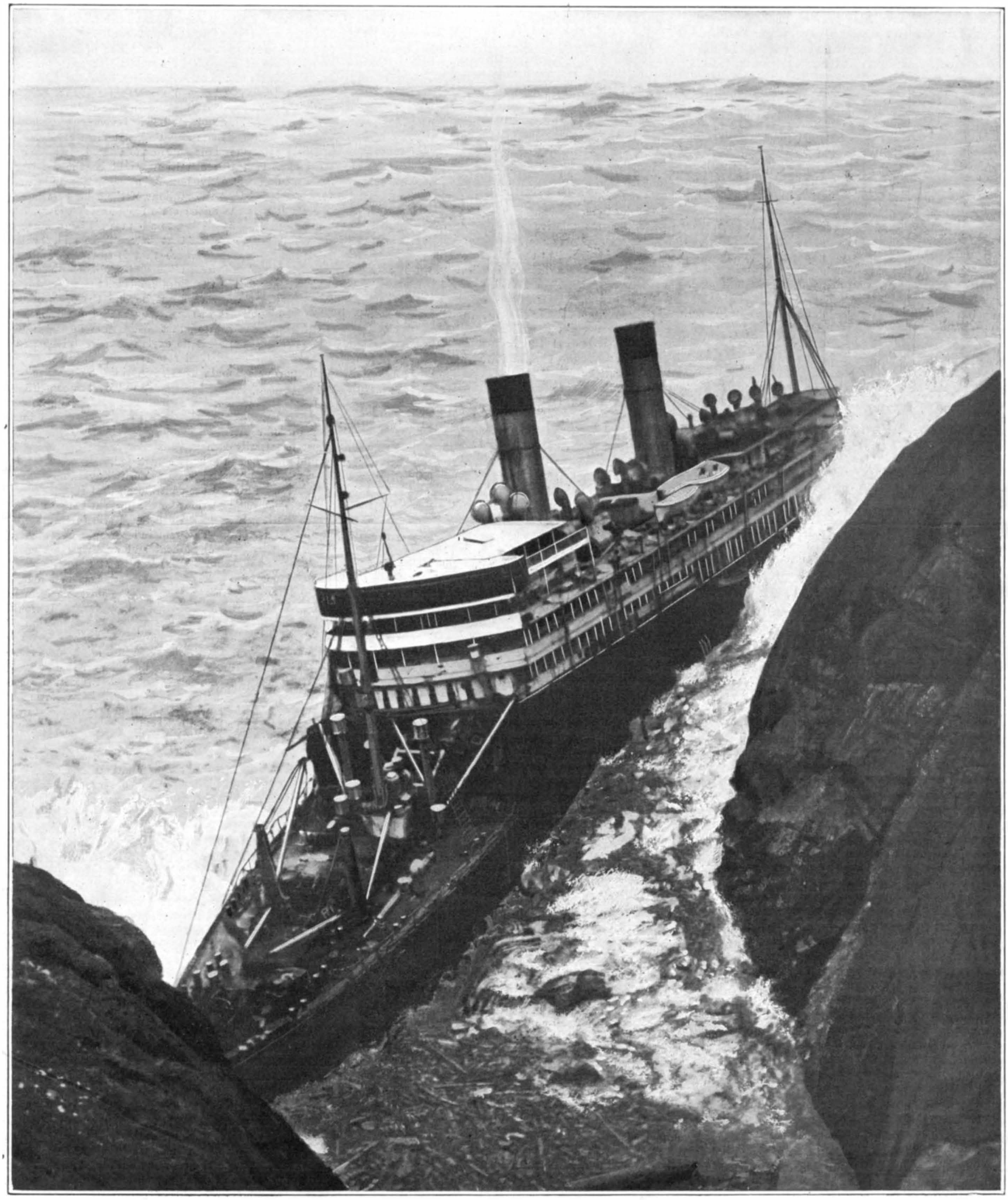
SCIENTIFIC AMERICAN SUPPLEMENT

VOLUME LXXXI
NUMBER 2112

★ NEW YORK, JUNE 24, 1916 ★

10 CENTS A COPY
$5.00 A YEAR



Wreck of the Steamship "Chiyo Maru," near Hong Kong.

A MARINE DISASTER ON THE COAST OF CHINA.—[See page 413.]

The Fallacy of the Nebular Hypothesis*

Celestial Mechanics and Other Facts That Demand a New Theory

By Daniel Buchanan

The Ptolemaic theory of the motions of the heavenly bodies takes precedence over all other theories not because of its strict adherence to the facts revealed by observation of celestial phenomena but because it held sway for the longest period of years. Our little theories rise and have their day but the day of the Ptolemaic theory, with slight modifications and accretions, extended from the time of Eudoxus in the fourth century B. C. down until the middle of the seventeenth century, when it was overthrown by the "alternative hypothesis" of Copernicus and the discoveries of Galileo. The theory derives its name from the famous Greek astronomer, Ptolemy, who flourished about the middle of the second century A. D. According to this theory, the earth is globular in shape and immovable at the center of the universe, while the sun, moon, planets and stars all revolve about it on crystalline spheres at varying distances. The outermost sphere contains the fixed stars and it rotates with such incredible velocity that all the stars, many of them so far distant that the light we now see left them before the dawn of the Christian era, complete a revolution in twenty-four hours.

This theory received the sanction of Aristotle and permeated many of the systems of theology of the early middle ages. It became the adopted child of the church, nurtured by theology and protected by Scripture. To doubt it was heresy, to attack it was blasphemy. Consequently all the righteous indignation of the faithful and orthodox was hurled upon Copernicus and Galileo, the former having offered an alternative hypothesis, the latter having substantiated that hypothesis by astronomical discovery. But the apparently unsuccessful struggle of Galileo against the Inquisition for the independence of scientific thought and investigation was not fought in vain. The Copernican theory triumphed in the following centuries and is now universally accepted as the only explanation of the motions of the heavenly bodies.

When the crystalline spheres of Ptolemy vanished there disappeared with them the motive power by means of which the heavenly bodies moved. The first theory to account for the motions of the planets, after the breakdown of the Ptolemaic hypothesis, was Descartes' famous Theory of Vortices. Descartes is best known through his contributions to philosophy and mathematics, but he was an astronomer as well. He might be called a "drawing-room astronomer" as he did not allow his imagination to be restricted by any secondary things such as facts or observations. His theory rested entirely upon a metaphysical basis. It is this: The heavens are filled with a liquid substance having the common property of all liquids. (Modern physicists make a somewhat analogous supposition concerning the ether.) This liquid is in rotation and at various places throughout the solar system are whirlpools or vortices, just as there are eddies in currents of water. The sun is at the center of a huge whirlpool and the planets are carried about it in different periods of time varying according to their distances from the sun. Each planet, in turn, is the vortex of a secondary eddy in which the respective satellites move. These secondary eddies are supposed to produce such changes in the density of the surrounding medium of the primary whirlpool that the planets move about the sun in ellipses instead of in circles. It is not difficult to show mathematically that on this hypothesis the sun would be at the center of the ellipses and not at one of the foci, and further that the weight of every body on the surface of a planet, except at the equator, would act in a direction which is not vertical. If this were true on the earth the people living in different latitudes would be distinguished not only by their differences in dialect, religion and attitude toward Home Rule, but also by the angles which their bodies would make with the true vertical. This theory was worthless in so far as it contributed anything directly, but it marked a new era in astronomy inasmuch as it attempted to explain the phenomena of the whole universe in accordance with the mechanical laws which experiment showed to be true on the earth.

While Galileo was substantiating the heliocentric theory of Copernicus and suffering for its sake mental if not physical torture at the hands of the Inquisition, the Danish astronomer, Tycho Brahe, was making systematic observations of the heavenly bodies, and from these records Kepler deduced the laws of planetary motion. Kepler's laws were all empirical and were formulated after several fanciful theories had been reluctantly discarded as they could not be made to conform with the observations of Tycho. Kepler's laws are: (1) that every planet moves in an ellipse with the sun at a focus; (2) that the line joining the sun to the planet moves over equal areas in equal intervals of time; and (3) that the squares of the periods of revolution of the planets about the sun vary as the cubes of their mean distances from the sun.

* *Queens Quarterly.*

The following articles have been consulted in the preparation of this paper: F. R. Moulton, "Test of the Nebular Hypothesis," *Astrophysical Journal*, vol. xi (1900), pp. 103-131; T. C. Chamberlain, "Test of the Nebular Hypothesis," *Journal of Geology*, vol. viii (1900), pp. 58-74.

The year after the death of Galileo there was born a diminutive child who was destined to be the discoverer of the law of force which governs the solar system and of the laws of motion by which its various members move. This child was afterward called Sir Isaac Newton. The scientific world awaited the coming of his giant intellect. Sufficient data concerning the motion of the planets had been collected and the truth all but divulged when Newton, in a contemplative mood (he was always contemplative, we may presume), saw the apple fall. The eating of the apple led to the fall of mankind, but the fall of the apple led a human intellect "to think God's thoughts after Him." From Kepler's laws Newton concluded that the propelling force which moves the planets in their orbits is neither the rotating crystalline spheres of Ptolemy nor yet the direct intervention of stalwart angels whose eternal duty was to make the worlds "go 'round," but is the mutual attraction between the sun and the various planets varying directly as the product of the masses and inversely as the squares of the distances.

Newton found a world in chaos governed by mysticisms, liable at any time to collapse should the crystalline spheres wear with constant use or should the angels become weary of their toil. He left a world governed by force in which the various members move "according to eternal laws." He was regarded by Laplace as not only the greatest genius that had ever existed but also the most fortunate, "for as there is but one universe it can happen but to one man in the world's history to be the interpreter of its laws."

When the nature of the universe had thus been settled, astronomers, mathematicians and philosophers turned their attention to the origin of the solar system and probable theories of evolution. From a consideration of the nature of the solar system we are almost forced to conclude that there has been a development from an earlier state in which the various members were more closely related. The planets all move about the sun in orbits which are very nearly circular, in sensibly the same plane, the plane of the ecliptic, and in the same direction. (This direction is called *direct* and it is the direction in which the sun itself rotates on its own axis in about twenty-five days. The opposite direction is called *retrograde*.) The closer a planet is to the sun the shorter is its period of revolution about the sun. A glance at the accompanying table[1] of distances and periods of planets shows that the relation between distance and period is consistent and obeys Kepler's third law.

Planet.	Distance from the Sun in Millions of miles.	Period of Revolution About the Sun in Years.
Mercury	36.0	0.24
Venus	67.2	0.62
Earth	92.9	1.0
Mars	141.5	1.88
Jupiter	483.3	11.86
Saturn	886.0	29.46
Uranus	1781.9	84.02
Neptune	2791.6	164.78

The satellites of the various planets all revolve about their respective primaries in nearly the same plane in which the planets themselves move. There are exceptions, to this, however. The four satellites of Uranus revolve in sensibly the same plane but it is inclined to the plane of the planet's orbit about 98 degrees or 82 degrees, according as the motion is considered direct or retrograde respectively. The orbit of the only known satellite of Neptune is inclined to the plane of Neptune's orbit 145 degrees or 35 degrees, according as the motion is considered direct or retrograde respectively. The satellites of the various planets, with the exceptions stated below, revolve in the same direction in which the planets move. The exceptions are the eighth satellite of Jupiter,[2] and the ninth satellite of Saturn,[3] discovered 1898. If we consider the motion of the satellites of Uranus as direct, then the plane of their orbits must be turned through 98 degrees. Similarly the plane of the orbit of Neptune's satellite must be turned through 145 degrees. The retrograde satellites of Jupiter and Saturn are in about the same plane as the other satellites and it is inconceivable that the plane of the orbit of one satellite of each planet should be turned over and not the planes of the other satellites.

[1] From Moulton's "Introduction to Astronomy," pp. 293-300.

[2] Jupiter has nine satellites. The four which can be seen in an ordinary telescope were discovered by Galileo. The next one, the fifth, was discovered by Barnard in 1892. The ninth was discovered in September, 1914.

[3] Saturn has ten satellites. The first was discovered in 1655 by Huyghens and the tenth in 1905 by W. H. Pickering.

When Laplace advanced his Nebular Hypothesis in 1796, the retrograde satellites of Jupiter and Saturn and Neptune's satellite had not been discovered.[4] Thus to Laplace all the planets and their satellites revolved in sensibly the same plane and in the same direction. He calculated that this condition would be the result of chance in one out of five hundred million cases, and therefore concluded that the motions of the solar system are the result of some initial state from which the system has evolved. This led him to advance his famous nebular hypothesis but "with that distrust," he said, "which everything ought to inspire that is not the result of observation or calculation."

According to the theory of Laplace, the solar atmosphere or nebula extended out beyond the orbit of the farthest planet. It was in a very heated condition and the whole mass rotated in the direction in which the planets now move, but no explanation was given as to the cause of the original rotation. The dimensions of this enormous nebula were maintained by the gaseous expansion due to excessive heat and by the centrifugal force of rotation. As the mass radiated heat into the surrounding space it would contract, and as the total amount of rotation, i. e., the moment of momentum, must necessarily remain constant, the rate of rotation would increase as the body contracted. Finally a condition would be reached when the centrifugal force at the equator would equal the centripetal, that is, the attraction of the central portions for the parts at the periphery, and when the contraction continued still further a ring would be left off. The remainder would continue to contract through loss of heat and another ring would be left off. Thus a ring was left off at the distance of each planet and what was left of the original nebula formed the sun. On account of the unstable form of the nebula the ring could scarcely be uniform. It would separate at one point and, through the attraction of that portion of the ring where a preponderance of matter had been left, the ring would form into a nucleus similar to the parent nebula. These secondary nebulæ would deposit rings at the distances of their respective satellites which, in turn, through the mutual gravitation of their parts, would contract into the satellites. Saturn's rings, it is claimed, are the only example of the secondary rings not yet contracted into a satellite.

This, in brief, is the nebular hypothesis—one of the boldest and most attractive speculations ever offered in science to account for the facts of observed phenomena. It had never been rigorously demonstrated to be true but it appealed to the imagination, as its grandeur seemed to blend with the gigantic task of constructing a universe.

There are two sets of facts which flatly contradict the nebular hypothesis. One set was not investigated, the other was not known, at the time the theory was proposed. These two sets are respectively the fundamental laws of dynamics and the facts revealed by astronomical discovery during the last century.

We shall first consider how the laws of dynamics contradict the nebular hypothesis. It is an indisputable fact that any system of particles of any kind whatever rotating about an axis preserves a constant moment of momentum whatever changes of form or arrangement the matter may undergo under its own interaction. The effect of foreign meteoroidal matter on the system has been slight and may be considered negligible. Let us now consider the moment of momentum of the original solar nebula. The greater its magnitude the greater will be its moment of momentum. Undoubtedly it must have extended many million miles beyond the orbit of the outermost planet, Neptune, before a ring could have been left off. But assuming that the solar nebula extended just to Neptune's orbit, an assumption which is the most favorable for the Laplacian theory, we shall find that the moment of momentum computed for the system postulated by Laplace is many times the amount of the present moment of momentum. If a sphere and an oblate spheroid (a sphere flattened at the poles) have

[4] Uranus was discovered in 1781, two of its satellites in 1787, the other two in 1851. Neptune and its satellite were discovered in 1846.

equal masses and equal equatorial radii, are composed of the same material (with differences in densities, however) and rotate with the same angular velocities, then the moment of momentum of the oblate spheroid will be greater. This is quite evident as the greatest difference between the sphere and the spheroid is in the polar regions where the effect upon the moment of momentum of the displacement of matter is least, and the spheroid must be denser in the equatorial regions to preserve the equality of mass. Thus, if we assume the original nebula to be a sphere, we shall obtain a smaller amount of momentum than if we assume it to be an oblate spheroid which is the figure of hydrodynamical equilibrium. On taking the law of density to be that determined by Ritter and G. H. Darwin[5] we obtain in the following table[6]

	Nebular Moment of Momentum.	Present M. of M.	Ratios.
Neptunian stage	4848.055	22.76661	213 to 1
Jovian stage	1996.420	14.18161	141 to 1
Terrestrial stage	857.330	0.71008	1208 to 1
Mercurial stage	512.290	0.67979	754 to 1

(first column) expressions for the computed moment of momentum at the various stages of evolution according to the Laplacian theory. The second column gives the present moment of momentum of the solar system. Thus 22.76661 represents the total amount of moment of momentum of the whole solar system; 14.18161 the amount if only the members of the system which extend out to and include Jupiter and its satellites are considered, and so on. The third column shows the discrepancies in the ratios, and as these discrepancies are not consistent or not even graded, it shows that they are not due to a fundamental error in the computations or in the assumptions on which the work is based. Thus the moment of momentum of the initial nebula of the Laplacian system is more than two hundred times greater than the present moment of momentum.

