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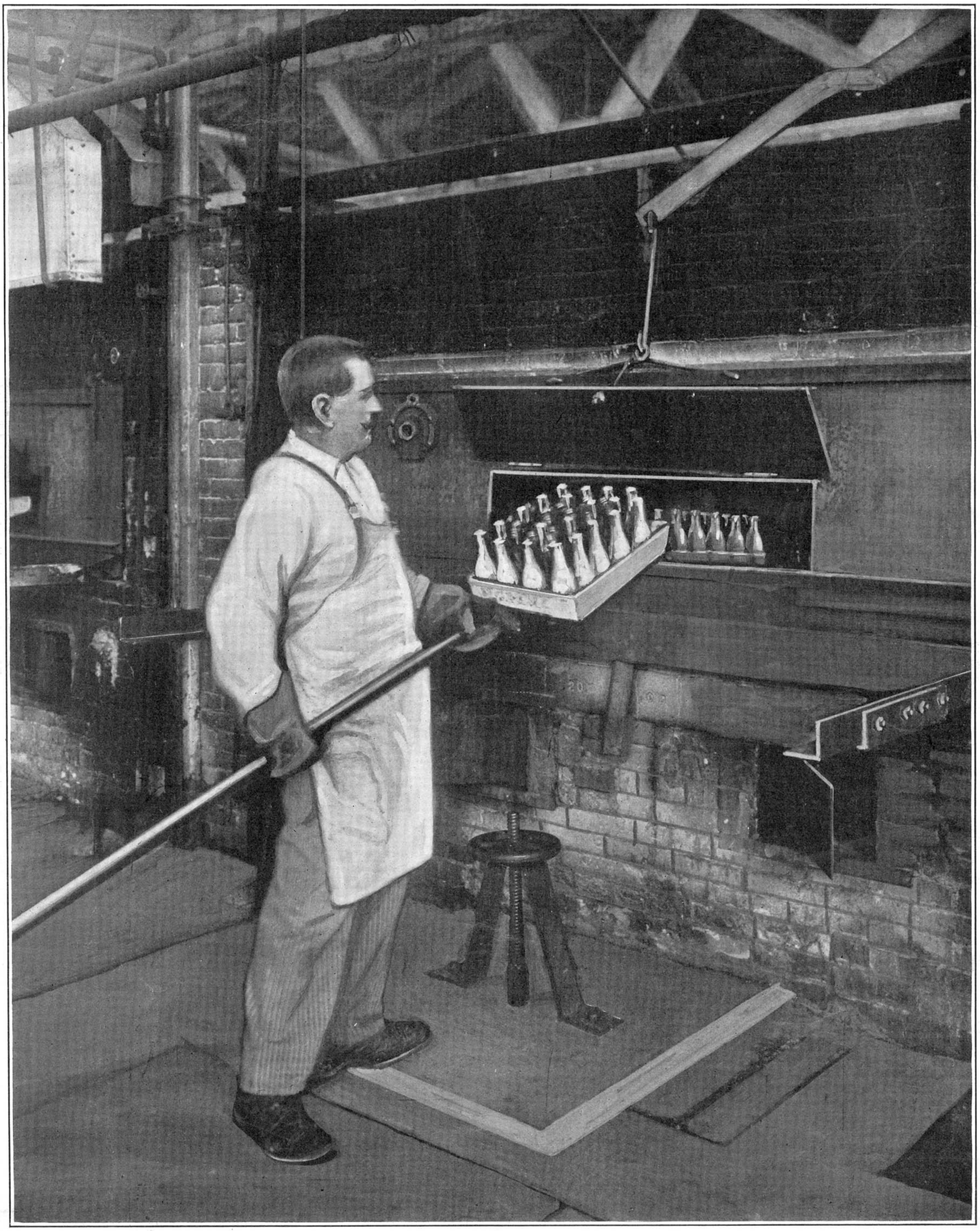

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THE MANUFACTURE OF BOTTLES.—[See page 360.]

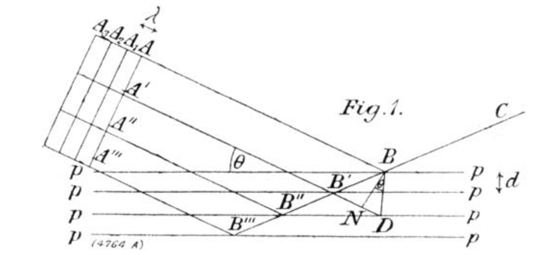
Rontgen Rays and Crystal Structure*

A Study of How Atoms Are Grouped in Solids

To the general public the Röntgen rays remain the X-rays—the name chosen by their discoverer—a scientific mystery, more fascinating than radium, which, after all, does not do much more than shine and decay, a thing a conservative mind does not approve of. That in decaying radium generates helium, and that the disintegration proceeds through an extraordinary series of stages, ranging in time-period from minutes to thousands of years, is hardly understood by people who are quite able to appreciate the wonderful things that medical men have achieved with the aid of Röntgen tubes. But the rays have done much more. They have helped to establish the actual existence of the atom and to reveal that the atom itself has a structure, and they promise to disclose the structure of the atoms in crystals—i. e., the way in which the atoms are grouped and arranged in solids. The student of elementary science soon grasps that solids are dreadfully complex by comparison with gases. The chemist can analyze solids as well as fluids. He splits a compound into its constituent elements, finds out the relative numbers of atoms of each constituent, counts, in conjunction with the physicist—for it is mainly physical chemistry, of course—the actual number of molecules or atoms, and assigns definite structures to the constitutions of certain substances. Those constitutions are not mere speculations; for compounds have synthetically been built up from their elements on the basis of these researches. But there science seemed to find its limit. Calcite, it has long been known, is $CaCO_3$, like limestone; in the kiln the carbonate behaves as if it were made up of CaO and CO_2; in solutions it seems to split into the ions Ca and CO_3. How are the atoms of Ca, C, O actually grouped in the crystal? If they were differently grouped, their properties would probably be different. What are the forces and the laws? The X-rays promise to answer these questions.

The X-rays first puzzled scientists by penetrating through opaque substances and by refusing to be reflected, refracted, or polarized. But there was a strong suspicion almost from the first that they were, after all, only rays of light, though of a light of extremely small wave-length, too delicate to be examined by ordinary apparatus. That assumption has been fully confirmed. The wave-length of sodium light is 5895×10^{-10} m., or Angström units (A.U.), or 5895×10^{-8} cm., and X-rays have wave-lengths of the order of 10^{-8} cm., about one ten-thousandth of the length of ordinary light waves. In a diffraction grating the spacings between the lines should be of the order of the wave-length of the incident light; that condition is fulfilled by ordinary gratings with about 20,000 lines to the inch. To rule a grating with 10,000 times as many lines would be out of the question; the distances between the lines should be of the order of inter-atomic distances. The ingenious idea occurred to Prof. M. von Laue then (in 1912) at Munich (he accepted a call to Zürich soon afterward) to make use of the ordered array of the atoms in a crystal as an X-ray grating. The experiments made by Laue in connection with W. Friedrich, P. Knipping, J. Herweg, E. Hupka and others, were surprisingly successful; crystals of zinc-blende, copper sulphide, rock salt, diamond, zinc, sulphur, etc., behaved like three-dimensional gratings. That was the origin of the new line of research. The experiments were made by letting a beam of Röntgen rays pass through a crystal on to a photographic plate; the black central spot produced on the plate was found surrounded by small dark spots of greater or smaller intensity, arranged symmetrically to the center and lying on circles or ellipses passing through the center, each spot representing a reinforcement of the waves in that direction. Crystals of copper sulphate gave such a radiograph, the powdered crystals did not. But long exposures (of many hours often) were required, and the interpretation of the radiographs in all their striking regularity, as given by Laue, was very complex; he published a memoir on the "Diffraction of Short Electromagnetic Waves by a Crystal" in the *Berichte* of the Bavarian Academy, Munich, June, 1912.

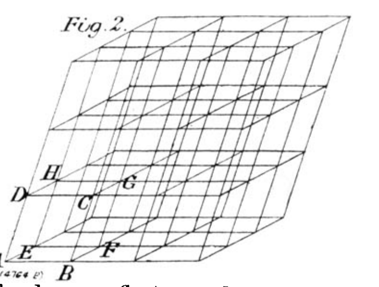
In a mathematical discussion of this memoir (*Proceedings* of the Cambridge Philosophical Society, February, 1913), Mr. W. Lawrence Bragg, of Cambridge, proposed a simpler interpretation of the phenomena, which he illustrated by the diagram, Fig. 1. Let a beam of homogeneous light A, A_1, A_2, A_3 of wave-length λ fall on a series of plane parallel surfaces *p* (all at the same distance apart *d*), each of which reflects a small proportion of the incident light and transmits the remainder; then reflection and interference will result as with thin films, except that there are a great many reflecting surfaces instead of the two of the soap film. The wave A B will partly be reflected, at its angle of incidence θ, in the direction B C, and will partly travel on into the crystal; this latter portion is not indicated in the diagram. The waves reflected at B^I, B^{II}, B^{III}, etc., will, under certain conditions, pass out in the same direction B C, and in the same phase. To find the conditions, draw B N at right angles to A^I, B^I and produce A^I, B^I until it cuts the plane B^{II} in D, which will be the mirror image of the point B in plane B^{II}; since then $B^I B = B^I D$, $A B = A^I D$, and $N D = B^I D$ (the distance by which the rays A B and $A^I B^I$, and hence also the broken rays A B C and $A^I B^I C$, will



differ) will be $2\ d \sin \theta$. If D N be equal to the wave-length λ or to a multiple of it, the waves reflected at B and B^I and similarly at B^{II}, etc., will all be in the same phase and reinforce one another. If D N differ only slightly from λ, the difference in phase will become greater and greater as the number of planes increases, and the resultant amplitude at C will practically be zero. Thus reflection (as different from ordinary reflection) will only take place when $\lambda = 2\ d \sin \theta$. This will be a reflection of the first order, and to mark this we write $\lambda = 2\ d \sin \theta_1$. If θ_1 be changed to θ_2, there will be again reflection of the second order for $2 \lambda = 2\ d \sin \theta_2$, and reflection of the third order for $2\ \lambda = 2\ d \sin \theta_3$, etc. At angles not satisfying this condition there will be no reflection.

Now in a regular crystal the atoms are probably arranged in parallel planes *p*, thousands of planes, all at spacings *d*; the *d* may or may not be equal to the distance between two atoms next to one another in the same plane. The planes will not form continuous walls; that is not necessary for reflection, since a cluster of

THE FUNDAMENTAL SPACE LATTICE



trees or a cloud can reflect sound waves as well nearly as a wall of rock. The atom-bearing planes are set in crystals at intervals of one or two Angström units. The characteristic X-rays used for this study are of the order of about half an Angström unit. This is a pregnant fact, to use the words of Prof. W. H. Bragg; the wave-lengths might easily have been ten or a hundred times the atom spacings, and then the investigation of crystal structure by means of X-rays would have been impossible. The method suggested by Mr. Bragg has been applied with brilliant success by Mr. Bragg himself and by his father, Prof. W. Henry Bragg, up till recently at Leeds, now at University College, London, and in this review we follow mainly the communications made by Prof. Bragg, who quite recently lectured upon the subject again before the Institute of Metals and at the Royal Institution. The Bragg method, it may broadly be said, works with reflected rays, while the Laue experiments were with transmitted rays. In their main conclusions the two methods are in entire agreement.

The Bragg relation, $\lambda = 2\ d \sin \theta$, may be utilized in two ways. When the λ is known, the θ are observed and the *d* determined; once the *d* values are determined, the λ can be checked. As the wave-lengths λ of X-rays have been measured by independent methods, and the θ can be measured within 1 minute of arc, the new research admits of considerable reliability. The apparatus used by Prof. Bragg is a kind of spectrometer without lenses. A pencil of homogeneous X-rays from anti-cathode of rhodium (or some other platinum metal) falls through two narrow slits on a crystal which is mounted on a platform; the reflected ray enters the slit of an ionization chamber (about 5 centimeters in diameter, 15 centimeters long) charged with a heavy vapor (methyl bromide is now preferred, sulphur dioxide was first used); the resulting ionization is measured by means of an electroscope and microscope. The crystal or the ionization chamber, or both together, may be turned on the platform to determine the angles at which decided reflection and ionization occur. There is always a slight diffuse reflection from the crystal surface; but the ionization maxima are easily distinguished. As natural crystal faces are often rough or distorted, the crystals are sand-papered or etched with acid, or cleavage faces are taken; elaborate preparation is not required. The rays used are the characteristic rays of the anti-cathode; rhodium emits four such rays, or two pairs, the principal ray having a λ of 0.614 Angström unit; the principal ray of palladium has a λ = 0.583, of silver 0.557 A.U., the wave-length decreasing by about 5 per cent as we pass from one atomic number to a higher number (Moseley). The ionization curve found is really the spectrum curve of these characteristic rays; with a rhodium target, therefore, the rhodium rays are repeated in the spectra of higher orders at decreasing intensity; the amplitude of the curve marks the intensity. The method thus does not give any lasting records; the reflected beam might be received on photographic paper—M. de Broglie places a cylinder of sensitized paper round the crystal—but Prof. Bragg rarely resorts to photography.

In order to elucidate the relation of the spacings to the crystal form, Prof. Bragg calls attention to wall-paper patterns. The position of any point in a pattern may be fixed with regard to two arbitrary systems of parallel lines crossing one another and cutting the pattern up into a number of rectangles or parallelograms. But unless the chosen points of intersection are the same corresponding, representative points, repeating at regular intervals, the parallelogram will not be a "unit" comprising the *ensemble* of the pattern. Similarly the atoms of crystals are referred to "space-lattices," a kind of scaffolding of three-dimensioned axes which, in the cubic system, cross all at right angles and at equal distances apart; in the other crystallographic systems the distances and angles are not all equal. When planes are passed through all the X, all the Y, and all the Z axes, the structure is cut up into cells, cubes, or parallelopipeds. Even the most complicated crystal can be referred to such a fundamental space-lattice as indicated in Fig. 2. But a cell will not necessarily be a fundamental unit, unless it comprises at least the full number of atoms making up the characteristic molecule (possibly group of molecules) of the substance. Each unit can be considered separately; but to understand the growth of crystals and the special relations, it is better to consider the space-lattice as unlimited in all directions. In the crystal models the axes are represented by wires, and the atoms by beads strung on them. Supposing the atoms to be spaced quite regularly, as in Fig. 3; each little dotted square (in the wall-paper), or each cube on that base (in the crystal), would represent a unit. In the alternating grouping of Fig. 4 each dotted square would again give a cube (1 or 2); but only one of the two (2) would represent a unit (the *c* in Fig. 4 will be explained presently); and in Fig. 5, four of the little squares would be required to make up a unit. The relations become clearer when small balls (atoms) are piled upon one another, which can be done in various ways; but the wire models are the most instructive, and when they are so held in the lantern beam (as Prof. Bragg does) that corresponding axes and atoms coincide, the arrangement of the atoms in the various planes can clearly be recognized.

When the pencil of X-rays falls on the plane A B C D (Fig. 2), the formula $\lambda = 2\ d \sin \theta$ gives the *d* as distance between that plane and the next parallel to it E F G H. When the pencil falls on the plane A E H D the distance of this plane from B F G C is determined. But planes may also be passed, e. g., through E B C H and corresponding points, cutting off the bevel of the edge A D; again, the nose of the crystal may be cut off, as Prof. Bragg calls it, by a plane through D and E B; and so on. The values of *d* determined in this way may or may not be equal; but they will always be in definite geometrical relations. The larger the angles of reflection observed the closer will be the spacing. Yet the deduction of the crystal structure from the *d* is not simple. In the case of a cubical lattice, for instance, the atoms may be arranged to cubes in three

*Engineering.

ways. When experimenting with rock salt (NaCl) and sylvine (KCl)—cubic crystals, very much alike in all properties—Mr. Bragg found that the *d* were not always in correspondence in the two crystals. There was parallelism when the atoms were referred: (*a*) to a simple cube (one atom at each corner), or (*b*) to a centered cube (one atom at each corner, one in the center of the cube); but when the atoms were referred (*c*) to a face-centered cube (one atom at alternating cubic corners, one in the center of a face, as in Fig. 4 (*c*), the analogy between rock salt and sylvine failed. This was found by considering cubic planes, planes beveling off the edges, and planes cutting off the noses, as mentioned, and in this way it was established that KCl gives a simple cube of type (*a*), and NaCl a face-centered cube of type (*c*), while ammonium chloride is one of the rare examples of type (*b*). The face-centered cube (*c*) is very common, and the crystals of copper, silver, gold, etc., belong to this class.

So far all these measurements were merely relative, however. Absolute determinations of the *d* can be made when the atomic weight and the density of the material are known, and in the case of rock salt the distance between two planes (cubic faces) was found to be 2.81 A.U. The consideration of the relative intensities of the spectrum lines of the various orders constitutes another very important step. The intensity of a spectrum line depends upon the atomic weight of the atoms in the plane. When all the atoms in all the planes are the same, the intensities should diminish, according to a simple law, with the higher orders, just as in the case of a regular grating. That was found to hold for crystals of elements, and nearly to hold for KCl, because the atomic weights of K (39) and of Cl (35.5) do not differ much. But it did not hold for NaCl (Na = 23, Cl = 35.5). If the atoms of Na and of Cl were arranged in alternating parallel layers, the intensities should indeed alternate, just as in the case of a grating ruled with alternating strong and weak lines. Mr. Bragg correctly interpreted these features, and it follows that his value for the *d* of NaCl (above given), i. e., 2.81 A.U., marks the distance between a sodium atom and the chloride atom next to it.

When the spacings between the parallel planes are not all the same, similar intensity variations should be observed. In the case of the diamond there is reason to assume that each carbon atom forms the center of a small, regular tetrahedron, with carbon atoms at the four corners, from which it is equally distant; the lattice is a face-centered cube all the same. When the model is built up, it is seen that the first layer of atoms lies in the base, the second layer at the distance 1 above the first, the third layer at the distance 3 above the second, the fourth at distance 1 above the third, and so on. It is as if a grating were ruled with lines spaced 1 and 3 divisions apart alternately. Such a grating would not give any second-order spectrum, and the second-order spectrum of the diamond was indeed found absent. The structure of zinc-blende (ZnS) is exactly like that of the diamond; but there layers of Zn and S alternate at the distances 1 and 3, and as the atomic weight of sulphur (32.07) is only about half that of zinc (65.37), the second-order spectrum is weak, but not quite suppressed. The structure also would explain why zinc-blende has a polarity, while the diamond has not; for, with the atoms arranged in alternating planes of Zn and S, it would make a difference whether the light rays struck a zinc layer (coming from the left) or a sulphur layer (coming from the right). Prof. Ogg, of the Cape, at present working at University College, has quite recently found that antimony and bismuth can be referred to tetrahedra, like the diamond; but the central atom is not equally distant from the others in their cases.

We will briefly notice some more complicated cases. Calcite crystallizes in regular rhombohedra, which ought to be perfectly symmetrical about a certain plane. The X-ray examination shows that layers of Ca and of CO_3 alternate in certain parallel planes; in other directions layers of Ca, CO, O, O succeed one another; the symmetry does not appear to be quite perfect, however; that is to say, the left and right half of a section only coincide when the one side has been slightly shifted (gliding symmetry). Dolomite, which is a double carbonate of calcium and magnesium, is found to be built up of layers of Ca, CO_3, Mg, CO_3, Ca, etc., and there is no plane of symmetry—which is in accordance with the views of crystallographers. The complicated structure of magnetite (Fe_3O_4 = FeO. Fe_2O_3) can be imitated by piling up layers of oxygen atoms and fitting iron atoms into the interstices; some of the iron atoms appear as centers of oxygen tetrahedrons (4 O atoms), in which the iron is bivalent, some as centers of octahedrons (6 atoms of O), in which the iron is tervalent; the two sets have some atoms in common and differ by 60 deg. in orientation.

Prof. Bragg's wire models, which can be taken to pieces, also help us to understand a puzzling point. The X-ray examination seems to concern itself merely about atoms, and not to recognize molecules. The one Na molecule in rock salt might equally well belong to any one of the six Cl atoms near it. But it is difficult to say in what condition the molecule really exists in the solid, and the X-ray examination does not entirely lose sight of the molecule. The whole crystal behaves like a big multiple molecule. If, in taking the model to pieces, a definite order is observed, the complex crystals of magnetite, as well as the simple rock salt cubes, break up into their molecules. That shows that there are various methods of breaking up a crystal, and that the surface of a crystal is more or less like an unsatisfied set of atoms, to which set arrangements of fresh atoms will easily attach themselves—an exceedingly fruitful conception, which would account for the growth of crystals as well as for surface adsorption.

