of living by increasing production in offices and factories through better lighting and continuous or at least two-shift operation. It can decrease rent in congested districts by reducing cost of operation and by conserving floor and wall space. The age of windowless buildings has arrived in certain highly congested places. How about ventilation and sanitation? They also have not been forgotten in the present struggle between the artificial and the natural.

The activities of primitive man were practically bounded by sunrise and sunset. Doubtless light was merely a by-product of the fire whose primary function was to furnish heat; nevertheless we may imagine primitive man with his burning pine knot exultant in his victory over Nature. Man's activities were no longer limited to daylight hours and greater opportunities were before him. Unnumbered centuries elapsed between the first burning fagot and the advent of the grease lamp and the wax candle. It is difficult to note the place where science entered the field of light-production. In a sense it has always been present for that which changes the mysteries of today into commonplace facts of tomorrow is science, in whatever guise. Science as we define it today attacked the problem of light-production in an organized manner not many years ago. The industrial progress of the past century is coincident with the great progress in light-production.

Contributed by M. Luckiesh, Director, Laboratory of Applied Science, National Lamp Works of General Electric Co., Nela Park, Cleveland, Ohio.

AN ELECTRON GUN

An Instrument for Directing a Stream of the Smallest Bodies Conceived To Have Separate Existence

J. B. JOHNSON

Have you ever seen electrons pattering against a glass screen, like bullets from a machine gun on a distant target? Of course, one cannot see either the electrons or the bullets, but only their effect on the target. An electron is the smallest thing yet conceived as having existence as a separate body. Physicists estimate the diameter of an electron as a very small fraction of the wave length of light, itself about one fifty-thousandth of an inch. These tiny corpuscles of negative electricity and the relatively much larger positive ions are believed to be ultimate constituents of matter.

By processes now in daily use electrons can be separated from the atoms of some substances. Cathode rays, or streams of electrons, can thus be produced. Electrons have velocities which may be almost as great as 186,000 miles per second, the velocity of light. Notwithstanding inconceivable minuteness and great speed, electrons are in a measure controllable and are used in many ways every day. Apparatus for dealing practically with things so intangible to our unaided sense partakes of the fascination of magic.

Many devices have been made to employ the properties of electrons both in physical research and in the industries. One might mention the three-element vacuum tube whose use in radio has made it a household article. Another device is the low-voltage cathode ray oscillograph, devised about two years ago by Dr. J. B. Johnson in the Bell System Laboratories of the Western Electric Company.

For this particular oscillograph conceive a pear-shaped clear glass bulb with a long cylindrical neck and a carefully rounded big end, nearly flat. The inside of the big end is made a fluorescent screen by coating it with a paste of suitable materials. Wherever and while electrons impinge on this screen, a brilliant spot or line of greenish light appears.

At the base of the neck is the "electron gun"—not an old-fashioned blunderbuss, but a modern machine gun concentrating its fire within a small circle. With an electric current flowing, the electrons are shot off from a small cathode made of oxide-coated platinum ribbon in the form of a loop with its closed end bent into a ring at a right angle to the electron stream. To reduce damage to the filament from the blows of relatively heavy positive ions, this form permits them to pass the main portion of the cathode with relatively few "direct hits."

Immediately above the cathode is a metal shield with a tiny hole through its center. Directly above this hole is a thin platinum tube one millimeter in diameter and one centimeter long, which is the electrical anode and also the barrel of the "gun." It points towards the center of the target, or screen. The whole "gun," its electrical connections and its appurtenances are sealed into the tube airtight. An almost perfect vacuum is created inside the tube and then a very small quantity of argon gas is admitted. This gas helps greatly in concentrating the fire of electrons on a definite spot.

In the directing of its fire the electron gun differs from the ball and powder variety. The electron gun is not swung about, but its stream of projectiles is deflected by means of electric or magnetic forces. The deflectors consist each of two pairs of small parallel metal plates. One pair is at right angles to the other, while both pairs are parallel to the axis of the gun, which is the direction of the undeflected electron stream. The deflector is a short distance above the anode (the barrel of the gun). Therefore the stream of electrons passes between the plates of each pair.

The usefulness of this tube oscillograph comes from the fact that the stream of electrons forms a nearly weightless pointer whose movement will accurately follow the changing conditions in the circuit to which it is connected. No frequency that can be produced in an electrical circuit is too high for this pointer to follow. Thus we can study the shapes of electrical waves from the lowest frequencies of power generators up through the speech range to the highest radio frequencies. This is very useful in generator design, in telephone engineering, in testing magnetic properties of materials, in radio, and in classroom demonstrations of all sorts of electrical phenomena.

Based on information supplied by Dr. J. B. Johnson, physicist, Research Laboratories of Western Electric Company, New York City.

LAKE BASKUNCHAK SALT

A Naturally Replenished Russian Deposit

R. S. BOTSFORD

During the last drive of the Russians against the Poles, large numbers surrendered on being given salt with some food, the salt being the inducement. Dyaks in Borneo fighting inland against Rajah Brooke surrendered when they ran out of salt to eat with their rice. A hostage chief I took out shooting at the coast accidentally put his finger wet with sea water into his mouth and cried out: Tuan, it is salt.

The great fishing industry on the Caspian Sea, in Astrakhan at the mouth of the Volga, is tied up with production of salt on Lake Baskunchak, 35 miles east of the river, 150 miles upstream. Disorganization resulting from war, by reducing production of salt and curtailing shipment of salt fish greatly augmented the recent famine.

Baskunchak salt industry has come down from antiquity, methods unchanged. Companies worked in allotted areas. Early in the war, groups of fishermen controlling 2500 boats combined to get at reasonable cost a constant supply for their fish and caviar, transported all over Russia. They got salt cheaply but wages rose and workmen were scarce. They desired therefore to harvest salt by machinery. My examination led to the method described below.

Baskunchak Lake is oval, 38 square miles area, served by a double-track railroad from Vladimirsky Pristan on the Volga skirting three-fifths of its circumference 30 to 150 yards from the edge, 7 feet above lake level. The region is arid. During the winter, the lake is covered with brine from rain percolating through surrounding hills so that for 150 to 400 yards from shore the salt is submerged 2 to 3.5 feet and the remainder about 1 foot, varying with the season; it is too cold to go into the lake, although the brine rarely freezes. During May and June, the brine evaporates, leaving the lake dry except for the rim, which remains about 1.5 feet deep, shading off towards shore and the center, which becomes quite dry, often slightly rippled and appears like ice. There is a hard layer like rock-salt all over the lake, with occasional softer spots, in the center 8 inches thick, but 4 feet at 400 yards from shore, getting less as shore is approached. Near shore the surface is soft.

On breaking through the hard layer brine rises to within 4 inches of the surface; beneath it clean translucent crystals are found locked together so that the salt must be disintegrated with tools before it can be shoveled up by workmen standing either in brine or on a plank straddling the hole. The brine circulates below the layer and so pumping does no good. The common salt has crystallized out leaving the bitter salts (glauber and others) in solution. Some prefer salt from the center below the hard layer, some prefer the layer, and many the soft deposit each season.

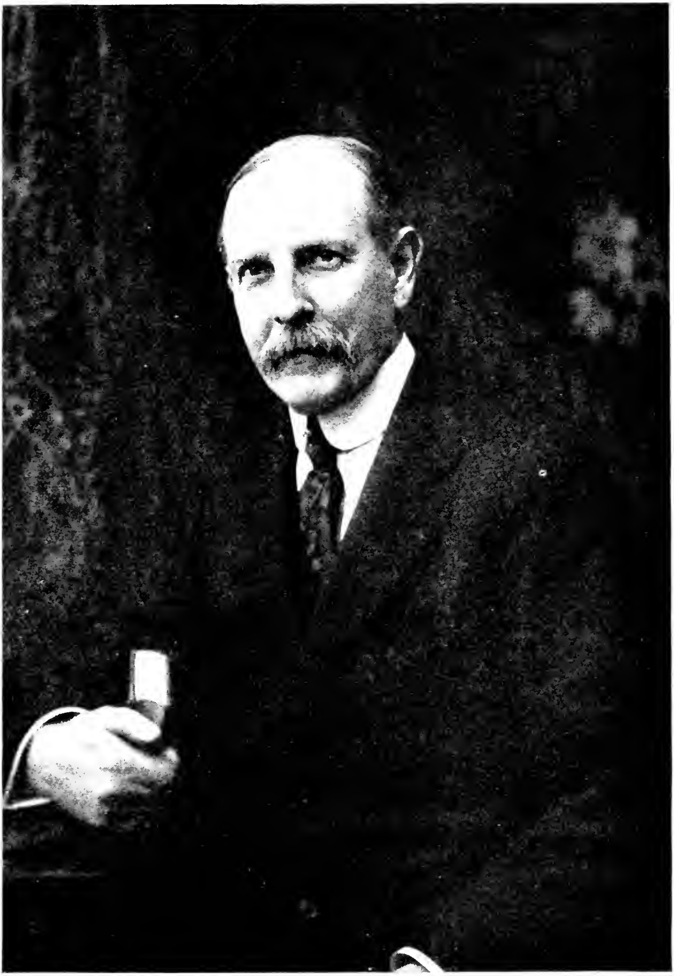
As soon as it got warm enough and the depth of brine lessened, workmen commenced at the edge scraping up the soft deposit with shovels, rinsed it and loaded it into small carts. Soon, some 5000 workmen were operating. Depending on the variety ordered they worked in the shallow brine or on the dry center, and scraped up surface salt, dug the hard layer, or the salt below, rinsing when necessary, draining, and then transporting in camel carts to shore, where it was stacked beside the railroad ready for transportation to the river. Here it is crushed to $\frac{1}{8}$ inch, loaded into barges and dispatched, mostly to Astrakhan. Surface salt as well as the hard layer is somewhat dull in appearance and contains dust. Newspapers raised question of pollution from the camels; it was evident that soon animals would be restricted from going on the lake. Cost of stacking salt 20 feet high on both sides of the track had been 23 cents per ton; in 1915, was $1.00; in 1916, $2.50; in 1917 so high as to discourage hand work and little was done, with disastrous effects on the fish industry. Requirements were half a million tons yearly, increasing to three-quarters. Owing to the brine no salt had been obtained below 6 feet, but it improves with depth. Borings near the middle of the lake penetrated 210 feet without reaching bottom.

The new method was to cut a hole well out from shore, where the salt is cleaner and the hard layer thinner, float a dredge to excavate the salt, piling it beside the cut to drain for a fortnight (an essential condition), and to construct a branch railroad alongside, loading the drained salt into cars, moving the track with successive cuts. Wooden ties are preserved by the brine and steel not seriously affected. Both dredge and shovel were oil-fired, with condensers to economise water, oil from Baku easily obtainable. The dredge and shovel were obtained, but did not reach the lake because of stoppage of transportation in 1918. When operations become possible, a central electrical power plant will be more economical.

Baskunchak is a truly remarkable lake with an apparently unlimited supply of salt suitable for use without refining.

Holes excavated filled in a year or two with new salt. And yet people starved for lack of salt to make the abundant sea food transportable.

Contributed by R. S. Botsford, Member, American Institute of Mining and Metallurgical Engineers, Engineer in Charge.



Arthur Edwin Kennelly

Professor of Electrical Engineering, Harvard University and Massachusetts Institute of Technology. From 1887 to 1894, principal electrical assistant to Thomas A. Edison. Member, National Academy of Sciences; Chevalier Legion d'Honneur, etc. Author of many treatises on electrical subjects. Narratives 1 and 100.

LABORATORY LIGHTNING

A Powerful Imitation Used in Studying Means for Protection

F. W. PEEK, JR.

Benjamin Franklin drew lightning from thunder clouds with a kite, a string, a key—and certain precautions.* Repetition of this experiment is not recommended to uninitiated seekers for electrical truth. Nowadays, experimenters produce lightning equivalents in the laboratory, under control. By these means physicists and electrical engineers have greatly improved devices for protecting telephone, power and other electrical lines and connected equipment. They have lessened interruptions to service and destruction of property, and have increased the safety of persons using or working near electrical equipment exposed to thunderstorm conditions. It is not alone direct lightning strokes but also charges quietly put upon the wire lines from the electrically disturbed atmosphere which may do mischief. An investigation has been conducted for several years by F. W. Peek, Jr., in the General Electric Company's laboratories at Pittsfield, Massachusetts, on the effect of transient, or lightning, voltages (electric pressures) on dielectrics (insulating substances).

Lightning voltages, starting at zero or the usual voltage in the wire line, may increase at the rate of millions or billions of volts per second; but the impulse is quickly over—a millionth of a second.

* So ran the old tradition, now questioned.

Beginning with a specially designed generator of moderate voltage and power, Peek increased the voltage and capacity of his generator from time to time until, during the past year, he could produce voltages higher than most lightning voltages induced on transmission lines, with a power that might instantaneously reach millions of kilowatts. In other words, 2,000,000 volts are available and single lightning strokes can be obtained that increase at the rate of 50 million million volts per second. These voltages are far in excess of any heretofore produced in a laboratory. The generator discharges with a loud, sharp report. Large wooden posts are readily split by the discharge. Photographs of the flashes show all the characteristics of lightning. But when it is considered that two million volts bridge only a few feet, the voltage of the lightning bolt from cloud to cloud or cloud to ground must be exceedingly high. It seemed necessary to approximate actual conditions in order to give the research high practical value. With this apparatus short lightning bolts have been produced, photographed and studied for their various effects upon transmission lines, insulators and protective devices.

One feature of protective devices for electrical apparatus is the gap, an air jump for the lightning current. The object of "lightning arresters" is to afford an easy path to ground for lightning voltages before apparatus is destroyed. The metal electrodes, or terminals of the wires, forming the sides of gaps are given various forms and have different properties depending upon their forms. Spheres, for example, perform differently from needle points. Spheres, in fact, permit a lightning voltage to pass readily, while points do not. One product of this research is an electrode made up of a sphere, a horn and a point. The lower the voltage at which a given arrester gap can be set, the greater its protective value. In practice, the setting must be such that the gap does not discharge (spark-over) under any normal operating condition. When gaps are outdoors, additions must be made to the setting to overcome the reducing effect of rain or moisture. The effect due to moisture differs greatly with the shape of the electrodes. It is minimum for points and maximum for plane surfaces. The horn gap is not affected to as great extent as the sphere gap. To overcome this a covered sphere has been devised and gives maximum protection. Combinations of sphere and horn or the covered sphere have greatly increased the protective value of lightning arresters.

A knowledge of the laws governing lightning permit engineers to design apparatus with maximum strength and arresters with minimum discharge path to ground. It usually takes a higher lightning voltage to jump a given gap than a low-frequency voltage (ordinary power current having, say, 60 cycles a second). Lightning voltages are measured by the distance jumped between spheres. Insulation that is not good and even materials that are conductors at operating voltages may be good insulation at lightning voltages. Whether the strings of insulators carrying transmission wires be wet with rain or dry, makes no difference in the voltage when a transient current induced by lightning sparks over a string of the insulators.

Lightning waves travel along a transmission line very much as water waves travel on the sea. When the end of the line is reached, the waves double up as do sea waves on reaching a wall. Although lightning waves travel with the velocity of light, their shape and height is readily measured as they speed along.

Investigations are also being made to determine the best methods of using lightning rods in the protection of buildings, magazines for explosives, and oil tanks.

Long, patiently, skillfully and ingeniously conducted researches like the one which this Narrative barely touches are the means by which the usefulness of electricity to Man is being increased.

Based on Information supplied by F. W. Peek, Jr., member, American Institute of Electrical Engineers, Consulting Engineer, General Electric Company's laboratories, Pittsfield, Massachusetts.

OLD NICK'S OWN METAL

Discovery of Its Canadian Sources

THOMAS W. GIBSON

In superstitious "Middle Ages" troubles were ascribed to unfriendly fairies and gnomes. Saxon miners having difficulty with certain copper ores blamed Old Nick and called the unknown troublesome ingredient kupfer-nickel, the evil spirit in copper. Nickel in old Saxon meant an obstinate person. Bactrian (province of ancient Persia) coins of 235 B. C. show by modern analysis 20 per cent nickel. Chinese, centuries ago, used an alloy containing nickel which they called paktong (peck = white and tung = copper). It was resonant, bright in appearance and resisted corrosion well. Many gongs were made of it and it was exported to Europe. Not until 1751 was nickel isolated as a chemical element and given the old Saxon name by Cronsted, a Swedish metallurgist.

Nickel-bearing ores are found in various quarters of the globe, the greatest deposits of all, in the Sudbury district of Ontario province, not being recognized until a generation ago. They are huge "lenses" of mixed pyrrhotite and chalcopyrite and now produce 80 or 85 per cent of the world's supply of nickel.

In 1856, a Canadian government surveyor, Salter by name, while running a meridian northward from Lake Huron past Whitefish Lake, noted that at certain places his compass was deflected ten to twelve degrees more than the normal deflection. He reported this incident to Murray, a government geologist, who found magnetic trap rock containing traces of nickel, but did not suspect that he was walking over the greatest deposit of nickel ore in the world, so far as has yet become known. Nickel was not then in general use nor in great demand. At any rate casual observation of indications in an inaccessible wooded wilderness excited no enthusiasm among prospectors.