In the cooling of the spheroidal nebula it is reasonable to suppose that there would be some systematic relationship between the masses of the rings separated and the moment of momenta of these masses. The accompanying table[7] shows that no such relationship exists.

Ring.	Percentage of Mass of the Parent Nebula.	Percentage of the Moment of Momentum.
Neptunian	0.00507	7.93
Uranian	0.00454	6.31
Saturnian	0.02852	27.78
Jovian	0.09530	94.97
Martian	0.0000323	0.36
Terrestrial	0.0003160	2.42
Venus	0.0002495	1.89
Mercurial	0.0000205	0.12

These figures, impassive and serene as figures always are, "half conceal and half reveal" what might have been a terrible tragedy. When the ring which forms the Jovian system was separated from the parent nebula, it carried with it less than one tenth of one per cent of the mass of the parent nebula but nearly 95 per cent of the moment of momentum! This is quite incredible. If it carried away but 1/19000 more of the mass with an equal proportion of the rotational momentum it would have exhausted the supply of the parent nebula. If this had happened the younger members of the solar system would not only have suffered from this profligate and lavish distribution of the inheritance of momentum upon the favored Jupiter, but they never would have existed at all. The prodigal parent would have wasted his substance of momentum upon the youngest member, his rotation would have ceased and the ring ceremonies have come to an eternal end.

By a second appeal to the laws of dynamics it can be shown that rings could not have been left off and that if they were left off they could not have contracted into planets or satellites. We show first that separate rings could not have been left off, but that if the process of leaving off matter once started, matter would have been left off *continually* and not *in rings*.

Two forces are acting upon a particle at the periphery of a rotating mass, both directed along the radius but in opposite directions, the centrifugal away from the center, and the centripetal toward the center. If the mass rotates as a solid both these forces vary directly as the distance of the particle from the center. If the mass is a sphere, the centrifugal and centripetal forces would become equal through an increase in rotation not only at the periphery but all over the whole equatorial plane at the same time. Thus no rings could be formed with subsequent contractions of the nebula. If the mass is spheroidal in shape the centripetal force would not increase so rapidly as *directly as the distance from the center* and the centripetal and centrifugal forces would become equal first at the extreme periphery and not at some point near the periphery, which would be necessary in order to deposit a ring. As the effect of cohesion would be very slight in this extremely tenuous nebula, if the process of leaving off matter once started matter would have been left off continually and not in rings.

Let us suppose now that a ring was deposited and that the distribution of mass in this ring was not uniform but that a preponderance of matter had accumulated at a region E. Denote the remaining parent nebula by S. Let us assume that E moves in a circle about S. We shall neglect the slight perturbations of the outer rings upon a particle M in the ring of which E forms a part. If we consider M infinitesimal, i. e., if it is attracted by S and E but is so small that its attractions upon S and E may be neglected, then if M is placed at either vertex of the equilateral triangles[8] with S E as base (denote these vertices by P and Q), it will remain stationary with respect to S and E. It has been shown by Moulton[9] that if the particle M is on the arc Q EEP but not at P or Q, then it is possible for it to unite with the nucleus E, but that if the particle is at any other point on the circle it cannot be precipitated upon E. Thus even if a considerable nucleus had collected at a certain portion of the ring, it could not collect the particles distributed beyond 60 degrees on either side of it. Hence the appeal to celestial mechanics shows that the Laplacian hypothesis is improbable if not impossible.

Let us now consider the second set of facts which contradict the nebular hypothesis, viz., the additional data collected through astronomical discovery in the last century.

The retrograde satellites flatly contradict the hypothesis of Laplace. It is inconceivable that the planetary nebula should be rotating in one direction when a ring was deposited to form a satellite and then change its direction of rotation before another ring was deposited. The only outside influences acting upon the nebula to change its rate of rotation are the tides produced by the parent nucleus, the perturbations of the other planets, and the accretion of meteoroidal matter. The last factor may be neglected as, by the theory of probability, the number of meteors which would tend to increase rotation about equals the number which would tend to decrease rotation. The chief effect of the perturbations of the other planets is to produce precession, and their tide-raising influences may be neglected in comparison with the tide-producing force of the parent nebula.

Consider now the case of either Jupiter or Saturn and their respective satellites. The argument is the same in both cases and we shall discuss only the case of Saturn. It is argued according to the Laplacian theory that the Saturnian nebula rotated in a retrograde direction when the ring which formed the ninth satellite was deposited. Through the effect of the tides produced by the solar nebula its rotation was then retarded until its period of rotation equaled its period of revolution—a condition of affairs which exists between the earth and the moon, as the moon keeps approximately the same face toward the earth. The rotation of the Saturnian nebula was still further reduced until it became zero and then it acquired a direct rotation after which the rings forming the inner (direct) satellites were deposited. This explanation seems plausible, but on closer examination it does not measure up with the facts.

The whole question of tides has been discussed by the late Sir George H. Darwin and he has shown that the character and magnitude of tidal influences depends upon the rigidity of the disturbed body and its period of rotation. The effect of tides is to decrease the rate of rotation and thus diminish the amount of moment of momentum. When the Saturnian nebula extended to the orbit of the ninth satellite, let us suppose it was rotating with a period of 29.5 years in the retrograde direction, and hence its moment of momentum was negative. Suppose the effect of tides changed its rotation from the retrograde direction to the direct; therefore its moment of momentum was increased from a negative quantity to a certain positive quantity. As tides decrease rotation, the maximum amount of moment of momentum would be obtained when the period of rotation of the nebula equaled its period of revolution, i. e., when its day and its year were the same. Now the greater the distance is from the center of Saturn when this condition of affairs existed, the greater would be the amount of moment of momentum. To make the case the most favorable for the nebular hypothesis, let us suppose that this distance extended out to the orbit of the ninth satellite. When the Saturnian mass had shrunk down to the orbit of Japetus, the innermost satellite, it was rotating with the period of Japetus and, as the amount of moment of momentum would decrease through the influence of tides, we would expect a smaller amount when the nebula extended to Japetus than when it reached out to the ninth satellite. The numerical computations show just the reverse, as the moment of momentum when the nebula extended to Japetus is found to be more than seven times greater than when it extended to the ninth satellite. Thus even with the additional aid of tide-producing influences, which Laplace did not include in his theory, the retrograde satellites squarely oppose the nebular hypothesis.

But what about Saturn's rings? Are they not living witnesses that rings were deposited? But even Saturn's rings rise up in witness against the Laplacian theory and testify that they had not been formed thus. It has been determined by means of the spectroscope that the outer portion of Saturn's rings rotates in a period of fifteen hours, while the inner portion rotates in six. This seems to accord with the nebular theory as the rotation increases with a diminution of mass. Accordingly we would expect the period of rotation of the planet itself to be less than six hours but the observations show that it rotates in ten hours. This condition of affairs would be impossible if no other force than those assumed in the Laplacian hypothesis were operating.

A story is told of a certain king who was about to make a formal visit to an eastern city. On his arrival at the city gate he was met by the mayor's deputy, who informed him, after due obeisance, "Your Majesty, there are ten reasons why his worship the mayor cannot receive your Majesty into the city to-day. The first one is that the mayor is dead, the second is—" But sufficient reason had been given. Thus other reasons might be given in detail which oppose the nebular hypothesis, but the retrograde satellites themselves are sufficient to disprove the theory. A brief statement concerning some of these facts must suffice.

The inclinations of the planes of the planetary orbits, to each other, to the general plane of the system, and to the plane of the sun's equator are not to be expected if the origin of the solar system is the ring theory. The high eccentricities of the inferior planets cannot be accounted for, since the ring theory requires the orbits of the planets to be more nearly circular the nearer they are to the sun. Just the opposite is the case as the eccentricity of Neptune's orbit is more than twice as great as that of Mercury. The orbits of the planetoids form a complicated system of interwoven loops which cannot be untangled by the Laplacian theory. As in the case of Saturn and its inner ring, one of Mars's satellites, Phobos, revolves about its primary in less than eight hours while the planet itself rotates in about twenty-four hours.

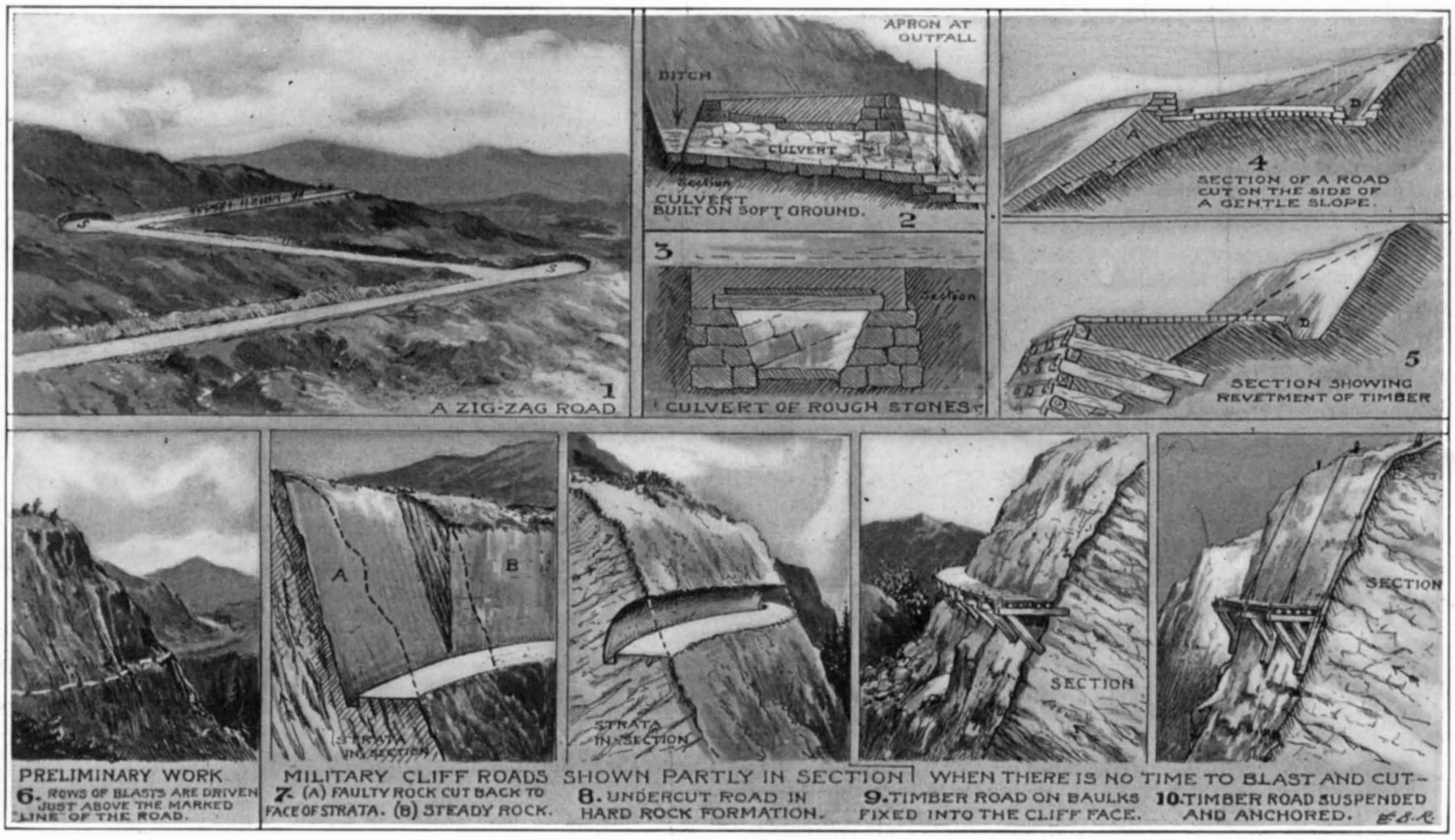
As there is no church which adopts the Laplacian hypothesis as a creed and no Inquisition to enforce adherence to its teaching, our faith and freedom are independent of our attitude toward this hypothesis. It is a purely scientific question and must be considered as such, irrespective of prejudice or tradition. If it agrees with the facts let us retain it, if it contradicts the facts let us reject it and endeavor to find a theory which is consistent with the revelations of modern science, both theoretical and practical. Just as the Ptolemaic theory had to be discarded when subsequent discoveries revealed its fallacy, so recent investigations lead us to reject the nebular hypothesis and seek a new theory. The theory which satisfies all the requirements of celestial mechanics and practical astronomy better than any previous one is the Planetesimal or Spirual Nebula Hypothesis formulated within the last decade by two professors in the University of Chicago, Prof. F. R. Moulton of the Department of Astronomy, and Prof. T. C. Chamberlain of the Department of Geology.

Drying Methods

An industry that is sure to be developed in the near future is drying of agricultural products, such as potatoes and also aqueous industrial residues, such as come from sugar making and from breweries. In France the process is now applied for drying fresh beets, and there are also three beet sugar works which employ it for the drying of the exhausted pulp. In the north of France there is now being worked an industrial process for making "sugar flour" from fresh beet pulp, and a dessiccator is employed here in the shape of a tower into the top of which the pulp is poured, and it comes in contact with warm air; then the pulp is delivered by a rotary device on a set of superposed gratings, where it receives hot air, commencing at a lower temperature and afterward using warmer air up to a temperature of 120 deg. C. Such dried beet pulp produces a flour which has the sweetening property of sugar to a certain extent, and could be used in all cases where the sugar is not required to be pure, such as in breweries, for special breads, for feeding stock, and the like. A ton of beets gives over 500 pounds of flour, which sells here for $2 the hundredweight. Its composition is: Albumens, 6 per cent; saccharose, 66; carbohydrates, 13; cellulose, 5; water, 6; miscellaneous, 4 per cent. Following the success of the present methods, it is thought that other industrial drying processes will be invented which will, for instance, enable stock to be fed on dried potatoes, as these are so difficult to keep in the usual state. Damp grains harvested in bad years can also be dried. Apparatus like this could use waste heat from factories.

[5] References given in Chamberlain's paper, *loc. cit.*, p. 63.
[6] Chamberlain, *loc. cit.*, p. 65.
[7] Chamberlain, *loc. cit.*, p. 69.

[8] These points are called the Lagrangean Equilateral Triangle solutions of the problem of three bodies.
Astrophysical Journal, vol. xi (1900).



From The Illustrated War News.

The Making of Military Roads*

Extensive Work Necessary for the Efficiency of an Army in the Field

As the success of an army in the field largely depends on the efficiency of its transport, the rapid construction of temporary roads within the war-area is frequently a matter of necessity.