When crystals are heated, the spacings between the atoms should widen, and the X-ray lines should be shifted and decrease in intensity; rock salt crystals show this when heated in an electric furnace, while being examined. Similarly, the expansion of crystals in different directions could be determined with very

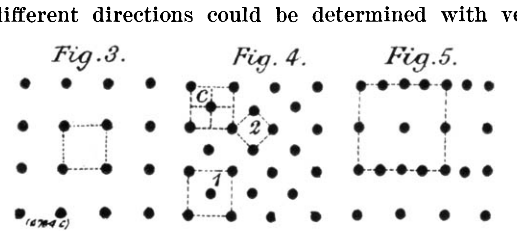


Fig. 3. Fig. 4. Fig. 5.

small specimens; the method does not require large specimens. The new method may also disclose why soft metals form hard alloys; further, in which way the hard and soft state of metals of Beilby, the surface films and cement films between the crystals, differ from one another. E. A. Owen and G. G. Blake have studied hard and annealed copper by X-rays. The examination, of course, presupposes a regular arrangement such as crystals offer. Experiments with glass, which is not crystalline, have failed, we believe, as they were expected to do. On the other hand, O. Lehmann has applied Laue's method to the study of liquid crystals; F. Terada has examined rock salt in the plastic state; P. Knipping has discovered a structure in liquid and in solid paraffin and in wax, and S. Nishikawa and S. Ono (likewise experimenting after Laue) discern crystals in fibrous asbestos, arranged along the fibers, but not in glass threads.

In their main conclusions, the two methods, of Laue and of Bragg, are in essential accord with one another, as we have already stated, and that should be so according to L. Ornstein and others. The objections to the former method are the long exposure, the unavoidable (though, in a sense, useful) presence of X-rays of different frequency under these conditions, the difficulty or impossibility of making quantitative measurements, and the difficulty of interpreting the results; according to G. Friedel, moreover, Laue's method does not bring out the full hemihedral symmetry. The quantitative ionization measurements (though not so accurate as the angle measurements) and the rapid working with homogeneous rays are the advantages of Bragg's method; the constancy of the radiation frequency can be checked by the comparison of the intensities of the different order spectra. Absorption, studied by C. G. Darwin, plays a part in both methods. It is satisfactory that Glocker agrees with W. L. Bragg and his co-workers as to NaCl and KCl; with A. Johnsen as to calcite; with E. Keller as to the diamond, and with P. P. Ewald and Friedrich as to zinc-blende, though not as to pyrites. On the other hand, F. M. Jaeger maintains that the theory is so far inadequate, on either lines, to deal with biaxial crystals; there is still one factor missing in the deductions.

X-ray investigation of crystals is young, of course. But there is a dearth of workers, and the war has cruelly put an end to the life of some investigators and has interrupted the work of others. Mr. H. G. J. Moseley was killed in the Dardanelles, Mr. S. E. Pierce in France; there may be other victims. M. de Broglie, who has tried both methods and modified them, attended one of Prof. Bragg's recent lectures in the uniform of a French medical officer. Mr. W. L. Bragg has gone to the front. It was pathetic to hear Prof. Bragg mention this at the Institute of Metals, lest credit be given to himself that was due to his son. Prof. Bragg has already lost one son in the war.

German Experiments on Carbon Tetrachloride as an Iusulating Fluid

Most of the fires which are so frequent in power houses and transforming stations have their origin in the oil used in the interrupters and transformers. On this account great interest must attach to any suggestion looking toward the replacement of this substance by some other insulating fluid, of equal electrostatic rigidity, but non-combustible.

The scarcity of all oils in the Central Empires has drawn the attention of German technologists to carbon tetrachloride, first proposed as a substitute for oil by a Frenchman, Peyrusson, in 1908; and the conditions under which this fluid might be employed have been closely studied by Vogelsang, whose conclusions, as published in *die Elektrotechnische Zeitschrift*, we summarize.

Carbon tetrachloride, CCl_4, is a liquid of density 1.63, boiling at 76.5 deg. Cent. and solidifying at 26.7 deg. Cent. While evaporating rapidly in air, it is an insulator and non-combustible. The density given represents a figure 1.8 times that for oil; and this, combined with its volatility, leads to considerable inconvenience in its use. All of the experimenter's efforts to prevent evaporation were practically without result; even when he tried covering the surface of the liquid with a float evaporation was almost normal, although there was but the smallest of apertures between the float and the sides of the container. So he concludes that the use of this liquid would involve the introduction of closed containers, which would be of doubtful practicability under the pressure developed at the moment when the interrupter performs its office, or of a protective film of some less volatile liquid.

The chemical affinities of the tetrachloride toward metals with which it might come in contact when used as a substitute for oil are shown by the results of several years' experimenting to be no obstacle. To be sure, at a temperature of 45 deg. Cent., its attack upon these metals is much more noticeable than at ordinary temperatures, copper, which normally is hardly affected at all, becoming covered, after a certain length of exposure at the higher degree of heat, by a greasy white coating which extends to a considerable depth. But aluminum, silver, lead and especially zinc, stand up well in the presence of the tetrachloride; so galvanization affords a sufficient means of protection. Rubber in any form whatever is incapable of exposure to the action of the fluid; but mica sheets remain unaffected, as does litharge cement, which becomes black outside but retains its solidity.

Tests of the electrostatic rigidity of the tetrachloride show that its behavior varies according to the duration of the tension. These tests indicate that the explosive distance between points is considerably greater than for oil, under tension lasting 2 seconds or less; but under tensions of 20 minutes' duration the tetrachloride was decidedly inferior to oil. The fact that the tetrachloride will support momentarily a voltage greatly in excess of its normal disruptive tension is in a way a favorable circumstance; for the dangerous tension is not the normal one, but rather the instantaneous peak load inevitably produced in service. As in the case of oil, the discoloration resulting from use, while considerable, does not seriously decrease the efficiency of the fluid.

While these analytical tests upon the tetrachloride reveal no fundamental feature disqualifying it from use as a substitute for oil, practical tests were not very encouraging. It was employed in a variety of interrupters constructed for oil, and under tensions never exceeding 10,000 volts, usually in the neighborhood of 5,000 volts. The most satisfactory means which the experimenter was able to devise for checking evaporation was the introduction of a layer of glycerine upon the surface of the tetrachloride; and in fairness to this substance, it must be admitted that most of the difficulties were due to the presence of the glycerine. It was found to be impossible to keep the glycerine film intact under actual operating conditions; and its penetration to the metal of the container and to the contact points invariably led to irregularities and even to accidents.

In reviewing these results, it appears that in any event it has been shown that the properties of insulation and non-combustibility are not incompatible, as had long been supposed. The obstacles have ceased to be theoretical, and have become practical. Vogelsang expresses confidence that when the present status of the matter has been brought home to the chemists, a satisfactory solution will not be long in the finding. The probability that such solution will be attained by mixture of several substances is indicated by the results of his own tests with a combination of 75 volumes of oil with 25 of carbon tetrachloride. This mixture, held at 100 deg. Cent. for 43 hours, lost only 5 per cent of its weight. But, of course, this is not a solution of the problem. It is not a diluting agent that is sought for oil, but an actual substitute.

Electrolytic Hydrogen*

A Modern Method for the Technical Production of an Important Gas

By Harry L. Barnitz, Ph.G.

There has been followed by every advancement in the entire generation of electric currents a great extension of the uses of electricity. The rapid growth in the last few years of power plants for generating electricity and the low cost of production has been accompanied by the development of electrochemical processes for the manufacture of materials formerly prepared in other ways; by the application of electrical methods to the extraction and refining of metals; and by the separation of elements and the production of new compounds, which electrical processes alone can effect. One of the more important relations between electricity and chemical action is the production of hydrogen.

It is not my purpose to go into past history regarding the earlier and various stages of development of the generating apparatus used for the electrolytical production of hydrogen, but to describe the method of production of hydrogen by one of the most recent and efficient electrolytic generating apparatus, known as electrolytic cell or generator as now used in the technical production of this important gas. The function of the electrolytic cell or generator is, by the aid of electricity, to separate water into its elements, hydrogen and oxygen.

Two types of generators are used, the unit and the filter press. The former I will take up first:

This type of cell is installed at the U. S. Navy Yard at Brooklyn and many large corporations. The total number of the unit type installations made is considerably in excess of fifty, with a yearly generating capacity of many hundreds of thousands of cubic feet of hydrogen.

The various parts of the unit type cells are shown in the second illustration.

The general dimensions are:

Height of cell 2 feet 10 inches, height over all 5 feet 6 inches, length over all 3 feet 9 inches, width over all 1 foot 9 inches, weight, empty, 1,000 pounds, weight, full, 1,500 pounds.

In each cell there is placed 100 pounds of soda or 165 pounds of potash, which, when water is added, forms the electrolyte. It is not necessary to replenish the soda or potash. This is explained chemically by the dissociation theory—which is when electrolyte is dissolved in water, a portion, at least, of its molecules break up into two parts, one charged with positive electricity, and the other with an equal amount of negative electricity. The charged portions of the molecule are called, respectively, positive and negative *ions*. Thus, if we take as the electrolyte, caustic potash, the first action is in the electrolysis, the dissociation of potassium hydroxide when it dissolves:

$$KOH \longleftrightarrow K + OH$$

Potassium Hydroxide Molecule — Potassium Ion — Hydroxyl Ion

When the potassium *ion* reaches the negative electrode, it loses its charge, becomes a potassium atom, and reacts with the water of the solution, forming potassium hydroxide again and liberating hydrogen:

$$2K + 2H_2O \longrightarrow 2KOH + H_2$$

Potassium — Water — Potassium Hydroxide — Hydrogen

The hydroxyl ions, when they lose their charges, react with each other, forming water and liberating oxygen:

$$OH + OH \longrightarrow H_2O + O$$

Hydrogen — Hydroxyl — Water — Oxygen

It will be seen the net result of these actions is the removal of one molecule of water from the solution and the liberation of two atoms of hydrogen and one atom of oxygen. So it will be seen that water in the cell only needs to be renewed and not the potassium hydroxide. The amount of water used is a little less than one gallon in twenty-four hours.

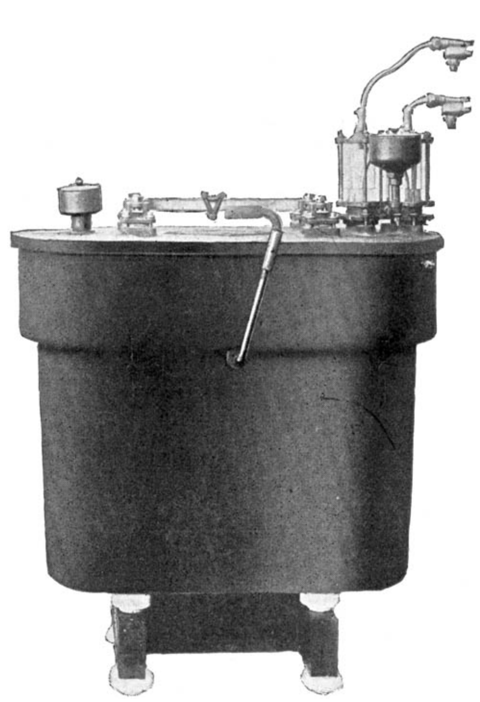
The generators when operating at about 30 degrees C with 28.9 per cent KOH solution will average at least 8 cubic feet of hydrogen and 4 cubic feet of oxygen per K.W.H. and at least 6.3 cubic feet of hydrogen and 3.2 cubic feet of oxygen per clock hour, measured at 20 degrees C. and 760 millimeters pressure when operating with 2 volts by 400 amperes D.C.

Purity of gases direct from the generators—hydrogen, 99.5 per cent or better oxygen 99 per cent or better.

*Read before the Aeronautical Society of America, March 21st, 1916.

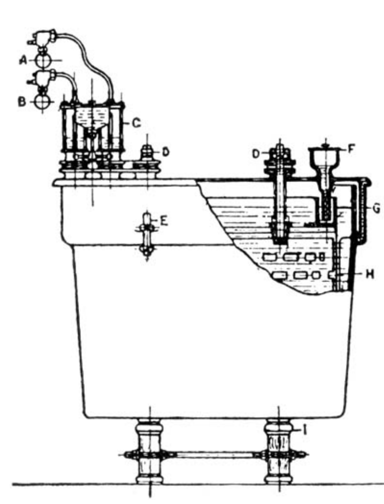
The features of the unit type generator referred to are:

(*a*) That the unit type generator produces the maximum quantity of pure hydrogen and oxygen simultaneously per KWH that can be produced, and at a minimum cost for upkeep.



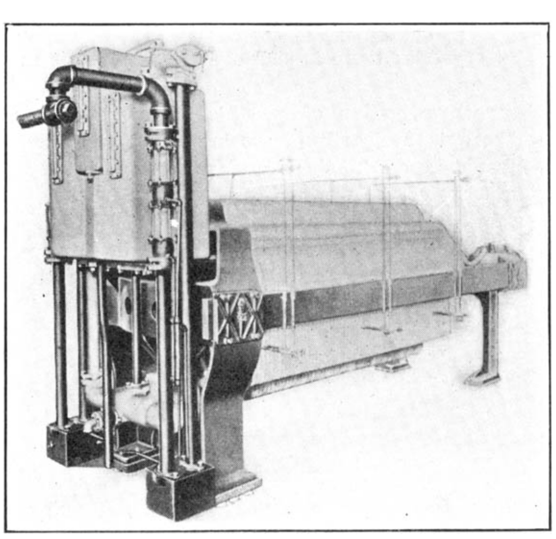
Unit type generator.

(*b*) It is so designated that by means of a special device called the hydraulic joint, any explosive mixture of the gases is prevented. In addition the sight feed indicators show whether the generator is functioning properly while the pressure equalizers counterbalance any excess pressure.



Section of unit type generator.

A, Oxygen off-take. *B*, Hydrogen off-take. *C*, Indicator and pressure equalizer. *D*, Positive electrode terminals. *E*, Negative electrode terminals. *F*, Filling cup. *G*, Hydraulic joint. *H*, Diaphragm. *I*, Insulating supports.



General view of a bipolar filter press type of oxygen-hydrogen generator; large size.

(*c*) A cell of this construction is practically indestructible. The parts are selected, manufactured and designed free from any perishable material. There are no moving parts to get out of order.

(*d*) The generators require only moderate supervision. As soon as the switch is turned on the gases begin to bubble through the sight feed indicators; as soon as the current is shut off, the production ceases. Generators can be operated continuously or intermittently.

(*e*) The generators produce the same quantity of gases of the same purities right along. The gases are of uniform high purity, unless some unusual condition prevails. The reports covering long periods in the operation show variation in the purity of hydrogen and oxygen and not exceeding two tenths of one per cent.

(*f*) The only attention the unit type generators require is the addition of the necessary amount of distilled water daily. In many plants the operating charge for labor does not exceed the cost of one or two hours of one man's time per day.

I will now take up the filter press type hydrogen and oxygen generator. This is the type of generator installed at the plant of the United States Naval Aeronautic Station at Pensacola, Fla. The fundamental principle of the unit type generator is embodied in the filter press type generator—the only change made is in the mechanical construction of the filter press type generator. It has distinct advantages for certain operating conditions over the unit type. Its principal feature is: maximum capacity in minimum space. Two size generators are made; the dimensions of the small size are 2 feet 6 inches wide, 12 feet long and 8 feet high, containing 60 bipolar plates 18 inches square with a voltage drop per plate of 2 volts and with a total voltage per generator 120 volts by 80 amperes D.C.

Capacity of hydrogen generated per hour 70 cubic feet.

Capacity of oxygen generated per hour 35 cubic feet.

Capacity of hydrogen generated per 24 hours 1,680 cubic feet.

Capacity of oxygen generated per 24 hours 840 cubic feet.

The large size generators have dimensions of 4 feet 6 inches wide, 14 feet 6 inches long, and 8 feet high, containing 60 bipolar plates, 36 inches square with a voltage drop per plate of 2 volts and with a total voltage of 120 by 320 amperes D.C.

Capacity on large generators:

	Cubic feet.
Hydrogen, per hour	280
Oxygen, per hour	140
Hydrogen, per 24 hours	6,720
Oxygen, per 24 hours	3,360

Efficiency is identical in both sizes when operating at about 70 deg. C. (which is normal temperature) with 28.9 per cent KOH solution each generator will give at least:

(1) 7.5 cubic feet hydrogen
(2) 3.75 cubic feet oxygen

per K.W.H. the gases to be measured at 20 deg. C., 760 millimeters pressure—400 pounds soda or 800 pounds potash will be required to produce the electrolyte.

Purity of the gases direct from the generator—hydrogen 99.9 per cent; oxygen 99.8 per cent.

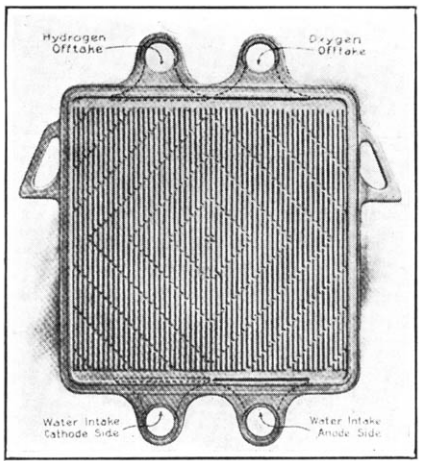
The filter press type generator consists mainly of a series of metallic plates (electrodes) clamped up together and supported in a heavy frame, electrically insulated from one another, and separated by diaphragms of porous fabric. Each pair of these electrodes forms a closed cell, divided by the diaphragm. These cells are filled with the electrolyte (an aqueous solution of caustic potash or soda) which acts as a conductor connecting up the plates in series.

An electric current admitted at one end plate passes on through the plates and through the solution to the other end plate. In its passage, it decomposes the water in the solution into the two gases—hydrogen and oxygen—which are released on opposite sides of each plate and emerge upward into the gas off-takes. The mingling of the hydrogen and oxygen in each cell or compart-

ment is prevented by the diaphragm which, while permitting the passage of the fluid, resists the passage of the gases, according to a well-known physical law.

As the gases are released and withdrawn, the distilled water is automatically replenished from a supply tank. The operation is continuous so long as current is supplied and electrolyte maintained.

In the smaller machine, the electrodes are carried on two steel rods supported on two heavy end pieces or pedestals of cast iron. In the larger generator the side rods are replaced by deep steel bars. The construction is one of extreme rigidity, absolute proof against any distortion and consequent disarrangement of electrodes; with resultant leakage. The electrodes are clamped together by a heavy screw working in the rear support.



Electrode from anode side, showing water intake and gas off-take channels and the corrugations that facilitate release of gases.

A feature of special note in the filter press generator is that a ball-thrust bearing is interposed between the end of the clamping screw and the rear end plate—which contributes to the nonleaking qualities of the machine by doing away with the tendency of the electrodes to "ride up" from the side bars under screw pressure.

The electrodes are of special design and are composed of special alloy—covered by patents. The anode side being heavily nickeled, which materially facilitates the electrolysis or decomposition, and to lower the voltage, while the cathode side is of iron. Incidentally these bi-metallic electrodes prevent the formation of rust and oxides, which would eventually shorten the life of the apparatus. The surfaces of the electrodes carry vertical corrugations which are interrupted by a large number of depressions to facilitate the flow of the electrolyte into the cell and the release of the gases from it.

At top and bottom of each electrode are two openings communicating by cored channels with opposite sides of the plate. Those at the bottom are for the water intakes and those at the top are for the gas off-takes. It will be seen that each half of each cell (separated by the diaphragm) has its own independent water intake and gas outlet, so that there can be no possibility of the two gases mingling through these channels. Any gas leakage which may occur between the electrodes escapes to the open air and not into the adjacent cell or into the gas off-takes.

These are of specially prepared asbestos fabric of a thickness and texture carefully worked out by long experience and experiment to give the best results. All around the edge of this fabric is molded a packing rim of pure rubber which is an integral part of the diaphragm and which rests in a recessed groove on the face of the electrode.

In a generator of this type an essential of power economy is that all the current supplied the machine shall pass through the electrolyte and none of it be by-passed through the metal of the machine or through the water inlet and gas outlets.

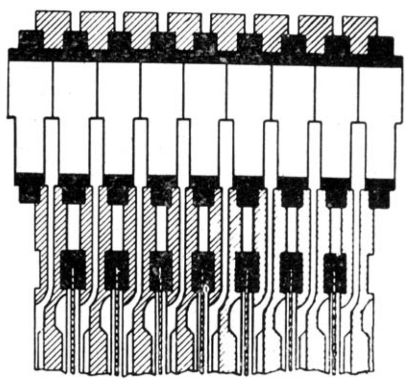
In the filter press type generator, the electrodes are insulated from the side bars of the frames by porcelain insulators resting on a wooden bar in the large machines and on fiber in the small machines. They are insulated from one another; first, by the pure rubber packing rim surrounding the diaphragms, second by nipples of pure rubber inserted in the water intake and gas off-take shoulders of the electrodes—these nipples, with everything clamped home, meeting one another and not only insulating the electrode shoulders but also providing an insulating tube in the interior of the water intakes and gas off-takes.

The gases rising from the electrodes and entering the gas off-takes carry with them a small percentage of the electrolyte, which if allowed to enter the external piping system would ground the apparatus.