Grading for the Canadian Pacific Railway in 1883 revealed the mineral wealth of the region. Thomas Flanagan, blacksmith in the construction gang, noticed an area on the right-of-way covered with gossan (decomposed rock, usually reddish, owing its color mostly to pyrites). He dug holes and found copper sulphide. When railroad building progressed to this spot, a "cut" exposed the deposit. Thomas Murray and his brother William purchased the "lot" of land in 1884, but sold to H. H. Vivian & Company, of Swansea, Wales, who started the "Murray Mine" in 1889 and a furnace in 1890. Vivian & Company quit operations in 1894, selling the property later for $75,000 to J. R. Booth and M. J. O'Brien. They prospected with diamond drills and revealed a very large body of ore, subsequently estimated at eight or nine million tons. These owners in turn sold to the British-America Nickel Corporation, Ltd., which has worked the property on a larger scale. The first smelter was built in 1888 by the Canadian Copper Company, which added a second the following year.

Copper ore exposures in railroad cuts attracted many prospectors. In three or four years they located most of the important bodies yet found. Among these finds the magnetic deposit noted by Salter and Murray in 1856 was rediscovered and has become the Creighton mine, pronounced the greatest nickel mine in the world. It is operated by the International Nickel Company, successor to the Canadian Copper Company. Of the large number of mines the Vermilion arrests attention because first worked as a gold mine. In 1902, an assay showed 4 ounces of silver, 4 ounces of palladium $1\frac{1}{2}$ ounces of platinum, $\frac{1}{3}$ ounce of gold per ton and the nickel and copper contents unusually high. This deposit, however, is small.

Not until 1887 was nickel recognized in the Sudbury ores, although that is the element which has contributed most to their value. What the geologists and assayers failed to detect was perceived by the smelters. Difficulty in smelting a shipment of ore in the Orford Copper Company's works, at Constable Hook, New Jersey, led to the detection of the nickel in the company's laboratory. S. J. Ritchie, President of the Canadian Copper Company, and R. M. Thompson, President of the Orford Copper Company, happened to be in the laboratory when the discovery was made that their troubles were due to the ancient evil sprite of the Saxon miners. It was unexpected news to both men. They found that they had a great nickel deposit instead of a great copper deposit, or more correctly a great nickel and copper deposit. This discovery changed the whole situation.

Advance of the arts and sciences since 1856 has vastly increased and diversified the demands for nickel, and this development continues. These uses range from coins, the nickel-plating of a great variety of objects, and solid nickel cooking utensils to nickel alloy steels for armor plate of battleships and important members of great modern bridges. Nickel-silver (formerly German silver) is a well known alloy of nickel, copper and zinc. Monel metal is an alloy of nickel and copper, made from the matte (an intermediate, impure product in the process of smelting) without previous separation of the metals. In North America the International Nickel Company is the greatest producer.

Based on information supplied by Thomas W. Gibson, Deputy Minister of Mines, Toronto, Ontario, member, Canadian Mining Institute and American Institute of Mining and Metallurgical Engineers.

SEALING BASE METALS TO GLASS

A New Art Necessitated by Modern Illumination and Communication

WILLIAM G. HOUSKEEPER

A novice will hardly succeed in melting glass to a piece of copper, or other base metal, so that it will stick in spite of changes of temperature. Many careful experiments were made before numerous difficulties were overcome and the art surely established. Various metals and glasses expand or contract differently with the same change of temperature. Ten years ago, platinum was the only readily available metal which had practically the same change in dimension with change in temperature as that of the glass then used for incandescent lamps. Ever since the discovery of the necessity for a vacuum in the incandescent lamp, the use of vacua in lamps, in amplifiers for "wireless" and in other electrical devices has extended, and more nearly perfect vacua have been created in everyday work.

Vacuum containers are mostly of glass, but the conductors of electric current into the vacuum are of metal. For incandescent lamps fine platinum wires were for years fused into the base of the lead glass bulb. Other metals differed so much from the glass in change of dimension for equal change of temperature that platinum was for a long time thought indispensable, although costly.

Growth of demand for platinum, together with increase of size and change of shape of metal parts in electrical devices, made the expense of platinum prohibitive and goaded research men to other solutions. Copper, silver, nickel, iron have appreciably greater thermal expansions than those of the glasses. Consequently round metal rods separated from the glass when they cooled from the high temperature at which the glass had been fused to the metal. The separation might be very slight, but it was sufficient to destroy a vacuum. Tungsten, now extensively used in incandescent lamps, has approximately the same thermal expansion as Pyrex glass, about one-third that of ordinary lead glass. Therefore seals can be made between them.

Then it was discovered that if small copper wire were hammered flat, glass could be sealed to it vacuum tight, the metal being pre-coated with borax to prevent oxidation during the heating. Larger and still larger flattened wires were sealed successfully. Copper foil and sheet copper were tried with good results. Knifelike edges at the sides of the metal strips were found essential. Tight seals, using larger and larger strips of copper but omitting the borax, followed in rapid succession. These preliminary experimental results, gotten by different operators, were so at variance with previous experience that complete chemical and mathematical investigations were carried through.

The adhesion of the glass to the copper is independent of the thickness of either, but the stresses which the joint may have to resist are directly dependent upon the thickness of either or of both. It is not possible to seal a heavy block of copper to a heavy block of glass. It is nevertheless, entirely possible to seal a very thin section of either substance to a large block of the other.

Step by step the art has been developed in the research laboratory of the Western Electric Company until there seems to be no limit to the size of the seals which can be made between metal and glass so long as the parts are duly proportioned and are not too large to be handled properly during the process.

Based on information supplied by Mr. William G. Houskeeper, Member, American Institute of Electrical Engineers, Research Laboratories of the American Telephone and Telegraph Company and the Western Electric Company.

STEEL CASTINGS

Competitors Co-operate in Industrial Research

W. J. CORBETT

Possibilities of improving quality of product and service to customers by intensive research were apparently disregarded until a few years ago. Producers were inclined to enthuse over lowering costs of production rather than rendering their products more satisfactory to consumers at the lowest ultimate cost. For systematically studying various phases of the business in order to produce better steel castings at the lowest possible cost, five independent manufacturers formed the Electric Steel Founders' Research Group in 1920. These companies realized that consumers are beginning to buy on a quality basis rather than invariably giving orders to the lowest bidder. Self-interest blended with desire to serve caused them to organize their resources to undertake research.

Research necessary to improve methods in a steel foundry to the desired extent would cost more than individual companies could afford. By uniting five manufacturers of similar products, and pooling their talents and troubles, an opportunity is provided for extensive co-operative research. Quality of product and methods of manufacture are being advanced with a thoroughness and speed which would be impossible by individual effort.

Formation of this group of separate and distinct companies to conduct co-operative research was an innovation in American industry. A plant will attain high development in the particular phase of the work in which its chief executives excel. By having in the Group, executives of foundries who excel in several phases of the business, each member is able to derive benefits from the others. This promotes development of well balanced methods for each.

Executives of each plant are free to go into any other plant in the group to see how certain processes or operations are carried on, and to get ideas for application in their own plant. During these visits, opinions are freely exchanged and inefficiencies are discovered. Researches to determine the causes and the best methods for increasing efficiency follow. The results of these studies are then transmitted to all the companies in the research group.

Co-operative effort is helpful also in buying new equipment. If a question arises concerning the best type of equipment for a certain purpose, studies are made at different plants on different kinds of equipment. Then operating efficiency and costs are compared and carefully analyzed to determine which type is best.

A large number of technical investigations have been and are being conducted at the various plants. Studies on molding and core sands at Sivyer Steel Casting Co., Milwaukee, Wisconsin, and Fort Pitt Steel Casting Co., McKeesport, Pennsylvania, have furnished valuable data for practical use in making castings of intricate design and thin metal sections. Experiments performed under practical conditions at Michigan Steel Casting Co., Detroit, Michigan, have determined the best practice in heat treating steel castings. Prevention of slag in castings was studied at Lebanon Steel Foundry, Lebanon, Pennsylvania, and the results are being used in practice. Methods of removing "risers" and "gates" from castings are being carefully investigated at Nugent Steel Castings Co., Chicago, Illinois. These investigations, along with many others, are furnishing valuable facts for the Group. They aid materially in producing castings which ordinarily would be considered difficult to make. All five companies give special attention to the physical properties of the castings.

Rigid inspection standards are a notable means for maintaining and improving quality of products. Commercial specifications for steel castings are supplemented by a complete set of inspection standards developed by the Group and governing the entire output of each plant. These standards are paramount in every case. Difficulties in manufacture, selling prices, and other considerations, are subordinated to the inspection standards in the sincere effort to produce the best castings for the purposes intended.

The researches of the Group are decreasing the final costs of castings to consumers. Some consumers have trouble in obtaining sound castings. Their machining costs and losses due to defects in castings are sometimes excessive. Frequently, they believe these to be unavoidable expenses and apparently are satisfied, or else form the opinion that the castings cannot be made satisfactorily in steel. This leads them to use some other material, which may not have the required physical properties to give maximum strength with minimum weight. A thorough study of these deficiencies leads to greater use of steel castings. By reducing the original weight, decreasing machining costs, eliminating breakages and replacements, the utility of steel castings is increased and the final cost is less than that of the material for which steel is substituted. This kind of effort has led to the use of steel castings where formerly it was believed intricacy of design and thinness of metal would prevent making certain parts of steel. Improvement of quality and development in methods of manufacture are extending the use of steel castings for parts formerly made of weaker metals. Activities are guided by Research Director R. A. Bull and Industrial Engineer W. J. Corbett from a central office in Chicago.

Based on information supplied by Mr. W. J. Corbett, Industrial Engineer of Electric Steel Founders' Research Group.

PERMALLOY

An Alloy of Nickel and Iron Possessing Remarkable Magnetic Properties

H. D. ARNOLD AND G. W. ELMEN

One of the most striking features of modern scientific research is the effect on well established arts of developments in fields not, at first sight, closely related. New industries have grown from such origins. In other instances quietly conducted abstruse investigations have greatly increased the usefulness, and, therefore, the value, of existing properties in which vast sums have been invested.

The announcement was recently made of a new alloy, called permalloy, which has such remarkable magnetic properties that its use in the manufacture of submarine cables will permit messages to be transmitted at speeds many times that now obtainable, and that is only one of the many applications that this new alloy is sure to find. An old message bearer, the cable, with advantages of control and privacy, has been given "new wind" in the race with its young rival in service to mankind, "wireless." Permalloy did not just happen; it is one of many results of modern, methodical, planned research. To be sure, there was pleasant surprise when test after test revealed and proved its remarkable properties.

Permalloy is an alloy of nickel and iron which is characterized by extremely high magnetic permeability at low magnetizing forces. Its extraordinary "magnetic permeability" means the ease with which magnetic "lines of force" penetrate it and make of it an electro-magnet. It is far the most easily magnetized and demagnetized of all metals now known. The particular composition which is best in this regard contains about 80 per cent nickel and 20 per cent iron. The mere mixture of the two metals is, however, not sufficient to secure the highest permeability. A special heat treatment is also required. When properly heat treated its initial permeability is more than thirty times that of soft iron.

Another interesting property of nickel-iron alloys of about this composition is extreme sensitiveness of magnetic properties to mechanical strain. So far as has been determined, however, it is only in connection with its magnetic properties that permalloy is unusual. The X-ray study of these alloys reveals that their crystal structure is like that of nickel. Permalloy can easily be cast in ingots, reduced to billets, drawn into rods and wire, and rolled to thin tape.

To the engineer the discovery of permalloy will mean the accomplishment of results heretofore believed impossible. For the scientist the principal interest in these high nickel-iron alloys may well lie in the large response of their magnetic properties to simple external controls. Without alteration of composition these properties may be adjusted through extraordinary ranges by strain, by magnetization, or by heat treatment. This allows a more definite study of the way in which these factors are related to magnetic properties than has been possible with materials hitherto available in which their effects are comparatively small and may be associated with complicated and irreversible changes in other properties. The behavior of permalloy demonstrates that ferromagnetization is associated with material structure in a different way than are the other ordinary physical and chemical properties, and its extreme sensitiveness to control gives us a powerful method for use in magnetic investigations.

Nickel-iron alloys containing more than 30 per cent nickel and having the arrangement of their crystals characteristic of nickel, possess remarkable magnetic properties. This series of alloys shows no mechanical, physical or electrical abnormalities and these qualities are little affected by heat treatment, which so profoundly affects the magnetic properties.

Much remains to be learned about magnetism, notwithstanding the fact that the phenomenon of magnetic attraction was observed many centuries ago.

Based on information supplied by H. D. Arnold, Ph.D., and G. W. Elmen, M.A., of the Research Laboratories of the American Telephone and Telegraph Company and the Western Electric Co., Inc.

Note: The first commercial Permalloy cable was laid during 1924 between New York and the Azores and is in successful service.

STREET LIGHTING, TRAFFIC ACCIDENTS AND CRIME

Benefits from Lighting When Intelligently used

E. A. ANDERSON AND O. F. HAAS

Roughly each increase of a million automobiles in use has added 1000 to the annual death toll. In 1922, 14,000 persons were killed in traffic accidents—twenty times as many as in 1907, 15 years earlier. Without doubt, increase in number of accidents would have been at a much higher rate had it not been for measures taken at the instance of safety engineers. Speed regulations and effective punishment of violators, standardized traffic codes, education against careless driving, licensing of drivers, and other safety measures are proving effective.

Over a year ago, the Engineering Department of the National Lamp Works completed a survey of traffic accidents in 32 cities in different parts of the country, having a total population of over seven million. The purpose was to determine the relation between light and darkness as regards traffic accident hazard. The total number of street accidents for a year in these cities was 31,475, of which 9,534, or about 30 per cent, occurred during the hours of darkness. The results of this investigation indicate that 17.6 per cent of all night traffic accidents may be attributed to lack of light. Assuming that the same proportion holds in all cities, of the total of 14,000 persons killed in 1922 by automobile accidents, 4200 were night fatalities, and of this number, 17.6 per cent, or about 740, are directly attributed to lack of sufficient illumination. Accepting the rate of 26 serious accidents to each death, there were over 19,000 serious accidents attributable to lack of light. Considering the monetary loss, it may be assumed that of the billion dollar total damage estimated by Dr. Crum and others as resulting from street accidents, $54,000,000 may be attributed to lack of light. According to census reports this is practically equal to the amount paid for street lighting of all kinds in the United States.

It has been estimated that at least $2.00 per capita per year is necessary to provide a reasonably adequate system of street lighting in an average city. Even with an allowance of this amount, however, which is nearly three times the present average, the most careful study of efficiency of arrangement and type of equipment, and of requirements of various districts of the city, needs to be made if the lighting as a whole is to provide a reasonably sure measure of safety and if at the same time the equipment is to have an appearance in keeping with modern municipal standards.

Types of common accidents which may be averted by good street lighting, are:

A. Driver runs into obstruction or break in pavement. Street lighting especially on thoroughfares, should reveal all small breaks in the pavement or obstructions on the street. These requirements necessitate a fairly uniform distribution of brightness on the street surface, in which obstructions and dangerous faults are seen as shadows, or as breaks in the sheen in streets with polished surfaces or wet pavements.

B. Driver strikes pedestrian stepping into street or waiting in street for street car. Spacing of lamps should be so close that there would be no dark areas between units. On wide streets satisfactory results can be obtained only with lamps on both sides of the street.

C. Driver collides with another machine or street car on entering thoroughfare from side street. On account of additional traffic, lighting requirements for thoroughfares are more exacting than those for side streets; also the thoroughfare system should be especially well illuminated at crossings. This increased illumination in a well designed system at once indicates to the driver that he is nearing a main artery of travel and warns him to be cautious.

D. Driver strikes pedestrian crossing at entrance to the thoroughfare. The likelihood of this type of accident is avoided by the treatment of the lighting system outlined in "C."

E. Driver over-runs at dead-end or at turn. A lamp of adequate power at the head of the dead-end street or on the outside of the turn illuminates the curb and surroundings. At especially dangerous spots where the traffic is heavy, warning beacons may be used to advantage.

In addition to value in preventing accidents, a survey in Cleveland showed that high levels of street lighting had important influence in reducing crime. Ward Harrison stated that 90 per cent of the street crimes took place after dark. In one district in which a "white way" installation was made, there was an 8 per cent reduction in crime during the year, whereas in the rest of the city during the same period, crimes increased 54 per cent. In other words, crimes in the district in which the lighting was installed were only 60 per cent of what might well have been expected if no change had been made in the lighting.

Based on information supplied by E. A. Anderson and O. F. Haas of the Engineering Department, National Lamp Works, of the General Electric Company, Cleveland, Ohio.