To accommodate a single line of wagons traveling in one direction, the width of the roadway must be 8 feet at least, although 10 feet is preferable. A road 12 feet wide will allow horsemen to pass the wagons. Traffic in the opposite direction on a single-line road may be dealt with if "sidings" can be provided into which a returning line of vehicles can be drawn while a convoy bound for the front passes on.

A road 6 feet wide will suffice for infantry to pass along in single file, or for pack animals which are proceeding in one direction only. When steam traction-engines are used, a road-width of 15 feet is usually provided, but in emergency a minimum of 12 feet will answer the purpose. In laying out roads for animal transport steep gradients should be avoided, even though a longer distance round may have to be traversed in order to save the animals from over-fatigue, sore backs, etc. Mules can work on a gradient of 1 in 8, or of 1 in 6, for short distances. Oxen should only have light loads on the former, and should not be expected to work on the latter slope. As a rule, a gradient of 1 in 10 should never be exceeded where it is possible to avoid it. Where camels are used, a gradient of 1 in 13 should be the maximum (Fig. 11).

In laying out a zig-zag road (Fig. 1) up a mountain side care should be taken to construct a level stretch at each angle, in line with the stretch of road immediately below, so that the draught-animals may be able to pull their loads right on to the level portion at the bend. These continuations or "spurs" [(*s*) (*s*), Fig. 1] may with convenience, wherever practicable, be extended far enough to be used as "sidings" in order to accommodate descending traffic while ascending vehicles pass by. The width of the roadway at the bends should be increased by 50 per cent.

Great care is taken to provide for efficient road drainage, particularly in mountainous country, as the action of uncontrolled streams, even where the amount of water running down may be comparatively small, would, in some cases, be absolutely destructive to the best-constructed road. A road constructed on the side of a hill usually has a ditch made at its side (*D*, Figs. 4 and 5) nearest to the upward slope, this ditch discharging into culverts carried under the road itself (Figs. 2 and 3). These culverts are usually built of stone, wherever this material is available, but faggots or brushwood can be used in its stead in places where a temporary road only is required. The lower "lip" of the culvert at its outfall beyond the road should be paved with stone to prevent erosion by the stream, the paving in question being called an "apron" (Fig. 2).

A road may be constructed along the face of an incline (Fig. 4) by excavating a portion of its width and utilizing the excavated material (*A*, Fig. 4) for the building of an embankment to complete the width. This arrangement, however, cannot always be adopted, as the incline may be too steep, in which case the whole width of the roadway must be excavated. When the first-named plan is followed a "revetment" of masonry or timber is sometimes required in order to prevent the embanked portion from giving way and sliding down the hill-side (Fig. 5).

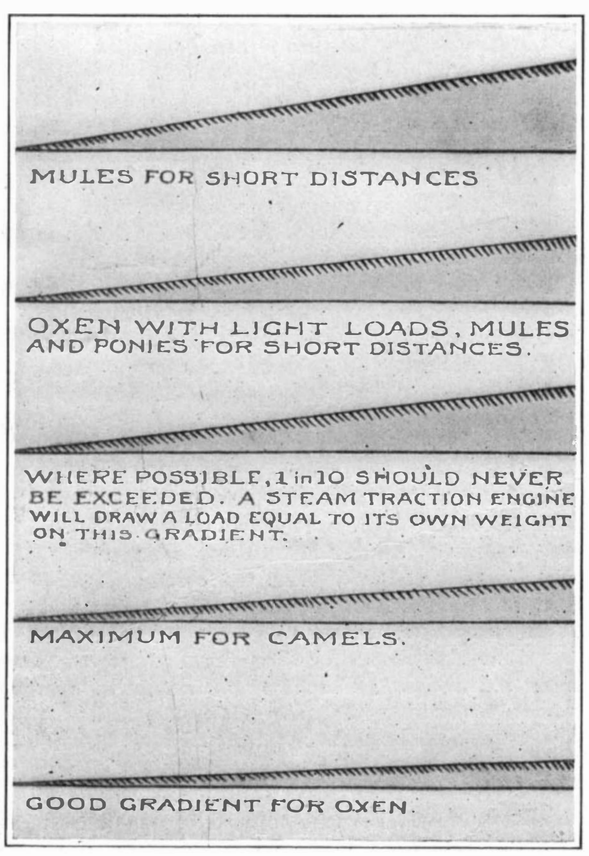


Fig. 11.—Gradients on military roads for various classes of transport.

When cliffs of a hard rock formation have to be negotiated the greatest possible care must be taken in carrying out the work, and it is necessa[illegible] into calculation the direction of the strata.

Should the strata be approximately vertical the whole of the rock above the road must be removed, as it would otherwise break away and come down (Fig. 7). If, on the other hand, the direction of the strata be almost horizontal (as shown in Fig. 8) the road may with safety be under-cut in the cliff face. When the time available will not permit of blasting and cutting in hard rock, a road can be carried along the face of a cliff on a number of timber brackets, which are either driven into the cliff face (Fig. 9) or are suspended from wire ropes attached to stakes driven into the cliff above (Fig. 10). A corduroy road, such as is laid along the bottom of the trenches in many places in Flanders, consists of a top layer of transverse tree-trunks or timbers set on the best foundation available and spiked together.

*From the *Illustrated War News.*

Collecting Minute Plankton

It appears to be of comparatively recent observation that certain varieties of plankton are so small as to escape observation entirely, unless special methods are used to extract them from the water. Usually the separation is carried out by employing fine gage filters, but these will not retain the very minute specimens we refer to, hence recent workers are making use of a centrifugal separator for plankton, which is electrically or hand operated. In this way a large amount can be had without needing to treat any great quantity of water, and such operation requires ten minutes or more. But when it comes to quantitative research, special precaution must be taken to treat the water as soon as possible, for some kinds of plankton are found to die very quickly, and even more, they leave no trace behind them as they dissolve in the water. Again, there must not be too great a difference of temperature between the water and the surrounding air. The centrifugal method gives surprising results as compared with the filter gage, for where the latter shows but a few the former gives innumerable specimens. Again, the very minute specimens escape entirely through the usual filter, and are only revealed by the centrifugal process.

Infusorial Earth for England.—Infusorial earth, or diatomite, also known as kieselguhr, is largely used for making dynamite. Before the war England drew most of her supplies of this material from Germany, but now has been compelled to seek other supplies, and samples from Australia and Tasmania have been examined with the result that a very satisfactory quality [illegible]cur deposits, near Ballarat in Victoria.

Throwing Liquid Fire

One of the Novel Weapons Brought Fourth by the War

Among the many scientific tools of destruction employed in the war, the so-called "Flammenwerfer" of the Germans—a more or less hose-like apparatus for hurling jets of flaming liquid—holds an important place, as much by virtue of the moral effect produced as by any material damage achieved, even though the latter may be considerable. Contrary to the generally accepted notion, this idea of projecting upon the adverse trenches and their occupants a rain of liquid fire was no sudden afterthought of the German mind. It was conceived, studied and perfected for several years before the war, and its history may be traced in the German patent office.

In the earliest models, the combustible liquid was propelled by a gas condenser out of a portable or fixed reservoir, and was lighted by some automatic device as it escaped from the nozzle of the projecting instrument. Subsequent improvements have been made with the sole object of overcoming certain disadvantages inherent in this model.

With the instrument described, the flaming jet can make its effects felt at a distance of forty or forty-five yards, but is not capable of exceeding that range effectively, because of the consumption of the liquid in transit. Further, with the main jet thus in ignition at the mouth of the apparatus, enough heat is given off to embarrass seriously the operator.

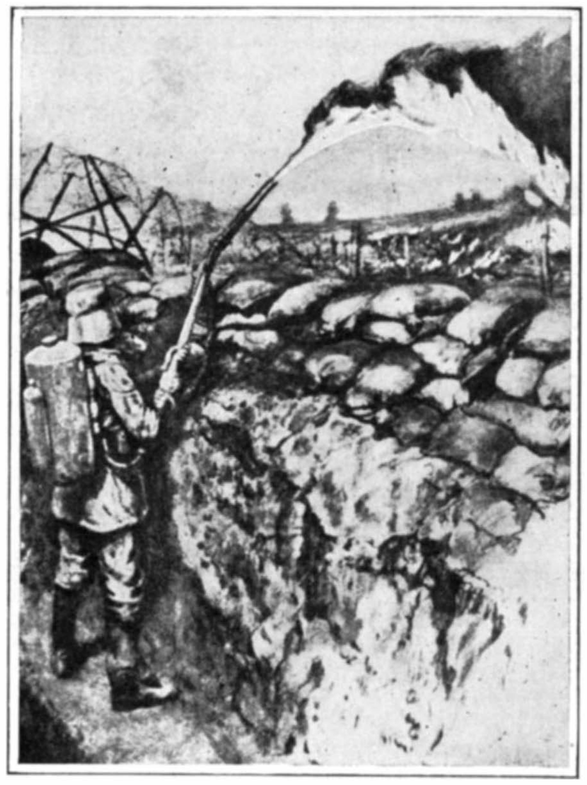
These facts made clear the desirability of a method of ignition whereby the inflammable fluid would not begin to burn until it had almost or quite reached its objective. Not only would useless consumption of the fuel be thus avoided, but the effective range would be increased, and the effects of the instrument, at a given range, greatly heightened.

To meet these demands, a double barreled liquid gun was devised, having the upper barrel much smaller than the lower, and pivoted so as to turn independently. (Fig. 1.) The fluid is shot from the two barrels simultaneously, but only that from the upper one ignites automatically. This small burning stream is so directed that it unites with the larger, non-burning one at any desired point, and then, of course, ignites the large jet. The small stream is then shut off, the large one continuing to flow. The flames do not spread backward along the jet toward the nozzle, but are carried forward to the target, and, striking the ground, form a veritable sheet of fire which continues to ignite the fluid as fast and as long as it falls.

Only at this one point is the large jet in contact with the flame. All combustion, therefore, takes place at the spot where it will do the most good—or harm—and at that point a very severe conflagration takes place, much more severe than is possible when the combustible fluid wastes its substance upon the air between gun and target. It is especially to be noted that flexibility of fire is not sacrificed. By gradual change in the trajectory, the objective can be shifted without interrupting the continuity of the ignition; so that the field may be developed in any direction desired, and a rain of fire of any sort whatever produced. Further, instead of allowing the liquid to burst into flame at the moment of impact, it is often advantageous to let it flow for some time "cold," until the entire objective region is saturated, then turning on the kindling jet, to produce a holocaust throughout that region.

The method of expulsion of the jet from the apparatus, as well as means of combustion, has been greatly improved. As indicated above, in the earliest Flammenwerfers devised by the Germans, the inflammable liquid was driven from its reservoir by pressure of carbonic acid or other gas. But, on account of the extraordinary powers of absorption manifested toward all gases by the hydrocarbons best adapted for use as the basis of liquid fire, the best part of the expulsive gases was merely dissolved in the liquid. Not only did this cause a direct and serious diminution in pressure, but it led to mixing of liquid and gas; so that as the fluid issued from the nozzle it no longer exhibited the uniform and compact structure necessary for accurate aiming and efficient combustion, but was composed of a frothy, bubbling mixture of liquid and gas, which, putting forth but feeble opposition to the atmosphere resistance, had its range materially shortened. All these difficulties are obviated by the substitution of a mechanical pump, or, if safety or convenience demand that the reservoir shall be at a considerable distance from the firing line, several pumps in series as motive power in the expulsion of the liuid from the gun.

The liquids most commonly employed in these Flammenwerfers are the low coal-tar oils resulting from the distillation of tar at a pressure of six atmospheres or more. The particular compound most used by the Germans is a mixture of gasoline and pitch. Under combustion this gives off a thick grayish smoke, which not merely obscures the vision of those under fire, but has an intolerable odor.



Operating a flame projector in a German trench.

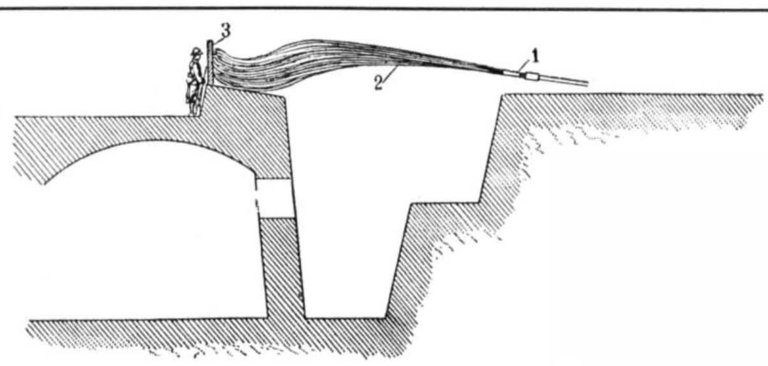


Fig. 1.—Early type of Flammenwerfer. Flame deflected by a shield.

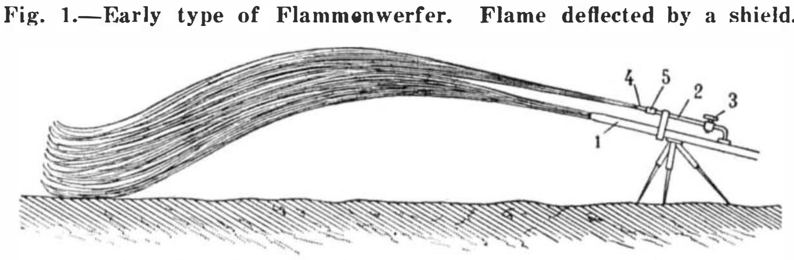


Fig. 2.—Improved type with attached ignition jet.

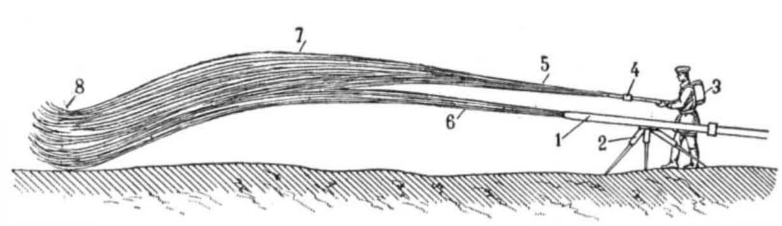


Fig. 3.—Improved apparatus with separate ignition jet.

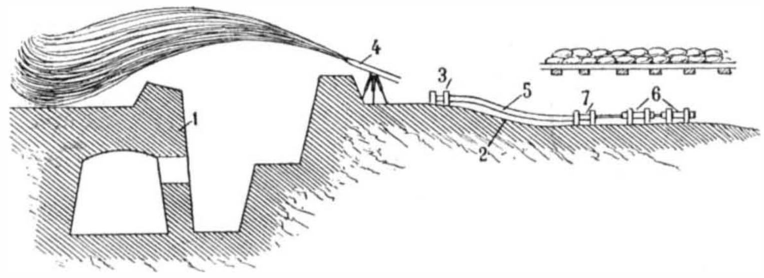


Fig. 4.—How the device is fed from a protected reservoir.

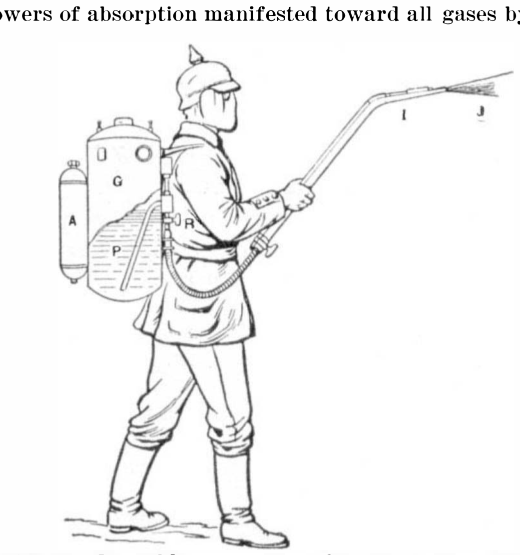


Fig. 5.—Portable apparatus for projecting flames. *A*, carbonic acid; *G*, gas; *P*, gasoline; *R*, valve; *I*, igniter for lighting the inflammable liquid; *J*, the flame.