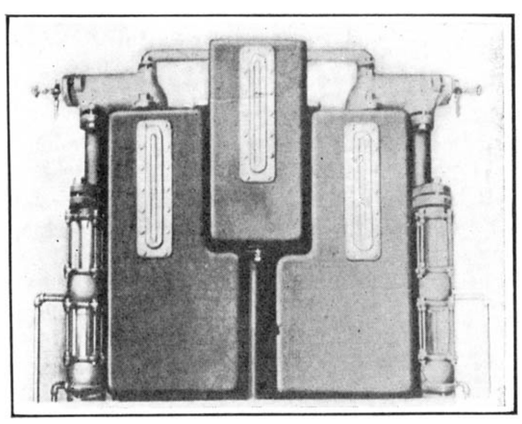
To guard against this contingency, there is provided in each gas off-take a special system of insulating sections—each consisting of two heavy glass tubes clamped between flanged drain sections so devised as to intercept and withdraw through an insulating connection the moisture entrained in the gases. The gases emerge through these insulators substantially dry and free from electrolyte.

Not only do these insulating connections prevent grounding and waste of current. They also permit two or more generators to be operated in series, instead of in parallel, with the advantage of keeping the production the same in each generator without the use of devices for cutting out electrodes or introducing resistance in the circuit. Each generator is independent of every other in the system.

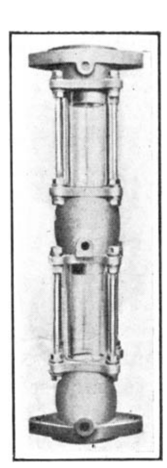
The two important features in electrical efficiency in this type generator are: "First, the composition alloy and nickel plating used in the manufacture of the electrodes; second, that the design of this generator is such



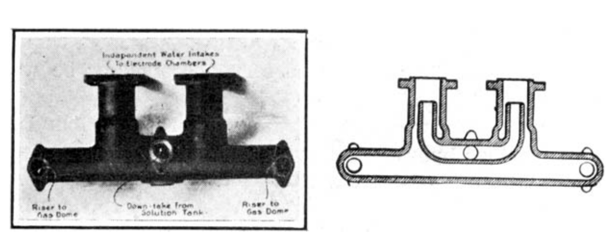
Partial section through assembled electrodes, diaphragms and gas off-takes, showing method of internal insulation by means of diaphragm packing rim and nipples in the gas off-take which clamp up to make a continuous insulating tube.



Upper front view of bipolar generator; gas domes at either side with sight indicators for fluid level; solution tank in the middle, with sight-indicator for fluid level; gas off-takes at top of each gas dome, connecting downward with the purgers at either side, drain pipes in place attached to insulating connections.



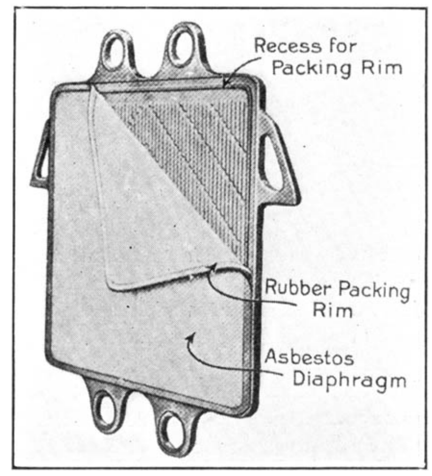
One of the insulating connections in the gas discharge piping; solution contained in the gases is intercepted at two points and drained off through the openings shown in the middle and bottom connections.



At left is the water-feed manifold, with the various connections indicated. At right is a section of the manifold, showing the internal diverting nozzles, which direct the water feed from the solution tank (middle connection) into the two water intakes to the electrode chambers.

as to retain within the apparatus most of the heat produced as a result of the ohmic resistance. This keeps the electrolyte and the electrodes at a comparatively high temperature, which adds to the efficiency of the electrolytic process. Furthermore, the electrolyte used—a solution of caustic soda or potash—has been found by experiment to utilize the current to best advantage.

Before starting the apparatus the generator is filled with the solution of electrolyte; as the decomposition proceeds and gases withdrawn, water must be supplied to the solution to maintain the right density. On the



Electrode with diaphragm partially removed, showing the method of holding and packing the diaphragm.

front of the generator and elevated above the electrodes, is a solution box or tank which receives the distilled water that is supplied to the electrode chambers or cells. From this tank a pipe descends to a water-feed manifold, the latter branching to two independent connections to the two separate water intakes to the cells. And from this manifold two risers lead, one to each of the two gas domes above.

Into these gas domes the oxygen and hydrogen are separately introduced as generated, the discharge taking place through an inverted "L" below the fluid level in the dome. This level is determined by—or is a resultant of—the static pressure due to the fluid in the solution box, and the gas pressure. The arrangement is such that the fluid level between the electrodes is automatically maintained at the proper point, at all times. And the rate of water feed is absolutely proportioned to and determined by the rate of gas generation.

A primary essential in a generator of this type is to minimize circulation through the diaphragms, the function of these diaphragms being only to segregate the two gases as released, at the same time permitting contact of the electrolyte through their pores.

The two independent water supplies—one to either side of each diaphragm, but both under exactly the same pressure due to the hydrostatic head between the electrodes—obviously put the diaphragms under balanced fluid pressure, and eliminate circulation through and over them due to unequal pressure on their two sides.

This has two vital results. First, it removes any tendency to cause a mingling of gases through the diaphragm. Second, it relieves the diaphragm material from all mechanical stress and obviates any destructive erosive action which might be caused by solid particles in the electrolyte being forced over or through the fabric. This absolute balance and control of water pressure, then, affects both the purity of the gases and the life of the apparatus.

The two gas off-takes discharge into two independent gas domes already referred to, the gas emerging below the fluid surface through an inverted "L." It is apparent, then, that the pressure on both bases, clear back to the individual cells, is the same, being that determined by the position of the inverted "L" in the fluid and by the hydrostatic head in the solution tank.

These balanced pressures in both gas off-takes forbid any mixture of the gases and contribute to the balancing of pressures on the diaphragms. It will be noted that gas and water pressures are predetermined and constant.

The gases escaping from the gas off-take "L's" rise through the fluid in the gas domes and pass out through the gas discharges at the top of the domes, thence downward to purgers on either side. These purgers are closed boxes of cast iron filled with water to a certain level. The gases escape below the surface of this water, pass upward through it and emerge thence to the supply lines and to the gasholders.

The function of these purgers is three-fold; first, to

catch any entrained fluid in the gas; second, to cool the gas; third, to act as a water-check-valve protecting the pressure system of the generator from any external variation or excess of pressure. Furthermore, each generator is thus made independent of every other in the plant.

A signal whistle is provided which gives notice when the level of the solution of the generator falls below the prescribed limit. Glass sight-feed indicators on the solution tank and gas domes show the fluid levels and reveal the generation of the gases. Gage glasses connecting with the electrodes at intervals along the generator show the fluid levels in the body of the apparatus.

To permit the emptying of solution from the generator when required, drain valves are provided. These are of the level-operated gate type, designed to obviate any leakage or wear due to the presence of solid matter in the fluid.

The only parts subject to deterioration and replacement are the rubber of the insulating nipples and diaphragms packing rims. Observations on this pure rubber insulation during the years of experimental work on this generator, demonstrate that it has a length of life highly satisfactory. The asbestos fabric of the diaphragms has been proved to be strong and durable, and it has already been pointed out that mechanical deterioration of the fabric is minimized by the balancing of pressure and the reduction of fluid circulation within the apparatus. The up-keep cost on the filter press type generator has been reduced to the practical limit.

It is as completely automatic as a high-duty device can be made. Practically the only attention required in operation is a maintenance of the water supply, and calls only for a minimum of attendance—at the most, only a small part of one man's time.

Is Vegetarianism Based on Sound Science?

Theories and Results Briefly Reviewed

By M. Helen Keith, Assistant in Animal Nutrition, University of Illinois

It is said that the number of people adopting the vegetarian diet is largely on the increase. The high cost of meats in these days leads many a family to face the proposition of adopting the plan from an economic motive. What are the reasons for and against it?

Although vegetarianism has been taken up frequently from reasons which may be called emotional, there is also much testimony as to great improvement in the physical condition of those who have adopted it. For instance, of Sarah Bernhardt it is said that she has "demonstrated that a vegetarian diet makes one younger and more elastic and gives a clear brain and steady nerve." Senator LaFollette says that he can do twice the work he did on the mixed diet and his head is vastly clearer. August Rodin, the sculptor, considers that his imagination works more clearly and the general tone of his production is higher. Wu Ting-fang thinks he has cured himself of many ills in this way and he expects to be able to prolong his life to one hundred and fifty or more years by refraining from all meats. It has been noticed that much of this testimony comes from individuals who have become overstout and needed to reduce their flesh, or from those to whom the change was made really one of general regulation of habits and control of diet.

Such testimonials as these are good, as far as they go. There is little doubt that many a person who has abused his body by overeating, or injudicious eating, would be much benefited by inflicting upon himself severe restrictions as to the amount, the kind, and the time of his eating. Testimony comes, however, also from others who have found that for themselves the attempt to live on the vegetarian diet has resulted, sooner or later, in a series of ailments and an impaired nervous condition. These cases are less likely to be heard from than the others. A statistical comparison of the testimony on both sides of the question, with statements as to the details of the conditions of the subjects, would be of interest.

The collection of such statistics which could be considered unbiased and fairly representative of human experience is impossible, but if one may infer from certain data on albino rats collected at Leland Stanford University, the case stands convincingly against the vegetable diet. Observations on the lower animals have the advantage that the effects of a particular dietary treatment cannot be influenced by any preconceived notion on the part of the subject as to how they will come out.

The report from the experiment is that: Rats fed on a mixed diet did more work, voluntarily, than those on a vegetable diet. The vegetarian rats aged much earlier in life. The growth of the vegetarians was greatly retarded. The ratio of maximum weights was 1.6 to 1 in favor of the omnivorous feeders. The effect on the general condition of the body was most overwhelmingly in favor of the omnivorous. The vegetarians were frail, weak, and showed extreme lassitude and indifference. The omnivorous were the reverse in all these respects. The average life of the omnivorous was 1,020 days, that of the vegetarians 555 days. This was a ratio of 1.83 to 1.

In this evidence every claim of the vegetarian meets a counter-claim. However, whether rats or men, whether statistical or unrelated, this type of evidence does not go deep enough and is not sufficiently definite to furnish a satisfactory basis for judgment as to the limitations of the method of treatment. With human subjects it has a disadvantage in the impossibility of eliminating personal prejudice and an advantage in the probable inclusion of a wide range of food materials within the designated field and a free choice of activity not affected by experimental conditions. But one must ask what is the physiological explanation of any advantage of either type of food? Are there any specific values in animal foods which give reasons why they should be eaten?

The physiologists and nutritional chemists have generally put it about this way: Although proteins, carbohydrates, fats, and salts are found in both classes of food, meat is *par excellence* a protein food, and the cereal grains and other vegetable products are carbohydrate foods. Fats and oils are abundant in both kingdoms; but, as a matter of fact, those which have been most used as foods are of animal origin. Proteins, carbohydrates, and fats are all used by the body for the production of heat and muscular energy; proteins also serve a specific need as building material in replacing the wear and tear of the body. Since all are present in vegetable foods as well as in animal foods, it is possible for a person to subsist on food of either type to the exclusion of the other; but a large use of meat means a large amount of protein, and the question of the liberal use of meat involves the much-discussed question of the desirability of a high-protein or a low-protein diet. As is more and more fully realized of late years, this last question of the protein requirement needs to be settled more on the ground of quality than of quantity, and until much more information is gathered with regard to just what proteins are of greatest value to the animal body it will be best to advocate a rather liberal allowance of protein, selected from as wide a field as may be. It is generally recognized that a large excess of protein is undesirable, and a diet made up entirely of meat could be endured only by those living in the Arctic regions and under strenuous exercise. On the other hand, a vegetable diet generally has so low a protein content that a large bulk of it must be eaten in order to secure a sufficient supply of protein.

The bulkiness of a vegetable diet is increased by a considerable content of water and of indigestible material, especially cellulose. But these factors are in themselves advantageous in a degree, because they facilitate the movement of the food along the digestive tract. A meal that is completely digested may be, like the inherited fortune, too much of a good thing obtained with so little of exertion as to make the recipient lazy and incompetent. On the other hand, poverty may demand such strenuous work as not to allow the worker to take advantage of all the good things that come along free. The indigestible materials themselves prevent the digestion and absorption of some of the digestible materials.

An excessive bulkiness may be avoided in part by the selection of foods that supply fats, for fat is a concentrated food. Fat is usually well digested, and a pound of fat furnishes more than twice as much heat to the body as a pound of carbohydrate or of protein. If fat meat, butter, and cream are taboo, substitutes from plant origin must be sought. For that reason, nuts are more freely used in the vegetarian diet than in the mixed diet. They furnish considerable fat and at the same time protein and carbohydrates in a form that is not bulky. They should be served ground or be well masticated.

Another form of fat of vegetable origin is found in the various hydrogenated vegetable oils which are coming into use of late, such as crisco. Several recent tests made in Germany and in America as to the utilization of hydrogenated peanut oil, sesame oil, and cottonseed oil all give evidence that these oils are without injurious effect on dogs and men, and are about as well digested and utilized as the lard with which they have been compared. In the experiments carried out with men in Jefferson Medical College, in Philadelphia, for example, the lard was utilized to the extent of 94.7 per cent and the hydrogenated oil (from cottonseed) to the extent of 93.33 per cent. The United States Department of Agriculture has begun an extensive investigation of the food value of various animal and vegetable fats in household use. A report on the digestibility of lard, beef fat, mutton fat, and butter has already been published (U. S. Dept. Agr., Bul. No. 310, 1915). The digestion percentages are: for butter fat and lard 97, for beef fat 93, and for mutton fat 88 per cent.

One need not, therefore, object to the vegetarian diet on the ground of the fat requirement in these days when so many forms of fat are brought to our markets. The war, however, is causing a rush of fats to the soap factories, because the soap-making process furnishes glycerin as a side-product, and the demand for glycerin for explosives is at present practically unlimited. The Germans are saving the raisin seeds from the mincemeat factories, in order to extract the oil which the seeds contain.

Under the conditions of scarcity of food, however, the greatest drain on the physical well-being is due to insufficiency of proteins. A certain amount of the protein components absolutely must be given with the food, or the body must find them by breaking down its own tissues. A man weighing 156 pounds contains about 30 pounds of protein, or 20 per cent of his live weight. If the man starves, he loses 5 parts per thousand of his protein store daily. If he is not starved but on a limited diet, carbohydrates and fats may somewhat reduce the loss but cannot entirely replace it. Of the proteins he may take to prevent this loss to the body those from animal sources are more effective than those from plant sources. Data from Rubner's laboratory, in Berlin, show the following as the lowest amounts of protein of the different kinds which, with an abundance of carbohydrates and fats, may suffice to keep the body from loss of protein:

Meat protein	30 grams
Milk protein	31 "
Rice protein	34 "
Potato protein	38 "
Bean protein	54 "
Bread protein	76 "
Indian corn protein	102 "

The numbers show that of this list much larger amounts are required of the bean protein, the bread protein, and the Indian corn protein than of the meat protein or the milk protein.

Such observations as these show plainly the advantage of animal protein over vegetable proteins in the extreme emergency. Another observation which has repeatedly been made, and which shows the advantage of the animal proteins, is that in general they are much more nearly all absorbed from the alimentary tract than are the vegetable proteins. There is considerable waste in the use of plant proteins. Certain recent evpriments indicate that this form of waste is due largely to what might be called the style of package. If the nutritive material is covered by a case of indigestible material, or even intimately mixed with such indigestible and hard, insoluble material, it may be expected that a part of it will escape unchanged. That is the condition in much of the cereal foods and vegetables. The waste due to the rapid movement of such foods through the canal is another hindering factor already mentioned. The animals that habitually live entirely on vegetable products are provided with means for reducing this waste. They can digest cellulose and they

have lengthened intestines. Man is not so provided.

With the idea in view that such factors might be the chief reasons for the differences in the absorption of the vegetable and animal proteins, experiments have been made in which a few isolated proteins purified were fed to dogs in a condition most favorable to absorption and compared as to the degree of absorption, the rate of metabolism, and the power to spare the body protein. No differences could then be noted characteristic of vegetable or animal protein. The wastefulness due to the style of package had been done away with in that case, and the vegetable proteins were of equal value with animal proteins.

There are two kinds of wastefulness in vegetable proteins, corresponding with the two ways by which the manufacturer persuades the woman to pay for more than she gets when she purchases his goods. He ties a ribbon around them and puts them in a Christmas box, and she pays thirty per cent. more for them than she would without. Vegetable proteins come boxed, and one, therefore, pays high for them. Moreover, in the article itself the manufacturer puts in shoddy, so that the woman pays the prices of linen and wool and receives part cotton. In like manner one pays for good body-building proteins and a part of what one gets proves to be of inferior value or incomplete for that purpose.

For example, more than half of the protein of Indian corn is zein, and nearly half of that of wheat is gliadin, and Professors Osborne and Mendel, of Yale University, have been proving by their rat and mouse experiments that neither of these proteins contains all of the constituents that are required for building up the tissue proteins of the animal body. Neither of these, nor certain other proteins examined, is satisfactory to serve as the sole protein, even with any amount of carbohydrate and fat. With animal foods, however, there seems to be less of such unsatisfactory protein. Either of the proteins of milk or the albumin of egg is sufficient in itself; and it may be presumed that meat proteins generally are complete, because they are to be used mainly for the building of meat (muscle) in the body of the animal eating the meat. Some of the vegetable proteins are complete in themselves, but the presence of the shoddy necessitates the purchase of a larger order of corn or wheat, for instance, than would be necessary of meat or milk. If one is to confine oneself to a vegetable diet, therefore, it is advisable to provide a liberal and varied supply of protein, unless one wishes to reduce the body protein. As judged by these considerations it is much safer to include meat, milk, and eggs in the diet.

Furthermore, during the last few years there has been brought out some positive evidence of injury resulting from an exclusively vegetable diet. In one set of experiments such effects were observed in several species of mamalia, even when the diet was made up of mixed cereals, legumes, and fresh vegetables. If fresh beef, ox liver, eggs, or milk was added to the vegetable diet, the health of the animal was protected. In animals that died as a result of an exclusive diet of vegetable substances there were signs of pathological conditions in the central nervous system and in the alimentary canal, and of histological changes in the organs. The experiments seem to demonstrate that the mixed diet supplies elements the lack of which in vegetable products may cause injury to vital tissues.

These experiments were carried out on monkeys, white mice and rats and hogs; but the effects are in some respects quite like those of pellagra and beriberi among men in communities where the food is very limited and consists entirely of cereals.

The disease pellagra is being actively investigated, both in Southern Italy, where it is abundant among the poor peasant class, and in our Southern States, where it has spread to a serious extent. The Italian peasants subsist almost entirely on Indian corn. From data derived by a number of physiological experiments in which were studied the effects of consuming a diet consisting of corn alone and of corn to which was added protein from other sources, the investigators conclude that pellagra is a "deficiency disease" produced by subsisting on a diet deficient in animal proteins. Studies made in the United States also (Public Health Report, 30, 1915) indicate emphatically that pellagra is a disease resulting from the use of a restricted diet, and that the development or recurrence of the disease can in a large percentage of the cases be prevented by an increase in the amount of fresh animal and leguminous proteins and a reduction in the amount of carbohydrates eaten.

The disease of beriberi has similarly been attributed to the continued use of a diet containing little beside rice. Such people should, if possible, be provided with some meat and milk to add to their corn or rice.

The general conclusion to be drawn from the scientific evidence is, therefore, that the meat-free diet is not as safe as the diet containing meat. While in many respects the food constituents from animal and vegetable sources are altogether equivalent and replaceable, and while it is undoubtedly possible for some people to live in perfect health and comfort on a well-regulated diet selected from vegetable sources, with the addition of milk and eggs, the selection of a suitable variety from these limited sources requires special care in the choice and probably special attention to the manner of preparation. It may be said emphatically that the narrow restriction of the diet to cereals leads to serious injury.

Newer Standpoint in the Study of Nutrition

By P. Haas, D.Sc., Ph.D.

In a lecture delivered recently before the Chemical Society, Prof. Hopkins chose for his subject "Newer Standpoints in the Study of Nutrition," and some of the more important points dealt with are contained in the following summary.

The protein molecule is not absorbed by the body as such and all processes of oxidation or molecular reconstruction are preceded by a complete hydrolysis into amino acids. The proof of this is two-fold; in the first place examination of the blood of anæsthetized animals before and after a meal shows that nitrogenous food is conveyed by the blood to the tissues mainly in the form of amino acids, and secondly, it has been repeatedly shown that animals may be kept alive on a diet of amino acids as their sole source of nitrogenous food, and that young animals will grow on the same diet. Furthermore, if proteins such as albumoses or peptones which we consume in ordinary food are injected into the blood-stream, they are rapidly excreted by the urine, showing that they are foreign to the blood, whereas amino acids injected into the blood-stream are metabolized quite normally. In starvation the life of the animal is maintained by drawing upon the tissue proteins for its supply of nitrogenous material, but here again, on examining the blood, one finds not the unchanged tissue proteins, but the amino acids arising from these by hydrolysis by means of autolytic ferments.