CHINESE INVENTIONS AND DISCOVERIES

Some Forerunners of Modern Arts

CHUNG-YU WANG

The remark of Gore about Western civilization, that "the origin of many important discoveries lies buried in the obscurity of past ages," is none the less true of Chinese inventions and discoveries. Whether we believe with Jespersen that the flexionless Chinese language represents a higher linguistic development than the flexional languages such as Latin or Greek or whether with Taylor that "Chinese would take rank with English as a world language" and that "the Chinese come out near the apex of human evolution," or not, we nevertheless would admit the fact that some of the fundamental discoveries and inventions of great import to the human race have been made or forestalled by the Chinese. In fact, China is self-contained, with a virtually continuous existence of 5000 years, developing step by step through various discoveries and inventions by her people. Truly, in the words of Faber, an eminent sinologue, "China forms a World in itself."

I shall enumerate a few of the important discoveries and inventions of China as indicating in a way the general trend of her development.

The Compass: Records show that Chow Kung in the Chow Dynasty, about 1122 B. C. used a kind of wagon equipped with an instrument that pointed always toward the north.

Paper was first made by Tsai Lun, out of tree fibres, rags and hemp, during the Dynasty of Eastern Han, the early part of the first century.

Printing: It has been mentioned that Fung To originated the art of stereotyped wooden plates about the year 932 A. D., but later investigation made by the sinologue Stanislas Julien has shown that the invention actually dated from the year 593. A record of this period proves this: "It was decreed that drawings and unpublished texts should be collected and engraved on wood for publication."

Glass was first manufactured by Pun Fang about the early part of the second century. It is recorded that he had a piece carved with 130 designs.

Seismograph: An instrument, resembling perhaps the present day seismograph, was invented by Chang Heng in the first century, during the Han Dynasty, which could record any slight earthquake not perceptible by human senses.

Metals: In Tai Hao's time (2852–2737 B. C.) metallic coin was already in circulation. The inventive genius of the ancient Chinese can nowhere be more explicitly shown than in the art of making alloys. An alloy, similar to German silver, under the name of Pait' ong, was obtained by fusing "red steel" with arsenic. The manufacture by the ancient Chinese of gongs and tom toms, with their perfect tones, still remains to us a mystery, although their chemical composition has been determined.

Medicine: We may laugh at some of the ridiculous prescriptions of Chinese doctors; but I believe that there is a great deal of Chinese medicine that is both useful and illuminating when viewed in the light of occidental medical science. The Chinese anesthetic, known as Ma Fat powder, a sort of hashish, was discovered by the famous Chinese surgeon, Hwa To, who lived in the early part of the second century, during the Eastern Han Dynasty. An old Chinese text tells us that Hwa To administered the medicine to his patients to render them unconscious before being operated upon. This happened long before ether or choroform was discovered in Europe.

Recently two experimenters at the Rockefeller Medical Institute in New York City obtained a white secretion, which they have named Bufin, by stimulating the parotid gland of the toad by means of electricity. Its physiological action is almost similar to that of digitalis. This is merely a rediscovery of a medicine long known in China. The identical white secretion is obtained to-day by the Chinese by touching the biggest wart-like swelling just behind the eye of a toad with a hot iron. The secretions thus obtained from many toads are allowed to evaporate slowly to a powder, which is now mainly used as a heart remedy.

Unfortunately for China, and indirectly for the World, the Chinese mind, through centuries of classical education, by which, as Carlyle pertinently remarks, "they do attempt to make their Men of Letters their Governors," has failed to progress from the inventions and discoveries of the ancients.

Contributed by Chung-Yu Wang, Consulting Mining Engineer, Hankow, China.

AERIAL MAPPING OF NEW YORK

One Method of Surveying from the Air

SHERMAN M. FAIRCHILD

New York has been mapped from the air. The last flight of the greatest aerial photographic mapping project has been completed. Over 2000 negatives were secured. They are now being corrected and assembled. About 3000 miles were flown and the five boroughs—Manhattan, the Bronx, Brooklyn, Queens, and Richmond—have been mapped. Three planes were over the city whenever there was a good photographic day. Included in the squadron was a Fokker C, 2-camera plane purchased especially for this contract as it is particularly adapted for high-altitude photography.

The camera used was the Fairchild automatic aerial camera with the "between-the-lens" shutter. It weighs 42 pounds, has over a thousand parts and is one of the finest examples of automatic precision machinery ever made. This is the official camera of the U. S. Army and Navy, the Canadian Government, and the Brazilian Government.

The map pictures the city with the minutest detail,—every structure from the contractor's temporary tool shed where construction is going on, to the skyscraper, backyards, gardens and parks with every tree and bush visible, avenues and alleys, streets and unrecorded foot paths, big league ball parks, water front clubs, with their yacht and motor boats, the boardwalk of Coney Island, and crowds of people appearing like small black dots. Even the congestion of traffic on busy thoroughfares is clearly shown.

Two distinct photographic maps are being made. The first includes the area of approximately 400 square miles within the official city limits at the scale of one inch equals 600 feet, in 140 sections, each about 14 x 21 inches. These sections are to be assembled in groups of four, to correspond with the 35 sectional plan maps laid out by the Board of Estimate and Apportionment.

The second map is being made at the scale of one inch equals 2000 feet, and covers 625 square miles, including the city proper and portions of the counties of Westchester and Nassau in New York State, and that part of New Jersey contiguous to the city. The completed map at this small scale will measure 10 by 8 feet.

Few days are suitable for photographic mapping as there must be little haze and no clouds. Prints with clouds and cloud shadows are rejected. The shore line had to be photographed at low tide. This requirement proved difficult as low tide could not be later than 2 P. M. on a day when other conditions were favorable. In one instance there was a wait of several weeks for a suitable day to get part of the shore line. It was also imperative that flying be completed before snow set in. Some of the work for the map mosaic was done at 16,000 feet altitude in the Fokker, too high for the plane to be seen with the naked eye. For this work a short focal length camera was used to take photographs at a very small scale for checking controls. Many times the photographic squadron started out on days that seemed suitable, only to be compelled to return without pictures on account of haze or cloud formation.

If the 2000 exposures necessary to cover the entire area with an allowance of 50 per cent end and 50 per cent side overlap were matched together they would make a single strip map covering 800 linear miles on the ground. The greatest accuracy was required. Negatives showing very small degree of tilt have to be adjusted in the printing process. All prints have to be brought to the required scale; a different ratio of enlargement or reduction is required for practically every print. This requires a finely calibrated adjustment of the enlarging camera.

In his recommendation to the Mayor, Arthur S. Tuttle, Chief Engineer of the Board of Estimate and Apportionment, wrote: "The numerous advantages which an aerial map of the entire city would afford in the study of municipal problems are too apparent for discussion."

Success is due primarily to the "between-the-lens" shutter. In 1918, Mr. Fairchild tested every known make of camera shutter and found that the largest exposure was $\frac{1}{125}$ of a second using an opening of $\frac{5}{8}$ inch. He developed his first "between-the-lens" shutter in the spring of 1918. It ran at a speed of $\frac{1}{220}$ of a second and had an opening of $2\frac{3}{8}$ inches. The efficiency of this camera was 70 per cent. There were then no others on the market that had so high efficiency; most of them averaged around 50 per cent.

His newest camera, known as the five-mile aerial camera, has a high efficiency shutter with a 4-inch opening, and a speed of $\frac{1}{125}$ of a second. This is the same as the speed of the old cameras in 1918, but this new shutter covers an area about 45 times larger than the old type. A lens of "F-5" 20-inch proportions is used, working at all times at full aperture. The shutter is of exceptionally rugged construction. On a recent break-down test it stood up for over 20,500 shots, losing only a negligible percentage of its speed and accuracy.

Another remarkable feature of this camera is that on special high-altitude photographic work it is operated from an enclosed cabin through the floor of the plane, being suspended on a special carriage. Before the plane leaves the ground, adjustments are made so that when in flight (approximately 80 miles an hour) and at a set altitude over the country to be mapped, the camera automatically makes the necessary exposures. There are about 110 exposures to 75 feet of film.

Based on information supplied by Mr. Sherman M. Fairchild, President, Fairchild Aerial Camera Corporation, New York City.

A SELF-LINING ALUNDUM FURNACE

A Story of a Man with a Hose

ALDUS C. HIGGINS

Niagara Falls power made possible a wonderful group of electro-chemical and electro-metallurgical industries. Cheap and abundant current did not, however, alone assure low-cost production. In some industries the early equipment left room for substantial savings. So it was in the manufacture of alundum, an artificial abrasive invented about twenty years ago, extensively used for grinding metals and other materials. To produce alundum, bauxite, a natural mineral, is fused; but since bauxite melts at about 2000 degrees Centigrade, the process is possible only with electric-arc furnaces.

The earlier furnaces were lined with expensive carbon blocks as no other lining was known which would withstand the very high temperatures. Several forms of furnace had been devised which made it possible to use the blocks over again. But after the blocks had been re-used several times they became worn and did not fit well. The carbon mixture with which they were patched occasionally gave out and the molten alundum flowed against the steel shell of the furnace. It was the custom of the furnace man to turn a hose on the red-hot spot before it was melted through.

Aldus C. Higgins, who was then in charge of the electric furnace plant of the Norton Company and constantly in the furnace room, noticed that wherever the "water cure" had been applied the spot never got hot again during the run.

This led him to believe that if the alundum could thus be chilled in spots it might by suitable application of water be made to form the whole lining for the furnace shell. He suggested trying a shell with a stream of water playing against its outside.

A slightly conical shell was built with a pipe full of holes around its top, to which the hose was connected. The flat bottom of the furnace was lined with carbon blocks and the water taken off in a trough outside. Not a furnace man could be gotten to run this experimental type. In prior use elsewhere of one or two electric furnaces cooled by water carried in pipes or in closed passages explosions had occurred killing and injuring furnace men. They were shown that they had been running water-cooled furnaces when they turned the hose on the old furnaces; but it was no use. So the superintendent and Higgins ran the experimental furnace. And the storyteller hath it, that they lived and prospered, and so did the company.

It worked from the first, and, with slight improvements, has been used ever since the Norton Company began the manufacture of alundum over twenty years ago. Some of the prominent technologists of those days figured out how inefficient the furnace was, how much heat was taken off by the water, and that it could not be used. Nevertheless, it saved the company a great deal of money and was awarded a silver medal at the St. Louis Exposition. Furthermore, the Franklin Institute bestowed its John Scott Medal on Mr. Higgins for the invention.

Given Niagara power, Higgins's "happy thought," Jacob's discovery of alundum and the invention of a practical electric-arc furnace by the Cowles Brothers, the process is fascinatingly simple. The flat, round iron bottom of the furnace, lined with carbon blocks, supporting the shell is mounted on a car. The carbon electrodes are suspended in the shell and raised and lowered by automatic regulators. An electric arc is established. Then calcined, crushed bauxite is fed to the arc. As the bauxite fuses, it flows out to the shell and is chilled by the water, meanwhile becoming alundum and self-lining the shell. More bauxite is fed and the electrodes are raised slowly until the shell is filled with alundum.

One type of furnace is 4 feet in diameter and 5 feet high and has two electrodes 4 by 12 inches in cross-section. It produces at each run an ingot of alundum weighing about 2.5 tons. There are larger types with four electrodes. The total production of alundum in 1923 was over 30,000 tons.

Just one more case of the observant, technically trained man who did the obvious thing (obvious to him)!

Based on information supplied by Mr. Aldus C. Higgins, Treasurer, Norton Company, Worcester, Massachusetts, and Niagara Falls, New York.

CONCRETE

As Soft as Mud, as Hard as Stone

A hundred years ago, Joseph Aspdin, a mason in an English town, got an idea. It led him to experiment. In time he produced a fine powder, which when mixed with water into a paste and allowed to stand would "set," forming a hard substance. This substance so resembled the building stone from the Isle of Portland that the powder was named Portland cement. As years passed, rocks, clays and marls were found in many countries from which Portland cement could be made. The industry took root in Pennsylvania and Indiana in 1872. A third of a million barrels were made in the United States in 1890; in 1923 more than 137,000,000 barrels were produced by 126 mills, for which the manufacturers received about $240,000,000.

"Concrete" is the name of many substances made by mixing ingredients. Among engineers, architects and general contractors, however, it has for several years meant usually one kind of substance, mixtures of Portland cement with water, sand and gravel, crushed stone, slag or cinders. There have been other kinds of hydraulic cements, and there are now, which are or have been used in making concrete.

Hydraulic cement concretes have several remarkable properties which have led to widespread use. They will set and harden under water. When freshly mixed, they are easily poured or packed into molds of almost any desirable form. They can be used with steel so as to combine economically the great tensile strength of this metal with stonelike resist-

Chung-Yu Wang

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Second Class, Chiaho (Golden Grain). Built first antimony refinery in China. Narrative 75.

ance to crushing. Concretes are very resistant to fire when made of suitable materials.

Concretes have been used for almost every purpose for which stones and bricks have been used and for many more. For years users of concrete thought it could be mixed and placed according to simple rules by unskilled labor with little supervision. But the use of concrete was extended to more elaborate structures,—especially reinforced concrete (combinations of concrete and steel). Factories, office buildings, houses, bridges, dams, pipes, and highway pavements demanded for economical and structural reasons higher development of the strength possibilities of the materials, greater dependability and more intelligent adaptation to specific purpose.

No longer was it sufficient to mix concrete by rule-of-thumb from any likely looking sand and stone. Concrete mixtures must be designed. But data on which to base designing did not exist; engineers began collecting them from experience "on the job" and from laboratory experiments. In 1914, the Portland cement manufacturers took a hand in these investigations; the Structural Materials Research Laboratory was established at Lewis Institute, Chicago. Since then several hundred thousand tests have been made there.

Several factors are involved in the making of concrete, the ingredients, their proportions, the mixing, the placing and the curing. Each has a large influence on density, strength and durability. The quality of each ingredient is important, cement, water and aggregate, by "aggregate" meaning sand or stone dust, and gravel, crushed stone, or other substances, mixed with the cement and water. Kinds of aggregates are numerous and various. For example, the laboratory mentioned has 2800 samples of different sands.

Sizes of aggregates and the proportions of the various sizes must be determined to suit the purpose for which the concrete is to be used. Sets of wire sieves with square meshes were found convenient for controlling the grading of the aggregates. Tests showed a relation between sizes and grading of aggregates and the strength of the concrete. Hence, one element in the designing of concrete mixtures was determined.

Further investigations brought to light two more important facts: (1) The quantity of mixing water should be the smallest which will produce a concrete sufficiently plastic for proper placing in the molds or forms; (2) The concrete must be cured under favorable conditions during its first few days (for example, it must have sufficient moisture for the hydration of the cement, which constitutes setting and hardening).

Strength of concrete was found to depend upon the ratio of the volume of mixing water to the volume of cement. So long as the mixture is workable, the less water, the stronger the concrete. "Sloppy" mixtures frequently sacrifice three-fourths of the possible strength.

A most important process occurs after the concrete has been "placed," the hydration of the cement, which transforms the plastic mass into a rock-like substance. As the word "hydration" signifies, the cement takes up water, which must be provided in suitable quantity. It has been possible to increase the wear resistance of concrete 65 per cent by providing proper moisture during the first 10 days of hardening.

For some engineers and architects there is little that is new in these paragraphs. But how many persons who live and work in concrete structures, travel through concrete-lined subways and tunnels, drink water conveyed through concrete aqueducts from behind concrete dams, and ride on concrete highways have any suspicion of the scientific research back of the cements and concrete?

Based on information from the Portland Cement Association, and other sources.

OXYGEN, IRON AND STEEL

Betterment of Economy and Quality in Ferrous Products

F. W. DAVIS

Oxygen, in the total by weight, exceeds all the other chemical elements put together in our earth and its atmosphere. It is the great supporter of combustion. In ordinary combustion processes, however, air is used as it occurs in nature, a mixture of a little less than 23 per cent of oxygen, 77 per cent of nitrogen and small quantities of moisture and several rare gases. But nitrogen is one of the most inert of all gases and so takes no active part in combustion.

Iron is obtained from ores by smelting, a process involving combustion and therefore requiring fuel and oxygen. With the advance of civilization the consumption of fuel and iron has increased greatly and has reached an enormous total. Nature's supplies of these minerals is not renewed. Man has used the best first, quite properly, but has not been so economical of high-grade raw materials as posterity in successive generations could wish. In more fields than one, the necessity is beginning to force more intelligent use of the best and development of methods for utilizing the inferior, while advancing standards for final products.

This Narrative differs from those which have been issued before in that it deals with a study in progress rather than the result of a finished research. Advantages to be gained by substituting oxygen for air, or enriching air with oxygen, for use in metallurgical furnaces are great. There are possibilities in other industries also, for example: ceramics and city gas supply. Likewise there have been great difficulties.

One difficulty was the high cost of oxygen. This has been surmounted. A committee of chemists and metallurgists co-operating with the United States Bureau of Mines has learned that the big factors in the price of commercial oxygen are compression into cylinders, storage and transportation. Large oxygen plants can be built to serve metallurgical purposes directly, capable of delivering oxygen through pipes at a cost not to exceed $3 per gross ton.

Iron was first smelted from oxide ores in forge furnaces by burning charcoal. This process was slow and wasteful of fuel, a large volume of gases passing off at high temperatures. In the first half of the 15th century, Germans attempted to use these hot gases for preheating the charge of ore, flux and fuel. This led to the first shaft, or blast, furnace. The shaft, or upper part, of the furnace was intended to reclaim part of the heat carried off, largely by the inert nitrogen. Although there have been revolutionary changes in mechanical equipment for smelting iron, the metallurgical features have remained almost the same for four centuries.