Electrolytic Iron

Referring to our former remarks about electrolytic iron, it appears that this subject is receiving a considerable development in Europe. We would refer especially to a patented process which is being applied on an industrial scale in France, and it is claimed with great success. The product is of a good quality and rivals Swedish iron. Starting with any kind of cast iron, the new process yields an electrolytic iron of great purity, as is shown by analysis. Iron tubes are now made on an industrial scale at this works, such tubes having usually 12 feet length, from 4 to 8 inches diameter and ¼ inch thick. Industrial uses of this quality of iron may be classed as: 1. Tubes. 2. Sheet. 3. Pure iron for use in melting process. The new tubes show a great advantage in having a uniform thickness for all diameters and lengths, and will stand heavy pressures. The sheet iron can now be had by direct process and without rolling in mills, thus obtaining very regular sheet in first quality iron. Such metal can support a great amount of working when cold, and hence is employed with good results for stamping processes, using annealed or tinned iron plate. As we already mentioned, one of the great future uses for electrolytic iron is in the construction of industrial electric apparatus on account of its high magnetic permeability and small loss due to heating of the iron. Remarkable results are already found in transformers, and these now have but little over half the usual size. Electric motors have their power increased 50 per cent for equal size and temperature as concerns the alternating current types, because of the diminished heat loss in the iron and the increased magnetic permeability. In the third class which we mentioned, iron for use in melting processes can now compete with Swedish makes for this purpose, and its quality is said to be more regular. It is excellent for the cementation process, and for tool steel and special steels it occupies the front rank.—*From Larousse Mensuel.*

The Purification of Water Supplies*

Various Systems Adopted and Some of the Results Obtained

By Edwin O. Jordan, Ph.D., Prof. of Bacteriology, University of Chicago

CLARIFICATION of a muddy water, the removal of an excess of iron, the softening of a hard water are all ends desirable in themselves, but they are not purification in the sense in which that term is here considered. Removal of turbidity may be economically and esthetically important; installation of a municipal water-softening plant may be demanded by considerations of convenience and economy, but softening and clarification of water are never matters primarily concerning public health. If a community desires and can afford to pay for a clear or a soft water, it can get it.

Most citizens would agree in principle, if not in practice, that the sanitary purity or direct relation of a water supply to health is by far its most important feature. Consideration of purification of water is therefore here restricted to the methods of rendering a contaminated or potentially dangerous supply safe for use.

The present necessity for water purification in civilized countries is a consequence of two factors; first, the greatly increased demand for water under modern conditions of life; second, the increasing density of population on most parts of the earth's surface. It is becoming more and more difficult to draw for a water supply of any size on a body of surface water that is uncontaminated or at all events not liable to occasional or accidental pollution; as is well known, infectious material discharged by a single human being is sufficient to poison many gallons of water and to cause hundreds of cases of disease. It is difficult also to obtain the volume of water sufficient for a large and rapidly growing community. Many of the smaller towns and villages in the United States rely on deep wells as a source of supply, and from a sanitary point of view such waters are usually excellent. In many regions, however, the amount of available underground water is limited, and if a large amount of water is required by a municipality, surface waters more or less exposed to pollution must be taken. Where surface waters are resorted to, the need for purifying them is so plain in some cases that there can be no question of its imperativeness, as with the Merrimac River, used by the city of Lawrence, Mass., the Hudson River, used by the city of Albany, and the Schuylkill River, drawn on by Philadelphia. In these cities, simple inspection of water sources is sufficient to show that the river water used as the source of supply is contaminated with fresh sewage, and in an untreated condition is grossly unfit for drinking purposes. Water purification in these cities has been followed by a marked diminution in the amount of certain diseases.

On the other hand, the need for purification of a surface water supply is not always so obviously urgent to the untrained judgment, and detailed observation of disease prevalence and of the bacterial character of a water is necessary before general agreement on the desirability of purification is reached. This has been the water supply history of some cities on the Great Lakes. The city of Cleveland hesitated for several years before undertaking the construction of a filter. Detroit and Buffalo have been rather recently convinced of the desirability of protecting their water supplies by chlorination.

Still other large cities are so fortunately situated in respect to surface water supplies that artificial purification for the time being is not considered necessary. These are practically all in localities where the watershed levied on is owned or controlled by the municipality, and where long storage of impounded waters in natural or artificial reservoirs can be trusted to effect a natural purification. New York and Boston are well-known examples of cities depending on protected and stored surface water.

Public water supplies, although not uncommon in the early history of southern Europe, were practically unknown in northern Europe in the middle ages, and the large modern water supply systems have been developed for the most part in the last seventy years. Storage of water was undoubtedly practiced in antiquity, but was not consciously resorted to as a means of purification, and the first deliberate attempt at purification of water on a large scale seems to have been less than 100 years ago, when, in 1829, a slow sand filter was built by one of the London water companies. Even in this instance the immediate end in view was clarification of a muddy water, and it was not until the connection between drinking water and disease became manifest about twenty years later that the filtration of the whole London water supply was more definitely undertaken as a hygienic measure. Purification of public water supplies became general in England and on the continent of Europe two or three decades earlier than in this country, owing, perhaps, to the greater density of population in many regions and to the glaring evidences of pollution in many streams serving as water sources. European cities that delayed or boggled water purification often suffered severely from water-borne diseases, as did the wealthy German city of Hamburg in the cholera epidemic of 1892-1893.

In the United States as in Europe, development of public water works has taken place almost wholly since 1850, and the introduction of methods of purification is yet more recent. A beginning in water purification had been made at Poughkeepsie, N. Y., and elsewhere before 1890, but progress has been much more rapid since that date, owing in large part to the impetus given to the study of water purification by the investigations of the state board of health of Massachusetts. These investigations, begun in 1887, were soon followed by the construction of a modern sand filter plant at Lawrence, Mass. (1893), and the striking success of this filter in reducing typhoid fever served as an object lesson to the whole country.

It was calculated by Hazen that in 1900, 6.3 per cent of the urban population of the country (towns of over 2,500 population) were supplied with filtered water, while in 1911, according to G. A. Johnson, this proportion had risen to over 20 per cent. Table 1, which I have compiled from the information given in the McGraw Waterworks Directory, and from other sources of information, shows the present condition in the larger cities of the United States.

TABLE 1.—CHARACTER OF WATER SUPPLIES IN CITIES OF THE UNITED STATES WITH OVER 10,000 POPULATION IN 1915

Water Supplies	Treated		Untreated		Unknown	
	No. of Cities	Population	No. of Cities	Population	No. of Cities	Population
Wells and springs........	28	2,491,810	76	2,215,163	63	1,765,559
Rivers and streams........	141	10,769,547	22	1,053,418	25	603,423
Impounding reservoirs.........	30	1,992,035	19	5,269,524	19	842,526
Lakes...........	38	5,493,206	25	1,886,312	16	464,690
Wells and rivers..........	15	571,566	5	92,301	7	452,812
Source not known.........	......	....	......	....	32	516,273
Totals...........	252	21,318,164	147	10,516,718	162	4,645,283

It will be noted that while over 60 per cent of the total city population of the United States is at present supplied with water treated by some method of purification, the actual proportion of the population supplied with hygienically safe water is far greater. The water from deep wells and from storage reservoirs is unquestionably in large part of excellent quality even if not subjected to artificial purification. It is fair to assume that 30,000,000 out of the 36,500,000 people living in cities with over 10,000 population are now provided with water initially pure or more or less effectively purified. Taking into consideration smaller towns and villages, it seems likely that at least 50 per cent of the total population of the United States is to-day supplied with water of a high degree of purity.

Hazen estimated that in 1904 water of a more or less unsatisfactory quality was supplied to approximately 52 per cent of the urban population of the United States in cities of more than 25,000 inhabitants; at present, 1915, this statement, as far as sanitary quality is concerned, would hardly hold true for more than 20 per cent.

MODERN METHODS OF PURIFICATION.

(*a*) *Storage.*—A high degree of natural purification of water can be effected by storage. When the water of small streams is impounded in a reservoir instead of being pumped directly into water mains, important changes occur. Suspended matter in part sinks to the bottom and the water becomes clearer, the color of the water is usually lessened owing to bleaching by the sunlight, and the total number of bacteria in the water is materially diminished. Most important of all, any disease-producing bacteria that may have found their way into the tributary streams tend to perish during the sojourn of the water in the reservoir. A cardinal factor in bringing about the death of pathogenic bacteria in water is time. So far as is known, disease germs introduced into water never multiply under natural conditions, but progressively and rather rapidly die off. The longer a water can be stored, therefore, either in an artificial reservoir or in a natural lake or pond with protected shores, the less liable it is to harbor disease germs. This principle of storage, based on the high mortality of typhoid bacilli and allied bacteria suspended in water, is being utilized in the treatment of many large surface water supplies apparently with high success. New York and Boston, as already mentioned, are relying mainly on this method to insure the purity of their supplies. The safety of the London supply is thought to depend very largely on storage. Adequate storage is often all that is needed. In cities where other methods of purification are employed, preliminary storage is highly advantageous since it reduces the burden on filters, and in other ways facilitates the application of special purifying treatment.

(*b*) *Slow Sand Filters.*—The use of beds of sand carefully superimposed on gravel in water-tight basins was probably the first method employed for water purification (London, 1829) on a large scale. The water is passed continuously on the sand, and flows through by gravity. The earlier European filtration plants were all of this type. In this country slow sand filters have been installed at Albany, N. Y., Pittsburgh, Washington, D. C., Philadelphia, and other cities. Through such filters water may be commonly passed at a rate of 3,000,000 gallons daily per acre of filtering surface, and if the water treated is not very turbid or badly polluted, a rate of 6,000,000 gallons or more daily may be permissible. It is important that the speed at which the water passes through the sand shall not vary suddenly or in different parts of the filter, and ingenious devices for regulating the flow are in use in order to maintain a uniform rate of filtration. Disturbance of the filtering surface by ice also impairs the efficiency of the operation, and in some instances has been followed by outbreaks of disease.

One of the principal elements of expense in the operation of slow sand filters is the necessity for removing and eventually cleaning and replacing the thin upper layer of sand which becomes clogged in operation. The frequency with which the sand surface must be scraped and renewed depends largely on the amount of suspended matter in the water treated and on the rate of operation. The use of ample preliminary settling basins or storage reservoirs will lessen the operating cost, as well as introduce an element of safety. Taking into consideration the interest on the capital invested in construction and other proper capital charges, together with the cost of maintenance, the average cost of purifying water by slow sand filters is about $8 per million gallons under present conditions in this country. On the basis of a daily per capita water consumption of 124 gallons, this involves an annual cost of about 36 cents per capita.

(*c*) *Rapid Sand Filtration.*—Slow sand filters are not adapted for use in many parts of the United States because the amount and fineness of the suspended matter in many American rivers leads to premature clogging of the sand and a total obstruction of operation. A somewhat different type of filter known as the mechanical or rapid filter has proved to have marked advantages in dealing with very muddy water, such as is found in the Ohio and Mississippi rivers. If a turbid water is first treated with some coagulating chemical, such as aluminium sulphate or iron sulphate, it can be passed through sand at a much higher rate than is possible with the untreated water. The development of rapid filtration with the use of a coagulant has been largely a matter of American invention, and in its beginning depended to a great extent on the use of patented processes and mechanical devices protected by patent. The expiration of some of these patents has opened the road for a wider application of this method, and has been followed by important developments. Experiments at Louisville and Cincinnati have established the applicability of the coagulating process to large volumes of water, and at present rapid sand filters are in operation at Cincinnati, Minneapolis, St. Louis and many smaller cities. Suitable automatic devices for controlling the application of the coagulating chemical are indispensable, since any material excess or deficiency of the coagulant is fatal to successful or economical operation. Many of the earlier installations of rapid filters by private firms were not properly supervised, and in some cases the original plant was improperly constructed or allowed to deteriorate so that the whole process for a time fell into a measure of disrepute.

*Read before the Pan-American Scientific Congress, Washington, D. C.

The cost of construction of rapid sand filters is much less than that of slow sand filters, but the cost of operation is greater. Reckoning all charges, the total cost per million gallons of water purified averages distinctly less (about $6 per million gallons) by the rapid than by the slow process.

(*d*) *Germicidal Treatment.*—Although in the course of years a great variety of chemical substances have been proposed for the disinfection or partial sterilization of water supplies, only a few of these have won any extended practical application. The use of *ozone* for water sterilization possesses certain theoretical advantages. Several small plants using ozone have been operated in European countries, but in practice the relatively high expense of generating the ozone and bringing it into intimate contact with the water to be treated has so far proved an obstacle to the utilization of this mode of treatment for large supplies. It is possible that the availability of cheap electric power for generating ozone, combined with other favorable factors, may, under some conditions, render ozonization desirable. The development of cheaper germicidal processes, however, has checked, perhaps permanently, the general introduction of ozonization.

The objection of high cost obtains also with respect to the use of *ultra-violet rays*. These rays, which are conveniently generated by specially constructed lamps, have a high germicidal power, and quickly destroy bacteria in clear water. Experimentally ultra-violet sterilization has very desirable qualities, but thus far, owing to the expense of operation and to the necessity for a preliminary clarification of very turbid waters, it has not been used in this country for large scale installations.

The use of *calcium hypochlorite* ("chloride of lime," or "bleaching powder") has for some years past quite overshadowed other methods of germicidal treatment. Variations in the character of the water and in the composition of the commercial bleaching powder affect the amount that it is necessary to add to secure germicidal efficiency, but in general the quantity of the powder used ranges from about 5 to 15 pounds for each million gallons of water treated. The cost of bleaching powder under normal conditions has been less than 2 cents a pound. Since the opening of the war, the cost has been greatly increased. Including the expense of application, hypochlorite treatment costs not more than one tenth as much as filtration. The action of the hypochlorite is similar to that of ozone, and depends on the strongly oxidizing powers of the hypochlorous acid that is formed when the bleaching powder is added to water. The advantages of the hypochlorite treatment are the cheapness, harmlessness, ease and speed with which it may be employed. The chief objection is the liability to the production of disagreeable tastes or odors which its use entails. Chlorin gas itself has a distinctly unpleasant odor even in small quantities, and the action of the hypochlorite on certain organic matters present in water also generates disagreeable tastes and smells. Complaints on this score in communities in which hypochlorite treatment of the water is practiced are especially common in cold weather. Waters differ in respect to their tendency to develop objectionable odors, and in practical operation some waters are very troublesome. An important improvement in the field of water disinfection has been the substitution of liquefied chlorin gas ("liquid chlorin") for calcium hypochlorite. The gas, which is generated by the electrolysis of brine, is dried, cooled and compressed, and is then marketed in liquid form in portable cylinders under pressure. The advantages claimed for the use of the gas include superior economy and simplicity in regulation. Liability to cause unpleasant odors is said to be much less by this mode of treatment. Overdosing, however, may occur both with liquid chlorin and bleaching powder.

RESULTS OF WATER PURIFICATION.