The fact that the animal is able to maintain itself on an amino acid mixture enables one to ascertain experimentally the relative value of individual amino acids and whether certain amino acids are indispensable to life or are possessed of any particular function in nutrition by virtue of their molecular structure. In all experiments in which animals are fed on amino acids it is essential to include in the mixture a minute quantity of vitamine in the form of a nitrogen-free alcoholic extract of fresh milk. Casein hydrolyzed by boiling for 40 hours with 20 per cent sulphuric acid forms a suitable amino acid mixture, but is deficient in cystine and tryptophan, the latter substance being destroyed by heating with acid. Accordingly, the hydrolysis mixture has to be treated with small quantities of these two acids in order to make it suitable for supporting growth. It has been found that if tryptophan is purposely withheld loss of body weight results almost immediately, and the animal dies more or less rapidly. The explanation offered for this phenomenon is that the body is unable to synthesize the indole ring requisite for the protein molecule from other substances than tryptophan. Similar effects are produced by the removal of the two amino acids histidine and arginine, and it is argued that this means that the body is unable to synthesize the guanidine and iminazole complexes from other sources than these two acids. In striking contrast to these observations it is found that the removal of two other acids, glutamic and aspartic, has no harmful effect, and this in spite of the fact that they are important constituents of casein, seeing that they make up no less than 28 per cent of the weight of the molecule. It may, however, be assumed that the body is in this case capable of making up the deficiency in such comparatively simple molecular structures by synthesis from fats or carbohydrates in the presence of ammonium salts, and that the synthesis can be maintained at a sufficient rate to keep pace with the requirements of the body. As illustrating the fact that one amino acid may to a certain extent replace another closely allied acid it has been found that growth could be maintained on an amino acid mixture containing no tyrosine but a small quantity of phenylalanine, which differs from the former acid only by a single atom of oxygen, as may be seen from the formulæ

$C_6H_4OH.CH_2CHNH_2COOH$ and $C_6H_5CH_2.CHNH_2COOH$
Tyrosine. Phenylalanine.

On the other hand gelatine, which contains neither tryptophan nor tyrosine, fails entirely to support life, but the fact that on addition of tryptophan life could be maintained points to the fact that the body contains some mechanism for synthesizing the benzene nucleus required for tyrosine although it is quite unable to produce indole.

With regard to the question as to whether particular amino acids are associated with any special function, some such connection has been established by the author between arginine and histidine on the one hand, and purines on the other, for he has been able to show in the case of rats that the excretion of allantoin fell off markedly when these two acids were removed from the diet, but rose again as soon as they were included. The relation between these particular acids and the purines is not far to seek on chemical grounds, since they are characterized by the peculiarity, not found in any other amino acids, of having a carbon atom between two nitrogen atoms, which arrangement is of course typical of the purines.

The causation of the staleness of bread forms the subject of an investigation by J. R. Katz (*Zeitsch. Physiol. Chem.*, 1915, 95, 104). The staleness of bread according to this author is not merely due to drying, since bread kept in an atmosphere saturated with moisture also becomes stale. What actually occurs is that the starch grains harden and become less able to absorb water and the soluble polysaccharides contained in them are rendered insoluble, with the result that the bread becomes harder and less sweet. The crumbly nature of the stale bread is due to the transfer of water from the starch grain as they harden to the gluten, which lessens the adherence of the particles to each other. Exactly the reverse process takes place in baking: the absorptive power for water and the proportion of water soluble polysaccharides is increased. Equilibrium is apparently attained at the baking temperature, and as the temperature falls the reaction goes in the reverse direction. In support of this view it has been shown that bread may be kept fresh for 24 hours if maintained at a temperature of 60 deg. Cent.—*Science Conspectus.*

Self-Luminous Switches and Sockets

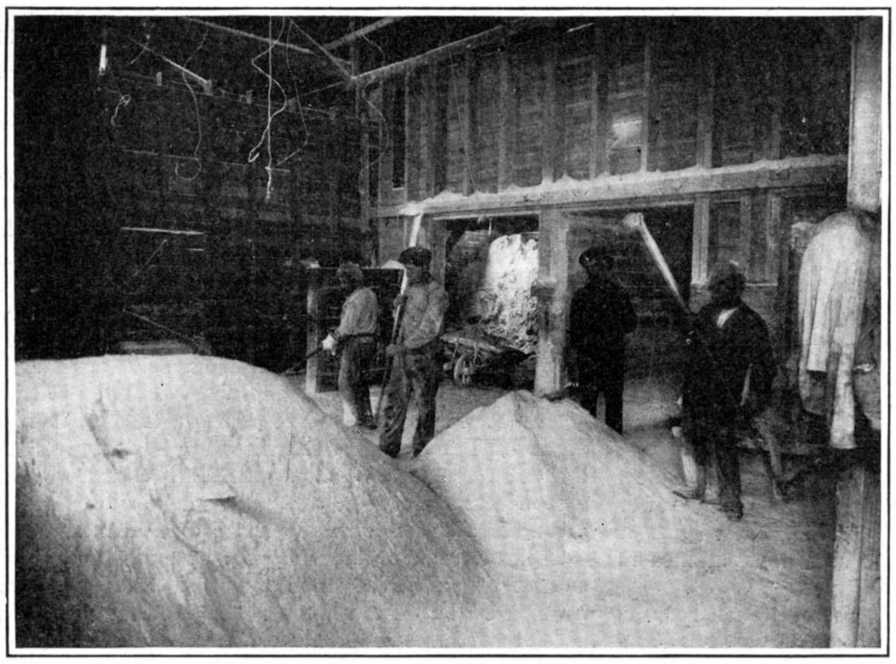
One of the large manufacturers of switches, sockets and supplies is now preparing to bring out a line of electric light switches and sockets painted with a self-luminous compound which will render their location visible in the dark. A "radium" paint will be used, similar to that already recently employed on luminous dial watches, compasses, etc. This paint is continuously self-luminous, and, it should be noted, is to be distinguished from the luminous paints and pull-chain balls which have been on the market for some years, which require exposure to strong light to make them luminous in the dark for a period of several hours.

The base, zinc sulphide, is the same for the new self-luminous paint as for the older phosphorescent paint which absorbs light and then gives it out again, shining with a greenish or bluish glow in the dark. The new paint, however, contains a small quantity of radium bromide, the alpha-particles of which, continuously bombarding the crystals of the sulphide, render it luminous in the dark with a pale greenish glow of about the intensity of a rubbed phosphorus match. By increasing the quantity of radium compound included in the paint the more brilliant can this phosphorescent glow be made. On aeroplane compasses used by the European armies, the luminous compound employed is of such intrinsic brilliancy that its glow can be seen even in contrast with twilight. Such a high mixture of radium compound, however, rapidly disintegrates the zinc sulphide, so that the life of the paint may be barely twelve months. In the intensity to be used on the new switches, which has been found most practical for average use on watch dials, etc., the figures are readily visible in a darkened room, and such paints have an assured luminous life of ten to fifteen years, if not longer.

It is proposed to tip the switch push buttons with this luminous compound, so that when entering a darkened room the user can quickly find the button, press it, and secure electric light.

In order that ordinary flush switches already installed may be made luminous, the electrical manufacturer referred to has devised the ingenious expedient of luminous-head screws which can be used to replace the present screws, giving visible points of luminosity by which the switch can be located in a darkened room.

The cost of the making and applying the self-luminous paint is, at present market prices for materials, about $1 per square inch. At this rate it is expected that the extra cost of equipping an ordinary electric light switch will be from 20 cents to 30 cents.—*Electrical World.*



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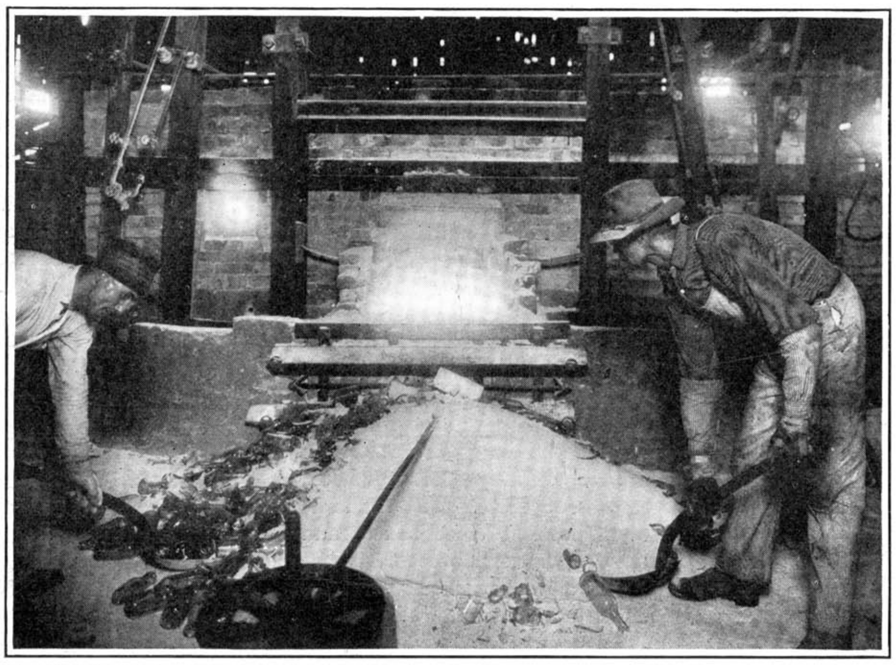
Mixing the ingredients used for making glass.



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Charging a melting furnace with the new mixture.

The Manufacture of Bottles

THERE is hardly a utensil more widely or more generally used than the glass bottle, for everything that exists in liquid form is put up in bottles; yet how often do we give a thought to the matter, or to how the millions of these indispensable receptacles are made?

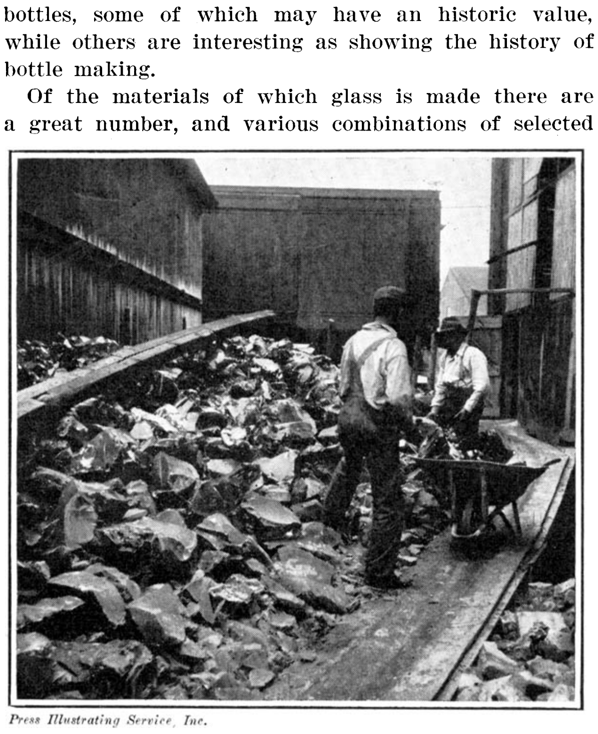
Who made the first bottle has never been determined, but the necessity for some means of transporting liquids, of which water was undoubtedly the first to be considered, must have existed from the beginning of the human race; and it is generally considered probable that the first receptacle for this purpose was made from the skin of an animal. This was removed with as little mutilation as possible, and all the unavoidable openings carefully sewn up, leaving a single leg for filling or emptying, which was tied up with a cord. These we know were used ages ago by many primitive people, and have since been employed extensively in many parts of the world; and even to-day they may be seen in use in some oriental countries. It was this kind of a bottle that was referred to in the Bible in the much quoted dictum relating to putting new wine into old bottles. The objection to this procedure was that the skin of an old bottle has become fully stretched, and weakened by use, and if new wine was put into it the pressure of the gases generated by the continued fermentation of the wine would burst the bottle.

As technical arts progressed other materials came into use for making bottles, which rendered them more convenient, and also more practical for containing different varieties of liquids, many of which would have attacked and destroyed an ordinary skin, or would have been affected by the skin; and it is reasonable to suppose that among these early materials one of the first to be adopted was burned clay, although we know that early in the history of Egypt bottles were made of many other materials, such as hard stone, wood, ivory, bone, porcelain and various metals.

Whatever the material employed for bottle making, the remains of ancient people, discovered in many localities, show that various kinds of receptacles for liquids were in use long before the glass bottle appeared; and this is but to be expected, as the making of glass was a refinement unknown until considerable progress had been made in the arts. It is a generally accepted fact, however, that glass making and glass bottles originated among the Egyptians, although at what date no one has presumed to state. Even in Egypt, however, the art of glass making, in its early history, appears to have been confined to certain localities, and was not practiced at all widely. From Egypt the art spread but slowly to neighboring countries, and to those who had commercial relations with her, and quite naturally articles made of glass were for many years luxuries confined to the wealthy. This is shown by the character of the early specimens of glassware that have been found, which clearly indicate that the manufacture of glass was conducted as a fine art, and articles of glass were by no means in common use until comparatively modern times, when the mechanical arts had greatly increased their field of operations, and later improvements in processes had reduced the cost of production.

A bottle is a receptacle for the storage and transportation of liquids, as distinguished from drinking vessels, and their particular characteristic is the constricted neck, which was designed to enable the bottle to be closed, and also to facilitate the pouring of its contents. According to the present day acceptance of the term a bottle is a glass receptacle, but the various earthenware jugs that are widely used are also bottles, as are the iron vessels for containing mercury, and the gutta-percha receptacles used for containing hydrofluoric acid. Neither does the shape nor size affect the character of the vessel as a bottle, for we find them of every conceivable shape that the imagination can devise, and in size from a minute capillary tube to the capacious carboy for containing corrosive liquids, such as the sulphuric, nitric and hydrochloric acids, so widely used in manufacturing processes. Speaking of the shapes of bottles, it may be noted that at various periods it has been the fashion to make bottles of odd, grotesque and unusual forms, both for the purpose of decorative effects, and to distinguish the maker or the nature of the contents, and many old-time bottles are found in Europe that are fantastic indeed; and it is not at all surprising to find that there is a fad for collecting bottles, some of which may have an historic value, while others are interesting as showing the history of bottle making.

Of the materials of which glass is made there are a great number, and various combinations of selected materials produce glass of special characteristics; but for bottles, except for particular uses, the cost of the ingredients is largely the determining factor, although questions of strength and also, in these days, of color must be considered. Before the art of glass making was so well understood the cheaper varieties of glass were always colored or stained by the impurities in the materials used; but now an excellent quality of white glass, as the translucent kind is commonly termed, is possible, although, as a result of custom rather than cost, dark colored glass is still employed for making bottles used for some purposes. Another reason for making colored bottles at the present time is for the purpose of protecting the contents from light, the action of which would produce chemical changes in the contained liquid, and these bottles are usually found of translucent blue or orange tinted glass.



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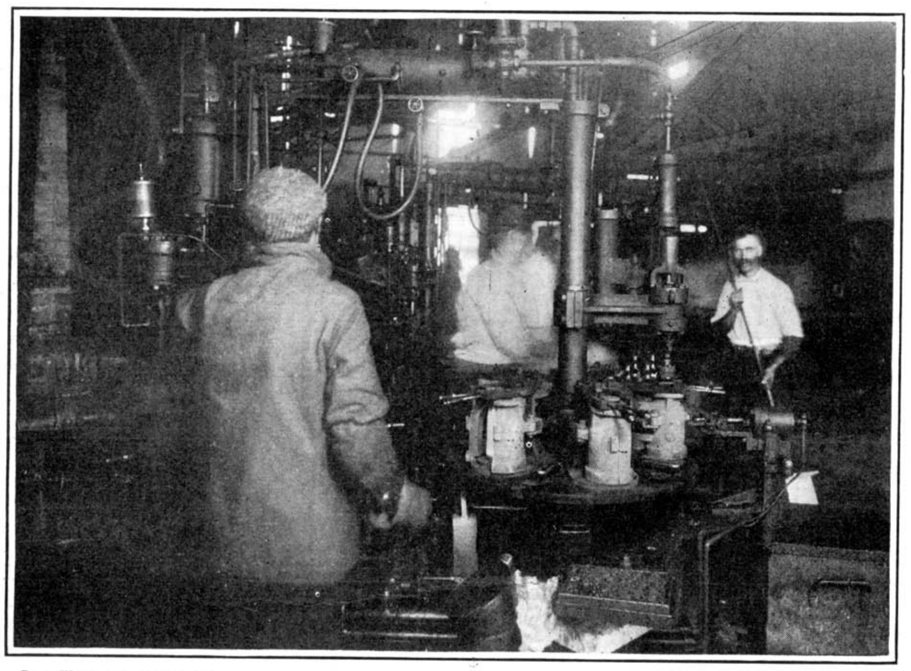
Rough glass used for making bottles.

The basis of bottle glass is a silicious sand, to which is sometimes added limestone, together with sulphate or carbonate of soda. These ingredients, in pulverized form, are thrown into a large tank furnace, where they are melted and combined, forming a thick liquid of syrupy consistency. The accompanying illustrations show these two operations; and in a smaller picture is seen another kind of raw material that is extensively used for bottle making. In the factories that make the better grades of glass, such as table ware and window glass, it is periodically desirable to clean out their melting pots, and there is also considerable damaged material that must be discarded; this is called "cullet," and it is sold to the bottle maker, who mixes it with his materials, together with all the damaged bottles that accumulate around the factory.

Formerly bottles were all hand made. A workman collected a ball of the pasty, molten glass on the end of a long iron tube, through which he blew with his mouth. This produced a hollow ball, like a soap bubble; and when it was of sufficient size the bubble was put into an iron mold that quickly shaped it, and brought it to the desired size as the workman continued to blow. This process, however, is too slow and expensive for the production of the millions of bottles that are now required, and machinery was devised both to enable greater numbers to be produced, and to reduce the cost. A number of such machines are in use, one of which is shown in an accompanying photograph, but the principle of operation is similar in all. A number of iron molds are located on a revolving table, the molds being constructed in three pieces, a bottom and two hinged body sections. The proper quantity of molten glass is placed in a mold, which is automatically closed as the table intermittently revolves. At the next station the mold comes under a plunger which closes the mold tightly, forms the neck of the bottle and makes a connection with a compressed air system. The operation of the machine also turns on the air pressure at the correct time, and the bottle is quickly blown. As the table revolves further the mold automatically opens and the red hot bottle is removed, when the mold is ready to take up a new cycle of operations.

If the newly formed bottles were allowed to cool off directly in the air the outer layers would harden and contract much more rapidly than the inner portions, and the result would be strong opposing tensions in the glass, tending to crack it, and only a slight shock would be necessary to break the bottle. For this reason it is necessary to cool the bottles so gradually that all parts will lose their heat at the same time, and this is done by passing them slowly through a long oven, which is heated at one end, and gradually becomes cooler at the other, or delivery end. The photograph on the first page of this issue shows the hot bottles being put into the hot end of this annealing oven, while in one of the smaller illustrations on page 361 shows the finished product being drawn from the furnace.

How many bottles are made annually in this country would be difficult to estimate, but when we consider the endless variety of kinds, sizes and shapes that are to be seen on every side, used for such a multitude of purposes, the total must reach a surprisingly great figure; and of these it is probable that a very large proportion are thrown away and wasted after once using. In the large cities, where all refuse is sorted over, great quantities of discarded bottles are saved and turned back into use, but in the greater part of the country a discarded bottle is permanently out of existence.



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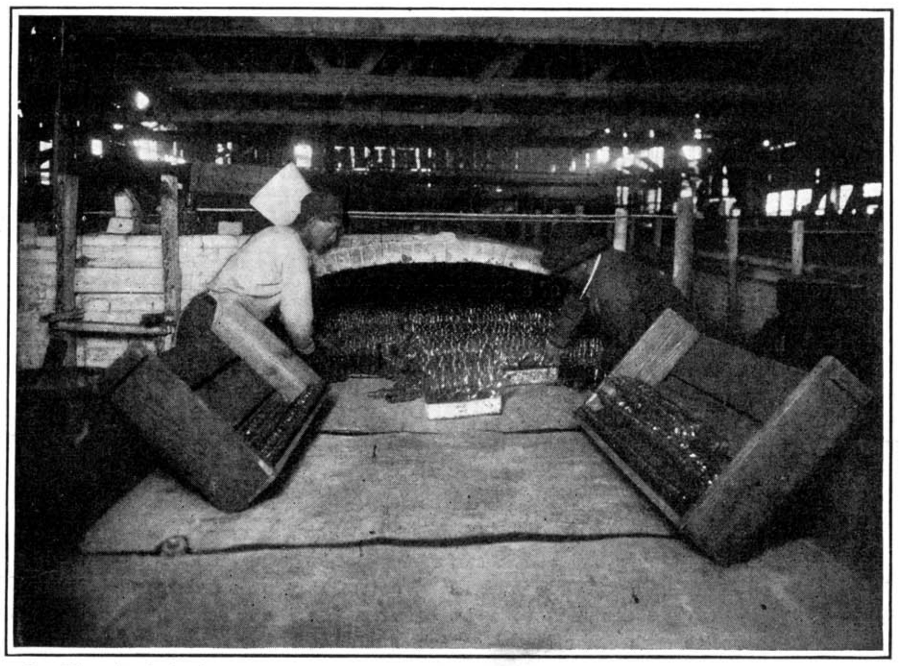
Molding glass bottles by machinery.