Application of oxygen will revolutionize smelting, probably changing the whole operation and equipment. Now, material changes in the heat at the hearth, the most active part of the furnace, can be accomplished only by charging fuel in the top, and will not be effective until the added fuel reaches the hearth 10 to 15 hours later. Were oxygen in use, the hearth heat would be continually and quickly controllable.

From an extended study of oxygenated air for blast furnaces the conclusions are: Decrease of production costs; increase of output per furnace; increase of flexibility of process—better control; increase in uniformity of product; utilization of lower grades of ore and cheaper fuel; reduction of sulphur, an objectionable impurity.

Bessemer steel making may also be helped. There are now two major processes, known as acid and basic from the nature of their slags. For best results the basic process requires pig iron containing from 2.5 to 3 per cent of phosphorus. In making basic steel, oxidation of the phosphorus contributes a large percentage of the total heat. The phosphorus, which is undesirable in the steel, is thus removed. In the acid process phosphorus is not removed. In the United States there are ores containing too little phosphorus for the basic process and too much to make acceptable steel by the acid process. With oxygen a good steel could be produced from these ores and a high-phosphorus slag obtained, valuable for fertilizer.

Although thermal efficiency of the Siemens-Martin, or open hearth, process of steel making is very low, improvement by aid of oxygen is impeded by serious difficulties. A furnace lining ("refractory") which will be infusible at much higher temperature is needed,—a "super-refractory." Given this, the major portion of the refining of the metal now occupying 3 to 5 hours could be done in less than half an hour; plant and materials cost could be substantially reduced, and steel of superior quality could be produced equal in every respect to that now made in electric furnaces.

Based on information supplied by F. W. Davis, metallurgist, U. S. Bureau of Mines, and printed with permission of Director H. Foster Bain.

ELECTRICAL STRUCTURE OF MATTER

The Most Modern Conception

SIR ERNEST RUTHERFORD

All men deal with matter in the gross and our bodies are of it constructed. Mysteries of matter, therefore, have a fascination for thoughtful laymen, as well as scientists and technologists. The atom has long been familiar as the ultimate unit of matter.

While the vaguest ideas were held as to the possible structure of atoms, there was a general belief among the more philosophically minded that the atoms could not be regarded as simple unconnected units. For the clarifying of these somewhat vague ideas, the proof in 1897 of the independent existence of the electron as a mobile electrified unit of mass minute compared with that of the lightest atom, was of extraordinary importance.

Our whole conception of the atom was revolutionized by the study of radioactivity. The discovery of radium provided the experimenter with powerful sources of radiation specially suitable for examining the nature of the characteristic radiations emitted by the radioactive bodies in general. The wonderful succession of changes that occur in uranium, more than thirty in number, was soon disclosed.

It was early surmised that electricity was atomic in nature. This view was confirmed and extended by a study of the charges of electricity carried by electrons. Skillful experiments by physicists added to the knowledge of the subject. One of the main difficulties has been the uncertainty as to the relative part played by positive and negative electricity in the structure of the atom. The electron has a negative charge of one fundamental unit, while the charged hydrogen atom has a charge of one positive unit. There is the strongest evidence that the atoms of matter are built up of these two electrical units.

It may be of interest to try to visualize the conception of the atom we have so far reached by taking for illustration the heaviest atom, uranium. At the center of the atom is a minute nucleus surrounded by a swirling group of 92 electrons, all in motion in definite orbits, and occupying but by no means filling a volume very large compared with that of the nucleus. Some of the electrons describe, nearly circular orbits round the nucleus; others, orbits of a more elliptical shape whose axes rotate rapidly round the nucleus. The motion of the electrons in the different groups is not necessarily confined to a definite region of the atom, but the electrons of one group may penetrate deeply into the region mainly occupied by another group, thus giving a type of inter-connection or coupling between the various groups. The maximum speed of any electron depends on the closeness of the approach to the nucleus, but the outermost electron will have a minimum speed of more than 600 miles per second, while the innermost K electrons have an average speed of more than 90,000 miles per second, or half the speed of light.

The nucleus atom has often been likened to a solar system where the sun corresponds to the nucleus and the planets to the electrons. The analogy, however, must not be pressed too far. Suppose, for example, we imagine that some large and swift celestial visitor traverses and escapes from our solar system without any catastrophe to itself or the planets. There will inevitably result permanent changes in the lengths of the month and year, and our system will never return to its original state. Contrast this with the effect of shooting an electron through the electronic structure of the atom. The motion of many of the electrons will be disturbed by its passage, and in special cases an electron may be removed from its orbit and hurled out of its atomic system. In a short time another electron will fall into the vacant place from one of the outer groups, and this vacant place in turn will be filled up, and so on until the atom is again reorganized. In all cases the final state of the electronic system is the same as in the beginning.

Contributed by Sir Ernest Rutherford, President, British Association for the Advancement of Science.

NEW CONTROLS FOR SCIENCE AND FOR INDUSTRY

Limiting Values of Properties of Materials

EUGENE C. BINGHAM

When a machine is to be built, its size and shape are controlled by the dimensions on the designer's drawings or in the specifications. But it is usually necessary to control other features also by stipulating the tensile and crushing strength, the hardness, the weight per cubic inch and other qualities of the materials to be used. In other kinds of work other kinds of controls become necessary depending upon the purposes to be accomplished and the properties or limitations which determine success.

The definite melting points, solubilities, fluidities and boiling points of pure chemical substances have furnished controls of inestimable value in the development of chemistry. Colloids (matter in jellylike, uncrystalline condition) do not possess definite melting-points, solubilities, fluidities, and similar qualities. Hence there can scarcely be any doubt but that the discovery of controls similar to those used in classical chemistry would mean much to the newer science. This is all the more true since colloid chemistry is involved in so many industries, of which we merely cite ceramics, metallurgy, plastics, road building, paint, varnish, and rubber.

Such controls may be obtained through the development of the new science of the flow of matter, Fluidity and Plasticity. It is a curious fact that the flow of electricity, which we cannot see, is so much better understood than the flow of readily visible substances, such as the soft solids—for example, the "clay slip" of the pottery manufacturer. The reason appears to be that electricity in wires is carried by one thing only, electrons, whereas in the flow of matter molecules are involved and they possess infinite variety. But this condition which appears at first to be a disadvantage may eventually be turned to account, for the character of the flow may be utilized to give important information about the sizes of the molecules.

As a liquid is compressed either by pressure or by cooling, its volume V approaches a limiting volume W at which the fluidity would be zero. It appears probable that when a liquid occupied the limiting volume, the molecules would touch one another.

The fluidity of a liquid originates not in the molecules themselves, but in the spaces between them, defined by the difference of volume, V-W. It is found that the fluidity is directly proportional to the free volume, V-W. Since it is easy to measure both the fluidity and the molecular volume, it is easy to calculate the total volume of the molecules at their limiting volume. This is perhaps the most important possible use for fluidity measurements since it opens the way to measuring not only the size of the molecules, but also those elusive chemical changes which take place on hydration, as when sugar dissolves in water.

It is known that clay differs from pitch in that a certain force is required before clay can be deformed continuously. This force, or shearing stress, is known as the *yield value*. The rate at which the material is deformed by forces above the yield value determines the *mobility*, the ease of change of form.

These properties are fundamental properties of all solids and determine the plasticity, hardness, malleability, shortness and the like. Pitch, previously mentioned, is not a solid at all, but a very viscous liquid. It may be so brittle that it will fly to pieces when struck with a hammer, yet there is no minimum shearing stress which is required to deform it continuously. For this reason pitch will not hold a shape given to it, but will flow under very small stresses such as arise from gravity when long continued.

In soft solids there is a relation very similar to the one found for liquids. When the particles are closely packed, the mobility is zero, but as a liquid medium is added the mobility increases in direct ratio to this addition, i.e., to the free volume. From the experimental results it appears that control properties may be obtained which are at least analogous to the important solubility and melting point of classical chemistry. If this actually turns out to be the case, Graham's prediction will be more than verified and one might say: "The plastometer is a colloidometer;" in other words, the instrument which measures plasticity will also measure the colloidal state.

An example of the need for plasticity controls may be cited. The American Society for Testing Materials some years ago conducted a test on 240 samples of paint, using a test fence at Arlington, Virginia. To give the paints a fair test all were made up to have the same apparent viscosity, but some of the paints flowed, carrying the pigment down and leaving bare spots. In the light of recent knowledge it appears that the paints should *not* all have had the same viscosity, but it appears probable that they should all have been made up to have the same *yield value*, in which case all of the paints would have formed a coating on their respective panels.

Contributed by Eugene C. Bingham, Director of the Gayley Chemical and Metallurgical Laboratory, Lafayette College, Easton, Pennsylvania.

MODERNIZING THE STEAM LOCOMOTIVE

Gains in Economy and Service Through Science and Engineering

GEORGE M. BASFORD

Modern steam locomotives are not merely big and heavy. With the simple combination of boiler, cylinders and running gear of the past as a basis, scientific research and mechanical development have been applied to make more steam per pound of fuel and to produce more power per pound of metal. We built heavier locomotives until stopped by the rail. We bought heavier rail until stopped by the cost. Then we improved the efficiency and increased the capacity of the locomotive.

More improvements are in sight. Several relatively new ones are ready for general application. The steam locomotive has not reached its limit of capacity, power or efficiency. Today's problem for the locomotive designer is the coordination of improvements and their carefully balanced incorporation into the rolling power-plant. Whenever this is done the locomotive takes a remarkable step forward.

Some items for coödination are: General design of locomotive, especially of boilers; superheater, with superheated steam for all auxiliaries; brick arch in fireboxes and other firebox improvements; thermic syphon, providing re-entrant firebox heating surfâce; booster, mechanical stoker; feed-water heater; economical steam expansion; higher steam pressures; track relief improvements; factors that make for greater serviceability.

By aid of these improvements you may have greater draw-bar pull at the same speed or greater speed for the same draw-bar pull, with no increase in fuel consumption. At 30 miles per hour two improved locomotives will pull as much as three plain ones. At speeds above 12 to 15 miles per hour the boiler pulls the train. Mechanical stoker improvements contribute increased power per unit of fuel fired. Higher steam pressures are coming rapidly. One railroad is operating 598 locomotives with economical steam expansion in heavy freight service. Between 20 and 25 per cent of the fuel is saved. This is a wonderfully promising development.

The booster is a supplementary engine with small cylinders applicable to the trailing wheels of any locomotive that has trailers. It is used in starting and at slow speeds, and cuts out automatically when the speed of the locomotive reaches about 15 miles an hour. Its operation is similar to the low gear of an automobile. It may be cut in at low speeds in order to get over a heavy grade which might be too steep for the main engine alone to negotiate.

Track relief improvements will permit increasing wheel loads without increasing track stresses. Track authorities are beginning to realize that the pounding of the moving locomotive, rather than its dead weight when standing, (dynamic rather than static loads) must govern in limiting locomotive weights. Mr. James Partington records dynamic augments of 27 per cent at 60 miles per hour and 39 per cent at 73 miles per hour for a powerful Mountain type passenger engine.

One locomotive builder advocates three-cylinder engines for heavy freight service. Service results will soon provide means for determining the value of this plan as compared with contemporary improvements.

Steam locomotives have heretofore been designed for relatively short runs, because until recently they have always been operated on relatively short divisions. This led to high "stand-by" losses. Continuous runs of 825 miles are now made by oil-burning locomotives and runs of over 500 miles with coal burners. This increased serviceability is already producing a marked effect upon efficiency. So also are operating improvements; distant operation of siding switches by low-voltage electrical machines, substitution of signal indication for time-wasting train orders, improved locomotive terminals and improved dispatching.

Mountain type engines are operating continuously over 484-mile districts with grades of 1.14 per cent in one direction and 1.55 per cent in the other direction, hauling 13 and 14 steel passenger cars. These engines produce 3,500 indicated horsepower with a weight of 98.5 pounds per horsepower. These are the locomotives to which Mr. Partington refers.

Every one thinks he knows all about the steam locomotive, because it has been with us so long, but today we have a new steam locomotive. This statement is proven by the epoch-making records of the Altoona test plant of the Pennsylvania Railroad. The new complete power-plant on wheels and rails produces power at the rate of one indicated horse-power for the consumption of 1.79 pounds of coal, with even higher efficiency to come. Records as low as 13.5 pounds of steam per indicated horse-power hour put the steam locomotive in the class of efficient non-condensing power-plants.

Few persons know that locomotives have been built and are in service with power enough and flexibility enough to enable them to haul 10,000 tons at 18 miles an hour on level track on the one hand and to haul trains of 4500 tons with ten minutes' clearance ahead of a passenger train which is scheduled at 49 miles per hour for 90 miles without a stop, on the other hand.

Contributed by George M. Basford, member, American Society of Mechanical Engineers, consulting engineer, New York.

THE METALLOGRAPHY (PLASTOGRAPHY) OF PAINT

A Research for Better Paints

F. G. BREYER

Modern metallography may be defined as the study of the internal physical structure of metals. Plastography is the study of plastic materials. (See Narrative 81.) Facts about the behavior of metals under many conditions have been compared with their internal physical structures as determined by the microscope, and a science upon which many of our greatest industries are dependent has been built up.

Paint films have an internal structure just as truly as steel. Microphotographs show steel to be made up of individual crystals surrounded and separated one from another by a continuous amorphous intercrystalline material. Paint likewise is made up of pigment particles surrounded by a continuous material, the drying oils.

Perhaps the methods that had thrown so much light on steel and other metals could be used to advantage on paint. This was the thought which three years ago caused the Research Division of the New Jersey Zinc Company to begin to study paint as an individual structural material.

Paint films are made by spraying paint on an amalgamated tinned sheet and drying under standard conditions. Any number of coats may be applied. After drying, the paint film can be easily stripped from the sheet and its properties studied.

The most important property of a paint film is its ability to expand and contract with the surface upon which it is applied and to retain this distensibility as the film ages—its ductile life, to continue the analogy to metal. The forces set up by the expansion and contraction of the surfaces on which paint is applied are so large that the tensile strength of the film, so long as it is above a certain minimum, is of little importance. A specially designed tensile machine has been built to measure the distensibility of the films.

By subjecting film specimens to various carefully controlled conditions and determining the effect of each of these conditions on the ductile life of the test piece, much new information on the design of paint has been obtained.

There are two important causes for loss of ductility in paints films:

First, actual destruction of the intercrystalline organic cementing material, or vehicle (the oil), by the ultra-violet rays in sunlight. This is the cause of loss of gloss and chalking of outdoor paints. Ordinary window glass filters the ultra-violet from sunlight; therefore, indoor paint lasts much longer than outdoor paint. Brittleness, occasioned by light destruction, is accompanied by a large decrease in tensile strength.

Second, gradual hardening of the vehicle by continued oxidation. This is the cause of paints failing by cracking. It is accompanied by a considerable increase in the tensile strength. In outdoor paints it can take place only when certain pigments opaque to ultra-violet light are used, so that the destructive action of the light is prevented.

Atmospheric moisture appears to accelerate the action of light but to retard the gradual hardening. All paint films absorb moisture from the air. If the air is humid, the amount is fairly high; under such conditions nearly all paints remain soft and ductile for a long time, unless broken down by light. If the air is dry, some paints lose moisture faster than others, and hence get more brittle. This difference is due to the presence or absence of certain moisture-holding materials dissolved in the vehicle. Just what these are and how they can best be added is not fully known as yet. It is known that when certain pigments are added, reaction products with the acids of the oil are formed which have this property.

From what has already been found out, it is easy to see why practical tests have shown mixed pigment paints to be superior to single pigment paints. By studying the opacity of different pigments to ultra-violet light and the moisture-holding properties of paint films made from them, it has been possible to design an outside paint which, with the materials at present available, gives maximum resistance to both light destruction and hardening for the least money. Intelligent designing of paints to meet special purposes is another result.

Pigments that give the softening effect are, in general, poor resisters of light destruction. When the exact nature of the moisture-holding substances shall have been discovered, it will be possible to displace these pigments entirely with the more opaque ones and maintain the ductile life of the film by the direct addition of the softening agents. The resulting outside paint will far outlast any now available and will be the direct result of the application of the metallographic method to the study of paint films.

Contributed by F. G. Breyer, Chief of Research Division, The New Jersey Zinc Company, Palmerton, Pennsylvania.

THE ENERGY IN THE ATOM

Can Man Utilize It?

SIR ERNEST RUTHERFORD

Discovery of extensive, convenient and dependable sources of cheap energy is a growing need of advancing humanity. Increasing knowledge of the structure of matter raised hopes in the breasts of scientists and laymen alike that within the atoms were stores of energy, almost inconceivably great, which Science would some day learn how to put at the service of mankind.