When a polluted water that serves as a source of municipal supply is treated by slow sand filtration, the most conspicuous immediate change in the health of the community is a drop in the typhoid death rate. This has been demonstrated repeatedly in European cities, as in Hamburg, for example, and in many American cities. In Lawrence, Albany, Pittsburgh and Philadelphia, slow sand filtration of a highly polluted river water has been followed by a reduction in the reported typhoid mortality to one third or even one fourth of that formerly prevailing. A decrease in water-caused infant mortality has also been noted;[1] it is yet unknown to what extent the connection between infant mortality and sewage-polluted water supplies is due to infection with the typhoid bacillus. In some instances, though not in all, the so-called Mills-Reincke phenomenon has been observed, namely, a decline in the general death rate minus the typhoid components, and in the reported deaths from certain other diseases such as tuberculosis and pneumonia, not commonly regarded as water-borne.[2]

[1]McLaughlin: *Pub. Health Rep.*, 1912, No. 77.

There is no doubt that some deaths from typhoid infection both in infants and adults have been and still are reported under some other designation. I have elsewhere[3] called attention to the decrease in reported deaths from "malaria" in Albany, N. Y., following the installation of a sand filter. It is unquestionably true that in other cities some of the deaths in the past reported as due to "malaria" or "typhomalaria" should have been properly classed with those from typhoid fever. Mistaken diagnosis may explain to some degree such decline in general death rates as cannot be referred directly to the diminution in deaths specifically attributed to typhoid fever. Thus in St. Louis (Table 2) a correspondence can be noted in some years between the number of reported deaths from typhoid fever and the reported deaths from "malarial fever." In more northern cities, in which, for various reasons, the diagnosis of death from "malaria" is less likely to be made, the same correspondence can yet be noticed under certain conditions (Table 3). There seems no escape from the conclusion that at least some—probably a large proportion—of the deaths recorded as due to "malarial fever" in these cities were in reality caused by typhoid infection.

TABLE 2.—DEATHS REPORTED IN ST. LOUIS

Year	Typhoid Fever	Malarial Fever
1890	140	226
1891	165	216
1892	441	326
1893	215	284
1894	171	179

TABLE 3.—DEATHS REPORTED IN CHICAGO, 1891

Month	Typhoid Fever	Malaria
January	67	7
February	61	9
March	71	16
April	136	18
May	408	22
June	167	7

It has further been shown by Dublin,[4] from a study of insurance records, that the normal expected mortality is doubled among typhoid convalescents during the first two years after their recovery from the disease. In his statistics, tuberculosis, diseases of the heart and kidneys, and pneumonia were prominent among the causes of death in a limited number of typhoid patients subsequent to recovery. If this conclusion proves generally valid, there must always be expected some lessening of the general mortality in addition to that due to the typhoid component, and perhaps in some cases a measurable diminution in the death rate from tuberculosis and other diseases accompanying a decrease in typhoid fever due to water purification. In a word certain individuals appear to be so affected by the typhoid infection that although surviving for a time, they die within two years from tuberculosis or cardiac lesions. To what extent the Mills-Reincke phenomenon and Hazen's theorem are explicable on this basis is matter for further investigation to determine.

Granting that many deaths from typhoid fever and its sequelae are prevented by slow sand filtration, the question may be raised as to what degree of safety is attained by this method, whether absolute or limited. The necessity of care in operation is well known. Bacterial and other observations clearly show that dangerous bacteria may pass through the sand, if there is any "accident" to the filter or any "disturbance" of its normal action. The epidemics of cholera at Altona, Germany, and typhoid fever at Lawrence, Mass., illustrate the way in which the formation of ice can interfere with the safe operation of a filter.

While the harm from such unusual interruption of normal filter action is sufficiently demonstrated, it is not so easy to measure the degree of danger existing under more ordinary conditions. Reliance on bacterial averages of effluents may be misplaced, since a low average may be reached even if occasional breaks occur in a long series of low numbers. Should typhoid bacilli pass through a filter during one hour in twenty-four or for one day in the year, absolute protection is plainly not afforded. While the data for a final judgment on this point do not exist, it must be admitted that there is some evidence that the attempts to treat a highly polluted raw water place at times too great a burden on the filter. Intestinal bacteria of the *Bacillus coli* type may appear in the effluent in such cases in numbers thought by some observers to indicate danger.[5]

Among the recent attempts to establish standards for safe drinking water may be noted the report of the commission appointed by the U. S. Treasury Department to consider standards for water supplied to the public by common carriers engaged in interstate commerce.[6] The commission reported as follows: "1. The total number of bacteria developing on standard agar plates incubated twenty-four hours at 37 centimeters shall not exceed 100 per cubic centimeter. . . . 2. Not more than one out of five 10 cubic centimeter portions of any sample examined shall show the presence of organisms of the *B. coli* group. . . ." A study of the records of filtration plants shows that in some instances the application of such a standard would lead at times to the condemnation of filter effluents. It has been suggested that the standard proposed is too severe for general municipal water supplies,[7] and perhaps this is a just criticism; but in any case it is clear that the margin of safety in some filtration plants is not very great.

[2]Sedgwick and MacNutt: *Jour. Infect. Dis.*, 1910, vii, 489.
[3]Jordan, E. O.: *Tr. Am. Soc. Civil Engineers*, Inter. Eng. Congress, 1905, liv, D, p. 206.
[4]Dublin: *Am. Jour. Pub. Health*, 1915, N. S., v, 20.
[5]McLaughlin: *Pub. Health Rep.*, Jan. 26, 1914.

The results of rapid or mechanical filtration are essentially similar to those of slow sand filtration. The percentage of bacterial removal reaches practically the same height as in the slow sand filter, and a marked decline in typhoid fever has been observed in many cities following the introduction of rapid filters. In Cincinnati, Columbus, Ohio, Paterson, N. J., and other cities, the typhoid death rate has sunk to low figures after rapid filters were installed. The necessity for careful and unremitting supervision of operation is quite as great in the case of rapid filters as with those of the slow sand type. The safety of the mechanical filter effluent is no more certain or absolute than that of slow sand filters.

Excellent results as regards bacterial efficiency and security from typhoid infection are achieved by bleaching powder and by liquid chlorin treatment. The chief difficulty experienced in this mode of water purification lies in the close approximation for many waters of the limit of germicidal efficiency and the limit of inoffensiveness. If unpleasant odors are produced by the chemical, the maintenance of an adequate bactericidal strength often proves difficult in the face of complaints from hundreds of water consumers. The city of Cleveland is thought to have suffered excessively from typhoid in 1913 in consequence of a decrease in the dosage of hypochlorite.[8] Temporary cessation of the hypochlorite, or reduction to an amount inadequately germicidal, may sometimes be followed by a definite typhoid epidemic, as in the outbreak which I investigated at Quincy, Ill., in 1913.[9]

TABLE 4.—DEATHS FROM TYPHOID PER HUNDRED THOUSAND POPULATION, MILWAUKEE, WIS.

Year	Death Rate	Remarks
1906-1910 (average)	27	
1911	19	Hypochlorite used intermittently
1912	25	Hypochlorite used continuously after September, 1912
1913	11	Hypochlorite used continuously after September, 1912
1914	8	Hypochlorite used continuously after September, 1912
1915	5†	Liquid chlorin treatment begun March 31, 1915

A remarkable reduction of typhoid has been observed in some cases to accompany the hypochlorite treatment. The experience of Milwaukee is in point.

Other similar instances are on record in which a marked typhoid decrease has been chiefly attributable to chlorin treatment of the public water supply. In such cases it is interesting to note that although clarification is not effected by the chlorin treatment, the sanitary success seems at least as great as when filtration is practiced.

TABLE 5.—METHODS OF WATER PURIFICATION IN CITIES OF THE UNITED STATES WITH OVER 10,000 POPULATION

	Number of Cities	Population
Slow sand filtration:		
With chlorin	13	2,886,233
Without chlorin	19	1,073,290
Rapid sand filtration:		
With chlorin	105	7,343,987
Without chlorin	46	3,835,980
Chlorin treatment alone	57	5,793,419

One noteworthy development of the chlorin treatment (hypochlorite or liquid chlorin) has been its application either to the raw water or to the effluents of slow sand and rapid filters. Hypochlorite dosage of the water applied to filters or of the filter effluents has, in fact, become an almost universal procedure (Table 5). It does not yet appear that this practice is accompanied by any measurable decline in typhoid fever in cities previously served by a modern well-operated filter.

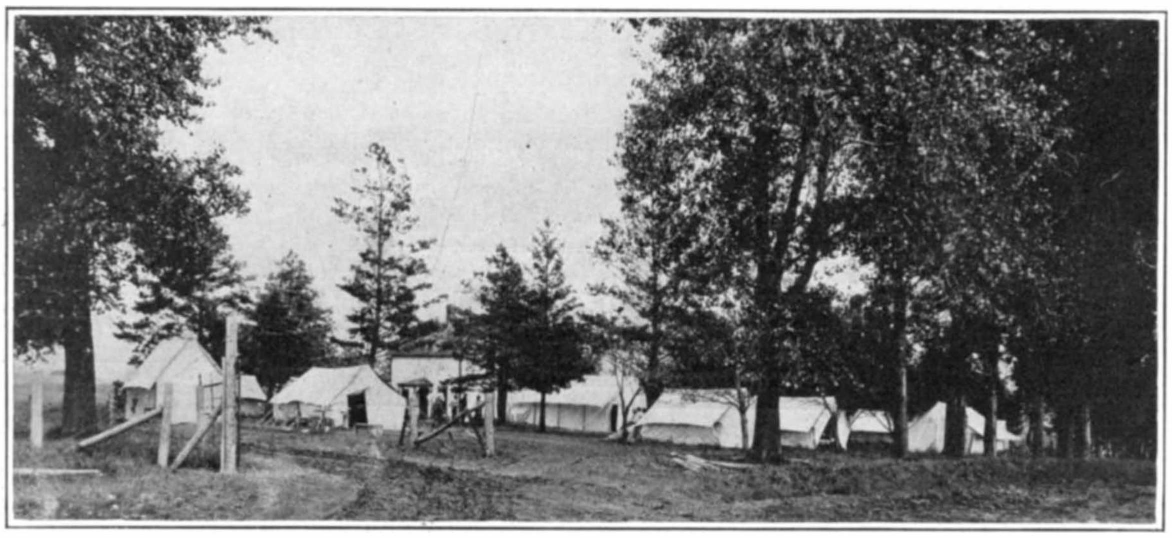
[6]Bacteriological Standard for Drinking Water, Reprint 232, *U. S. Pub. Health Rep.*, 1914.
[7]Fuller: *Jour. Franklin Institute*, July, 1915, p. 42.
[8]Collins and Perkins: *Cleveland Med. Jour.*, 1914, xiii, 786.
[9]Jordan, E. O.: *Jour. Infect. Dis.*, 1913, xiii, 16.

Making Roads and Men

Modern Methods That Are a Double Benefit to the Public

By O. R. Geyer

WHILE the use of convict labor in road building work has become a settled institution in a few of the Western States, the greatest success of the system is found in the development of the men rather than their accomplishments as road builders. This does not mean that convict labor is not a success in this new departure, however, as some of the best roads to be found in Iowa and Colorado, the leaders in the use of prisoners as road workers, have been built by men taken from the prisons. Not only are these two States securing good highways, but hundreds of men cast out by society are being started back into the world with a measure of their former self respect and confidence. As a humanitarian move, the use of prisoners in building roads is one of the most advanced steps taken in many years, in the opinion of leading experts. "We are building men and roads," one warden has said in describing the results of the new system.



A camp of 52 convict road-builders near Cherokee, Iowa.

Iowa employed one hundred prisoners as road builders last season, and got some very good results, though the work done by the two prison camps of fifty men each was but a drop in the bucket compared to the State's need in the good roads line. Because of the rate at which the State charged up for prison labor, convict labor was found to be more expensive than ordinary day labor. It was established that the State cannot expect the best results when convicts are put to work at drudgery jobs, as not even driving will keep them from soldiering and getting grouchy. When the men were employed in building concrete roads or other work in which there was some interest they were cheerful and worked hard, but shoveling dirt ten hours a day is not a task at which the best results can be secured from convict labor. Day laborers are more satisfactory at work of this kind, as they know they will not get paid unless they deliver a day's work.

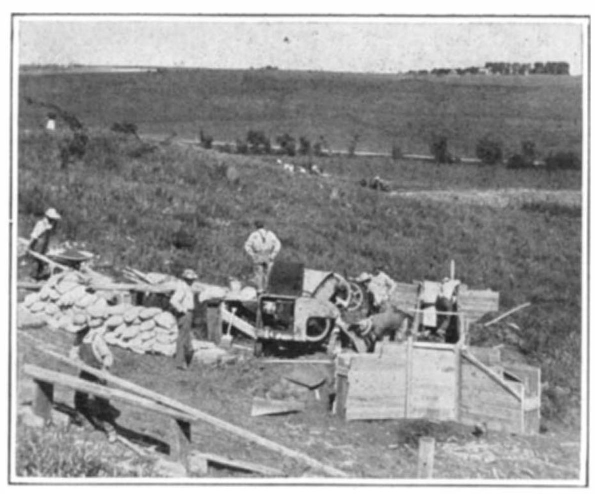
However, the State of Iowa proposes to continue the use of prison road camps this season, chiefly as a means of getting the men out into the open, building them up and making better men of them before they return to the world. This transition stage is a highly profitable work for the State, and a veritable godsend for the men themselves. Good honest tan replaces the prison pallor and their reliance upon themselves and self-confidence is restored in a great measure. As remakers of society's outcasts the State road camps are an unqualified success.

The experience in Iowa has not been repeated in Colorado, as that State has found convict built roads a highly paying proposition for the State as well as the men. In fact, Colorado has been the leader in the development of prison labor for road building purposes. One thousand miles of permanent roads, the equal of any to be found in Europe, have been built by men from the State prison in the last few years. An equally important accomplishment of the system in Colorado has been the fact that 62 per cent of the men who entered the State road camps were redeemed before their terms of service were ended, according to Warden Thomas J. Tynan of the Colorado penitentiary at Cañon City. Warden Tynan has been working his honor men on the public roads of the State for the last seven years.

The waste of convict labor in the United States is one of the country's biggest problems, Tynan believes. In his opinion there are enough men in the prisons of the country to build $200,000 worth of permanent roads each day of the working season. The early abandonment of the contract labor system in those prisons which still retain the plan and the adoption of a system similar to the Colorado plan is assured, according to Warden Tynan.

Colorado has had from 300 to 400 prisoners at work on her roads each year. The men rarely attempt to escape, the number who break their pledge being less than two per cent of the total number employed in the road camps. Most of these men become honest, efficient workers, and leave the prison at the expiration of their time capable of earning an honest living. Many of the men become experts in various phases of road building work, and do better work than the ordinary day laborer, in the opinion of the Colorado warden. Then, too, Colorado has found that the men take more pride in doing good work, as they are not working for money so much as for shortened prison terms.

The prisoners welcome the opportunity to become members of the road gangs. The man who enters the prison with an indeterminate sentence of from five to ten years hanging over him knows that by hard, honest work he can shorten his term of service to two and one half years, and most of them do. They are relieved of the prison restraints and are given an opportunity to put their minds to constructive work, as Colorado's mountains provide many problems for the road builders. There are no armed guards hidden about the camp to instill terror and the men are allowed to range over a wide area and, in many cases, work without direct supervision. Escapes from the camps are few in number despite the opportunities offered, as the men realize that recapture will mean that they must serve their maximum sentences.



The Cherokee culvert gang.

Road projects have been carried on in sixty-two Colorado counties, through the impetus given the good roads cause by the prison workers. The gangs are scattered over six counties at a time, and as rapidly as the highway commissioner lays out the projects the men are put to work. The State and counties divide the cost equally, while the men do the work.

Road-making by convicts, near Ames, Iowa.

The Colorado idea has won such favor that other States are planning to inaugurate prison road camps this year. Kansas proposes to begin work of this sort with a gang of 100 men the first year and will gradually increase the number of men as experience justifies it.