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Finished bottles coming from the annealing furnace.

Observations on the Economy of the House Spider, Tegenaria Atrica*

By Theodore Savory

THE ease with which house spiders, or in fact any sedentary spider, may be kept alive in captivity is partly responsible for many observations which, while they are of the greatest interest to the specialist in arachnology, may be of some value to the general zoologist. A brief note of a few of these appeared in the *Field* of January 9, 1915, and it is here proposed to continue and elaborate them.

We have all watched the garden spider, when uncertain of its prey's presence on the outskirts of its web, give one of the threads a tug which decides the question. The house spider's modification of this is of peculiar interest. Its tarsi fixed in the silken sheet, it draws in each leg a distance of a millimeter or two, thus decreasing the perimeter of the figure surrounding it, and giving just that twitch to the web that is required to make a fly or other insect move on. As the garden spider wraps up its captive, so does the house spider, lest its struggles irrevocably destroy the web. For this purpose it holds the fly down on to the sheet of the web, and, itself walking around it, twists it up in sufficient silk to suppress it.

There is, I believe, a little rhyme about a centipede, which runs—

A centipede was happy quite
Until a toad in fun,
Cried "Pray, which leg moves after which?"
This roused her doubts to such a pitch,
She fell exhausted in a ditch,
Not knowing how to run.

Wondering myself how a spider ordered the movements of its eight legs, I allowed several to tire themselves by struggling on the surface of water and then set them to run slowly over a regular surface, so that their motion could be carefully watched. It was thus rendered evident that—

1. The longest legs, those of the first and fourth pairs, move along the lines of their own directions by vertical bending of the joints; the shorter legs of the second and third pairs move forward by rotation from the coxæ, at right angles to their own directions.

2. First near leg moves with the fourth off leg. (*a*)
Second near leg moves with the third off leg. (*b*)
Third near leg moves with the second off leg. (*c*)
Fourth near leg moves with the first off leg. (*d*)

3. Walking consists of (*a*) and (*c*) simultaneously, followed by (*b*) and (*d*) simultaneously.

During this investigation it became quite clear that the spiders that were tiring themselves on the water were most certainly swimming. A spider dropped on the surface of a sheet of water does not sink. From below, total reflection shows that a film of air lies between its ventral surface and that of the liquid, while so long as the creature remains still the legs indent the surface but do not pierce the "skin" caused by capillarity. Motion, when induced, begins with extreme rapidity, but after half a minute slackens and proceeds in precisely the same manner as in walking.

The first and fourth pair of legs slide over the surface, the latter lying flat thereon for the last two joints. It would seem that they have little if any propulsive effect. The second pair penetrates the surface about two joints deep, the third pair one joint. I think that nearly all the propulsive effort is afforded by these pairs. It is manifest that these Tegenaria were indeed swimming, and not, like Lycosidæ, Pisauridæ, etc., running on the water. For, in these latter cases, the first and fourth pair of legs are not slipping; the second and third pairs are not thrust into the water; and the body is supported on the legs in the ordinary way and not resting on the water. Again, though entirely distinct from the subaqueous activities of the water spider, it resembles them in that free and not dissolved oxygen is provided.

Finally, the spiders that have swum and walked at my command were returned to their cages and one and all settled down at once to what was, perhaps, the most interesting series of actions of all. They proceeded to complete their toilet after their bath! The use of the palpi for cleaning the falces and fangs after a meal was described in some detail by the present writer in the *Field* of May 23, 1914, but these were a far more elaborate process. The following operations were observed:

1. The second and third pairs of legs are dried where necessary by pulling them slowly through the opening and shutting maxillæ, and finishing with a long stationary "suck."

2. The palpi are dried in the same way.

3. The first and fourth pairs of legs are cleaned a little as in 1, but mainly by rubbing carefully with the second and third pairs followed by a sucking of that limb.

4. The ventral side was dried by rubbing the metatarsus over it; and this joint is then sucked. A very few applications seemed to suffice.

These separate actions do not take place in any orderly manner. A little of one is followed by a little of another, and often 2 and 3 are simultaneous. The spider dodges from limb to limb and from side to side with no regard for sequence. The whole operation may take as much as half an hour.[1]

The ecdysis of one of these spiders is readily witnessed since, before moulting, the legs turn to a dull, almost black tint. A male which I saw undergo its final moult in extracting its legs from the old skins, heaved fourteen times a minute as regularly as clockwork for half an hour and then, hastening, pulled for ten minutes seventeen times to the minute. This gives a total of nearly six hundred pulls to remove a leg about thirty millimeters long. Smaller spiders can moult completely in a quarter of an hour or twenty minutes. After ecdysis, the legs, palpi, and falces are a quite pale green and do not turn brown until some hours later.

Some interesting and fairly original results have been obtained concerning the fertilization of the females by the male and her willingness to accept his advances or to eat him.

A male placed on the web of a female at once utters the sexual call by drumming on the web with his palpi, in exactly the same way as Warburton and Moggeridge have described in the cases of the wolf and trap-door spiders. In many cases this brings out a fierce paramour and leads the male to think more of his own life than that of the future generation. In happier circumstances, the female takes absolutely no notice of his presence, when he will cautiously advance towards her and with his long forelegs tentatively feel her outstretched forelegs. If the female is even yet motionless, it is well and he can proceed with the essentials of his suit. The actual fertilization requires about ten to fifteen minutes with each palpus.

Oviposition has been well described by Warburton in an almost classical memoir, and I have but few additions to contribute. The sign of preparation which has usually been considered infallible is the spinning of a little sheet of closely woven silk, upon the lower surface of which the eggs are deposited. A spider of mine, however, last Autumn spun this sheet and subsequently made no attempt to lay eggs or complete the cocoon, in fact it was obviously not the possessor of any eggs at the time when the sheet was spun. Warburton tells how the spider will finish its cocoon even if the eggs be removed immediately after laying. I have one example of the opposite case in which the spider placed the eggs in position but made no effort to cover or protect them in any way, and incidentally enabled me to secure a unique photograph of a spider's egg-cocoon at the middle of construction.

It is not necessary to take Warburton's advice and sacrifice a night's rest to see the egg-laying, for a spider which, like mine, spends all its days in a dark cupboard may often be deluded into laying its eggs in daylight. Three cocoons is the usual number, appearing at intervals of a fortnight, and each containing from 75 to 85 eggs. A spider that I caught in the early days of April, 1914, having laid three cocoons by June, refused to die of old age and lived until December, producing no less than eight additional cocoons of fertile eggs in that time. These last cocoons contained only about 40 eggs each. Such an unnatural extension of life I can only attribute to the fact that this spider was an object of interest to a large number of friends—contemporaries at Aldenham School—and that it was thus supplied with a relatively enormous amount of food.

The egg is originally quite spherical and a pale primrose-yellow in color. It later becomes ovoid and then develops tightly folded but obvious legs. The young when first able to move have a primrose abdomen and creamy translucent legs and cephalothorax, are about two millimeters long, and weigh just a centigramme. First the eyes become visible as black dots, and next the legs change to a greenish yellow. Later the cephalothorax becomes yellowish brown, and the abdomen dark green, with a lighter pattern of the same design as that on the adult spider. Ultimately the color becomes brown and remains so.

One reference to a half-finished investigation in conclusion. Dr. A. H. Cooke, studying the attack on the mussel by a particular foe, found that the creature tended to plunge its weapon into the most vital spot of its prey. This conclusion was reached by accumulation of the pierced shells of the mussel. The little that I was able to do at the end of last Autumn seems at present to render it quite possible that the spider, too, deals the *coup de grâce* to the trussed-up insect also in the most vital spot.

*Science Progress.

[1] My sister, V. Savory, has recently observed these same actions performed by the garden spider, *Epeira diademata*.

To overcome the weakness of aluminium long distance transmission cables, several aluminium strands are laid up on a steel wire center. This enables the cables to be properly stretched on the poles.

Allotropic Changes in Iron and Other Metals*

A New Thermo-Electric Method of Studying Structural Conditions Not Yet Fully Understood

By Prof. Carl Benedicks, Fil.D. (Physical Laboratory of the University of Stockholm).

In a closed circuit, consisting of a homogeneous metal, no electromotive force, capable of causing a current, is produced, howsoever the temperature of any part may be changed, according to Magnus. If, however, the metal has an allotropic transition point (two-phase point), and some part of the circuit be heated, and remain at a stationary temperature above this point, the circuit can no longer be said to be homogeneous, as the hottest part, according to the assumption, corresponds with a new allotropic state—forming a new phase. However, even in this case, no electromotive force comes into play, as the differences of potential, which *a priori* may be assumed to exist between the two phases, equalize each other at the contact surfaces, on account of the equality of temperature of the contact surfaces. If, on the contrary, the local heating be not stationary, there is always a possibility that the two contact surfaces may differ in temperature. Let us assume, as a special case, that the locally heated zone might travel with a constant speed along the conductor. Now, it is known that the temperature of a given transition is always somewhat higher on heating than on cooling, which depends on the fact that a real allotropic transformation takes a definite time to perform in every case. Thus the contact surfaces between the two phases, as already stated, will have slightly different temperatures, and there is a possibility that a measurable thermo-electric force will come into action. In fact, it was stated by F. T. Trouton,[1] as early as 1886, that a thermo-electric current is produced when an iron wire is moved through a flame, so that probably a local heating above 900 degrees may occur. This phenomenon, which, though simple, affords a good lecture experiment,[2] was correctly explained by G. F. Gerald as depending on what Sir W. F. Barrett[3] in an interesting note, describes as thermo-electric hysteresis.

In near relation to this effect an observation made shortly before by H. Le Chatelier[4] on silver iodide bears closely on the same point. The substance was enclosed between two metal electrodes, the circuit thus consisting of two different conductors. It was found that at the transition point strong electromotive forces appeared, which primarily were to be ascribed to a thermo-electric action. It was proposed by Le Chatelier to take advantage of this phenomenon for the study of allotropic transformations. At his suggestion, O. Boudouard[5] made some determinations on nickel steel. Le Chatelier[6] himself published some curves for special steels obtained by this method (platinum wires were fixed at the ends of a short steel specimen, and the electromotive force between them was observed on ordinary heating or cooling). This method, however, has not been generally accepted, probably on account of a serious inconvenience already pointed out by Le Chatelier. In fact, the electromotive forces which come into play with this arrangement (immovable, bimetallic specimen) are occasioned by the inevitable, totally uncontrolled local temperature variations of the furnace, with the consequence that even "the direction of the current observed at the very moment of transition may change with each experiment.[7] Thus, if the temperature degree of a transition point can be determined, by this method, every quantitative conclusion as to the intensity of the transformation seems to be excluded.

It might now be asked whether it is not possible to overcome this inconvenience and to find a quantitative method, if, according to the foregoing explanation, *a local heating, traveling with uniform speed along a wire, is made use of*. It has occurred to the author, first, that this might furnish a quantitative method for ascertaining the existence of allotropic points in the metal (two-phase allotropy); further, that this method might possibly give useful information even in the case of an inner molecular equilibrium, changing with temperature (one-phase allotropy). In fact, the molecular changes even in this case probably take some definite time to occur, and the equilibrium, at a given temperature, ought not to be quite identical on heating and on cooling; thus generally a thermo-electromotive force should come into play, even though only single phase is present. Since, according to the theory advanced by the author,[8] and lately treated in a careful way by K. Honda,[9] such a one-phase allotropy interval exists below the two-phase point $A3$, it seems to be of special interest to study iron by this method, especially at the temperature interval below $A3$.

Experimental Arrangement.—According to the principles explained above, the experimental arrangement was a very simple one (Fig. 1), as follows:

The metal wire AA' to be studied moves through a little electric furnace B, the maximum temperature of which is measured by a platinum platinum-rhodium thermo-couple, with a compensating arrangement C (St. Lindeck and R. Rothe). The free ends of AA', at F (constant temperature), are connected with the copper wires leading to a mirror galvanometer G.

The central part of the wire, AA', is stretched by two strings, running over a horizontal wheel E and two small vertical pulleys H, H', and loaded with the weights P, P'. A uniform motion is communicated to AA' in the one or the other direction by a third string, which is wound on a cylindrical drum by the clock-work J (gramophone movement); by suitable guides I is easily brought into line with the string at H or at H'.

The wire AA' was sufficiently protected against oxidation by passing it through a fixed silica capillary tube D.

The furnace being heated to a suitable temperature, the deviations of the galvanometer G were read with AA' moving first in one and then in the other direction. The half of this difference in millimeters is given as the deviation U.

The sensibility of the galvanometer (resistance about 100 ohms) was such that 1 millimeter corresponded with 5.6×10^{-6} volts.

The value of the electromotive force resulting must be influenced by several factors, not taking into account the nature of the material itself and the temperature, namely (1) the speed of displacement; (2) the section of the specimen, and (3) the temperature distribution in the furnace.

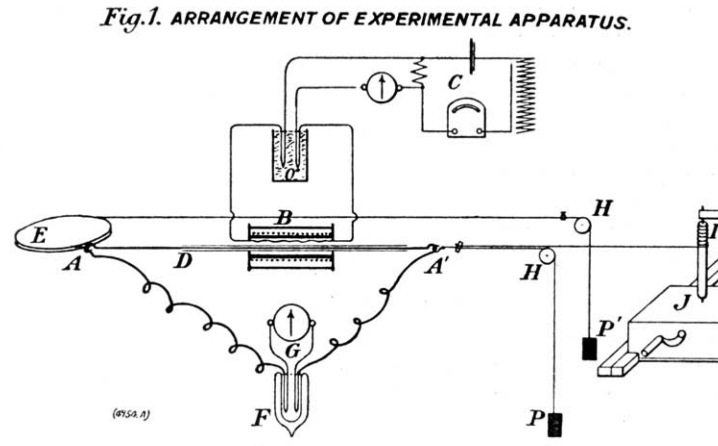
1. Smaller variations in the speed of displacement were found to have very little influence, except for the purest iron. A constant speed of 1.6 millimeters per second was adopted throughout.

2. The diameter of the wire especially investigated was 1.01 millimeters. Owing to this thickness a load P, P', amounting to 125 grammes, could be used, which was enough to secure a very uniform displacement of the wire.

As will be seen from Series I. and II. on the one hand, and III. on the other, the influence of the diameter of the wire is probably very slight.

3. In order to obtain an idea of the temperature distribution of the heated zone through which the wire had to pass, the mean of the observations of the temperature T at the different distances X from the middle of the furnace is given as follows:

Fig. 1. ARRANGEMENT OF EXPERIMENTAL APPARATUS.



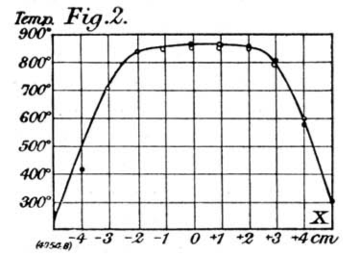
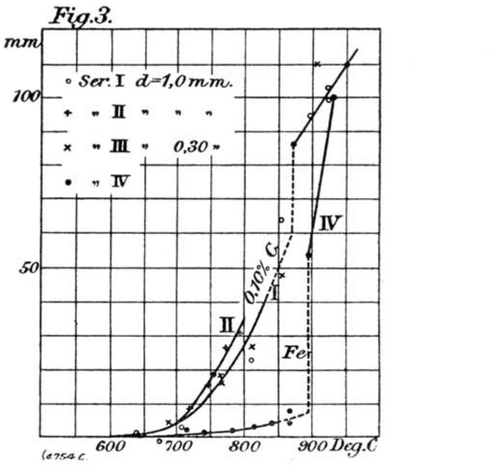


Fig. 2.

Fig. 3.



Distance X. Millimeters.	Temperature T. Degrees Centigrade.
+ 50	300
40	587
30	797
20	848
+ 10	857
00	858
— 10	859
— 20	837
30	710
40	410
— 50	255

This distribution is graphically shown in Fig. 2.

Material Used.—The iron selected for investigation was obtained in April, 1912, from the Kohlswa Iron Works. It contains 0.10 per cent of carbon, but is otherwise of a remarkable purity, as shown by the following analysis, performed at the Kohlswa laboratory:

0.10	0.014	0.03	0.026	0.007
Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.

Delivered as rolled wire 5.2 millimeters in diameter, it was further drawn down to the diameter mentioned of 1.01 millimeters at the wire-works of the Nya Garphytte Fabriks Aktiebolag, Latorps Bruk.

Since for the special control Series III. a thinner wire was desirable, the author drew the wire further, in an ordinary drawing-plate. On this occasion the—as it seems to him—very interesting observation was made, that this material—obviously on account of its great purity—could be directly drawn through the finest hole of the plate, 0.23 millimeter, and further in sapphire holes to 0.09 millimeter, *without the slightest annealing*, and without any real hardness being produced by this severe cold-working. This fact seems to prove that iron of a high state of purity, even at 0.10 per cent carbon, has considerably more "liquid inner friction," and considerably less "solid inner friction,"[10] than has been generally believed—even in view of the extremely high mechanical deformability of pure iron in $A3$, found by the author two years ago.[11]

*Paper taken as read at the meeting of the Iron and Steel Institute. Reported in *Engineering*.

[1] *Proceedings* of the Royal Dublin Society, 1887, vol. v.

[2] The flame, which may possibly cause some chemical alteration, can then be conveniently replaced by a small electric heating device.

[3] Transactions of the Royal Dublin Society, 1900 (2), vol. vii., page 127; *Philosophical Magazine*, 1900 (5), vol. xlix., page 309.

[4] *Comptes Rendus*, 1886, vol. cii., page 917.

[5] *Revue de Métallurgie*, 1904, vol. i., page 80.

[6] *Ibid.*, page 134.

[7] *Ibid.*, page 138.

[8] *Journal of the Iron and Steel Institute*, 1912, No. II., page 242; 1914, No. I., page 407.

[9] *Ibid.*, 1915, No. I., page 199; *Sci. Reports* of the Tohoku Imperial University, 1915, vol. iv., page 169.

[10] *Cf.* H. I. Hannover, *Mekanisk Teknologi*, II., 3 Ed., Copenhagen, 1915, footnote, page 68.

[11] *Journal of the Iron and Steel Institute*, 1914, No. I., page 431.

It can be questioned whether this extremely high softness[12] of pure low-carbon iron is favorable to the well-known Beilby hard amorphous state theory.

Since it was highly desirable to make determinations, by the method now described, on still purer iron wire, which was, however, not available, the following method was tried and found to be practicable. A small thin specimen of the extremely pure electrolytic iron used by Doctors J. E. Stead and H. C. H. Carpenter,[13] kindly presented by Professor Carpenter, was carefully rounded off at the corners, after which a strip about 1.3 millimeters broad and of sufficient length, was cut off round the piece. This strip was straightened, and strengthened —especially against oxidation—by forming it into a U-section.

Experimental Results.—Determinations at a given temperature, as was to be expected, showed no difference when made during heating or cooling of the furnace.

A blank experiment was performed with a one-millimeter copper wire in the same interval of temperature as that finally used. After a first annealing, nó deviation of the galvanometer whatever was obtained, which agrees with the known absence of allotropic change in this metal.

The result of the first series (I.) of experiments on the Kohlswa iron wire is given in the following table:

Temperature T. Degrees Centigrade.	Deviation U in Millimeters.	Mean.
642	+ 1.9	
	— 0.3	1.1
708	5.1	
	1.2	3.2
755	18.7	
	18.5	18.6
810	21.2	
	23.4	22.3
854	64	
	61	63
873	84	
	88	86
898	—	94
925	99	
	102	100.5
950	—	110

These determinations are reproduced graphically in Fig. 3 as small circles.

It will be seen that this thermo-electric hysteresis effect is already sensible somewhat above 600 degrees; other determinations not given here seem to corroborate this lower limit, though in a somewhat uncertain manner. The effect increases with increasing velocity, as it seems, up to about 875 degrees, where an increase at constant rate sets in, corresponding with the γ-range. It may be said that $A3$ is clearly shown by a discontinuity.

This first series, however, is not sufficiently accurate to enable it to be decided whether, between 600 degrees and 875 degrees, the increase is a continuous one, or whether there might be a discontinuity at $A2$ (768 degrees). A second series (II.) was carried out between 700 degrees and 800 degrees, marked by vertical crosses. The observed values do not show any discontinuity.

A third series (III.) was performed on the same material, drawn out to 0.30 millimeter wire. Owing to the fact that the stretching weights were only 20 grammes the motion was less regular than before. It will be seen, however, that the observed points (diagonal crosses) do not differ much from previous observations. This indicates that the slight oxidation which occurred has apparently no sensible effect on the observations, which also seems probable from other points of view, and that the diameter has but a very slight influence.

A fourth series (IV.) was executed on the strip of pure electrolytical iron, as mentioned above (shown by full circles). In this case, as might be expected from the known influence of impurities, the effect is generally much less strong than with the 0.10 per cent carbon iron; the difference is less pronounced at the highest temperature, where, of course, the γ-state prevails even in the absence of every trace of impurity. In any case, in a qualitative way, the effect is the same.