The important question of the energy relations involved in the formation and disintegration of atomic nuclei was first opened up by the study of radioactivity. For example, it is well known that the total evolution of energy during the complete disintegration of one gramme of radium is many millions of times greater than in the complete combustion of an equal weight of coal. It is known that this energy is initially mostly emitted in the kinetic form of swift alpha and beta particles, and the energy of motion of these bodies is ultimately converted into heat when they are stopped by matter.

Since it was believed that the radioactive elements were analogous in structure to the ordinary inactive elements the idea naturally arose that the atoms of all the elements contained a similar concentration of energy, which would be available for use if only some simple method could be discovered of promoting and controlling their disintegration.

It is quite true that, if we were able to hasten the radioactive processes in uranium and thorium so that the whole cycle of their disintegration could be confined to a few days instead of being spread over thousands of millions of years, these elements would provide very convenient sources of energy on a sufficient scale to be of considerable practical importance. Unfortunately, although many experiments have been tried, there is no evidence that the rate of disintegration of these elements can be altered in the slightest degree by the most powerful laboratory agencies.

With increase in our knowledge of atomic structure there has been a gradual change of our point of view on this important question, and there is by no means the same certainty today as a decade ago that the atoms of an element contain hidden stores of energy.

It may be that the elements, uranium and thorium, represent the sole survivals in the earth today of types of elements that were common in the long distant ages, when the atoms now composing the earth were in course of formation. A fraction of the atoms of uranium and thorium formed at that time has survived over the long interval on account of their very slow rate of transformation.

It is thus possible to regard these atoms as having not yet completed the cycle of changes which the ordinary atoms have long since passed through, and that the atoms are still in the "excited" state where the nuclear units have not yet arranged themselves in positions of ultimate equilibrium but still have a surplus of energy which can only be released in the form of the characteristic radiation from active matter. On such a view, the presence of a store of energy ready for release is not a property of all atoms, but only of a special class of atoms like the radioactive atoms which have not yet reached the final state for equilibrium.

On the other hand, another method of attack on this question has become important during the last few years, based on the comparison of the relative masses of the elements. This new point of view can best be illustrated by a comparison of the atomic masses of hydrogen and helium. It seems very probable that helium is a very close combination of four hydrogen nuclei and two electrons. On modern views there is believed to be a very close connection between mass and energy, and the loss in mass in the synthesis of the helium nucleus from hydrogen nuclei indicates that a large amount of energy in the form of radiation has been released in the building of the helium nucleus from its components.

It is easy to calculate from this loss of mass that the energy set free in forming one gramme of helium is large even compared with that liberated in the total disintegration of one gramme of radium. For example, calculation shows that the energy released in the formation of one pound of helium gas is equivalent to the energy emitted in the complete combustion of about eight thousand tons of pure carbon.

It must be acknowledged that these arguments are somewhat speculative in character, for no certain experimental evidence has yet been obtained that helium can be formed from hydrogen.

The evidence of the slow rate of stellar evolution, however, certainly indicates that the synthesis of helium, and perhaps other elements of higher atomic weight, may take place slowly in the interior of hot stars.

Our information on this subject of energy changes in the formation or disintegration of atoms in general is as yet too uncertain and speculative to give any decided opinion on future possibilities in this direction.

Contributed by Sir Ernest Rutherford, President, British Association for the Advancement of Science.

TALKING ACROSS THE OCEAN

Progress in Transatlantic Wireless Telephony

H. D. ARNOLD AND LLOYD ESPENSCHIED

In 1915, by means of radio, voice was first heard across the Atlantic. Speech transmitted from the Navy station at Arlington, Virginia, by engineers of the Bell System was audible at the Eiffel tower, Paris, when conditions were exceptionally favorable.

January 15, 1923, a group of 60 persons in London, by pre-arrangement, listened to messages spoken by officials of the American Telephone and Telegraph Company from their offices in New York. During the two hours in which transmission was carried on, the words were received in London with as much clearness and uniformity as they would be received over an ordinary wire telephone circuit. Part of the time a "loud speaker" was used in connection with the receiving set. Reporters easily transcribed all the remarks.

These tests were made by co-operation between the engineers of the American Telephone and Telegraph Company and the Western Electric Company, and the engineers of the Radio Corporation of America and associated companies. The sending apparatus was installed in the Rocky Point, Long Island, station of the Radio Corporation.

Those talking tests were part of an investigation of trans-oceanic radio telephony. The experimenters of these companies are determining: 1. effectiveness of new methods and apparatus for telephonically modulating and transmitting the large amounts of power needed: 2. efficacy of improved methods for receiving the transmission and for so selecting it as to give an extremely sharp differentiation between the ranges of frequencies transmitted and all the frequencies outside of this range: 3. transmission characteristics for transatlantic distances and variation of the characteristics with time of day and season of year. Static interference is being measured. This investigation is still in progress.

Hitherto, with the ordinary method of transmission, three bands of electrical waves are radiated through the ether. That is to say, the power given out may be considered in three parts: 1. a central band of power at a wave-length or number of waves per second known to radio engineers as the carrier frequency: 2. power in a side band of frequencies extending from the carrier frequency upwards and having a width equal to the frequencies appearing in the telephone waves: 3. power in another side band extending from the carrier downward. The power at the carrier frequency is more than two-thirds of the total.

In this transatlantic investigation, a new method of transmission, radiating only one side band without the carrier, is being employed. It possesses important advantages: all the power radiated is effective in conveying the message. In the ordinary method most of the power is not thus effective. Stability of transmission is improved. The frequency band required for transmission is reduced thus conserving wave-length space in the ether and simplifying the transmitting antenna problem.

The importance of conserving frequency range will be appreciated when it is realized that the total range available for transatlantic telephony is distinctly limited. The most suitable range has not been accurately determined. Its upper limit may be 60,000 cycles a second (5000 meters wave-length) because of the large attenuation suffered during the daylight hours by frequencies higher than this. Transatlantic telegraphy preempts frequencies below 30,000 cycles (10,000 meters). Therefore, for the present at least, these transatlantic telephone experiments are limited to a range of some 30,000 cycles.

Transmission of speech requires as a minimum for good quality a single-side-band about 3000 cycles wide. Allowing for variations and for clearances between channels in the ether it is doubtful whether channels could be made to average closer than one every 4000 cycles for single-side-band transmission and one every 7000 cycles for the ordinary double-side-band transmission. Were the whole range from 30,000 to 60,000 cycles devoted to telephony to the exclusion of telegraphy, only about four channels could be obtained by the older methods and seven by the new. Hence the new system increases the capacity of the available region in the ether by 75 per cent.

The new system also saves two-thirds of the power. This is an important economy in the large quantities of high frequency power demanded for transoceanic telephoning. Water-cooled vacuum tubes have proved admirably suited for use in high-power radio service.

A new type of radio telephone system has been developed. It has important advantages for transoceanic telephony. It has been put into successful experimental operation across the Atlantic. Sustained one-way telephonic transmission across this ocean has been attained for the first time by means of this system.

Prepared from information furnished by Dr. H. D. Arnold and Mr. Lloyd Espenschied, of the Research Laboratories of the American Telephone and Telegraph Company and the Western Electric Company, Incorporated.

ETHYLENE

A Gas That Puts Plants and Animals to Sleep

WILLIAM CROCKER

"What is the effect of illuminating gas upon carnations?" was asked Dr. Lee I. Knight and Dr. William Crocker at the University of Chicago in 1908 by a disheartened florist. He had lost the carnation crop in large greenhouses three succeeding years, in the Fall, when cold weather forced him to close the ventilators. The third year he began detecting a slight odor of illuminating gas. This led to removal of a leaky pipe. After that, carnation production went on without mishap.

The attempt to answer the florist revealed that buds and flowers of carnations are very sensitive to traces of illuminating gas in the air. One part in 20,000 kills medium sized buds; one part in 40,000 buds just ready to open, and one part in 80,000 causes open flowers to "go to sleep," within twelve hours, never to open again. Illuminating gas is a mixture of carbon monoxide, hydrogen, methane, ethylene, acetylene, and other gases formed by destructive distillation of coal, or "cracking" of petroleum, or both. Of these ethylene is most effective with plants; one part in 2,000,000 of air causes carnations to "go to sleep" in twelve hours. There is no chemical method anywhere nearly delicate enough to detect such small concentrations of ethylene in the air, yet investigators have found other plants still more sensitive to it. The sweet pea, tomato, castor bean, salvia and others are changed in growth by dilutions as great as one part in 10,000,000. Some plants on the other hand are not injured or changed in their growth by considerable concentrations of illuminating gas or ethylene, for example, canna, calla, easter lillies, and several sorts of ferns.

Roots of plants are injured by illuminating gas in the soil. Again ethylene is the most effective constituent. Although it takes much higher concentrations to injure or kill roots, the soil furnishes a favorable medium for building up such concentrations. It is easy to pass illuminating gas into the soil about a tree at such rate that no odor will be detected above ground and yet the tree will be killed within a few weeks. Findings of botanists on the effect of illuminating gas on plants have not always been gratefully received by gas companies, but have certainly led to general good by inducing greater precautions.

Doctor Luckhardt, an animal physiologist at the University of Chicago, asked: "If ethylene has such remarkable effects upon plants, how does it affect animals?" Contrarily, he finds low concentrations without effect on animals; but applied in concentrations of 80 to 85 per cent in combination with oxygen, it is a wonderful anaesthetic. It lacks or has in only low degree, the bad qualities of ether, chloroform and nitrous oxide. It has no lethal action, does not induce sweating, and produces little nausea or gas pains; one recovers quickly, so quickly, indeed, that incision pains are often still felt. It promises to displace the older anaesthetics for many types of surgical operations.

When any carbon compound is burned with insufficient oxygen, or with an excess of oxygen but a low temperature, combustion is incomplete and some reduced gases such as carbon monoxide and ethylene are formed. This occurs in the burning of a sheet of paper, a kerosene stove, a brush pile or a pile of rubbish, in an operating gas engine, and when one smokes a pipe, cigar or cigarette.

For many years, kerosene stoves have been burned in citrus fruit curing houses of California, and for a much shorter period in Alabama and Florida, for yellowing the fruits. A decade ago, it was shown that these stoves were effective not because of the heat but because of some carbon vapor or gas from incomplete combustion. The exhaust from an automobile engine is likewise effective. These stoves needed much attention, were sources of numerous fires, often blackened the fruit with soot and gave very irrgular results. About two years ago, the citrus producers asked the U. S. Bureau of Chemistry to determine the constituent of kerosene smoke that was effective, in order that they might avoid the troubles and carry on the yellowing under controlled conditions. Dr. F. E. Denny found ethylene effectively useful in concentrations varying from 1 part in a million up to 1 part in 5000 of air and through a considerable range of temperature. He has worked out a simple practical method of citrus fruit yellowing now generally adopted in California, which produces the yellowing in about half the time and puts the process under exact control.

Smoke collecting from an accidental fire in the basement of a greenhouse in the Azores caused quick regular ripening of the pineapples there. It is a regular practice in the Azores now to build smudges in greenhouses to get timely and regular ripening of this crop. There is little doubt that the smoke is effective through the ethylene it contains and that better results can be attained by releasing a little ethylene in the greenhouse from a tank.

Chloroform and ether were formerly the best known agents for forcing dormant plant organs into immediate growth as well as for hastening plant development. The main drawback with them is that there is a narrow margin between the concentration that will force and the concentration that will kill. In other words the poisonous or lethal factor is high in these anaesthetics. The lethal factor in ethylene is low. In citrus fruits, for instance, ethylene can be used over a wide range of effective concentrations without injury. On this account it promises to be much superior to ether and chloroform as a forcing agent. Further investigation may show that some closely related compounds, such as acetylene and propylene, are still more effective.

Contributed by William Crocker, Ph.D., Director, Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.

CLEAR FUSED QUARTZ

A Glass-Like Substance of Superior Physical Qualities

EDWARD R. BERRY

By nine years of persistent scientific research, a process has been developed for commercial production of clear fused quartz in large quantities and in relatively large masses. Not only important industries, but also advances in the sciences and arts are favorably affected. As silicon dioxide constitutes no less than three-fifths of the outer ten miles of the Earth, the only evident limitations are mechanical, mostly in the size, strength and operation of equipment for production in quantity, and the cost.

Most important of the properties of this substance as they now appear are: 1. ability to transmit wave lengths of the spectrum ranging from invisible infra-red, or heat rays, through the visible colors to the extremely short invisible ultra-violet rays, at the other end; 2. an extremely low coefficient of thermal expansion (0.00000058 per degree Centigrade), one-fourteenth that of glass, one seventeenth that of platinum and one-thirty-fourth that of copper.

Our country's copy of the international standard of length is a platinum bar having two studs 100 centimeters apart, housed in the Bureau of Standards, at Washington. Great precautions are taken to keep it at constant temperature. A rod of fused quartz one meter long expands only about six-tenths of a millimeter (approximately the full length of a hyphen in this type) for a temperature rise of 1000 degrees Centigrade (1800 Fahr.).

A rod one meter long (39.37 inches) will emit at either end about 93 per cent of the visible light passed into the other end. It can transmit visible and invisible rays around curves, with little loss. In other words, it is very transparent. Its specific gravity is 2.21. The practical value of these and other properties are apparent.

Because of its small change of length with large change of temperature it may be utilized in pendulums of clocks. Tuning forks do not appreciably change pitch. When glass and fused quartz thermometers were placed in melting ice (zero Centigrade), then immediately heated to 515 degrees and again put in melting ice, the glass thermometer read 4 degrees below zero but the quartz thermometer read exactly zero.

For accurate work in astronomy it is essential that the huge reflectors (mirrors) and lenses do not suffer the slightest change of size or shape. For glass, heretofore the only substance available, this has necessitated maintaining a constant temperature by elaborate precautions. For lenses and reflectors of fused quartz these precautions may be omitted or at least much reduced.

Glass condenser lenses in large motion-picture machines have short life, often breaking in a day or two, because frequently subjected to high temperatures. Quartz lenses operated six to eight months were yet in service.

A quarter-inch-diameter glass tube heated red and slowly dipped into water splinters. A mass of fused quartz heated by oxygen flame to 3200° Fahrenheit (melting point of platinum) when dipped into water, cools without cracking.

Ultra-violet rays from a mercury vapor lamp of quartz may be directed and localized through a quartz rod, curved as found necessary, so that cavities of the human body and

Nicolas Leonard Sadi Carnot—1796 to 1832

Son of Napoleon's great marshal, Lazare Carnot. In 1824, he published "Reflections on the Motive Power of Heat," a little book containing the first statement of the laws on which modern engines using heat are based. Narrative 94.

other places hitherto difficult of access for examination, may be photographed or observed directly.

To produce clear fused quartz the clean natural crystals, of small size are packed as densely as possible in a graphite or carbon crucible, so that in the inevitable cracking of the crystals as the temperature is raised the parts cannot separate and permit gas which may be present in small quantities to enter the crevices and form bubbles. In a modified vacuum furnace, the quartz is heated to melting (about 1800°C.) quickly as possible (in 45 minutes or less) while the pressure is kept as low as possible. The resulting transparent slugs, containing a few small bubbles, are placed in another graphite crucible suspended in a verticle carbon tube furnace, with a graphite piston closely fitting the crucible and weighted. The slugs are heated to fusion, the bubbles mostly collapsed by the weight, which also extrudes the quartz through the bottom of the crucible in rods, tubes and other desired forms. When large blocks are to be made, a vacuum furnace is used which is capable of withstanding very high pressure. As soon as the quartz is fused, the vacuum valve is closed and the pressure raised. Thus are produced very large blocks of quartz freer from bubbles than many kinds of the best optical glass.

Prepared from information supplied by General Electric Company, based on the researches of Dr. Edward R. Berry, Assistant Director, Thomson Research Laboratory, West Lynn, Massachusetts, and his assistants, L. B. Miller, P. K. Devers.

PLANTS THAT STARVE FOR IRON

Feeding Them Through Their Leaves

WILLIAM CROCKER

More than a decade ago the pineapple growers of Hawaii were confronted by a very perplexing problem. Plants grown on certain Hawaiian soils unusually rich in manganese were always yellow, or chlorotic, and would not produce profitable crops. The growers figured that, if they only knew the reason and could get a remedy, large additional areas would be available for this paying industry.

About this time, in Porto Rico, an observation was recorded and some scientific work done that finally gave the desired reason and the needed remedy. Growers there had observed that pineapples grown on calcareous soils were always yellow and of poor growth. In 1911, Mr. Gile, Agricultural Chemist for the Porto Rico Station, showed that this chlorotic condition was due to the inability of the pineapple to absorb sufficient iron from these lime-rich soils. The lime rendered the iron too slightly soluble for absorption. He also showed that the plant grew perfectly on these soils if iron sulfate were sprayed on the leaves. In other words, instead of feeding the salts through the roots as is usual, he fed through the leaves.

The growers of Hawaii reasoned: "If the yellowing of pineapples on the calcareous soils of Porto Rico is due to iron deficiency, perhaps the same is true on the manganous soil of Hawaii." They began spraying with iron sulfate and sure enough, the plants took on a deep green color and grew vigorously. The application, in several sprayings, of 50 pounds of iron sulfate per year per acre gave perfect growth, but 3000 pounds added to the soil per year did not affect the chlorotic condition. The manganous soils in Hawaii, like the calcareous soils in Porto Rico, rendered the iron salt insoluble.