As Iowa had second place among the States using prison laborers for road work, the experiment in that State was watched with no little interest. Two camps of fifty men each were maintained near State institutions. The Iowa men are allowed five cents an hour for their work. The camp at Ames, near Iowa State College, cost the State $10,000 last season, about $2,000 of which was paid the men for work they did in building a concrete road near Columbus Junction. The remainder was earned at road, bridge and sewer work around Ames.

The Ames camp was a model of its kind. The men were allowed the greatest possible freedom from restraint and prison rules, a lone unarmed guard being maintained at the camp. At one of the camps the men converted the parlor of a vacant farm house into a barber shop, where they got their shaves each day. There were no marks on the clothing of the men to distinguish them from ordinary day laborers, and there was no conflict with the citizens in the vicinity.

At one camp a culvert gang of four men was stationed more than a mile from the other men, and there was no guard in sight. Two of these men, each over fifty years, were serving life terms for murder, but they were going about their work as earnestly as though they were free men earning their own living. Before being put to work on the culvert job these four men had manufactured 7,000 concrete posts for use on one of the State farms. They became such experts that they were able to make thirty posts and one corner post each day.

Missouri tried out the plan with equal success from the standpoint of the men last year, and this year will enlarge this feature of its work of redeeming its convicts. The Missouri camp consisted of twenty-five men. One example of how the camp was handled was a Fourth of July celebration to which Highway Commissioner Frank Buffum contributed. The day after the Fourth "Convict 16,666" was employed as a scribe to write the following letter to Commissioner Buffum:

"We fully enjoyed the Fourth of July celebration, and each one of us was more than delighted. We also wish to thank you for the reading material and, more than all, we thank you and appreciate the interest you have manifested in us. It inspires us to do our best and we feel we are making good.

"We were more than sorry and deeply deplored the escape of the two men who were later recaptured. The kindness you have shown and the kindness of the citizens here almost make us forget that we are prisoners. We wish to assure you that we also have an interest in this project and will do all we can to assist you in making this road camp a decided success."

It was signed by "The Road Bunch," and accounts in no small measure for the support Missouri intends giving the movement this year and in the following years.

A Case of Arsenic Poisoning

ACCORDING to *The Engineer*, a peculiar case of arsenic poisoning is noted in the recently issued report for 1914 of the British Chief Inspector of Factories and Workshops. The workman had been cleaning out a saturator, in an ammonium sulphate plant, and had placed an acid residue containing a large amount of arsenic—apparently derived from the sulphuric acid used—in a galvanized iron pail. The acid in the residue reacted with the zinc lining and arseniuretted hydrogen was formed by a secondary reaction, thereby poisoning the workman. Only wooden or fiber pails should be used for such work.

The two "life-termers" are expert concrete workers.

Squad of prisoners grading a road near Woodward, Iowa.

Capillarity and Soap Films

At a recent discussion before the Royal Institution, Sir James Dewar, F.R.S., opened the proceedings by making a further communication on "Problems in Capillarity," on which he discoursed a year ago. He had then spoken of the diffusion of gases through very thin membranes of rubber, and had studied the diffusion of gases not only into a vacuum, but also at higher pressures (up to 20 atmospheres) and at temperatures ranging from —40 degrees up to 40 deg. Cent. on the curves he exhibited. The curves exhibited showed that the rate of diffusion, measured in cubic centimeters per day per square centimeter of membrane, increased in all cases, and strikingly above 0 deg. Cent., as the temperature rose, the order of increase for different gases being: carbon monoxide, air, helium, oxygen, hydrogen and carbon dioxide; the latter two gases diffused much more rapidly, especially at higher temperatures, than the other gases. When the ratios were plotted logarithmically, all the lines showed breaks at 0 deg. Cent.; the speaker did not comment on this peculiarity, nor on the peculiar order of the gases. The very sensitive manometer used in those experiments was a U-tube, partly filled with oil, in which a vacuum was maintained in both limbs, and any water-vapor likely to be introduced, together with the gas, into the apparatus was condensed by charcoal and liquid air. The continuation of the inquiry into the properties of thin films and into capillarity was an appropriate subject for the Royal Institution; for it had been the last subject that had occupied Faraday. Sir James himself had felt the need of much thinner films than his rubber membranes, which had a thickness of 0.01 millimeter or 0.02 millimeter, and he had hence turned his attention to soap films.

Soap films, and especially the thinnest "black" soap films, were considered exceedingly delicate, and the question arose whether they were intrinsically unstable or whether they merely collapsed because they were disturbed or were contaminated by the liquid or the air. It was certainly quite easy to keep a black soap film for months. The speaker put a closed glass jar, about 9 inches in diameter, on the lecture-table; near the bottom of the jar a black film formed a perfect horizontal partition. The term "black" must not be misunderstood; the film was perfectly transparent, and therefore practically invisible, but appeared black in reflected light. Plateau (of Brussels, who did such wonderful work on soap bubbles, even when blind) had estimated the thickness of the black film at $120 + 10^{-6}$ millimeters Reinold and Rucker had come down to 40 and 12 of the same units, millionths of a millimeter, Johonnot to 5, Rayleigh and Devaux (by different methods with different films) to 1.13 and to 2 or 3; Sir James's horizontal film, just mentioned, was not more than one millionth of a millimeter in thickness. Yet the jar was not treated with any care, and Sir James demonstrated that the black film, if properly made in pure air or in a vacuum, was not at all unstable. He showed one film forming an equatorial plane in a sphere, and this would bear being shaken; the film moved within the sphere, always reassuming its equatorial position of equilibrium, horizontal or vertical; this film was not even quite black, but appeared slightly colored. Then a vertical film was projected on to the screen; the upper, thinnest part (the lower part in the inverted image seen) was black, the black was very slowly spreading downward, as the liquid drained that way, and the whole film would have become black in a couple of hours; yet the parts of the liquid which were streaming down through the black portion and the colored bands underneath it, did not destroy the film. Another sphere, showing a film, half black and half colored, was rocked to and fro, together with a scale on which the advance of the black portion could be measured, the demarkation line being quite sharp; that line always tended to keep horizontal, while the sphere was being tilted. This stability of films, Sir James had discovered, was, moreover, known a hundred years ago; a Dr. Read of Edinburgh had, at the time when Wollaston described his cryophorus, put a small phial containing soap solution in a can of boiling water, closed the phial, and had "thrown" a bubble, which he had been able to keep for a long time. This "throwing" of a bubble or film by shaking the bottle, Sir James showed, required a knack. His bottles resembled thermometer tubes, wide but rather short, and contained soap solution in the bulbs; this solution was first put into the tube, which was then exhausted and sealed. When the bulb was heated (by the hand), a bubble or curved film was seen to start, say from the right, travel over to the left, and then rise as a horizontal film (Fig. 1); the next moment a bubble would start from the left and travel over to the right; some of the tubes exhibited contained more than a dozen horizontal films. One of the tubes exhibited had a conical side pocket; a film traveling past that opening would partly enter it, and when the pocket was warmed externally by the hand, a bubble would be seen to swell out from the opening, reach over to the other glass wall, and then split into two horizontal films. The diagram, Fig. 1, very crudely indicates the beautiful phenomena; the dotted lines in the upper part of the diagram mark the position of loops of wire, fixed in horizontal or vertical planes, as will be described lower down. In some of the tubes exhibited the films looked slightly convex or concave; they traveled up and down the tube under temporary illumination by the lantern beam. Those multiple films were easily produced by violently shaking the tubes so that they were all full of froth; the films would afterward make their appearance as the froth liquefied; it was essential that the tubes should be highly evacuated, so that a click could be heard when the shaken liquid struck the other end of a tube.

Fig. 1.

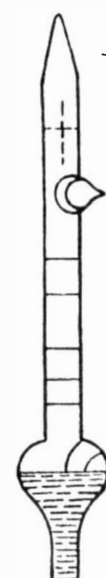
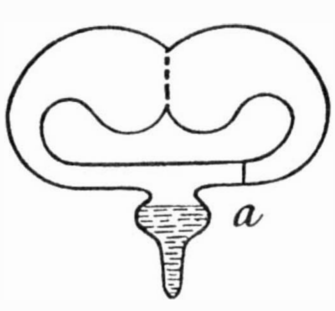


Fig. 2.



As these tubes were not convenient for some measurements, however, Sir James devised another form of apparatus. These were Y tubes, the two upper open ends of which were so bent and blown out into spherical cups that the rims touched one another. Thus a closed vessel was obtained, which was hermetically sealed after putting in some soap solution and evacuating, the shape being somewhat as in Fig. 2. The main soap film would form across the stricture where the two cups were fused together (indicated by the dotted line of Fig. 2). But smaller films would also form in the narrower part of the tubes, and such a film (at *a*) would act like a stop-cock; to remove such a stop-cock, that part of the tube was heated or cooled from outside, by a piece of glowing wire or coal or by liquid air. The whole vessel fitted into a wooden box, black inside, and could be illuminated within the box by a small electric torch placed in a pocket of the box. With the aid of this apparatus the stability of the films above mentioned could further be demonstrated, and the rate of advance of the black portion could be measured. One of the rectangular vertical films exhibited showed (directly observed, not projected) quite sharply four blacks (or a first black and three gray bands, immediately following one another, without transition tints, in horizontal stripes), a white, and finally a yellow portion. When the tube was tilted so that the liquid washed over the film which was being kept in a vertical plane, irregular streams were seen to run down the film; but the film cleared quickly, and in two minutes nearly the whole film appeared uniformly black of the first order; immediately underneath the black followed a series of narrow colored horizontal lines, and finally a silvery portion. This beautiful film had a length of more than two inches.

The measurements on the rate of fall (advance) of the black line were also made with the straight tubes mentioned, into the upper portions of which circular or rectangular loops of platinum wire were inserted in various positions. Thus, the films might be horizontal or vertical, and the rectangles supporting them might have their long or their short sides vertical. These remarks will explain the following table on the "Rate of Fall of Black Line in Millimeters per Minute:"

Circle	Film vertical in air	0.24 to 0.16
	Film vertical in vacuum	0.20 to 0.5
	Film vertical in vacuum on wire	0.33 to 0.16
Film horizontal in air		0.12
Film horizontal in vacuum		0.09
Rectangle, long side vertical		4 to 0.4
Rectangle, short side vertical		0.2 to 0.016

Another table exhibited, to which the lecturer did not have time to refer, however, showed that the surface tensions in the colored and the black films varied very little in magnitude; expressed in milligrammes per centimeter, these surface tensions ranged from 26.5 in a colorless film to 26.3 in a slightly colored film, to 26.1 in a film 5 per cent of the area of which showed the first black, and to 25.9 in a film showing the second black all over.

The speaker then alluded to other means of producing films; for example, by dropping oil on clean water. An American physicist had recently taken collodion solution instead of oil, and obtained thereby films 7 by 10^{-6} millimeter in thickness. Those films shriveled up and cracked near their edges as the solvent (amyl ether) evaporated, and the dry blackish film could be lifted off with the aid of a platinum-wire loop; such a film afterward looked black if consisting of one thickness only, or silvery white if partly folded over.

In concluding, the lecturer pointed out that such researches were not by any means so far removed from practical value as might appear. Utilization of the peculiarities of surface tension had, at the Broken Hill mines in Australia, rendered possible the separation of the intimately mixed sulphides of zinc and lead from the complex silicates accompanying them. When the crushed ore was stirred with plenty of water, no separation took place by gravitation. When a few drops of oil or of oleic acid were then added to the pulp mixture, and the mixture was violently shaken into a froth (various means are used for this purpose in practice), the sulphide particles were lifted up to the top (probably by the air bubbles adhering to the greasy particles), while the silicates settled at the bottom. Thus an industrially very important separation by "oil flotation" had been worked out at Broken Hill.—*Engineering.*

Electricity on the Farm

A recent issue of the *Electrical World* describes a handy electric installation on a farm in Massachusetts. Besides lighting the house, barns and various sheds a power line is laid out, with junction box connections at various points where power may be required. A 7.5 horse-power motor is mounted on skids, on which it can easily be hauled by a horse to any place where its services are required, and it is used for sawing wood cutting ensilage and other farm work. Another piece of apparatus is a 2 horse-power milker, by which four cows can be milked in fifteen minutes, and as there are forty cows on the farm this means a saving of four men. A small motor pump completes the equipment, which, while apparently small, takes care of a great deal of hard work.

Economy in Study—V

Examination Preparedness

By George Van N. Dearborn, A.M. (Harv.), M.D., Ph.D., (Col.)

In order to be fully up-to-date, we use the term "Examination-Preparedness," and study now how to prepare for and how to perform mental examinations of all kinds. These are practical points with a low minimum of theory about them.

It is undoubtedly frequently suggested by instructors of all kinds who hold examinations that the direfully dreaded examinations will take care of themselves if systematic work be vigorously done conscientiously through the course. It might be useful to you did I enlarge on this vexed examination-question somewhat. First, let me cordially emphasize the above statement, for however true and important, I have no hope at all of making students, male or female, young or old, civil service or naval, in the elementary school or in the university, indolents or "greasy grinds," believe it so as to act upon it to any appreciably profitable extent. They never have (save one or two wise ones, here and there), and they probably never will. None the less, the fact holds that if you do study properly and, so to say, conscientiously, and furthermore scientifically, *the examinations will take care of themselves.* There are a number of reasons why the matter is so important which we need not stop to give, but one important one concerns the effect on the mind of worry. On the Harvard marking-system, if you take your ease you will get E's and not A's. Ease and E's go together, but A's are not "aisy." It is our present business to show as clearly as may be how they may be made so.

The chief requirements of proper study for this specific purpose we may suggest in three parts. 1st, *the entire necessity for conscientious, thoughtful study; for an adequate amount of real study with the attention complete.* It seems sometimes surprising that you do not take for granted this matter of plain common sense. 2nd, *the keeping of your notes posted up daily* in your brain and thus everything you learn integrated with the preceding acquirements. If you have taken no notes, begin to make some from your lectures and your textbooks, and from your memory, for these will certainly be better than anything else for this examination purpose. 3rd, to get a good examination mark, *you should have somehow a weekly or at least a monthly review,* because, as we have seen already, review is the chief means to the integration of any subject in your mind. Notes *should be* kept on the analytic plan of complexes or symbols, which have been already explained, headings, sub-headings, and so on, on rational systematic lines.

Such subconscious preparation is theoretically the only proper way. Examinations are *incidents, and not ends,* and they are a necessary evil to every instructor. If study for examination is done along these lines, in this general manner, learning is really learning. Thus, too, there is no worry. No worry-excitement arises in the mind as the "critical" time approaches, no phobia to disturb and even undermine the mental and bodily processes, and disarrange the ready association of ideas. There is a vast waste of energy in worry; fear (worry is fear) starves the brain by using up its food over-fast on itself.

On the other hand, the prospect and the certainty of an examination provide the requisite emotional tone to give study its necessary concreteness and practicality. Examination is thus an incentive to vigorous study and therefore more or less necessary. If these ordeals had not been shown to be necessary by centuries of world-wide experience, it is absolutely certain they would have been abandoned, because they constitute to the conscientious teacher and instructor the most disagreeable and laborious portion of the entire educative work. Examinations are a necessary factor in the process of learning. Nothing can take their important part, nothing, at least, that is now over the pedagogic horizon.

Theoretically examinations should be always at unannounced times, thus training the student in continual preparedness and insuring a degree of attention to the daily work which can be obtained scarcely any other way. It develops the important subconscious habit of "attending to business." It trains, too, in the power of suddenly turning one's attention and then of using it to its utmost—mental dynamogeny. This, as President A. L. Lowell points out, is frequently required in real life, this power of clearly and vigorously turning your mind to any required topic on demand at an unexpected moment.