It was rather interesting to find, consistently with the impurity effect just mentioned, that while for the iron with 0.10 per cent carbon the speed of the motion had but very little influence, for the purest iron the effect was stronger if the speed exceeded the normal value.

The total appearance of the curves is similar to the well-known dilation curves (Charpy and Grenet), inasmuch as both obviously belong to the allotropy type *IIa*. The new determinations have the special interest of proving the existence of molecular changes, demanding a definite time to occur.

It is scarcely necessary to point out that these new facts give additional support to the theory expounded by the author, that a continuous molecular change does occur in the α-phase at the temperatures up to $A3$, or, in other words, that the α-phase has an increasing solubility for the molecules, or atoms, which are to be considered as characteristic for the γ-phase. Whereas $A3$ is a true allotropic point, where two phases co-exist, this is not the case with $A2$. On the other hand (and this might be the principal result), it has been found that a local heating, traveling with definite speed, constitutes a method which may be of value for allotropy investigations, not only for iron, but for other metals or alloys as well.

As for iron, it would be highly desirable to use pure iron wire, of sufficient length and diameter, and to repeat the determinations with greater accuracy, and with greater velocity, than it was possible to do here, on account of want of material.

Summary.—The principle is described and an experimental arrangement is shown for a method of determining an effect of thermo-electrical hysteresis (Barrett) in metals, which are characterized by allotropy (both two-phase and single-phase). The metal to be investigated is moved, in the form of a wire, with constant speed through a small furnace, the maximum temperature T of which is known; between the free ends of the wire an electromotive force may appear, if molecular changes occur in the metal at temperatures below T.

2. It has been found that this thermo-electric hysteresis effect, for iron, shows a very marked discontinuity at $A3$ (Fig. 3). Above this point the effect is very strong, following a straight line, but it is also very considerable at lower temperatures, even as low as about 600 degrees.

As might be expected, the effect is considerably stronger in iron with 0.10 per cent carbon than in carbonless iron.

No discontinuity corresponding to $A2$ could be found.

3. These experimental results give additional support to the theory of the allotropy of iron, as expounded by the author. However, their accuracy is not very high, and it is desirable that they should be repeated, especially on homogeneous solid wire of purest iron.

The author has the pleasure of acknowledging his indebtedness to Mr. L. U. Lindberg, Kohlswa, for the valuable specially selected research material, and to Mr. G. Tidholm, Garphyttan, for his kindness in drawing the wire.

[12]In this connection it might be pointed out how important it is that laboratories, equipped with good technical mechanical appliances, should be at the disposal of scientific men, offering the possibility of autoptic observations. Exactly the same one-millimeter iron wire, on the request of Dr. Bengt Beckman, Upsala, was sent by me to the Cryogene Laboratory, of Leyden, where it was to be used for researches by Professor H. Kamerling Onnes and Dr. Beckman. This wire was drawn by Heraeus in Hanau to a diameter of 0.1 millimeter. If, in Hanau, some observations were made of the very peculiar viscosity properties of this iron, they apparently have not been reported to these authors (*Comm. Phys. Labor.*, Leyden, No. 132, page 7, 1913). At the Garphytte Works, the management, Mr. G. Tidholm, found that this iron was so excellent for drawing purposes that inquiries were made as to whether it could be obtained in commercial quantities. It was only after having gained personal experience in the fine drawing of this material that the author could get some idea of this remarkable occurrence of "liquid inner friction" in iron, which, according to a private communication, was likewise unknown to Professor Hannover, to whom a sample was sent.

[13]*Journal of the Iron and Steel Institute*, 1913, No. II., page 119.

An Apparatus for Strengthening the Lungs and Improving Respiration

Respiratory gymnastics and its therapeutic effects are put in evidence in a very striking manner by an eminent Paris physician, Dr. J. Pescher, who is one of the leading lights in hospital practice in this city, and he is now introducing it in several of the clinics. The apparatus, which he calls "spiroscope," makes use of a 3-quart bottle suitably arranged with a rubber tube so as to connect with the mouth of the person, the bottle being disposed on a shelf or grating on the top of an enameled ware reservoir of somewhat larger size than the bottle, so that the bottle can be plunged into the reservoir in order to fill it. With the bottle filled with water, the object is to force water out of it by blowing from the lungs, and to this end the bottle has a side neck near the bottom containing a good-sized metal or other tube extending out a few inches and then turned up a short distance. Through another side neck is put a small glass tube which runs through a rubber stopper and has its end turned up, while the outer end has a rubber tube fitted on it so as to lead to the mouth of the person. With the bottle filled with water and the stopper tightly inserted, the water will not run out through the opening at the bottom, and it is required to blow in air from the lungs in order to expel water by way of this lower opening. The person blows into the tube by expiration from the lungs and he can see this action by the bubbles that rise in the water. The air pressure expels the water out of the lower opening and it falls into the reservoir below. When the bottle becomes emptied in one or several operations, it can be filled up again by uncorking and plunging it into the reservoir, then replacing it ready for another operation. While raising in position care should be taken to pinch the rubber tube so as to prevent a siphon action. The rubber tube is fitted with a mouthpiece and also with a stopcock.

When blown into from the lungs, the bottle lets out a volume of water which is practically equal to that of the air expelled from the lungs, and in this way the person's actual lung capacity can be estimated, or rather that portion of the lungs which he really makes use of, either normally, or in different breathing exercises. The contents of the bottle represents a healthy person's lung capacity, so that he can empty it at one breath, but as a rule most persons fall short of this and in abnormal cases the lung capacity is much less. The side of the bottle carries a graduated scale for lung capacities, and after first observing his lung capacity and often making graphic charts which show the movements of the lungs, the object is to have the person expel larger amounts of water and therefore to take a deeper breath each time. He is also taught to breathe more regularly, and this is necessary for many persons. In short, the respiratory organs are put through a course of training which is of great benefit, in increasing the capacity of the lungs and causing more regular breathing habits. As Dr. Pescher points out, this method amplifies the respiration and increases the amount of oxygen absorbed by the blood, and thus it acts to increase the vitality of the whole organism. Very useful graphic charts are obtained by connecting suitable instruments with the above device, as we already mentioned. Turning to some of the valuable effects that come from the use of the spiroscope, the author brings out its curative or tonic effects in the case of children who have a badly developed chest and lungs and who thus have defective breathing which is, of course, very detrimental to the health of the system, and he says that by a regular training for only a few weeks he was able to double their respiratory capacity. The method is really an amusement for them, so that they need not be persuaded to use it, which is, of course, all the better for its success. In the case of a great number of children, their condition was quite transformed.

Because it aerates and fortifies the lungs, the use of the device is one of the best means for strengthening the lungs against tuberculosis, as well as pleurisy and other diseases. Care should be taken, of course, not to overdo matters in the case of a weak subject, so that the method is to be used with prudence, commencing with a small amount of exercise and taking care not to injure the lungs when these are delicate. Proceeding in this way for several years and treating a great number of patients, the author never found the least bad effect. In case of atrophy of the lungs in aged persons, due to lack of exercise and defective breathing, he commences the treatment by the expiration alone, and states that he never saw a case in which the patient's condition was not greatly improved. We should say that the apparatus actually employed has some slight differences from the above, but which could not be brought out without diagrams. For instance, the apparatus is simplified by having both tubes pass through the same opening in the bottle, the small one running through the large one.

Observation of the graphic charts produced by the use of the method, show some instructive results, and among others that nervous persons always have a limited breathing capacity, for it is shown that they take their breath in an irregular way and also incompletely. The person himself can observe this by noticing the way the air bubbles appear in the water, and he can thus take account of the defects in his breathing and endeavor to amend them, so that such persons soon come to breathe more regularly. Dr. Pescher is now making use of his method on quite a large scale at one of the leading Paris hospitals, where a special clinic has been fitted up for the purpose. He employs the method more especially for wounded soldiers, and mentions one case as an example, where an officer having a wound in the breast commenced his exercises by an expiration of only half a liter, but in 3 weeks he was able to empty the whole of the 3-liter apparatus, and his general condition was much improved.

Proportional Drawing

Some Geometrical Problems of Value to Draughtsmen

By L. A. Brown

THE object of this article is to present several of the most commonly used and most practical methods of proportionally enlarging or reducing drawings.

There are a number of methods, each having their merits for particular conditions.

Because of the merits of the method illustrated by Figs. 8 to 12, and its adaptability to such a wide range of conditions, the writer has prepared this article; and for the benefit of draughtsmen without a knowledge of geometry he has endeavored to use as simple terms as possible, rather than to make the article a treatise and to prove by geometrical procedure each step here described, although the methods are all founded on old geometrical principles.

Let us consider first a few methods of dividing lines into certain proportional parts.

Section 1.—To divide a line into any number of equal parts. See Fig. 1.

Given the line *A B* to divide into eight equal parts.

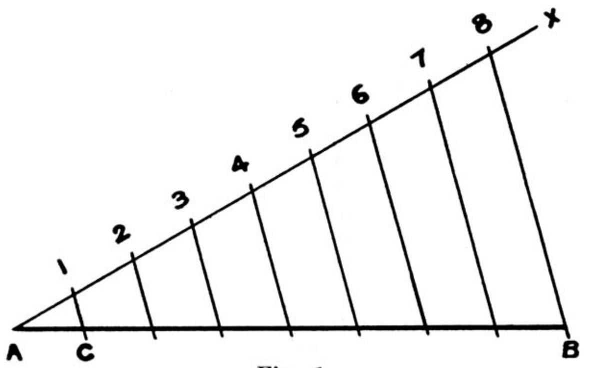


Fig. 1.

From *A* draw the line *A X* at any convenient angle to *A B*.

On *A X* lay off 8 equal spaces of any length and number them from *1* to *8*.

Join *8* and *B*.

Then draw parallels to *8 B*, passing through each of the other points, and cutting *A B*, dividing *A B* into 8 equal parts.

Section 2.—Given a line of a certain number of units to find the unit. See Fig. 1.

The number of units in this case is 8.

Proceed as in Section 1 as far as joining *8* and *B*.

Then draw *1 C* parallel to *8 B*.

A C is the unit desired.

Section 3.—To divide a line into proportionate parts. See Fig. 2.

The line *A B* contains 11 units; required to cut it at 5 and 6½ units from *A*.

Draw line *A X* and lay off 11 equal spaces on it.

Join *11* and *B*.

Bisect the seventh space, giving point *6 1/2*.

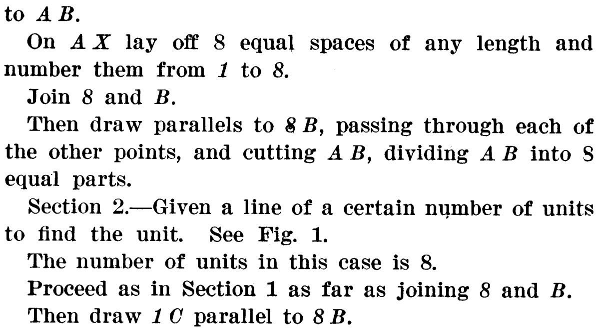


Fig. 2.

Draw parallels to *11 B* through *6 1/2* and *5*, cutting *A B* at *D* and *C*, respectively, which are the desired divisions.

Section 4.—Given three lines *L*, *M* and *N* of varying lengths and the line *A B*. To cut *A B* into three parts proportional to *L*, *M* and *N*.

Draw *A X* and on it lay off *A 5* equal to *L*; from *5* to *6 1/2* equal to *M*, and from *6 1/2* to *11* equal to *N*.

Connect *11* and *B* and proceed as in Section 3.

Section 5.—Given a line of 5 units to produce until it is 11 units in length. See Fig. 2.

A C equals *5* units.

Produce *A C* indefinitely.

Draw *A X* and lay off on it 11 equal spaces.

Join *5* and *C*.

Through *11* draw a parallel to *5 C*, cutting *A C* produced at *B*.

A B is 11 units in length.

Section 6.—Having given two lines *M* and *N*, to construct a third line that shall be to *N* as *N* is to *M*. See Fig. 3.

Draw *A B* equal to *M*.

At *A* erect *A C* perpendicular to *A B* and equal to *N*.

Join *C* and *B*.

With center *A* and radius *A C* cut *A B* at *C'*.

Draw *C' D* parallel to *C B*, cutting *A C* at *D*.

A D is the line required.

Section 7.—To divide a line into equal parts by means of a scale. See Fig. 4.

Draw line *M X* and on it lay off as many equal spaces as desired, in this case 10.

Draw *M N* perpendicular to *M X*.

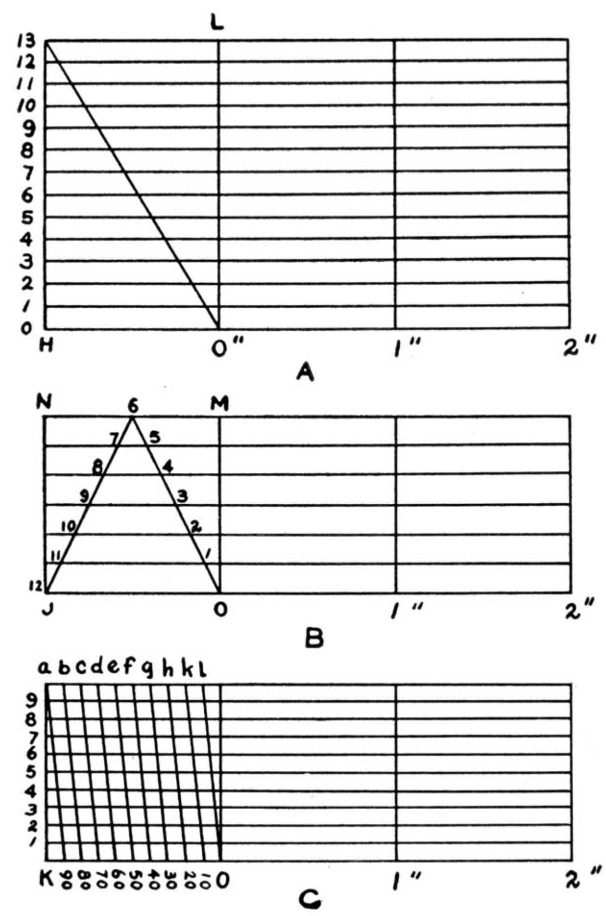


Fig. 5.

Draw parallels to *M N* through each point of division on *M X*.

With radius equal to the line to be divided, and with center *O*, describe an arc *S T*, cutting the lines of the scale.

If you wish to divide the line into 5 equal parts, join *O* and the intersection of the arc *S T* with line *5*, thus cutting the line *A* into 5 equal parts.

To cut into 9 parts, join the intersection of *S T* with line *9*.

Fractions of units may be obtained as illustrated in Fig. 4.

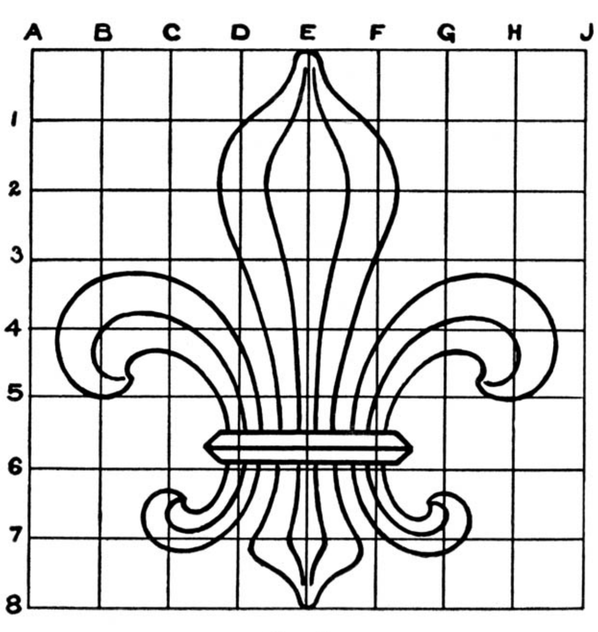


Fig. 6.

A scale of this sort might be made on tracing paper and placed over any line which required division and the divisions pricked through. In this way the scale could be used a great many times.

Section 8.—To divide an inch into any number of equal parts by a scale. See Fig. 5 *a*.

In this case the inch is to be divided into 13 equal parts.

Construct a scale as *A*, Fig. 5.

The distances *H O″*, *O″ 1″*, and *1″ 2″* each being one inch.

The vertical spaces *0* to *13* may be of any convenient length, but must be equal.

Join *O″* and *13*.

Measuring from line *O″ L* on the horizontal line *1* to the diagonal is 1/13 of an inch.

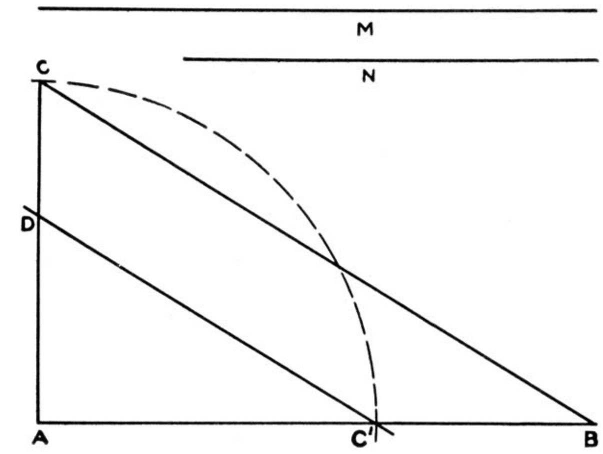


Fig. 3.

From *O″ L* to the diagonal on line *8* is 8/13 of an inch.

To measure 2 7/13 inches, measure from line *2″* along line 7 to the diagonal.

Section 9.—To divide an inch into 12 equal parts by means of a scale. See Fig. 5 *b*.

Construct a scale as Fig. 5 *b* with line *O M* divided into 6 equal spaces.

Distances *J O*, *O 1″* and *1″2″* are one inch in length.

Point *6* must exactly bisect line *M N*.

Join *6* and *O*, and *6* and *J*, thus dividing the inch into 12 equal parts.

This scale may be used to measure twelfths of an inch, or as a scale representing 1 inch to a foot.

Third, fourth and sixth parts of an inch may be measured on this scale.

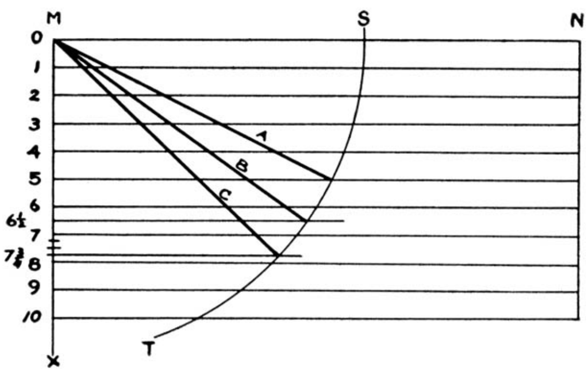


Fig. 4.

This method cannot be used for odd numbers, but may be used for even numbers other than 12. Measure as in Section 8.

Section 10.—To divide an inch into 100 equal parts by means of a scale. See Fig. 5 *c*.

Construct a scale as Fig. 5 *c*.

Divide the inch at the left hand end into 10 equal parts each way and number as in Fig. 5 *c*.

Join *a* and *90*, *b* and *80*, etc., each one of these diagonals cutting each tenth into 10 equal parts or one hundredth parts of an inch.

To measure on this scale 2.07 inches, measure along line 7 from line *2″* to the diagonal *O l*. Or to measure 2.34 inches, measure from line *2″* along line *4* to the diagonal *30 g*.

An inch may be divided into 16ths, 25ths, 36ths, 49ths, 64ths, etc., by dividing its sides into 4, 5, 6, 7, 8, etc., parts, respectively, and proceeding as above.

Section 11.—A commonly practiced and very useful method of enlarging or reducing drawings is by use of the square as in Fig. 6.

To use this method, one measurement in the figure to be produced as the height or width, must be known.

Taking the height of the original drawing, divide it into any convenient number of equal parts, as 8, and construct squares of this dimension sufficient to cover all parts of the figure.

For convenience in locating corresponding points it is well to complete the rectangle and to number the lines.

Having done this with the original figure, divide the height of the figure to be constructed into the same number of equal parts and proceed with the chart of squares in the same manner as in the original figure.

Then draw in the figure, making the lines cut the squares in the same relations as in the original.

Section 12.—Another treatment of the above method sometimes used when a figure is long and narrow is illustrated in Fig. 7.

Divide the long dimension into a convenient number of equal parts and, for the short dimension, divide one of these parts again into a convenient number of equal parts and lay off as many of these smaller parts as are required to cover the width of the drawing. Then proceed as in Section 11.

Section 13.—Before describing the following methods it might be well to speak briefly of the use to be made of the drawing instruments in their construction.

A number of mechanical instruments for proportional drawing have been constructed, such as the pantagraph, the cheaper grades of which are quite limited in their scope and not very reliable, and those which are reliable and first class cost a first class sum, too much for the ordinary draughtsman.

Proportional dividers are widely used and for some purposes work fairly, but at best they only locate points.

In the following methods nothing but the ordinary implements, essential to the work of any draughtsman, are used.