The soils of Hawaii, like most soils, are very rich in iron, containing from 9 to 33 per cent expressed as iron oxide. Plants need but a trace of iron and yet in the midst of plenty these pineapples were starving.

In 1914, the Hawaiian Islands were canning about 2½ million cases of pineapples. In 1923, the total output was more than 5 million cases. Next to sugar cane, pineapple canning is their largest industry and has an annual value of more than $20,000,000, an enormous industry for a territory with one-fourth of a million population. The greater part of this industry was made possible by the simple discovery that pineapples grown on the manganous soils were starved for iron and that this iron could be supplied as a spray through the foliage.

This discovery has proved also that it is a paying practice to use iron sulfate sprays for pineapples on many soils. Gile taught us to modify certain ideas concerning fundamentals in soil fertility. It was commonly assumed in the United States that if a little lime on soils was a good thing, more was better, or at least not harmful. Fortunately one or the other of two protective conditions have generally existed with these lime prodigals. They have used coarse limestone that reacted with the acids of the soils relatively slowly, scarcely neutralizing the soil, let alone rendering it basic; or they have been working with soils rich in humus, in which iron remains sufficiently available even with a great excess of lime.

Gile's work has led also to the discovery that in general, plants do better on a slightly acid than on a neutral or alkaline soil. Over-liming is likely to produce chlorosis. Lime, like most other good things, must be used with moderation.

Very recently it has been found that coniferous seedlings in many Federal nurseries in western United States, where alkaline soils are common, show chlorosis and can be successfully grown only by the application of iron sulfate sprays.

Directly or indirectly, animals and men get most of their salts from plants. A few years ago on certain pasture lands of New Zealand, sheep and cattle developed "bush sickness." "Bush sickness" produced gradual wasting away and final death of animals kept continuously on these pastures. It was later found that if the plants on these pastures were sprayed with iron sulfate and certain other salts, the sickness entirely disappeared. Animals feeding upon this vegetation did not get enough iron. The vegetation growing in certain swamp lands of Minnesota is, likewise, too deficient in phosphorus for the use of animals. It is common now to attribute certain types of goitre to deficiency in iodine supplied by the vegetation of different regions. Research in the chemistry of plants is closely related in many ways to the well-being of mankind.

Contributed by William Crocker, Ph.D., Director, Boyce Thompson Institute for Plant Research, Inc., Yonkers, N. Y.

MAKING CORNCOBS USEFUL

Pipes, Pentosan-Adhesives and Furfural

FREDERICK B. LA FORGE, GERALD H. MAINS AND O. R. SWEENEY

One county in Missouri grows a kind of Indian corn because its large cobs make good tobacco pipes. Some cobs are burned as fuel on farms. A "maple sugar" flavor is made by boiling cobs with water. Meat smoked with cobs has a flavor said to be better than that from hickory. There are other minor uses. But what use can be made of 15 to 20 million tons of cobs wasted annually in the corn belt? Chemists of the Department of Agriculture, working on the subject since 1918, have discovered new values in cobs and processes for making them commercially available. Iowa State College is investigating production from cobs of furfural, oxalic and acetic acids, methanol (wood alcohol), charcoal, activated char, pitch, tar, oils, cob flour, incense, punk, a plastic material, and fermentation products.

The pith, woody shell, and scaly exterior, or chaff, of the cob, physically so different, chemically are alike. Cobs season in 11 days; wood requires one to two years. Great saving results in interest on raw material carried in stock for cob products.

When cobs are cooked for a few minutes under pressure in superheated water, adhesive materials are extracted. These compounds belong to the carbohydrate group of chemicals, to which also belong starch, dextrine and sugars. * Pen-

* Pentosans: a group of chemical compounds found in many plant materials, including corncobs, oat hulls, peanut shells and cottonseed hulls.

tosan adhesives can be used for pasting fibre boxes and cheap paper bags, and for other purposes not demanding high-grade, strong adhesives. A special use proposed is in manufacture of briquettes from fine sizes of anthractie, of which a superabundance results in preparing that coal for market. Thus utilization of waste cobs could enhance materially the value of near-waste coal; much experimental work has been done.

When cobs are digested for about two hours with steam under 135 pounds pressure per square inch, with a very little sulfuric acid, a different product results, furfural. Furfural is an aromatic liquid about one-sixth heavier than water, boiling at 161°C., soluble in 11 parts of water, nearly colorless when first prepared but darkening on exposure to air and light. It can be obtained also from oat hulls, bagasse, bran and other vegetable substances. Its use has been limited because of the high cost by methods heretofore employed. In 1920, possibly 50 pounds were used in the United States, only as a laboratory reagent; the price was about $30. In France and Germany furfural has been made as a by-product in the manufacture of alcohol from wood waste. The Miner Laboratories, of Chicago, by independent research, developed a process for furfural from oat hulls in large quantities. Annual production is now thousands of pounds, and since 1922 the price has been reduced to 25 cents.

Researchers of the Department of Agriculture, continuing their investigation at the Arlington Farm, Virginia, worked out practical processes and equipment for furfural from cobs in large quantities, at still lower cost. On a scale of 50 tons of cobs a day, yielding 4.5 tons, fufural could be produced for about six cents a pound, making no allowance for income from by-products. Furfural can now be made at much lower cost than formaldehyde, and can replace it in a number of fields.

Attention has turned to discovery of additional uses for furfural and enlargement of its market. More than sixty patents on its production and utilization have been issued, mostly within the past five years, in the United States and other countries.

During the war, a shortage of acetone could easily have been met by distilling cobs.

If cobs be treated with phenol or cresol in presence of an acid, a sticky mass results on heating, which ages to a hard black substance which can be pressed into shape.

There is a promising field in the manufacture of resins similar to Bakelite, suitable for parts of electrical instruments, for printing plates and various other molded articles. These phenol furfural resins are infusible and insoluble; they have high insulating qualities, great strength and great resistance to water and chemicals. They have a large field in radio equipment. Phonograph records may be made from them. There are also innumerable uses for fibre impregnated with these resins where great toughness and resistance are of value.

A fusible furfural resin is useable in varnish manufacture. Furfural is a paint and varnish remover; to apply it economically and effectively to vertical and inclined surfaces, it is mixed into a paste with starch, gum arabic, wood flour or other inert material.

Furfural is combustible but not particularly flammable. It burns slowly with a luminous flame. Its possibilities as a motor fuel have been exaggerated. Furfural is a fungicide, germicide and preservative. Derivatives of furfural give some promise as vulcanization accelerators in the rubber industry.

The solid residue of the cobs can be used as fuel in the process of making furfural, or it may be utilized in the manufacture of certain substitutes for wood, for example, wall-board. It may also be purified and used as a substitute for wood flour, and to some extent in paper manufacture.

Chemist and engineer appear to have laid foundations for one or more new industries based on waste products.

Prepared from information furnished by Frederick B. LaForge and Gerald H. Mains, Bureau of Chemistry, Department of Agriculture, Washington, and O. R. Sweeney, Head of Chemical Engineering Department, Iowa State College.

SUSPENSION INSULATORS

Keeping the Electricity on the Line

HAROLD B. SMITH

In order that electrical energy may be utilized at a distance from the point of generation, effective resistance must be offered to the escape of the current from the conductor. This resistance is provided by insulation, which takes many forms. For long-distance overland transmission, first for telegraphy, then for telephony, and later for power, bare wires have been supported on poles or towers. Between the wire and the pole or tower, an electrical barrier must be interposed of such shape and strength as to hold the wire securely against wind and sleet and other forces, while preventing flow of current from the wire. Almost everyone is familiar with the grooved glass caps screwed on the wooden pins on the arms of telegraph poles. It became necessary first to improve this type of insulator and then to devise others for the vastly larger currents of much higher voltage adopted for efficient transmission of power.

As rapidly as science and engineering could make advance possible, voltages for long-distance power transmission have been increased, from a few thousand in 1890 to 220,000 volts in 1923.* At one stage, about 1900, 60,000 volts was believed the absolute limit, but research discovered new laws and now 330,000 volts or more are a practical possibility. Without development of line insulators this progress would

* In 1896, electrical energy generated by The Niagara Falls Power Company was first transmitted 22 miles to Buffalo at 11,000 volts.

have been impossible. Persons observant of power lines in recent years have seen insulators put on one and then more "petticoats" and change form in numerous ways. For high-tension (high-voltage) lines, insulators, in many systems, have been taken from the pins and suspended from the cross-arms. One insulator proving insufficient with increasing voltage, two to fifteen or more have been hung in a string. Many other changes, not detectable by the passerby, have been important.

Development has been based largely on cut-and-try experimentation; but there have been also many instances of fundamental research. In one of these, Harold B. Smith sought to place the surface of the insulator under more favorable electrical conditions, to simplify the form of insulating surface for convenience in manufacture, to avoid corona prior to breakdown, to prevent arcing along the insulating surface, to reduce weight, length and cost, to raise the voltage per unit, and to eliminate porcelain, if possible. (Corona is a phenomenon of the escape of electricity from the conductor. It occurs with high voltages and causes loss.)

Principles and elements of design not previously used were introduced. Numerous models were tested at Worcester Polytechnic Institute and at the Pittsburgh plant of the Westinghouse Company. Early tests under favorable conditions to determine certain facts gave encouragement. Designs were then modified and tests made under conditions simulating bad weather. After experiments on many models, a type was found which would not break down, when dry, until a voltage of 280,000 or over was reached, and, when wet, would hold 200,000 volts or more.

One important new feature is the creation of a hollow electric "field" around the insulating member. (By a hollow electric "field" is meant one surrounded symmetrically along its axis by a stronger field of higher average and maximum potential gradient.) To study the form of "field" for each model, shredded asbestos was used, making the lines of electrical flow visible and permitting them to be photographed.

The preferred experimental type is receiving service tests on transmission lines under various climatic conditions. It has three principal parts: a hood of sheet metal, in shape resembling an inverted hand-basin with very wide brim, a spindle of impregnated wood, and at the lower end of this spindle a torus (doughnut-shaped ring) of metal tube. Tentative dimensions are: overall length 30 to 40 inches; diameter of hood, 45 inches; diameter of torus, 17 inches overall, and diameter of tube of which torus is made, 6 inches. The spindle is the insulating element. Satisfactory electrical and mechanical properties have been secured.

Not trusting eyes unaided to make sure that no corona or sparks were passing across the insulator models, polar high-speed stereoscopic photographs were taken, some of them at the rate of 520 per second. Neither streamer nor arc was detected along the insulating spindle, nor could be blown upon it by strong air currents.

Shapes and material of hood and torus resulted from efforts to distribute the electrical flux and to form a favorable electrical field around the spindle under all weather conditions, avoiding corona until the breakdown limit had almost been reached, and preventing arcing along the insulating surface.

It is expected that one of these insulators at each point of suspension will be sufficient on 110,000-volt power lines, that two will suffice for 220,000-volt lines, and three on 330,000-volt lines. This systematic research may prove epoch-making in insulation of power transmission lines.

Based on information supplied by Harold B. Smith, Fellow, American Institute of Electrical Engineers, Professor of Electrical Engineering, Worcester Polytechnic Institute, Worcester, Massachusetts.

SILICON STEEL

An Alloy Which Has Saved Millions of Tons of Coal

SIR ROBERT A. HADFIELD

When Sir Robert A. Hadfield produced manganese steel, as recorded in Narrative 35, he opened an area of vast possibilities, the field of alloy steels. He and other metallurgists pressed its exploration successfully. The world has profited greatly. Without these alloy steels, having remarkable properties, the progress of Mankind would have been retarded. There would be no automobiles, no airplanes. Many machines, structures and processes would have been impracticable. Hundreds of articles in daily use could not be made, or would cost much more.

Silicon steel, also invented by Sir Robert A. Hadfield, is a member of this family of alloys. First produced in quantity about 1906, it has in eighteen years saved through the electrical industry alone, more than enough money to build the Panama Canal. Reduction in waste of energy in electrical equipment is estimated to save now more than five million tons of coal a year. Many hundred thousand tons of silicon steel have been manufactured, mostly in thin plates for cores of electrical transformers.

Late in the 19th century, the best core material available was giving much trouble. Researchers were struggling with the problems. Hence the great importance of this invention, which was named "Low Hysteresis Steel" because of its remarkable magnetic properties. "Hysteresis" is a term used by engineers and scientists in several connections.

In brief, magnetic hysteresis is the tendency of magnetic materials to persist in any magnetic state which already exists. It leads to loss of energy, which appears as heat, when the magnetic state of the object is changed. This and other losses are greatly reduced by silicon steel.

The first experimental transformer made by Hadfield with silicon steel in 1903, weighed 30 pounds. The first one made for service has been in successful use in Sheffield, England, since 1905. Its core weighs 830 pounds; if made of the best transformer iron then available, it would have weighed 1120 pounds and its electrical energy losses would have been more than one-third greater at the beginning. With silicon steel, the losses continued to decrease until they were much less than one-half what they would have been with the iron. With the iron core, the losses would have increased, at least for a time. Electrical manufacturers now regularly make transformers the larger ones of which each contain thousands of pounds of this steel.

Few laymen know transformers by sight, although many have heard the name. Without transformers many wonderfully dependable electrical services would be far less satisfactory, or almost impracticable.

Silicon steel was not the result of a "hunch" or a "happy thought." Hadfield's invention of manganese steel was followed by the no less important invention by him of silicon steel. This attracted the attention of scientific workers and in 1888 a committee of the British Association invited him to assist in investigating the effect of high percentages of silicon. In September, 1889, he reported some of his discoveries to the Iron and Steel Institute of Great Britain. Only partial success had yet been achieved; as so often happens, one discovery led to others. In the year 1899, Sir William Barrett F.R.S. (then Professor of Experimental Physics at the Royal College of Science, Dublin) discovered its extraordinary magnetic and electrical characteristics; and during the next three years with the able help of Mr. W. Brown, B. Sc. (an old pupil and assistant of the late Lord Kelvin), co-operated with Sir Robert Hadfield in further research. Joint papers by Barrett, Brown and Hadfield were read to the Royal Dublin Society and to the Institution of Electrical Engineers in the years 1899 and 1902.

Not, however, until several years later, after much experimental work had been done and many difficulties overcome, was Hadfield able to produce silicon steel as a marketable commodity.

Hadfield was granted a United States patent in 1903 for his invention, which consisted in heating steel containing $2\frac{1}{2}$ to 4 per cent of silicon to about 900 to 1100 degrees Centigrade, cooling it, then reheating it to between 700 and 850 degrees Centigrade, and thereupon allowing it to cool slowly. Other improved methods followed and further patents were obtained.

Silicon steel, under low magnetizing forces, is far more magnetic than the best Swedish iron. Furthermore, it does not suffer from "ageing;" that is, its good magnetic properties do not deteriorate, as happened with the iron.

Silicon, the pure metalloid, has not been seen by many persons; but silica (silicon dioxide) is familiar to everybody in sand and quartz. Silica is the principal ingredient of glass; it is one of the most abundant substances of the outer crust of the earth. All iron and steel contain at least minute quantities of silicon.

Hadfield discovered how to combine large percentages of silicon with iron and make a special steel for much needed purposes and this steel when appropriately treated developed the desired magnetic and other physical qualities.

Thus success rewarded systematic research.

Compiled from information supplied on request by Sir Robert Hadfield.

AMERICAN POTASH

Discovery of Polyhalite in Texas

DAVID WHITE, GEORGE R. MANSFIELD, J. A. UDDEN AND JAMES F. SANBORN

Without renewal of potash, nitrogen and phosphorus in the soil profitable raising of crops from which food and clothing come cannot be continued indefinitely. These are the three important ingredients of artificial fertilizers. Potash is used also for many industrial and domestic purposes. In 1923, the United States consumed 783,689 short tons of crude potash salts, for which the users paid $16,189,243, all but 4 per cent* imported from Germany and France.

Early in the history of this country, potash was obtained by leaching wood ashes. This industry grew until its product attained a value of $1,401,000 for 1850. From that year it declined, especially after 1890, being displaced by foreign potash. Potash mineral deposits were discovered in Germany in 1857, in Alsace in 1904, and in Spain in 1912.

For the first fifteen years of the 20th century the American industry practically was extinct, the supply coming from Germany. In 1910, the German government virtually created a government potash monopoly with control over both production and prices. This act was accompanied by a sharp advance in price to American consumers, despite contracts then existing and antedating this act. This situa-

* This represents 8 per cent of the potash (K_2O) content of the crude salts, however, due to the superior quality of the product of the largest American producer.

tion led to determined efforts by the United States government to find cheap domestic sources of potash, and in 1911 Congress provided for investigations by both the Geological Survey and the Bureau of Soils.