Oral Examinations.—Oral examination is the ideal form. It is generally far more efficient as a means of testing one's ignorance or knowledge of a subject than is a written examination. The universal objection to this kind is that it requires too much of the examiner's time. It requires less on the part of the student, but greatly more on that of the instructor. Any one, however, who has taken a university doctorate examination, in the focus of a concave mirror of inquisitors, appreciates that it is the method above all others for finding out how little a student knows about a difficult subject. Here it is possible to ask fifty questions instead of five or ten. One can almost see the associational machine *work,* and therefore can understand whether it be adequate or not. He sees the living mechanism and not only its product. Theoretically there should be more and more oral examinations in all kinds of schools; this matter is making progress, in the medical schools especially. Written examinations are a make-shift, but they are much better than nothing. Oral examinations are far more psychological than written ones, and give the really efficient mind and knowledge a better chance. About as many, I take it, are handicapped psychologically by the inability to write explicitly as by the inability to talk quickly, briefly, and intelligently. So far as the student's welfare is concerned, there is no reason to suppose that oral examinations would be a handicap. On the contrary, in the long run the demanded training in self-possession, repartee, wit, quick reply, would be of much use to almost everyone. This too is of course at heart a matter of physical training—as "skill," already sufficiently discussed. Oral examinations require self-poise above all else save *real knowledge.*

Practical Examinations, such as are given in physiology, physics, chemistry, etc., are the ideal examinations on whatever subjects allow of their being conducted. Their unpopularity shows their difficulty. They are the only kind of examination that show one's real and practical efficiency. They make a test of what one can do, actually perform, rather than what he has merely learned about second-hand. Undoubtedly they are over-done in some professional schools. The proper place in general for the practical examination is in the Normal School, for there teachers are trained, and they must know how things should be actually done.

In written examinations, at least, *knowledge as to the range and kind of questions* asked in previous examinations is a right and not a privilege. The possible scope and methods are very numerous, and the student therefore necessarily has to "get the range" of the examiner, and of the subject as he presents it. Therefore, if the previous examination papers are on display it is certainly the psychological duty of each student to get access to them; no competent examiner will refuse.

The *personality,* too, of the examiner is worth a bit of careful study. Strange as it may seem to young pupils, the instructor has fads and habits like other folks. Here is where general human natural intelligence comes to the aid of the students. In certain cases some knowledge of the examiner is only less important than knowledge of the subject of the examination. This is a personal, confidential point which should not be published widely, for some non-human logicians do not yet understand the motivity of human behavior and possibly might deny their humanity.

Plenty of sleep for a week or more before an examination is well worth the time it costs. Every hour so spent is worth at least treble what you might expect unless you understand the efficiency-advantage of rested brain-units over those that are fatigued. Sleep clears the cobwebs out of the brain and memory, so that the billions of neurons can work in association far better than when they are fatigued.

General invigoration of the entire organism improves the memory and the reasoning powers. Therefore much outdoor exercise is especially highly expedient during the few weeks before examination-time. In this way one tones up the whole organism and puts it, as the athletes say, "on edge." A saline *purge* or one of cascara or of castor oil two nights before a difficult examination is a wholly expedient and often very useful procedure. In this manner one avoids that feeling of toxemic headache and general malaise which is incompatible with clear thinking and with accurate work. This is one of the commonest modes of temporary rejuvenation, and worth noting, because it is less common than it should be.

A *light* breakfast or a *light* lunch is necessary before an examination on the physiological principle that the blood, which is limited in quantity, cannot be both in the brain and in the stomach at the same time. This light meal, a short time before an examination, might very well include a cup of coffee or tea, not too strong, provided the student be not wholly unaccustomed to its use. This obviously is not a good time to try experiments as to your personal reaction toward drugs of any kind.

One sometimes gains very much *by looking over the entire material* of the examination *immediately before the examination-hour.* A large amount should be surveyed in a very short time—ten minutes or so on the whole subject matter—not by any means a time long enough to tire, but often in practice extremely productive in suggesting partly forgotten facts and principles which (as experience often shows) are just the ones required a short time later.

If the examination is to be a written one, prepare at least two fountain pens, well filled and clean. Or sharpen four or five pencils which are neither too hard nor too soft. If they are too hard, the examiner is apt to be seduced into mild pedagogic wrath when he reads the "book;" whereas, if they are too soft it is difficult to make a neat paper of it. This matter of writing-materials is far more important than the average student is apt to consider, so if "marks" be of any object (and sometimes they appear so to the examinee) one might follow to good advantage the habit of the newspaper men who use a large number of soft pencils and write large script. So much for a few practical points as to *preparing* for an examination.

Our next search is as to the scientific manner of actually *doing* the examination. The mental attitude as you actually approach this concrete problem is of the utmost importance. One should set about an important examination with a grim determination to "eat it up" bodily, as the medical students say. This is what we mean by dynamogeny, which has been already referred to in previous lectures. This appears psychologically in the form of a conscious determination, a vigorous determination reinforced by a strong self-suggested feeling of encouragement; it is auto-suggestion plus an emotional tone. Since the work in Cannon's laboratory especially (see above), we realize that this dynamogeny depends in part on the increased amount, however minute, of adrenin in the blood, but especially, perhaps, of sugar there. This "dynamogeny" is a matter of great and practical importance, and no longer the mystery that it used to be. This in general is an extremely important power, and for the writing of an examination it may mean all the difference in the world, all the contrast between failure and success. In the same way the man who is shaken into pneumonia with a firm determination that it shall not kill him, enjoys a far better chance that it really will not kill him than does one who is over-frightened by the prospect of undergoing this irresponsible disease. There is a force in this human organism of ours which it would be difficult sometimes to stay in bounds, and this force can be used in the successful performance of examinations as well as elsewhere. Reduced to scientific terms, it means the more or less controllable force of the influence of the mind over the body, to which there is no assignable limit in sight.

As one enters an examination-room, if there be any choice, one should choose a good light without having to face the unprotected brightness of the open sunny sky, which would irritate the brain. One would choose a place where there might be ample rest also for the elbows, for all of these subconscious strains on the central nervous system *count* in a long examination and help to weary and retard the action of the brain. One should choose a *cool* place rather than a warm one in the room. One should insist that the room should be adequately and amply ventilated, because it is better that it should be open to the air than too restricted. The ideal temperature is 65 deg. Fahr., for the excitement and the attention of the work is sure to raise one's personal temperature somewhat, and this, in combination with a too warm atmosphere, would produce a flow of sweat which would be uncomfortable and so distract one's thoughtful attention.

As in all other forms of long mental strain, the wise student will frequently rest his eyes and the muscles of his head and neck by often looking around the room. This changes (lengthens) the focus of the eyes and thereby rests all parts of this extremely deli-

cate seeing-mechanism. At least once in every fifteen minutes a minute or two is used with the greatest economy in looking around the room—away from your neighbor.

It is almost impracticable to say much about penmanship. The matter is undoubtedly an important one, however, from the student's point of view, and not less than from the examiner's. The obvious fact is that plain writing in the long run of emotional examiners distinctly tends toward high marks. The writing must not be too fine, such as that made with a very hard pencil, and it must not be too difficult to read because of poor handwriting. Relative illegibility puts the examiner in bad humor, and that is a bad policy for the examinee. It is worth while to put plainly on the examination-question papers given to the students that "the answers should be concise and systematic, and the writing must be plain."

It is inexpedient to enlarge upon the necessity of *good English*, yet there is, none the less, a widespread tendency in schools in the United States to use the English of all written examinations, if not those that are oral, as a test of one's general intelligence. This is one of the important things for the advancement of general intelligence. The reading and the grading of examinations is positively the worst of all school-work, especially where the school is large. One instructor I know reads more than thirteen hundred "exam-books" in a college year. Under these conditions one would expect that the feelings of the average examiner would be unable to stand much further strain and remain free from uncontrollable resentment. Therefore write good legible English.

Do not think that an examiner is going to take anything "for granted;" theoretically he should not and in practice he may not. Details, then, and explicitness, are wholly necessary for the securing of high marks. It is statements, true statements, showing knowledge and understanding, that count; the more of them in general, the more credit marks a student receives. But please observe that not all words are statements. Far from it. If one may be pardoned for the slang because of its explicitness, all "hot air" should be left out of an examination. It wastes the good humor of the examiner, which is a very costly kind of waste under the circumstances. It is *ideas* in general, not words, that count: in fact, words that do not express any ideas are rather worse than nothing, because they waste the time and precious patience of the examiner. It is obvious that in many respects the examination is a test between the student and his examiner.

Pictures and diagrams, especially when labeled and explained by text, are an ideal way of partly writing an examination and oftentimes students deficient in the power of good English or of good chirography, handwriting, can remember pictures when they cannot describe the conditions explicitly. This in itself is an important power of education, this faculty of remembering, of understanding, and reproducing pictures and diagrams.

In long examinations where the hours are apt to be crowded, as in many professional examinations, the syllabus-style should not be objected to by the examiner. *Schematic arrangement* is of the utmost importance in writing a paper which is to be high-marked. We have called attention to this matter already—subdivisions under properly logical headings. You may be sure that an examiner will always appreciate this arrangement, for it relieves him of work and shows that the student really understands, in a psychological way, the material which he has offered. *Conciseness* is important, but is not brevity necessarily: it means brevity only so far as consistent with fullness and clearness.

Good humor is important here as in other situations in life, in this writing of examinations and still more in an oral examination. Here the native intelligence of many individuals shows itself to the best advantage, as they realize that dons and professors, and even state boards of registration, are human, after all, little as some students suspect it. *All your wits and a bit of wit.* might be your motto. But not too *much* humor, and not too *much* wit, for some examiners think it undignified to smile, heaven help their vanity; and so discount the work of the humorous student. Flattery and titles are absolutely fatal in an examination, for the average examiner will not stand that; and in general confidential notes appealing to some person who is interested or to personal relations of the examiner, are not highly productive of scholastic success.

You *should plan out the entire time allotted* for the examination, allowing so many minutes for each question with an ample time for reviewing at the end. It is a good plan, having done this, to remember the limit of time to be devoted to each question and if necessary return to an unfinished answer afterward. On the other hand, provided the question can be satisfactorily answered or answered as fully as is possible, one should go immediately to the next question. It is an extremely common error, and one highly harmful to the average student, to hurry through an examination and not really think, or at least succeed in recalling, what he really knows. There is no excuse for this, save in highly professional examinations in which the examinee is given just time enough to write rapidly what he should with scarcely a moment at all for search-thinking or for recall. An examination should give ordinarily some time for thought on each question, and it is highly important that this time should be so respectively used.

It is a common error also to think well and hard at first, to push one's mind well in the early part of the examination, but to stop the effort when a little tired, although the examination be only partly completed, the latter part being slighted. Examinations test the entire intelligence, or they should do so, and one is not intelligent or a proper student whose mind is so little trained or so weak as to make this mistake. The old trick of writing one half, or as much as may be, of the paper and then saying the "time is up" or "no time to finish" of course deceives no one. The last question is just as important as the first one, and it is the student's business to be sure that it be answered as well as the first, if he be looking for good marks. Bluffing is dead fatal to success in the long run, even if it does hit the mark now and then. This is seen as pretending to have knowledge which you know perfectly well you have not, trusting that the examiner will mistake mere words for the statements required. One would expect the feminine mind to be more successful in this than the masculine. Do not confuse this with *intuition* which is appreciated subconscious knowledge. Oftentimes there is more in your subconscious mind than you know of, and regularly only by the actual expressive motor reaction of trying to write it do the associations which occur in your mind show themselves in consciousness.

Do not judge an examiner's mind by your own. It is generally true and germane explicit ideas that count, and not your particular notions of these essential ideas.

Examinations require above all things else (save learning) self-possession for a highly successful outcome. Adequate physical training, systematic and continuous, will help one to this self-possession like nothing else save actual practice in this highly human educational art. To avoid examination is to cheat your learning mind.

[This article concludes the series on "Economy in Study."]

The War-Zeppelin

By C. Dienstbach

Upon mention of the name "Zeppelin," the mind of the non-German invariably conjures up thought of some dark, deep secret of construction, whereby a normally non-buoyant and non-dirigible apparatus is made to soar and to steer; of secret agents, engaged in plot and intrigue to steal this secret out of Germany. Such an impression is wholly erroneous; no stolen documents are necessary to reveal the construction of the Zeppelin, involving as it does nothing but the amply known original design. The only dirigible that has held its own against the aeroplane owes its existence, not so much to the mind of the inventor, as to his bull-dog courage and tenacity of purpose, and his liberality in enlisting the flower of the world's engineers and manufacturers for the perfecting of the details of his simple original design.

Indeed, Count Zeppelin is credited with displaying toward any suggestion of deviation from his original designs, that same strong will which enabled him to overcome the tremendous difficulties of private experimenting with a type of aircraft declared by governments to be too costly. But examination of the mangled remains of novel Zeppelins shot down by allied gunners makes it clear that he has finally agreed to such a change under the stern demands of military necessity.

One is puzzled, however, to find that the features to whose sacrifice he has assented are real merits. The new model is fearfully tail-heavy. Not only is the stern elongated, heavy, and lacking in lifting power of itself, but it is loaded down with single plane rudders weighing far more than the old multiples, and with a rear car holding three engines and three propellers; while the forward car carries but one engine and one propeller. Unless the rear car is moved far forward this machine could never ride horizontally. And along with this transformation we see a shortening and thickening of the hull, which almost amounts to abandonment of the pencil shape characteristic of the Zeppelin, long recognized as the fastest shape for given power.

The solution of this mystery is that the new airship is not so much a super-Zeppelin as a war-Zeppelin, a makeshift to meet hurriedly the exigencies of the hour. Circumstances developed by the war make it clear that the speed and general efficiency of the Zeppelin have been found not quite sufficient. The problem confronted the Friedrichshafen engineers of increasing the speed at any cost, of increasing likewise the lifting power, the height of normal flight, and the cruising radius.

There was but one way to accomplish all this—by increasing the displacement to a considerable degree. This sounds feasible enough; indeed, rumors of the construction of mammoth Zeppelins have this long time been afloat in America; but the initiated have realized that no such airship as these reports dealt with could be built or even harbored with the existing sheds. These sheds admitted the increasing of the diameter of the ante-bellum Zeppelin, but not its length. So the German engineers have taken the only course open, and produced this new type, of sufficiently increased displacement to support engines giving the required speed, elevation and endurance, and have put up with the necessary evils of such construction as best they could.

The head resistance of the large cross-section no longer permitted the neglect of certain aero-dynamical niceties which had always been a feature of the Count's designs. The well-lifting, blunt stern, so favorable for taking the weight of the rudders from the rest of the hull, had to go, a certain compensation being found in the opportunity thus offered of cutting down the head resistance of the rudders without too greatly increasing their weight. The lifting power being more concentrated, the load must likewise be massed; hence the heavy rear car. Finally, another advantage dear to the Count's heart had to be sacrificed, the position of the propellers at the center of resistance.

And so we have these war-Zeppelins—clumsy and inconvenient as they are, yet developing sufficient power to more than overcome their defects. But in the nature of things, when external conditions again permit, mammoth dirigibles must return to the Zeppelin principle. Otherwise half the benefit of increased displacement would go to waste. An object lesson in the importance of the original Zeppelin shape is to be had in any great fresh- and salt-water harbor like Rotterdam. The river-boat is slender, like the true Zeppelin; the other would gladly imitate this shape if it could; but the great ocean waves would break it in two if it did—an accident which has actually befallen torpedo-boat destroyers in which everything was sacrificed for speed. In the air, on the other hand, there is no stress comparable to that of the ocean waves. Of two airships of equal cross-section the longer encounters the greater aerodynamic resistance; its increased power for carrying engines more than overcomes this, so that it is actually faster.