In Fig. 8 we have the figure *A B C* and wish to construct four smaller sizes, whose lengths, *A D*, *A E*, *A F* and *A G*, are given.

To locate their widths, or a point in each corresponding to *C* in the original figure, place a triangle so that one edge passes through points *B* and *C*, then a straight edge against the edge of the triangle as illustrated in Fig. 8.

A steel ruler, other straight edge, a T square, or another triangle may be used for the purpose.

Hold the straight edge firm and slide the triangle along it to *D*, then draw a line passing through *D* and cutting *A C* at *H*. Then slide the triangle along the straight edge to *E* and draw a line passing through *E* and cutting *A C* at *I*. Continue this process until all the points have been located. Fig. 8 is drawn simply to illustrate the use of the tools. To carry out the process we will use Fig. 9.

In Fig. 9 we have the original figure, $O\ A\ A^2\ A^1$, and we now wish to construct five similar figures with their bases, *O B*, *O C*, *O D*, *O E*, *O F*, respectively.

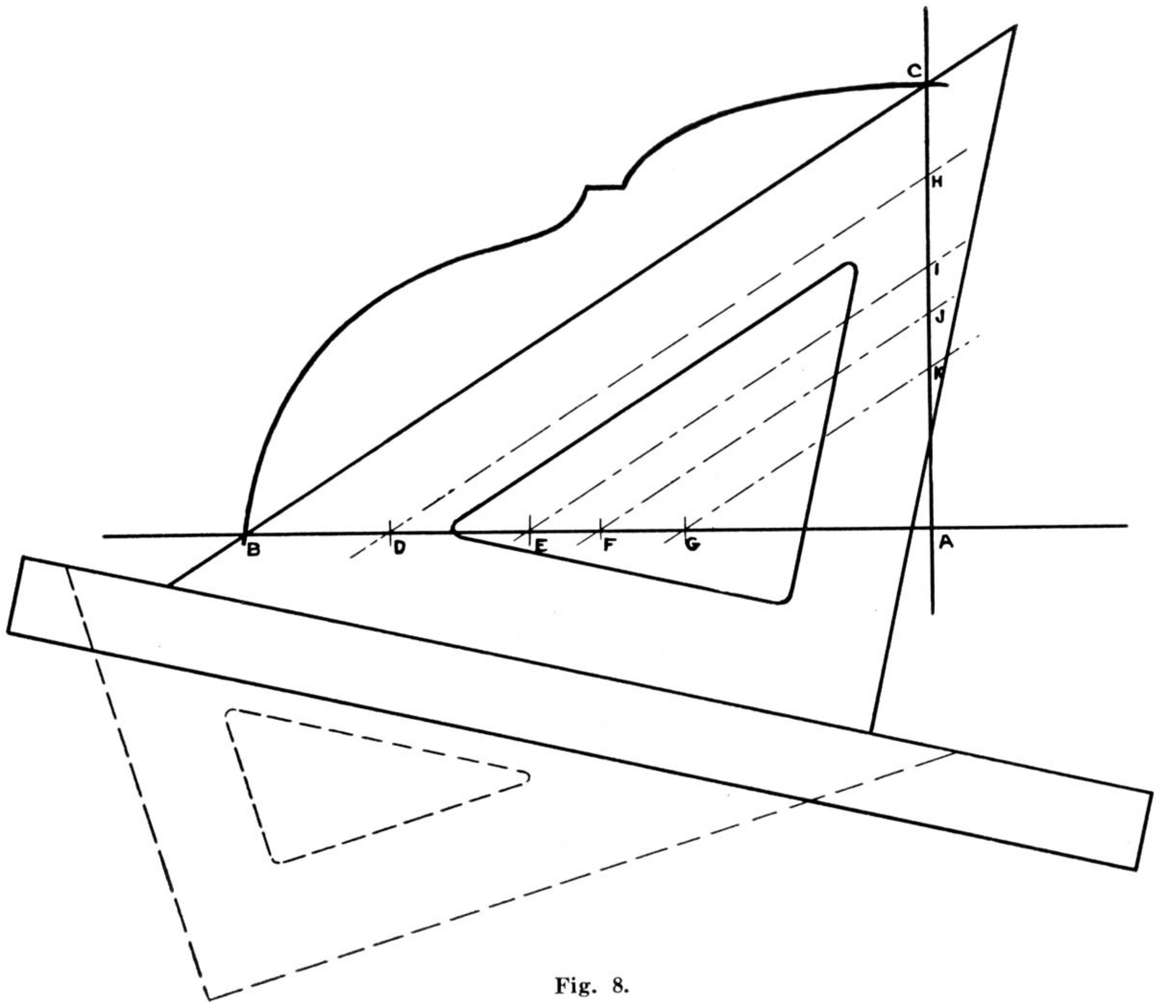


Fig. 8.

Start by drawing lines radiating from *O* passing through all angles or important points as A^2, but where there are curves it is well to draw the radiating lines near enough together so that the curves between such lines are nearly straight lines. The object of making these sections of the curve as near straight lines as possible is that when the line is plotted by straight lines the result will be as nearly as possible to the curve desired. It will be seen in Fig. 9, near A^1, where the curve is quite flat, that the lines are farther apart, and near *A*, where the curve is more abrupt, the lines are closer together.

Having made as many radiating lines as are deemed necessary, proceed as in Fig. 8, placing the triangle so that it passes through *A* and A^1, and, having adjusted the straight edge, slide the triangle along to *B* and cut $O\ A^1$ at B^1. Then slide along to *C* and cut $O\ A^1$ *at* C^1. Proceed in this manner until D^1, E^1 and F^1 are located.

The next important points to locate are those similar in position to A^2.

Place the triangle so that it passes through *A* and A^2 and slide along as before, locating B^2, etc. It is often well to prove the position of a point like this by checking it from A^1, thereby being sure that no error has been made in checking from the first point.

If there are other important points in a line it is well to locate them before starting to plot the line.

Now, starting from *A*, place the triangle so that it passes through points *A* and *G*, then slide the triangle along drawing lines from *B*, *C*, *D*, *E* and *F*, cutting line *G O* similarly.

It might be well again to call attention to the necessity of keeping the straight edge firm in its position, which may be done with the thumb and little finger, and the triangle operated by the other three fingers, because if the straight edge moves it will upset the whole work.

Then place the edge of the triangle so that it passes through *G* and *H*, and slide along in the same manner as before. Keep up this process until you have completed the line and finished at points A^1, B^1, etc. If thought more convenient, after having gone as far as A^2, one can start from A^1 and proceed to A^2. If you come out exactly at A^2 you may know that there has been no error in the work; if not, there is error somewhere, and it may be detected by checking the points between A^1 and A^2 from *A*, and those between *A* and A^2 from A^1 or some other point that has been established.

The result will be as shown in Fig. 9, that the figures will be plotted by short, straight lines, but so near to the original curve that they may be easily converted into it. The points of intersection with the radiating lines will have been located exactly, and if the radiating lines have been drawn close enough together the result will be about as near the curve desired as can be drawn.

In Fig. 9 the original figure is the largest, but it could

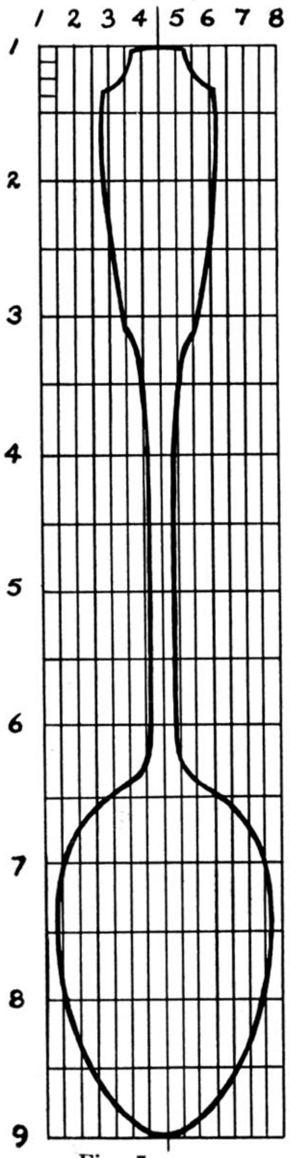


Fig. 7.

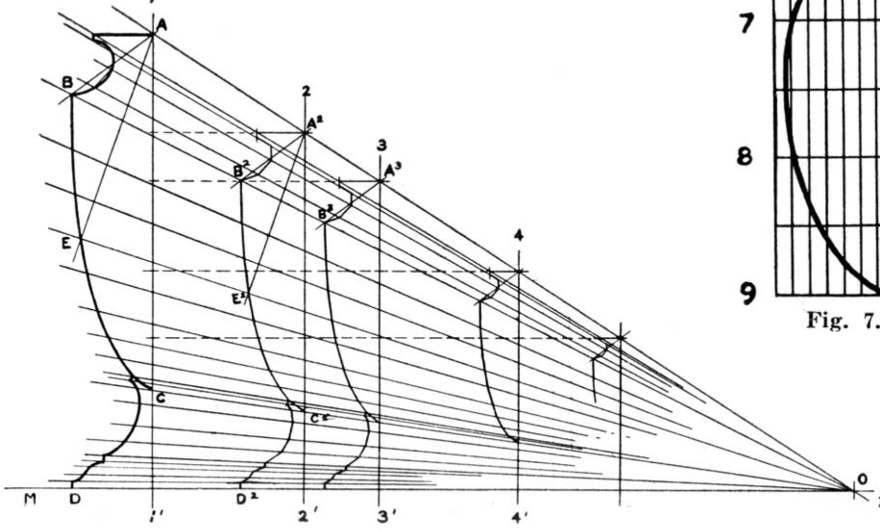


Fig. 10.

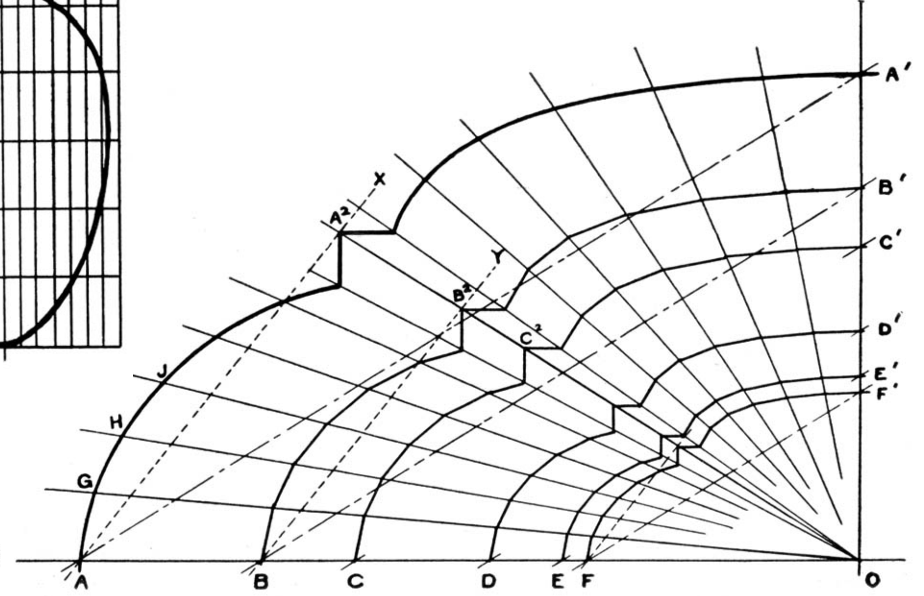


Fig. 9.

have been in the position of $O\,C\,C^1$ and figures made both larger and smaller than the original, or it might have been the smallest.

This process may seem quite elaborate at first, but when one becomes accustomed to it it is found very simple, as the writer can testify from several years'

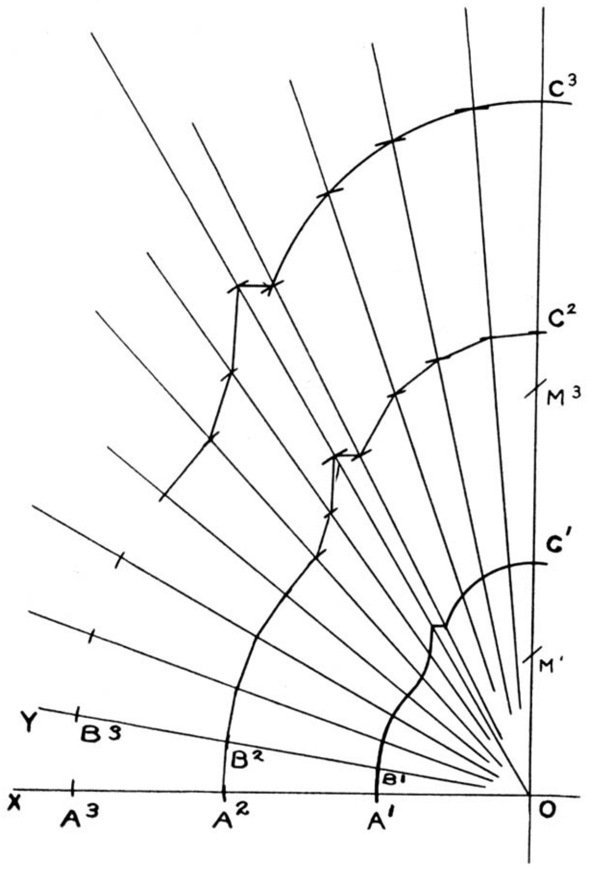


Fig. 11.

use, and it has the advantage over all other methods that when several sizes of the same thing are to be drawn they can all be carried through together, whereas with other methods the whole process must be gone through for each size separately. With this process six figures can be constructed as quickly as two or three by the square or the point of similitude methods, and they are in a position for comparison by the eye all the time. Even for constructing one figure similar to another the writer prefers this, in most cases, to all other methods. By this method points are located and a section of the line drawn in one operation.

The correctness of any series of measurements may also be proven by mathematics, by determining the ratio of one to the other.

Section 14.—In Fig. 10 we approach the problem from a little different angle. We have a vase shape to draw, or one half of it, and it is composed of two parts, a body and base, therefore it is awkward to work from a common center in the center line of the vase, unless the body and the foot be separated and treated as two drawings and put together after being constructed. In a condition of this sort, or where the forms to be drawn are quite long and narrow, even if of a single part, it is better to use a base line, as $M\,X$ in Fig. 10, and locate the figures at intervals along this line.

Draw $M\,X$ any length and the line $I\,I^1$ perpendicular to it. Use the line $I\,I^1$ as the center line for the original drawing.

Choose a point O on $M\,X$ at a convenient distance from the line $I\,I^1$.

Then draw a line passing through A and O, also as many lines as necessary from O cutting the figure as was done in Fig. 9, and for the same reason.

To locate the positions of the center lines of the other sizes, it is well to lay off on $I\,I^1$ their various heights from the base line and then draw lines parallel to the base line through these points, cutting $A\,O$ at A^2, A^3, etc. From these points drop perpendiculars to the base line.

Place the triangle so that it passes through points A and B, then slide along and draw lines $A^2\,B^2$, $A^3\,B^3$, etc.

Points C^2, etc., are located by the line from O cutting the center lines.

Points D^2, etc., may be located from C^2, etc., or A^2, etc., or any of the crossings on the center line, but they must always be located from corresponding points.

Having located the principal points, proceed as in Fig. 9 to plot the outlines of the figures. The points E^2, etc., are simply testing points.

When only one enlargement or reduction is to be made the center lines of the two figures, of actual length, may be placed parallel to each other at a convenient distance and lines drawn, passing through ends of these center lines, meeting at the point from which the radiating lines are to be drawn.

Section 15.—Fig. 11 looks similar to Fig. 9, but it involves a different process. In this case we have a figure $A^1\,B^1\,C^1\,O$ and wish to make others two and three times the diameters of $A^1\,B^1\,C^1\,O$.

Draw radiating lines as in Fig. 11. Then, with dividers opened to distance $O\,A^1$, space A^2 and A^3 of the same length on line $O\,X$. With radius $O\,B^1$ space off B^2 and B^3 on $O\,Y$. This process should be carried out throughout the figure and the points connected by straight lines.

This is a very limited method and not nearly as desirable as the former methods, but it is entered simply as being possible.

It will be observed that a portion of the outline in

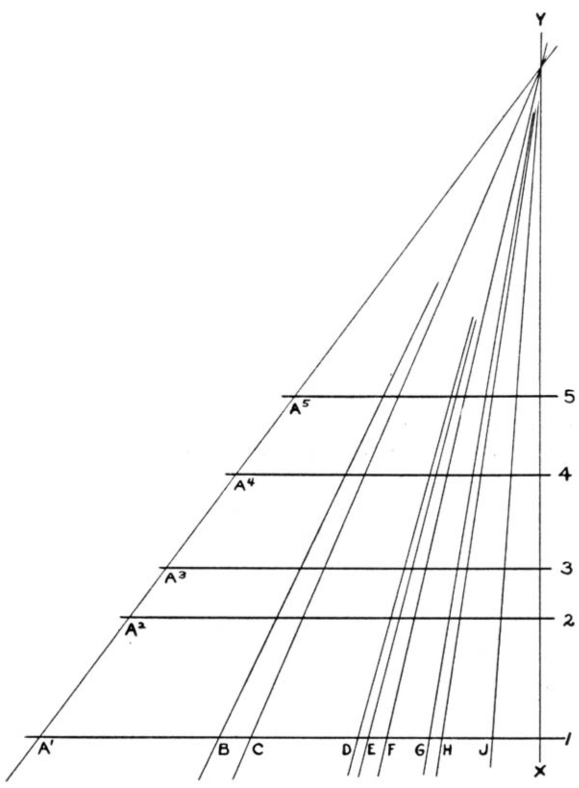


Fig. 12.

Fig. 11 is a part of a circle. In such a case the center of the circle should be located as at M^1. The center of the circle used in figure $A^3\,B^3\,C^3\,O$ can be located by lining up A^1 and M^1 and then checking M^3 from A^3. This could be done in either of the preceding methods if part of the line were an arc of a circle. In case the arc of the circle is used it will be unnecessary to make radiating lines in that part of the figure.

A very useful help in drawings that are rather complicated, and would be rather confusing if lines were drawn to all the points to be located, is to take a piece of tracing paper and on it construct a scale as in Fig. 12, with lines in the same ratio to each other as the drawings being constructed, though they may be but a fraction of the size of the original drawing. Any measurement may be taken from the original figure and its corresponding measurements produced upon the scale and pricked through onto the drawing.

Section 16.—The proof of the foregoing processes is based on the geometrical fact that homologous sides of similar triangles are proportional. It is very evident that the triangles occupying relative positions in these figures are similar. First, because their sides are

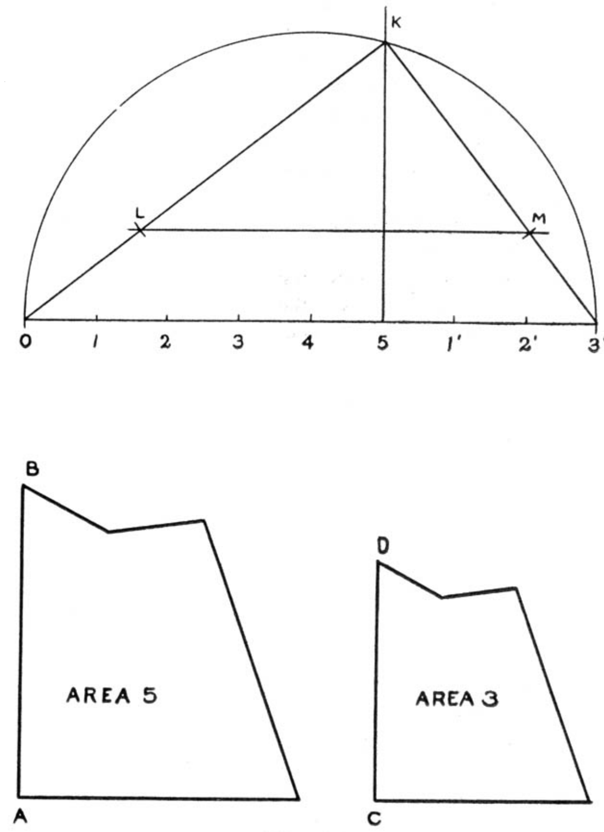


Fig. 14.

parallel. (Triangles which have their sides respectively parallel are similar.) Second, the angles are equal. (Triangles which are mutually equiangular are similar.)

It will be observed that there is a series of triangles between each two adjacent radiating lines, as in Fig. 9 the lines $A\,O$ and $G\,O$ form two sides of a series of triangles and the lines cutting across them, which are parallel, complete the triangles. If, as has been shown, each triangle is in proportion to those occupying similar positions in the other sizes, the whole figures must be in proportion.

There are also several other proofs that might be used to show that the figures are in true proportion.

Section 17.—Another process, known as the inverse similitude, may be used, but it is not very practical, as it treats with but one reduction or enlargement at a time, and the figures are in inverted positions so that their relations are not so easily seen, yet the result by this process is correct.

Given figure $A\,B\,C\,D$ (Fig. 13) to construct a similar figure the sides of which shall have the same relation to $A\,B$, $B\,C$, etc., that the line J has to the line H.