The war threw the United States upon its own resources for potash as for many other chemicals prevously gotten from Europe. Geologists and chemists sought potash from all possible sources and had some success. In 1918, the banner year, there were 128 plants producing 55,000 tons, mostly from Nebraska salt lakes and as a by-product from manufacture of sugar, salt, cement, and steel. Small quantities were gotten from kelp, wool washings, wood ashes, and distillery wastes, from the minerals alunite, leucite, glauconite, and from silicate rocks. In 1922, there were 12 plants. In September of that year, potash went on to the tariff free list. Again the industry almost vanished, but the situation is different from that before the war. Persons interested are now informed of great resources in this country, and a potash plant that gives promise of permanent production has been in operation at Searles Lake California, since April, 1922. An important geological discovery has also been made supplementing the ingenious processes devised by chemists for obtaining potash as a by-product.

In 1912, Professor J. A. Udden, of the University of Texas, found traces of potash in brine from a well drilled for oil at Spur in Dickens County. In 1914 he found small fragments of crystals of a red potash-bearing salt at a depth of 875 to 925 feet in a well at Boden, Potter County. Subsequently such fragments were found by observers engaged jointly by the U. S. Geological Survey and the University of Texas, in many wells drilled for oil. Although drillers for oil have little interest in anything else and their records consequently are unsatisfactory to geologists exploring for other minerals, nevertheless the existence of extensive beds of potash mineral at accessible depth and of profitable richness appears to have been established. Extensive, skillfully directed drilling remains to be done in order to locate the best deposits and to determine their areas and thicknesses with a precision on which commercial developments can be based.

Polyhalite is the mineralogical name of the potash-bearing mineral discovered in the oil wells of western Texas and eastern New Mexico. It contains when pure 15.6 per cent of potash (potassium oxide). In color it ranges from dark brick red to light red and salmon, or it may be colorless. It is composed of the sulfates of magnesium, potassium and calcium and is a low-grade ore of potash. It is soluble, and, as all sulfates are beneficial to most soils, the rock as mined would be a water-soluble fertilizer containing at a maximum the equivalent of 15.6 per cent pure potash. This fertilizer would be good for the western cotton and beet sugar regions and for the fruit-growing country, to which it could be supplied in competition with the low-priced German and French potash.

Polyhalite occurs in connection with salt beds known to underlie an area of about 100,000 square miles in Texas, New Mexico, Oklahoma and Kansas. These beds are of great thickness and on an estimated average of 200 feet contain 30,000 billion tons of rock salt, the largest known deposit. The salt was deposited from the sea millions of years ago, long before the Rocky Mountains were in existence. At times the concentration of this sea water by evaporation became so great that not only common salt (sodium chloride) was deposited, but also potassium salts. The area embracing the discoveries of potash hitherto made, is about 275 by 125 miles. The most promising region lies between the 101st and 104th meridians and between parallels of 31° and 33°, in the Staked Plains of western Texas and southeastern New Mexico. These occurrences of polyhalite are in the Permian formation, as it is named by geologists, the formation in which the German beds also occur.

Potash occurs in many rocks but becomes available for plant food slowly by weathering of the rocks. For intensive agriculture this process needs to be supplemented by artificial fertilization, and in many agricultural regions there are no such rocks. No important attempt has yet been made to mine potash in the United States, but it is being successfully extracted from Searles Lake brines. As depletion of natural soil fertility progresses and industrial demand for potash increases the importance to the nation of the polyhalite deposits in Texas and New Mexico will be apprehended.

Prepared from information supplied by David White and George R. Mansfield, of U. S. Geological Survey; J. A. Udden, University of Texas, and James F. Sanborn, Consulting Engineer, New York.

LIGHTHOUSE ILLUMINATION

Progress Resulting from Research

JOHN S. CONWAY

Coast lighting in America dates back to 1716, when the first lighthouse on this continent was built at the entrance to Boston Harbor by the Province of Massachusetts. One of the earliest acts of the First Congress, on the organization of our federal government was to take over the colonial lights, of which there were twelve in operation, with four others planned or partly constructed.

One of the partly constructed lights was on Cape Henry, at the southerly entrance of Chesapeake Bay, where a project undertaken by Virginia was completed by the United States in 1792, being the first lighthouse built by the government. It was an octagonal sandstone tower 72 feet high costing $15,200. The old tower was replaced in 1881 by a structure, still in use, 165 feet high, built of flanged cast-iron plates bolted together, with brick masonry lining.

The original illuminant was fish oil, superseded about 1810 by sperm oil, burned in a lamp constructed on the Argand principle, with a rough reflector and bull's-eye magnifier, enclosed in a lantern glazed with panes about 12 inches square. By 1840, the reflectors were made on correct optical principles approaching the paraboloid in form, heavily silvered and properly placed. The lantern was also improved by making the frames lighter, the panes larger, and by providing adequate ventilation.

In 1857, a first-order Fresnel lens was installed. About

1822, Augustin Fresnel, a French physicist, devised a system of lenses for concentrating and directing the light of a lamp. Each lens is built up of glass prisms in panels. The central portions are refracting only, and the upper and lower portions both refracting and reflecting. The lens encloses the lamp, which is at the central focus. This device gives greater brilliancy with less consumption of illuminant.

Improvements were made from time to time in the illuminant, passing from sperm oil to rapeseed or colza oil, as the yearly diminution of the whale catch made the cost of sperm oil prohibitive, then to lard oil, and finally to kerosene, burned in a lamp with five concentric wicks, consuming about 200 gallons per month, giving an effective beam through the lens of about 6000 candlepower. In 1910, the wick lamp was discarded in favor of vaporized kerosene burned under an incandescent mantle, increasing the effective candlepower of the beam to 22,000, at the same time decreasing the fuel consumption to a little more than half.

This light, although of reasonably satisfactory intensity, was fixed in character, and with the installation of bright electiric lights at seaside resorts in the vicinity, it became desirable to change the station to a flashing light. While studying suggested improvements, it was found that a high-power electric incandescent lamp would be advantageous, provided means were devised for creating the necessary downward divergence through the lens. Experiments led to the development of a spherical mirror used with a 1000-watt tungsten filament lamp so arranged that an image of the light source is reflected into the upper catadioptric (both reflecting and refracting) prisms of the lens, giving the proper downward divergence.

Commercial current for the light is furnished from a local supply, and a flasher such as used for electric signs produces two short flashes of one second each followed by a flash of seven seconds, this cycle being repeated three times a minute. To guard against interruption of current, the station is equipped with a heavy-duty generating set consisting of a 6-horse-power semi-Diesel oil engine directly connected to a 4-kilowatt generator, along with a set of storage batteries which are kept charged for immediate service whenever needed.

A lamp exchanger was developed to replace burnt-out lamps, the spare lamp being automatically revolved into focus. On account of the flashing characteristic, a timing device was introduced, making contact when the current is interrupted for a period between 30 and 45 seconds, thereby operating the lamp changer on an auxiliary current, which also rings an alarm signal when contact is made, summoning the keepers. Should the second lamp burn out, the alarm signal will sound at once. With this device a continuous night watch is not necessary; hence it has been practicable to dismiss one attendant.

The effective candlepower of the beam is now approximately 80,000, an increase of nearly four times the brightness of the former incandescent oil-vapor fixed light, and the present annual cost per beam candlepower is about one-seventh of the former figures. Annual expense of maintenance has been reduced about $1500. Moreover, the light is highly praised by master mariners entering Chesapeake Bay.

This old lighthouse, therefore, in its 132 years furnishes an example of correlation of pure and applied science, by means of which the illuminating apparatus has steadily kept pace with results from study and experiment. The history of the Lighthouse Service is one long story of improving the aids to navigation and the protection of seafaring life and property along our coasts, always with the inexorable demand for absolute dependability under all conditions.

Contributed by John S. Conway, Member, Am. Soc. Civil Engineers and Am. Soc. Mechanical Engineers, Deputy Commissioner of Lighthouses, Department of Commerce, Washington, D. C.

NICOLAS LEONARD SADI CARNOT

REFLECTIONS ON THE MOTIVE-POWER OF HEAT

C. H. PEABODY

It is fitting that engineers of the United States should commemorate the centenary of the publication of Sadi Carnot's work on the Motive Power of Heat.

Sadi's father was the organizer of victory for the French people at the time of the Revolution. Sadi was born June 1, 1796, in the smaller Luxembourg and named Nicolas-Leonard-Sadi. Prenatal conditions gave him a delicate constitution, which he so fortified by correct living and judicious exercise, that he showed no lack of energy, but on occasion exhibited courage, physical strength and dexterity. At sixteen he entered the Polytechinic School and the next year he left it, first in artillery.

A portrait at the age of 17 years shows a slender sub-lieutenant of engineers with a firm, refined face and a mathematical head. Being too young for the school at Metz, he continued another year at Paris, and took part in military exploits at Vincennes in the Polytechnic battalion. He was appointed lieutenant at 23 and managed to continue his studies at Paris for a time. He appears to have hidden extreme sensibility by a reserved manner, but to have had a just appreciation of his own ability unbiased by egotism.

In 1824, at the age of 28, he published his *Reflections*. This modest work by an unknown young officer, dealing with ideas far in advance of his times and couched in language that few engineers could appreciate, passed out of print and appeared to be lost, until Lord Kelvin, then a young and brilliant mathematician, discovered it, revealed its extraordinary merits and restated the propositions in the forms of modern thermodynamics.

In 1832, Carnot had an attack of scarlet fever, followed by cholera, which carried him off on August 24. Thus was lost to France and to the world one of the clearest and most brilliant intellects of all time.

Let us try to follow the working of his mind as shown in his *Reflections*, premising that the experiments of Gay-Lussac and Dalton were then young and that before Regnault (1811–1878) the properties of steam were but dimly known. He accepted the caloric theory that heat was a substance and though his investigations led him toward the modern energetic theory of heat, his data were insufficient to reach such a conclusion.

His attention is given first to the steam engine, then the only known heat engine. He questions whether there is a natural limit to improvements in economy and concludes that general principles must include all possible forms of heat engines. He determines at once that the work of heat is due to its fall in temperature similar to the fall of water on a water wheel. The idea itself leads in the right direction and he appears not to be misled by the unfortunate parallelism. The production of motive power is, in his mind, due to the transportation of caloric from a hot to a cold body, with steam as an agent.

Then he questions whether the action varies with the agent. To find an answer he invents his ideal heat engine and thereby so clarifies the problem that he comes wondrously near the modern theory of thermodynamics and its quantitative results. He describes the combination of his hot body A, his cold body B, his working cylinder of non-conducting material, and his working substance; he develops his cycle of operations with steam as the working substance, consisting of supply of heat from the boiler, adiabatic expansion, and rejection of heat to the condenser.

He then introduces the idea of the reversible cycle, perhaps the most important of all for thermodynamics. With the steam engine he gets into trouble with the feed water when he reverses the cycle, and so turns to the idea of the hot-air engine, for which the cycle is clearly expressed and the reversibility demonstrated. From study of the reversible cycle, he demonstrates that the efficiency of the ideal engine is independent of the working substance; otherwise a combination of a reversed engine with a more efficient direct engine would make power, an idea which he rejects as unthinkable.

He concludes his discussion of the ideal engine with the requirements that all heat absorbed must be taken at the temperature of the hot body A, and heat must be rejected only at the temperature of the cold body B. This clearly stated ideal cycle is perhaps the most practical invention relating to heat engineering.

Continuing his study of the properties of air, he just missed discovering the constant ratio of the specific heats at constant volume and at constant temperature. He makes a computation of what we now recognize as the mechanical equivalent of heat and comes within 15 per cent of the Joule function.

He concludes that the fall of caloric produces more motive power at inferior than at superior temperatures. In other words, it is better to get a more perfect vacuum than to raise steam pressure; a fact but recently realized by the modern development of steam turbines.

No wonder that Carnot, unknown to his contemporaries, is the head of the corner of the edifice of heat engineering.

Contributed by C. H. Peabody, Dr. Eng., Professor Emeritus of Naval Architecture and Marine Engineering, Massachusetts Institute of Technology, Cambridge.

THE EARTH INDUCTOR COMPASS

A New Instrument for Air and Marine Navigation

BUREAU OF STANDARDS

Most useful of all navigation instruments, whether for sea or for air, is the compass; but for airplane use the ordinary type of magnetic compass has not proved satisfactory. Changes in speed and direction are much more rapid in airplanes than in ships, and because of its inertia the mariner's compass card, if set oscillating, requires considerable time to come to rest again.

There is, however, a second possible method of picking up an indication of direction from the invisible network of magnetic lines of force which cover the earth. If a coil of wire is rapidly rotated in the earth's magnetic field, an electric current is generated in the coil, the intensity of which depends upon the orientation of the axis of the coil with respect to these lines of force. If the current is taken from such a coil by means of brushes and commutator as with a direct-current electrical machine, the current depends also upon the position of these brushes with respect to the lines of force. A compass of this type is known as an earth inductor compass.

Many attempts have been made to construct a compass operating on this principle, especially since the establishment of aviation and the recognition of the fact that the present type of needle compass is not dependable in the air. Until recently, however, none of these attempts had proved practical, and the Great War, which so stimulated invention, came to a close without a completely satisfactory type of airplane compass having been produced on either side of the conflict.

The U. S. Army Air Service recognized this weak point in the equipment of aircraft, and enlisted the coöperation of certain instrument manufacturers and of the Bureau of Standards in the attempt to find a remedy. The first satisfactory model of earth inductor compass was produced by Dr. Paul R. Heyl and Dr. L. J. Briggs, of the Bureau of Standards. Other models, embodying certain structural improvements, but no new principles, have since been constructed for the Air Service by several instrument companies.

For this invention Dr. Heyl and Dr. Briggs were awarded the Magellan gold medal for the best invention of the year pertaining to navigation.

The method used in reading this instrument is a null one. The arrangement is such that when the ship is on its correct course a galvanometer on the instrument board reads zero, but if the ship deviates to the right or left of the course the galvanometer indicates that fact. There are two ways in which this can be accomplished. One is by shifting the collector brushes on the commutator until the current is zero when the ship is on its course. The armature revolves on a vertical axis.

A still better method is to use four brushes and a wheatstone bridge arrangement for balancing the currents. With this method the rotating parts can be placed in the tail of an airplane or at the masthead of a ship where the armature will not be affected by the ship's magnetism. Four wires, which may be of any desired length, connect the brushes to the balancing mechanism and galvanometer, and these parts, being unaffected by magnetism, can be located in the cockpit or the cabin wherever convenient.

Very satisfactory results have been obtained by the Air Service in using this type of compass. Several long flights have been made completely above the clouds, relying entirely upon the earth inductor compass and other instruments. Results have been obtained that would have been impossible with the ordinary type of compass.

All of the airplanes which took part in the flight around the world in 1924 were equipped with the earth inductor compass.

Systematic research by trained men solved this problem and gave the world a surer and safer direction indicator for navigation of the waters and the air.

Contributed by the Bureau of Standards, of the Department of Commerce, George K. Burgess, Director, Herbert Hoover, Secretary of Commerce.

BRINGING HIGH ALTITUDES DOWN TO EARTH

Altitude Chambers for Testing Airplane Engines

BUREAU OF STANDARDS

Persons who go for the first time to altitudes more than a mile above sea level often experience unpleasant symptoms due to the reduced air pressure, and the consequently greater difficulty in taking in through the lungs enough air to support the bodily processes. Above 25,000 feet mountain climbers have carried oxygen.

Airplane engines suffer from the altitude in much the same way. The amount of power they are able to deliver depends upon the amount of air they are able to take in at each stroke, and this decreases with increase of altitude. At 19,000 feet it is only about half what it is at sea level. Hence it was obvious from the start that the performance of an airplane engine flying at high altitude could not be correctly measured by the usual laboratory test at or near sea level. When the first Liberty motor was made, it was taken to the summit of Pike's Peak for an altitude test. This procedure had the obvious drawback of necessitating the transportation of engine, instruments and observers to the mountain top, and besides, it gave results at only one altitude.

When the Interallied Commission visited the United States in 1917, shortly after our entrance into the war, its members urged that equipment be provided for a more extensive study of airplane engine performance than was possible under this this plan. At their suggestion an altitude chamber was constructed at the Bureau of Standards, in Washington. In this chamber the cold and the low air pressures found at altitudes up to 30,000 feet can be reproduced and the engine run and tested under these conditions. Subsequently two more such chambers were built.

Almost immediately the new equipment proved its usefulness. The Commission had recommended as essential for aviation use a grade of gasoline much more volatile than that used commercially. Gasoline is a mixture of numerous hydrocarbons. The quantity which can be distilled from a given supply of crude oil is reduced by increasing the volatility. To have produced in large quantities the grade of gasoline recommended by the Commission would have greatly curtailed the supply for military uses other than aviation and for domestic consumption.

A program of tests was undertaken, using different grades of gasoline at various altitudes, and it was found that the grade then in commercial use was good enough for airplane engines. Such gasoline was therefore used during the war, and as a result the country suffered only from "gasless Sundays" whereas otherwise gasless weeks might have been necessary.

The new equipment also proved useful as a means of learning the causes of engine failure in flight. The pilot usually can tell the conditions under which his engine has failed; by reproducing these conditions in the altitude chamber the failure can often be reproduced and the reason for it learned. On one occasion an engine stopped while under test in the chamber, and the cause was traced to the clogging of the intake manifold with snow. It is believed that many airplanes have been wrecked because of such failure, but the cause had never been determined as the snow would melt out before an investigation could be made.