Draw $A\,X$ at any convenient angle to $A\,D$ and on it lay off $A\,E$ equal to H and $E\,A^1$ equal to J.

From D draw an indefinite line through E.

From A^1 draw a line parallel to $A\,D$ cutting $D\,E$ produced at D^1.

From B draw an indefinite line through E.

From A^1 draw a line parallel to $A\,B$ cutting $B\,E$ produced at B^1.

From C draw an indefinite line through E.

From D^1 draw a line parallel to $C\,D$ cutting $C\,E$ produced at C^1.

Then draw as many intermediate lines as necessary and plot the curved line between B^1 and C^1, as was done in Figs. 9 or 10.

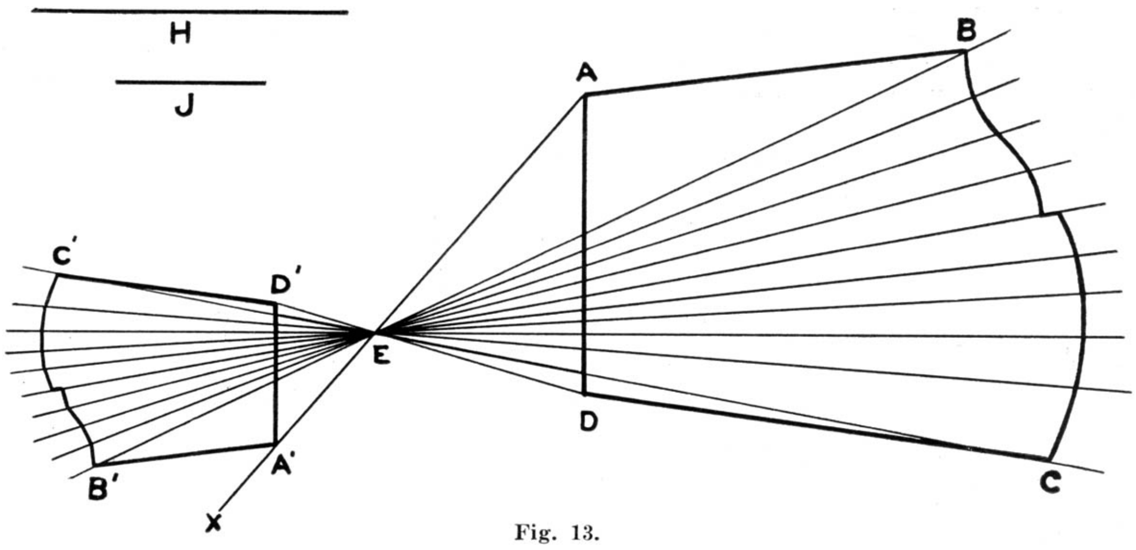


Fig. 13.

Section 18.—Triangular boxwood scales, being graduated 10, 20, 30, 40, 50 and 60 parts to the inch, are also quite useful in proportional drawing, as when you have a ratio of 2 to 3 or 5 to 4, corresponding measurements may be made directly with the scale.

Section 19.—Proportional area. Given a figure with an area of 5 units (Fig. 14), to construct a similar figure with an area of 3 units.

On a straight line lay off 5 equal units of any length and then 3 more of the same length, as in Fig. 14.

With one half $O\,3^1$, or one half the combined number of units, as a radius, describe a semicircle on $O\,3^1$.

At 5, or the junction of the two sets of units, erect a perpendicular to $O\,3^1$, cutting the semicircle at K.

Join K and O, and K and 3^1.

Then with center K and radius equal to $A\,B$, lay off $K\,L$ on $K\,O$ equal to $A\,B$.

Draw a line through L parallel to $O\,3^1$, cutting $K\,3^1$ at M.

$K\,M$ is the line required on which to construct a figure of 3 units in area.

Take $C\,D$ equal to $K\,M$ and construct the figure by some method of proportional drawing.

Section 20.—Proportional volume. The question of proportional volume involves a little of mathematics in connection with the drawing. In this case we are concerned with three dimensions, length, breadth and height.

Given a body, or drawing of a body, of a certain size, the capacity of which is known; to make a drawing of another body an exact duplicate in form but of another given capacity.

We must find a dimension in the body to be constructed similar to a dimension in the original body.

Take any dimension on the original as a basis to work with, say the height.

Cube this dimension.

Divide this product by the capacity of the original body, be it cubic inches, ounces or gallons.

Then multiply the result by the capacity of the body whose dimension is to be found.

Find the cube root of this product, which will be the dimension desired, or the height of the body to be constructed.

Having the height of the second body and a drawing of the original body it will be a simple matter, by some of the processes of proportional drawing already explained, to make the drawing of the body of the required capacity.

The United States Lighthouse Service—II

Its History, Growth and Methods

Concluded from SCIENTIFIC AMERICAN SUPPLEMENT No. 2134, Page 347, November 25, 1916

FOG SIGNALS.

THE first fog signal in the United States was a cannon, installed at Boston Light in 1719, which was fired when necessary to answer the signals of ships in thick weather. Guns of various types were used at other lighthouses but have now been generally abandoned.

Bells were introduced at a comparatively early date, and at first were usually small and rung by hand to answer vessels. Larger bells were developed and striking machinery, governed by clockwork, devised for ringing a regular code or characteristic. Many bells are now in use, ranging from small hand bells up to 4,000 pounds in weight, and are of value for inside waters, harbors, etc., but are not sufficiently powerful for use on the seacoast.

Trumpets were the next improvement, and were first introduced about 1855. The original device consisted of a steel reed or tongue inclosed in a box with a large trumpet or resonator; the apparatus was sounded by means of compressed air produced by horse-power operating through suitable machinery. A modification was made, using an Ericsson hot-air engine instead of the horse as the motive power, and trumpets so equipped were established at a number of stations. A somewhat similar device, known now as a reed horn, is in use at a number of inside stations and is generally operated by compressed air, the compressors being driven by internal-combustion kerosene or gasoline engines. The sound is of moderate volume only and is not sufficiently loud for rough outside stations.

Steam whistles were investigated first in 1855, and an installation of a 5-inch whistle was made at Beavertail, R. I., in the Fall of 1857. The first station regularly equipped was at Cape Elizabeth, Me., where the installation was placed in commission on June 15th, 1869. This consisted of a 10-inch locomotive-type whistle, giving an 8-second blast every minute. This was the most powerful apparatus devised up to that time, and in point of volume and carrying power of the sound is still considered a very efficient aid.

Experiments with sirens were first made in 1867, and the first service installation was at Sandy Hook East Beacon on March 31st, 1868. Steam at about 70 pounds pressure was used here, but compressed air is now generally employed as the sounding medium, though steam is used at a few places. The compressors are driven by internal-combustion engines. The principal advantages of the compressed-air siren are distinctiveness of note, which is entirely unlike the ordinary whistle, and quickness of starting, rarely over 10 minutes being required in any case, while some of the more recent installations may be sounded almost instantaneously.

Other types are the "sireno," an electrically driven blower siren, and the "diaphone," an instrument similar to the siren but having a reciprocating piston instead of a rotor. The diaphone is used quite extensively in the Canadian lighthouse service and a few installations have recently been made in this country. An experimental installation has also been made of an acetylene fog gun, which consists of an apparatus for firing an explosive mixture of air and acetylene gas by means of an electric spark.

Practically all fog signals as now installed are provided with a governing device for timing the strokes or blasts; this usually consists of a clockwork whereby the cycle is repeated every minute in order to facilitate identification.

Fog signals, though of the greatest value to the mariner, are subject to a number of aberrations, so that they can not be relied upon implicitly. Sound is conveyed irregularly through the atmosphere and mariners can not place dependence on judging their distance from the fog signal by the power of the sound. Under certain conditions of the atmosphere the sound may be lost a short distance from the signal, as there may be silent areas or zones; or the sound may carry much farther in one direction than in another, and these conditions may vary in the same locality within short intervals of time.

It is often observed that in any given direction from a fog signal, and near its limit of audibility, the sound may become extremely faint, and at a greater distance it may again become quite distinct. It should never, therefore, be assumed that fog signals are not in operation because the sound is not heard, even when in close proximity.

Submarine signals, which have been introduced in recent years, have as a rule a more effective and constant range of audibility than signals sounded in air. Such a signal consists essentially of a specially designed bell, submerged sufficiently to avoid wave disturbance, with some form of striking mechanism. On light vessels the bell is usually swung over the ship's side on a chain attached to a davit, and the striking device is operated pneumatically to ring a certain set of blows at prescribed intervals. At light stations the bell is usually supported on a tripod, placed on the sea bottom, a short distance away from the light, and the striking mechanism operated electrically through a cable, with characteristic number of blows at regular intervals. When attached to buoys a swinging vane is provided which is forced up and down as the buoy surges in the sea. The motion of the vane causes a spring to stretch, which is released at a sufficient tension, striking a blow on the bell. The blows are of equal intensity, although the interval between them varies with the condition of the sea, and no regular code of blows is therefore practicable.

In order to obtain the best results with submarine bells, a receiving apparatus, somewhat similar to a telephone, has been devised for attachment to a vessel. This is apparently more effective in vessels of deep draft, and a ship so equipped may determine the approximate bearing of the signal. The sound may be heard also on vessels not equipped with receiving apparatus, by observers below the water line, and particularly in iron or steel ships, but the bearing of the signal can not then be readily determined.

BUOYS.

Buoys are, as a rule, employed to mark shoals or other obstructions, to indicate the approaches to and limits of channels or the fairway passage through a channel, and in some cases to define anchorage grounds. There were some buoys in service at the time of the transfer of the lighthouses to the Federal Government in 1789. Buoys originally were either solid wooden spars or built up in various shapes of wooden staves, like barrels. Wooden spars are still exclusively used, particularly in inside waters; but built-up buoys are now constructed of iron or steel plates.

In order to give the proper distinctiveness, buoys are given certain characteristic colors and numbers; and following the uniform practice of maritime nations generally, Congress has prescribed that all buoys along the coast or in bays, harbors, sounds, or channels shall be colored and numbered so that passing up the coast or sound or entering the bay, harbor, or channel, red buoys with even numbers shall be passed on the starboard or right hand; black buoys with odd numbers on the port or left hand; buoys with red and black horizontal stripes without numbers shall be passed on either hand, and indicate rocks, shoals, or other obstructions, with channels on either side of them; and buoys in channel ways shall be colored with black and white perpendicular stripes, without numbers, and may be passed close-to, indicating mid-channels. Buoys to mark abrupt turning points in channels or obstructions requiring unusual prominence, are fitted with perches or staves surmounted by balls, cages, or other distinctive marks.

To assist further in distinguishing buoys, the ordinary unlighted types are made in two principal shapes in the portion showing above the water line: Nun buoys, conical in pattern with pointed tops, and can buoys, cylinder shaped with flat tops. When placed on the sides of channels, nun buoys, properly colored and numbered, are placed on the starboard or right-hand side going in from sea, and can buoys on the port or left-hand side.

Buoys may be divided broadly into two general classes, lighted and unlighted, of which the latter are in the great majority. Unlighted buoys comprise spars, both wooden and iron, can, nun, bell, and whistling buoys, with a few other types for special purposes. Lighted buoys are provided with some form of gas apparatus and a lantern; frequently a bell or whistle is also attached, in which case they are known as combination buoys.

Bell buoys are built of steel plates, with flat deck, and carry a bronze bell and usually 4 iron clappers. The motion of the buoy in the sea causes these clappers to strike the bell, so that the action is entirely automatic.

Whistling buoys are built of steel plates, and consist of a pear-shaped body with the smaller end uppermost, with a long open tube on the lower end. This tube extends throughout the length of the buoy, and is closed at the upper end by a headplate on which is mounted a check valve and a whistle on the superstructure of the buoy. The sound is produced by the air in the upper portion of the tube being compressed by the falling of the buoy in the waves, its means of escape being through the whistle. A fresh supply of air is drawn through the check valve as the buoy rises again. Like the bell buoy, the sound is automatic, depending solely on the motion of the waves, and therefore the whistle may be silent when the sea is very smooth.

All of the lighted buoys now in service use compressed gas, either oil gas or acetylene. Various types of self-generating acetylene buoys have been in use, operating on the carbide-to-water and water-to-carbide principles, but have been abandoned on account of uncertainty of length of run difficulty of cleaning, and danger of explosion.

In the types now in use the gas, at a pressure of about 12 atmospheres, is contained either directly in the body of the buoy or in tanks fitted into compartments of the body, and is piped to the lantern at the top of the superstructure. If the light is flashing, as is commonly the case, a small pilot light burns continuously and ignites the main burner as gas is admitted from the flashing chamber, which is a regulating compartment in the base of the lantern provided with a flexible diaphragm and valves for cutting off and opening the flow of gas at intervals, the operation being due to the pressure of the gas in the reservoirs. The length of the light and dark periods may be adjusted to produce the desired characteristic, such as 5 seconds light, 5 seconds dark, etc. Some types burn the gas as an ordinary flat flame, while others make use of an incandescent mantle, which is, however, not wholly satisfactory in rough water on account of breakage.

Gas buoys burn continuously by night and day for

intervals of a month to a year without recharging.

LIGHT VESSELS.

The Lighthouse Service maintains light vessels on 53 stations, and has for this purpose 66 light vessels, of which 13 are relief vessels; all figures being those of June 30th, 1915. They are generally employed for marking dangers at sea, approaches or entrances to harbors, or important points in the courses of vessels, where a lighthouse would not be feasible or economical, and are of particular value in providing both a light and a fog signal which may be approached close-to, thus enabling mariners to fix their position at sea with reasonable certainty. In this respect light vessels are superior to lighthouses, as in the case of the latter, in the majority of instances, due allowance must be made for a safe distance in passing. A valuable secondary advantage is the fact that light vessels may be shifted to meet varying conditions of traffic, such as changes in shoals or channels, use of deeper draft vessels, and similar contingencies.

The first light vessel established in this Service was in the Summer of 1820, at Willoughby Spit, Hampton Roads, Chesapeake Bay, Va. The first outside vessel was placed 7 miles off Sandy Hook, N. J., in 1823. The idea of lightboats, as they were then called, became popular, and by 1839 there were 30 in service, most of them being small craft in inside waters. The largest vessel was that on the Sandy Hook station, which had a tonnage of 230.

By the year 1852 there were 38 light vessels in service, of which number 26 were in bays or sounds. Several vessels of the composite type, with steel frames and wooden sheathing, have been constructed; but the modern tendency has been toward all-steel construction. Another practical feature of design which has greatly increased the efficiency of light vessels is the use of propelling machinery, thus enabling them to proceed to and from their stations under their own power and to assist them in maintaining their positions in heavy weather.

The question of the proper form of the hull of a light vessel presents many interesting and complex problems in naval architecture, steadiness and ease of motion being the chief requirements for the general efficiency of the light, as well as for the comfort of those on board. The scantling throughout is much heavier than ordinarily required in vessels of similar size, for the double purpose of providing great excess strength as well as guarding against the injurious effects of corrosion, and an ample number of water-tight bulkheads is provided below the main deck, to increase the stiffness and safety of the vessel. The main mooring chain is, as a rule, composed of links made of the best double-refined wrought iron, 1⅝ inches in diameter, with cast-iron studs, and tested to a proof strain of over 80,000 pounds. Such chain weighs approximately 160 pounds per fathom (6 feet), so that the entire weight of a standard 120 fathom cable is about 9 tons. Specially designed cast-steel mushroom anchors, in weights up to 7,000 pounds, are used for mooring to the bottom, and in the case of vessels in severely exposed position in deep water a spherical mooring buoy, strongly braced to resist collapsing pressures, is shackled into the submerged portion of the chain, tending to carry a portion of the weight, and forming a double catenary which is of value in avoiding injurious strains on the vessel as it surges in rough weather.

The largest vessel in the Service is 135 feet 5 inches long, of 685 tons, while the smallest is 80 feet 6 inches long, of 87 tons. Some of the more recent vessels are provided with internal-combustion kerosene engines, which it is believed will be more economical than steam.

The complement of a first-class light vessel is generally 4 officers and 10 men, which is varied in the case of smaller and less exposed vessels as conditions justify, down to a minimum of 3 men all told, for the smallest size of inside lightships.

Ordinary ship's lanterns served for lights on the early vessels, while the fog signal was a hand bell or horn. When reflector lights were introduced, each light was composed of 8 lamps with reflectors 12 inches in diameter, set upon a ring which encircled the mast, the whole apparatus being inclosed in a lantern with large panes of glass to protect the light from the wind. When not in use the lanterns were kept in a small house at the base of the mast, and were lighted and hoisted to the masthead at night. This arrangement is still in use on some of the older vessels. Sometimes such lights are shown on two masts. White lights are commonly employed, red being used occasionally when necessary to give distinctiveness.

In recent years a tubular steel mast, of diameter sufficient to contain a ladder, has been installed. This is surmounted by a helical bar lantern of the type used in lighthouses on shore, containing a regular lighthouse lens. Any illuminant may be employed in such a lantern, such as electric light, incandescent oil vapor, acetylene, or oil gas, as desired. The 12-inch steam whistle is still used on many light vessels as the main signal, and a pneumatically operated submarine bell is frequently added as an auxiliary.

Four of the most important light vessels on the Atlantic and Gulf coasts, those on Nantucket Shoals, Diamond Shoal (Cape Hatteras), and Frying Pan Shoals, also the vessel on Heald Bank, are equipped with radio, and these installations have been found of considerable value, and it is expected that the number will be increased.

Light vessels are distinguishable in the daytime by their unusual shape and rig, including generally some form of cagework as a day-mark at the mastheads, and by their characteristic painting and lettering. The hull is often painted red or straw color, although many other colors or combinations of color are employed to make adjacent vessels as different as possible, and a short station name is painted on the sides of the vessel in the largest size letters practicable.

Lighthouse tenders are vessels employed to look after the buoyage, to supply the light vessels and isolated light stations both with the ordinary articles for maintenance and materials for construction or repair, and also for inspection purposes when necessary. Forty-seven vessels were in commission during the year ended June 20th, 1915, ranging from 39 to 1,053 tons.

While the business of the Service is primarily concerned with the maintenance of aids to navigation, it frequently happens that opportunity presents itself to give assistance to persons or vessels in distress, and in such cases it is the duty of light keepers and their assistants, and of officers and crews of lighthouse vessels, to give or summon aid to vessels in distress, and to assist in saving life and property whenever it is practicable to do so. The records of the Service are replete with many heroic incidents of this character.

Heavy penalties are prescribed by law for obstruction to or interference with any aid to navigation. Exhibiting a false light, or extinguishing a true light, with intent to bring any vessel into danger, is a felony punishable by imprisonment of not less than 10 years, or for life.

The material for this article was derived from *The United States Lighthouse Service, 1915*, published by the Department of Commerce.

Passivity of Iron

In an article by A. Smits, in the *Chem.-Zeitung*, a theory of the passivity of iron is developed, based on the assumption that in addition to unchanged atoms and free electrons, the metal contains two different kinds of ions of different valency, viz., α ("base") ions and β ("noble") ions. These two kinds of ions are in equilibrium and the production of the passive state is to be ascribed to destruction of this equilibrium. In the anodic solution of a metal, polarization occurs because the metal tends to dissolve more rapidly than the equilibrium mentioned is established, so that a concentration of "noble" ions takes place at the surface of the metal. Ordinary iron always contains hydrogen, and it is known that hydrogen ions, like halogen ions, greatly accelerate the change from the passive to the active state, i. e., they catalytically accelerate the establishment of equilibrium between the two kinds of ions. In the anodic solution of iron, a portion of the hydrogen also dissolves, and as the concentration of hydrogen in the iron thus falls, so the tendency for the equilibrium to be disturbed increases. By increasing the current density so that the potential rises to the value corresponding to the anodic evolution of oxygen, hydrogen is removed completely from the surface of the iron, and the disturbance of the equilibrium (production of passive state) reaches a maximum. This condition persists for a short time when the current is cut off, but hydrogen soon diffuses from the interior to the surface of the iron, where it catalytically accelerates the re-establishment of equilibrium, and hence of the active state. When iron is immersed in strong nitric acid, the α ("base") ions dissolve with great rapidity and hydrogen ions are also removed from the surface of the metal, so that the passive condition is established. In ferrous chloride solution, on the other hand, passivity is not produced, because both the chlorine ions and the halogen ions catalytically accelerate the change from the passive to the active condition. Active iron in dissolving sends ferrous ions almost exclusively into solution, and it would be anticipated from the usual formula for expressing the single potential, that the potential would be more strongly negative in a ferric than in a ferrous solution. Actually the reverse is the case, and the following explanation is suggested. Since iron sends ferrous ions almost exclusively into solution, the solution with which iron is in electromotive equilibrium must likewise contain ferrous ions almost exclusively. When immersed in ferric sulphate solution, iron tends to alter the composition of the solution so as to make it approach that of a solution in electromotive equilibrium with the metal, i. e., the iron sends ferrous ions into the solution with a velocity greater than that with which ionic equilibrium in the iron is established; hence there is a concentration of ferric ions at the surface of the iron, and the potential becomes more positive.—*Abstract published in Jour. Soc. of Chem. Eng.*

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