The altitude chamber consists essentially of a small room in which the pressure can be reduced to that encountered at the altitude desired. The walls are of reinforced concrete about 16 inches thick, and the doors are correspondingly strong. Ammonia refrigerating coils in the top serve to lower the temperature of the chamber. The temperature of the air entering the carburetor can be regulated separately from that in the chamber.

The engine is placed in this chamber. The exhaust passes out through a huge vacuum pump and the intake air enters through a pressure reducing valve. The dynamometer for measuring the power output of the engine, and all the measuring instruments and controls, are placed outside the chamber. No one is inside while the test is in progress. A special type of indicator has been devised which is better for use on highspeed engines than the usual type. It is in two parts, and the part that must be attached to the engine cylinder does not require attention during the test. The other part, on which the adjustments and readings are made, goes on the dynamometer shaft and is entirely outside the altitude chamber, where it is readily accessible.

Science and engineering have thus provided convenient, efficient and economical means for making high altitude tests of engines and other equipment on the earth at comfortable altitudes, under controllable conditions.

Contributed by Bureau of Standards of the Department of Commerce, George K. Burgess, Director, Herbert Hoover, Secretary of Commerce.

LOCATING VESSELS IN FOG

The Radio Compass

JOHN S. CONWAY

When fog blankets the sea, visibility is gone and sound is deficient in directive properties. Development of radio has overcome the perils. The directive property of the loop, or coil, antenna dates back to Hertz, who made successful experiments in 1888, based on Faraday's fundamental discovery in 1831 of electromagnetic induction. Studies of other physicists have produced the radiogoniometer, radio direction finder, or radio compass, the term most frequently used in this country. It is not self-setting, but must be adjusted by trial

Several types of radio compass have been perfected, differing in appearance, but depending upon the same principles. One has an outside coil mounted vertically on a spindle, rotatable in a horizontal plane, controlled by a hand wheel and fitted with a pointer. Another consists of two large fixed loops at right angles to each other, connected to a small rotating coil on the operating panel. Each is provided with the usual radio receiving, detecting, adjusting, and tuning apparatus. The pointer may be placed over the ship's magnetic compass thus giving at a glance the bearing of the radio signal station.

As the coil and pointer are rotated, the maximum intensity of sound is heard when the plane of the coil coincides with the direction to a radio signal, and the intensity gradually diminishes, reaching a minimum when the plane of the coil is at right angles. Radio waves are accompanied by a magnetic force, which is horizontal and at right angles to the direction in which the waves are traveling. Hence when the coil is on edge to the wave, it is threaded by the maximal number of magnetic lines of force, and the amplified signal is heard at a maximum. Conversely, when the coil is broadside to the direction of the transmitting station, no magnetic lines of force thread the coil and therefore no current is induced in it and no sound is heard in the receivers. At intermediate positions the current induced in the coil varies in proportion to the angle between the plane of the coil and the wave front.

In the U. S. Lighthouse Service, important lighthouses and lightships are selected for equipment with automatic apparatus sending signals of definite characteristics during fog or thick weather. The mechanism has a timing switch driven by a small motor producing the signal at regular intervals. The antennas are the same as for ordinary radio communication. The frequency is 300,000 cycles per second, the international standard for such signals, giving a wave length of 1000 meters. The range of usefulness is from 30 to 100 miles, depending upon atmospherics and the sensitiveness of the receiving apparatus. Each station is assigned an identifying signal, a brief combination of dots or dashes repeated rapidly for a period, followed by a silent interval.

To determine the position of a vessel, the navigator rotates the coil of his radio compass until the maximum signal is heard, establishing the identity of the station. He then turns the coil until the minimum intensity is reached, which is generally used for determining direction because of its more accurate definition, the coil being at right angles to the direction from which the signal comes. The pointer shows the bearing within one degree of arc. The navigator needs no knowledge of radio telegraphy.

The radio fog signal is valuable as a leading mark, to enable a vessel to make a lighthouse or lightship at the approach to a harbor. When two or more sending stations are within range of audibility, the intersection of the bearings may be laid down on a chart and the position of the vessel thus fixed. This system, for the first time in marine history, affords a practicable means by which a navigator may obtain accurate bearings on invisible objects. It will enable vessels to locate each other in fog when approaching or needing assistance.

Possiblity of utilizing the directive element of radio signals for locating vessels in fog was recognized by the Lighthouse Service in 1912; but application was dependent on improvement of the radio compass. After development of a more effective compass at the Bureau of Standards in 1915 and 1916, trials were carried out early in 1917 with a transmitting set at Navesink Lighthouse, New Jersey, and a radio compass on the lighthouse steamer *Tulip*. This work was interrupted by the war and resumed after the armistice, resulting in the establishment of several stations.

Based on this combination of radio physics and engineering, this country was the first to establish regular radio fog signal stations, those at the entrance to New York having been in operation since May, 1921. Benefits from the fundamental researches of Faraday and Hertz continue to multiply, although at first of little more than academic interest. But if men are not encouraged in fundamental research, whence will future benefits come?

Contributed by John S. Conway, Member, American Society of Civil Engineers and American Society of Mechanical Engineers, Deputy Commissioner of Lighthouses, Department of Commerce, Washington, D. C.

HOW FOOD GOT INTO TIN CANS AND GLASS JARS

Origin of Canning

A. W. BITTING AND JAMES H. COLLINS

Man, the Hunter, gorged and starved by turns because the food he killed could not be kept long. The capacity of savages for gorging is incredible; Bitting says a single Esquimo will consume a quarter of a musk ox and twenty pounds of fat within twenty-four hours. Man, the Herder, tamed and kept animals alive until meat was wanted, or used their milk; the Masai, in Africa, keep cattle, but never eat their meat, living upon milk with blood drawn periodically from the living animal. Only within 150 years has food been preserved by scientific methods.

After herding, Man became a tiller of the soil, and grew non-perishable grains and pulses. Then followed drying in the sun and air; heat was not used until the end of the eighteenth century. Fermentation was another early process for preserving fruit juices and milk. Smoking and salting were developed later, the latter largely by the Romans; then pickling.

Little progress was made during the Middle Ages, but in the second half of the seventeenth century a real scientific attack was begun when Jean Baptiste van Helmont (1577–1644), Robert Boyle (1627–1691) and Becher (1628–1685) investigated the phenomena of fermentation. Perhaps Antoni van Leeuwenhoeck, the "father of miscroscopy," first saw some of the larger bacteria in 1675, but almost a century passed before Müller began to study them in 1773. Needham put forth the theory of "spontaneous generation" in 1745, boiling flasks of meat extract, closing them tightly, and opening them after a few days, when they were found to be swarming with infusoria, which he believed had developed spontaneously. But in 1778 Lazerro Spallanzani (1729–1799) disproved this theory by better sealing of the flasks, excluding bacteria from the outer air, and the contents were unchanged.

These investigators were groping in the field that Pasteur was to explore and map nearly a century later. But between them came self-taught Nicolas Appert, of wide experience in handling foods, who anticipated Pasteur and by heat sterilization developed the method of food preservation now known as "canning."

Appert successfully preserved fruits, vegetables, meats, fish and other foods by heat sterilization and hermetical sealing. Born in France in 1750, he was forty-five years old when Napoleon offered a prize for a process that would keep perishable foods fresh, chiefly for use at sea. This was in 1795, and fifteen years passed before his method was described in a treatise giving the process to the world.

Appert lived until 1841, but knew no such term as "canning," for his food was preserved in glass bottles, sealed with cork. Though he set up the first establishment for "hermetically sealing," still conducted by the Appert family in Paris, the first marked development of his process was made in England, where several manufacturers adopted it, and an inventor named Peter Durand substituted a tin canister for the glass bottle.

Another member of the Appert family (M. Raymond Chevallier-Appert, 1801–1892) developed the steam retort, or "autoclave," by which it was possible to get sterilizing temperatures higher than that of boiling water, which the senior Appert had used. This was such an improvement that, in 1852, he exhibited a whole sheep that had been cooked and sealed in a huge can four months before. Later, Isaac Solomon, an American, found that the temperature of boiling water could be raised by adding calcium chloride, and an improved autoclave was developed by another American, A. K. Shriver.

These improvements were followed by a phenomenal demand in the United States for canned foods during our Civil War. They became familiar and popular. An independent research was carried out by Gail Borden, the American inventor of sweetened condensed milk, in the fifties. Popular demand led to building automatic machines for preparing and handling foods, and for making cans and glass containers. The National Canners' Association was formed in 1907 to push chemical and bacteriological research further for the improvement of canned foods, both in glass and tin. The Association began research work in 1910 and organized its laboratory in 1913. Today, investigation is proceeding along scientific lines. The apparatus and the methods are highly refined compared with those of the early investigators, who suspected that there was some mysterious relation between fermentation and food spoilage.

Based on information in "The History of Food Conservation," by A. W. Bitting, M.D. (Canning Age, September, 1924) and "The Story of Canned Foods," by James H. Collins (Dutton, New York, 1924).

VANADIUM

A Chemical Curiosity Put to Use

B. D. SAKLATWALLA

This silver-white metal appears to have derived its name from Vanadis, a goddess of Norse mythology. But the tales of mythology are no more romantic than the narrative of the search for vanadium, when once its possibilities for usefulness began to be perceived. The story of vanadium is a history of geographical exploration, scientific research and technical development, sustained by human pluck and persistence through great difficulties and many discouragements to ultimate success. The world is enriched by the victories of business foresight coöperating with scientific talent.

The chemical element, vanadium, was discovered in 1801 by Del Rio, a mineralogist in Mexico, but pratically for a century it remained in oblivion, being relegated to the specimen cabinets of mineralogical museums. It aroused the scientific curiosity of such eminent chemists as Wöhler, Berzelius, and Sir Henry Roscoe, who studied its chemistry without finding any practical application for it in the arts. In 1900, Professor Arnold, who was connected with the University of Sheffield, England, pre-eminent centre of the cutlery and tool-steel world, conceived the idea that this strange element might impart some beneficial properties to tool-steel. He experimented on a small scale in his laboratory and found that the addition of vanadium had wonderfully increased the cutting qualities of his steel. As vanadium was not commonly found in minerals, and was considered a rare element costing much more even than gold, the knowledge of its useful properties in steel could not be readily commercialized.

It was left to the adventurous spirit and commercial vision, inborn of the American business man, to overcome these obstacles. Two brothers, J. J. and J. M. Flannery, of Pittsburgh, having heard of this strange metal element and its stranger influences in steel, and being born and raised in the cradle of the American steel industry, Pittsburgh, conceived the idea of obtaining financial aid from a few of their business friends, in order to make this element commercially available to the industry of their home town. They scoured all the world for possible sources of vanadium minerals. Finally, they succeeded in locating the richest and most unusual deposit of vanadium sulphide, a mineral known as patronite, in the Peruvian Andes, at an altitude of over sixteen thousand feet above sea-level.

This discovery of the only known deposit of vanadium ore, while a stupendous task in itself, was only the beginning of the difficulties which the small company organized by the Flannerys, had to face. They had to convince the steel-makers at home that the use of vanadium had salutary effects. American steel-makers had not heard of vanadium before. After they had convinced the steel-makers, the Flannerys were confronted with the problem of reducing the vanadium to metal out of the ore. No one had done this commercially before. Undaunted, they turned again to the world and obtained the services of the best suited men for the task. With full belief in the success of their undertaking, they devoted all their available funds to building up from the bottom the metallurgy of vanadium, by scientific research, with the aid of these men.

For the very serviceable result, the world should thank the pioneering spirit of the Flannerys and their collaborators, for this result is one of the most potent metallurgical factors in the rapid progress of our industries, namely: "Vanadium Steel." Vanadium is an essential component of all high-speed tool steel, which fashions all our machines of peace and war, big or small, from monster guns to automobile engines. Again, the stresses developed by our present tendency to speed could not have been overcome without the use of vanadium. It is for this reason vanadium steel is used largely in the construction of automobiles, aeroplanes, and railroad equipment. It has thus contributed immeasurably to our comfort and safety and to our rapid industrial advance.

Where could we find a more romantic tale than that of the adventurous spirit and commercial foresight of a few business men who succeeded in discovering an isolated deposit of an unknown mineral at the top of the world, and in gathering together a coterie of scientific and technical talent to solve new metallurgical problems, thus founding a branch of metallurgical industry, which has fortunately proved of such immense value to our modern civilization?

Conveyed at first on the backs of Llamas and later by narrow-gage railways and trucks, from the perpetual snows of Andean heights, vanadium finds its way into the elevated temperatures of metallurgical furnaces. It imparts to steel qualities which make possible the cutting of metals at speeds so high that the tool glows at a red heat. Its possibilities for service to mankind have only begun to be explored.

Contributed by B. D. Saklatwalla, Ph.D., Member, American Institute of Mining and Metallurgical Engineers, Vice-President, Vanadium Corporation of America, Bridgeville, Pennsylvania.

A RETROSPECT IN RESEARCH

Lord Kelvin and Atlantic Cables

A. E. KENNELLY

The ninety and nine narratives which have already appeared in this unique historical series, will, it is confidently believed, have satisfied their open-minded readers that the history of advance in industrial production dependent on scientific research, is replete with fascination, personality and the best aspirations of the human spirit. They breathe sympathy with the work of the past, and inspiration for the hope of the future, through patient study of the great universal ruling mind.

Having reached the centennial number of the series, it seems advantageous to look back, and make such deductions concerning research in the past as occasion may inspire. The past year has seen the centennial anniversary of Lord Kelvin's birth, and the award of the Kelvin medal to a distinguished American engineer and inventor. The story of Lord Kelvin's life is told very entertainingly by the gifted biographer, the late Dr. Silvanus P. Thompson, to whose two-volume book on "The Life of William Thomson, Baron Kelvin of Largs," the more particularly interested reader may refer.

Lord Kelvin was conspicuously a scientist, a second wrangler in the Cambridge Mathematical Tripos of 1845, Professor of Natural Philosophy at Glasgow University from 1846 to 1899, a recipient of honorary Doctor's degrees from twenty-one universities all over the scientific world, the writer of 661 identified scientific papers and the grantee of 69 letters patent for inventions.

At the time of his early manhood, the world of industry was evidently far removed from the world of science. It is inevitable that sound industry must rest upon science; but the connection between them was remote and inconspicuous in 1850. Industrial leaders, in almost all instances, depended exclusively upon experience and skill. Their attitude of mind towards research and applied science, in considerable contrast to latterday conditions, was usually one of hostility and contempt. It is today being recognized that while experience and skill are just as necessary as ever, eternal vigilance is equally necessary on the scientific as on the competitive economic and administrative fronts, if advance is to be maintained. It was Lord Kelvin's crowning achievement to break down some of the then existing barriers between science and industry, to their great mutual advantage.

A single instance of this Kelvin instinct may be outlined here. It is referred to in Thompson's biography. In 1857, it will be remembered that the British battleship, "Agamemnon," with Kelvin on board as observer, met the U. S. frigate, "Niagara," in mid-Atlantic, to lay the first attempted trans-atlantic cable. Starting from a splice between cables on board the two vessels, they began paying out in opposite directions, towards Ireland and Newfoundland respectively. The cable broke in deep water after some hundreds of nautical miles had been laid, and the attempt had to be postponed until the following year.

Kelvin became engrossed in the mechanical and electrical problems of ocean cables. On the electrical side, he developed his now classical theory of the speed of sending messages, and showed that for a given length and total capacitance of the cable, with its signalling apparatus, the speed of transmission, in words per minute, would be inversely proportional to the total resistance of the conductor. It was therefore desirable to use, in any long cable, a copper conductor of the lowest resistance and of the highest available conductivity.

On returning to England in 1857, he secured samples of copper wire used in cable manufacture, and found that they differed in conductivity as much as 2.5 to 1. Having had chemical analyses made of these samples, and finding that the conductivity increased with the degree of chemical purity of the copper, he urged the directors of the Atlantic Cable Company to specify high-conductivity copper in their contracts for conductor material. For a long time he pleaded in vain, the contractors declaring that the requirement was expensive and useless.

Kelvin finally succeeded in having the clause inserted into a contract for a new length of Atlantic cable, late in the year 1857, and he installed a set of electric conductivity measuring apparatus at the cable factory, to ensure compliance with the requirement. This was the first factory testing laboratory in the industry. It soon became recognized that Kelvin's contention was economically well justified, and a special branch of "conductivity copper" production sprang up, to meet the demand. So thoroughly incorporated in the electrical industry has high-conductivity copper become, that it is now hard to realize that it came into being as the result of hard and patient endeavor, based on scientific research.

The foregoing episode from Lord Kelvin's applications of science to industry is typical of many developments during the last century, which have become incorporated in our daily life, and without which the very existence of present-day populations on our planet, would probably be unsustainable. Some of them have been outlined in these narratives. More than ever in the future must we look to discovery and invention, if we are not to retrocede. These come not as unbidden guests. They must be worked for diligently and with research.

Contributed by Professor A. E. Kennelly, Harvard University and Massachusetts Institute of Technology, author of Research Narrative No. 1.

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