Wireless for Motorboats

One lesson of the present war, states *Motorschiff und Motorboat*, for August and September, 1915, is the great value of the motorboat in naval operations, not merely for scouting purposes, but as auxiliaries to larger vessels engaged in active service, and also in squadrons, for certain lines of independent operations. It points out that for the maximum development of these possibilities a wireless installation is an obvious necessity, and gives a lengthy statement of the progress made by German manufacturers in designing outfits suitable for such purpose.

The current necessary for transmission over a given distance is so greatly in excess of that required for receiving from the same distance, that in the limited space of a motorboat no very competent transmission apparatus can be set up. But fortunately it is not essential for the motorboat, when engaged in any of the operations for which it has been found suitable, to send messages more than a few miles. On the other hand, it often is desirable to receive from bases hundreds, or even thousands, of miles away; and this is perfectly feasible. An amateur, working in London, with what might fairly be described as a pocket outfit, requiring next to no current at all, was able to listen in on messages from Madrid, Algiers, Gibraltar, Bergen and Copenhagen; and a similar instrument has been known to receive, in Paris, news items sent out from Sayville.

Whether equipping his craft for use as a naval auxiliary or merely for pleasure, no motorboat owner could ask more than this. Such an apparatus can be purchased (in Germany, at least) for less than $100, and can be installed and operated on the smallest motorboat. The principal point in which the installation differs from that of a land station is in the device for grounding the current. The motorboat cannot have a ground wire; but the conductivity of water makes a "sea wire," attached to a copper plate on the hull below the water-line, quite as effective. For short distance work the aerial lines can be strung from mast-head to mast-head or flag-pole; for long distance receiving they are better sent up on a kite. That the motorboatist is under no serious disadvantage from his inability to erect a high pole is evidenced by the case of an Englishman who got signals from Malta, 1,500 miles away, by means of a kite.

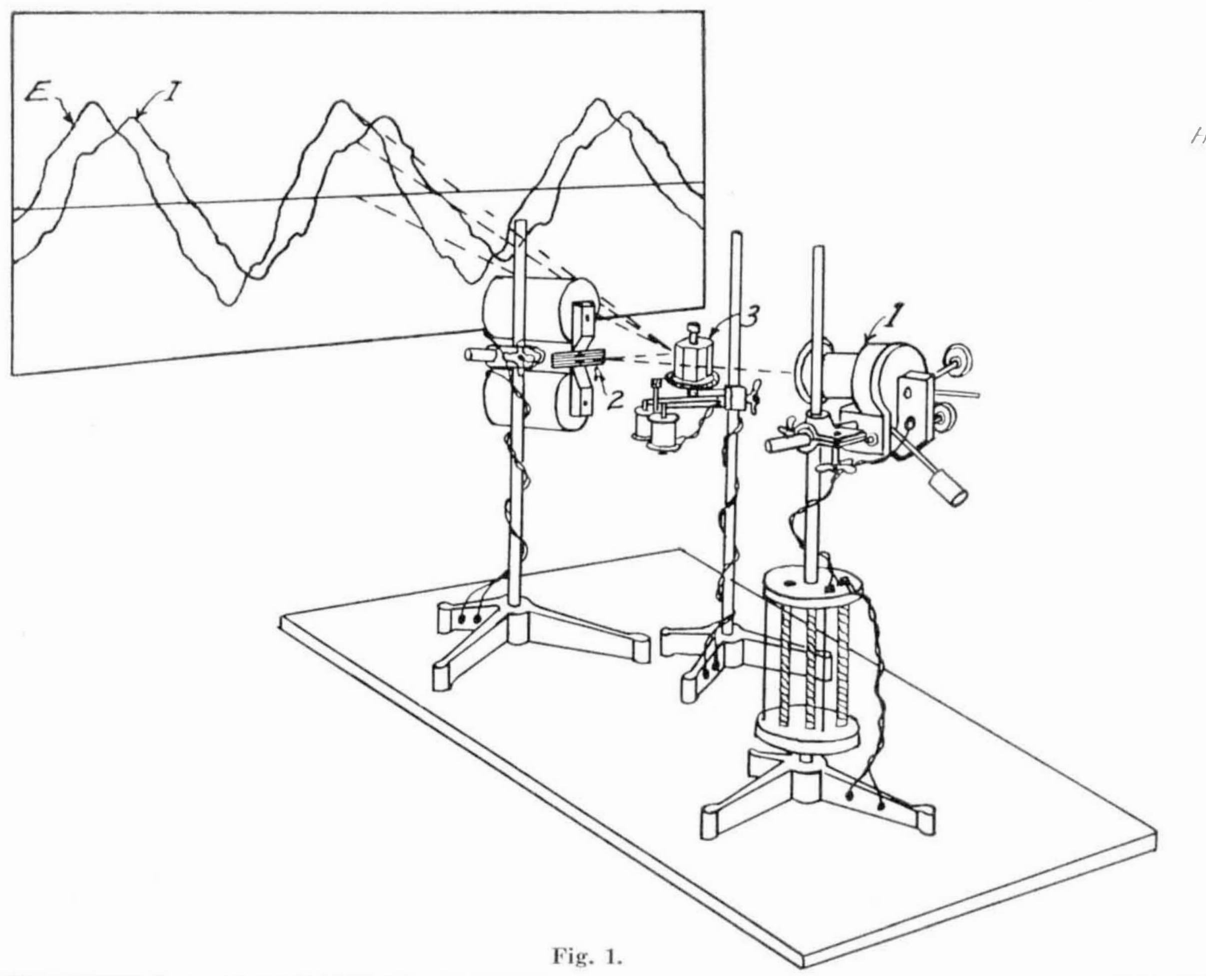


Fig. 1.

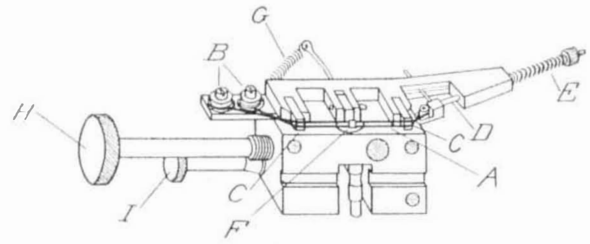


Fig. 2.

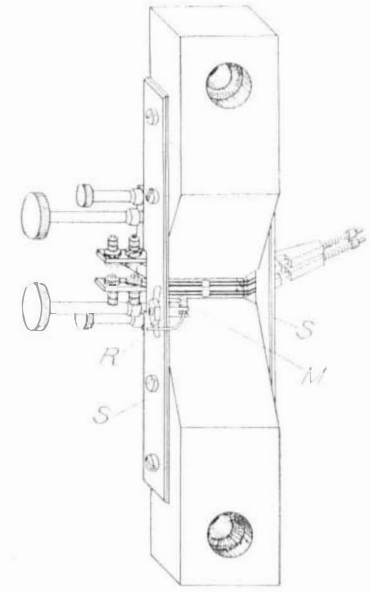


Fig. 3.

A Lecture-Room Oscillograph*

An Instrument for Projecting Images of Alternating-Current and Voltage Waves Without Distortion

By H. G. Crane and C. L. Dawes

The oscillograph has proved itself indispensable as a device for investigating alternating-current waves, switching, and other transient and recurring phenomena. In fact, the recent phenomenal advancements in the size and design of electrical apparatus are in a large measure due to information obtained by means of the oscillograph. Furthermore, the oscillograph is very useful in educational work, especially for making experimental demonstrations of the effects of resistance, inductance, capacity and harmonics upon the current and voltage relations in alternating-current circuits. The mental picture obtained in this way makes a much deeper impression upon the student's mind than the customary method of sketching the waves upon the blackboard.

However, it has been found in connection with work at Harvard University that the ordinary oscillograph is not adapted for demonstration purposes in the lecture room even before small bodies of students, owing to the comparatively small amplitude of the wave images. Because of this limitation of the ordinary oscillograph as a lecture-room device, the writers have developed an instrument that is capable of projecting upon the ordinary stereopticon screen images of alternating-current and voltage waves without appreciable distortion. Further, these wave projections are of such magnitude that they may be readily seen at distances of 200 feet and more from the screen.

Owing to the high degree of flexibility required by a lecture-room instrument, because of varying projection distances and the many relative positions that the apparatus, the audience and the screen may bear to one another, it seemed advisable to make and mount each element of the instrument as a separate unit capable of being placed in the most advantageous position for any given set of conditions. Consequently, in the instrument under discussion, the arc lamp with its optical system, the magnet and the vibrators, the rotating mirror and its driving motor, are each mounted upon a separate stand and can be readily adjusted to the desired height or position above the base. The shunt and the multiplier are also separate units. Fig. 1 shows a diagram of the entire apparatus assembled. The arrangement has one other great advantage from the teaching point of view. The student sees each element essential to the operation of an oscillograph in its simplest form, and, further, he sees at a glance the relation that each part bears to the operation of the oscillograph.

The units of the instrument are mounted upon their respective standards by means of sliding clamps. Suitable hand screws hold the clamps in position upon the upright rod of each standard. This construction allows each element to be raised, lowered and adjusted to any desired position. The total height of each standard is 24 inches (61 centimeters).

In order that the wave images projected upon the screen may be bright enough to be seen clearly some distance away, a very intense source of light is required. To obtain such a light it has been found necessary to design a special arc lamp. This arc lamp is inclosed in a cylindrical iron casing, and the arc is formed between two pencil carbons arranged at right angles to each other. The carbons are fed by hand through grooved rollers, one being fed from the rear and the other from beneath the cylindrical casing. The arc will burn fifteen minutes without attention. The horizontal carbon is positive, and from its crater comes the light that is utilized in the instrument. An adjustable diaphragm containing a small circular orifice is set in front of the crater of the positive carbon. The size of this orifice determines the cross-section of the beam of light that is thrown upon the screen. Because of the existence of a hot positive crater just behind this orifice it has the appearance of a small incandescent circle. The light from this circle passes through an achromatic lens mounted in the front of the cylindrical casing. This lens gathers the light coming from this incandescent circle and compresses it into a small bundle of parallel beams of high intensity, which is admirably suitable for projection purposes. This feature of the arc lamp, together with its portability, makes it very useful in connection with experimental or optical work requiring concentrated and parallel beams of light.

VIBRATOR ELEMENT OF THE OSCILLOGRAPH.

The vibrators are the most essential and delicate element of the oscillograph. In designing it is necessary to maintain natural frequency and degree of damping high enough to insure reasonable accuracy in reproducing circuit conditions. After much experimenting, it was found that the higher optical efficiency and the greater simplicity of air-damped vibrators more than compensated for the slight errors introduced by insufficient damping. Fig. 2 shows the details of a vibrator element.

A phosphor-bronze filament *A* extends from the base of one of the binding posts *B* over the ivory bridge *C* to the small ivory pulley on the rod *D*, and back again over the bridge to the other binding post. The ends of the filament are clamped to the binding posts by small machine screws and washers. This method of holding the filament has been found superior to the usual method of soldering because of the facility with which the filament may be replaced without the use of any tools other than a screwdriver. The rod *D* passes through a hole and is then encircled by the spring *E*, which keeps the filament at a constant tension. This tension may be adjusted by means of a small knurled nut. A small plane mirror *F* about 1/16 inch (1.5 millimeter) square is cemented across the two sides of the filament at the center points of the bridge. To obtain an amplitude of vibration of 12 inches each side of the zero line at a distance of 10 feet from the screen, these vibrators each require about 200 milliamperes.

The vibrator is suitably attached to a swivel pin, which is so mounted that the vibrator can be turned in two directions at right angles to each other. A spring *G*, pulling in a 45-degree direction, holds the vibrator against both its vertical and its horizontal stops. By means of the knurled head *H* the vibrator may be rotated around a horizontal axis, and by means of the knurled head *I* it may be rotated about a vertical axis. These adjustments allow the spot to be brought to any desired position upon the screen.

By actual test we have found that the natural frequency of this type of vibrator ranges from 1,500 to 2,000 cycles per second, depending upon the degree of compression of the spring *E* (Fig. 2). Therefore the vibrator will respond with a fair degree of accuracy to harmonics as high as the nineteenth in a circuit having a fundamental frequency of sixty cycles per second, and also to telephone frequencies which average 800 cycles per second. The higher natural frequencies are obtained by increasing the filament tension and are therefore at the expense of the sensitivity or amplitude of vibration. The errors due to the temperature coefficient of expansion of the filament are made small by making the filament fairly heavy and thereby reducing the I^2R loss.

SPECIAL VIBRATOR FOR TELEPHONE WORK.

A special vibrator has been developed for telephone work. It is necessary that such a vibrator have a specially high natural frequency in order that it may follow accurately the currents of telephonic frequencies. Therefore a lighter filament, a smaller mirror and a closer spacing of the filament on the bridge are used, thus reducing the moment of inertia of the moving system. As only one vibrator is ordinarily required for a telephone circuit, the air-gap of the magnet may be materially reduced and thus increase to a certain extent the flux density in the gap. This further increases the sensitivity.

*Courtesy of the *Electrical World*.

This type of vibrator requires about 100 milliamperes to produce an amplitude of 1 foot on a screen 8 feet from the vibrator. In a recent demonstration before the Boston Section of the American Institute of Electrical Engineers such a vibrator was used in this oscillograph to project upon a screen telephonic current waves pro-

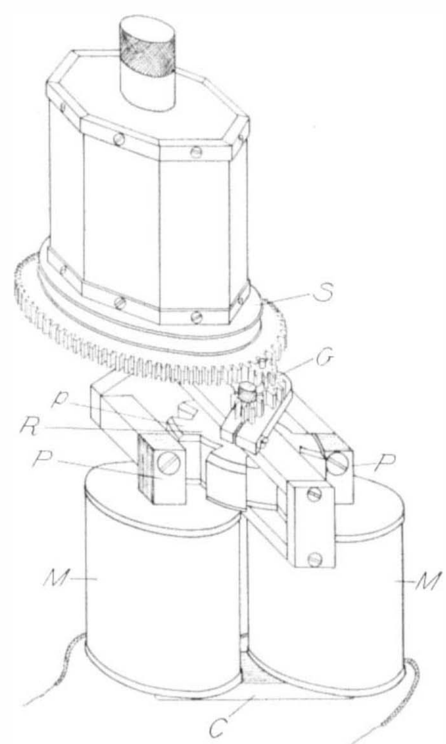


Fig. 4.

duced by speaking in and producing other sound waves in the vicinity of a local telephone transmitter. This same vibrator was also used to throw upon the screen the current waves resulting from conversation between Boston and San Francisco over the transcontinental line. When President Carty of the A. I. E. E. and Dr. Pupin addressed the section on that evening through the medium of 500 individual telephone receivers, their voice waves were thrown simultaneously upon the screen by this oscillograph.

POLE PIECES AND ROTATING MIRROR.

In Fig. 3 the vibrator units are shown attached to the iron pole pieces of the magnet. These two-pole pieces are held together by means of two brass straps *SS*. A small auxiliary mirror *M* is mounted upon a small movable brass block. This block is free to turn in a horizontal or in a vertical direction as desired, and is adjusted by means of a small curved rod *R*; it is held stationary in the desired position by friction. This mirror projects a zero line constantly upon the screen, eliminating the use of an extra vibrator for this purpose. The magnet is excited from 110 volts direct current and takes about 0.3 ampere. It weighs about 25 pounds. The pole pieces (Fig. 3) are held to the core of the magnets by two bolts, one in each piece, making it easy to remove them. The connecting wires are brought to substantial binding posts on the base of the standard as is clearly shown in the accompanying Fig. 1.

The rotating mirror (Fig. 4) is composed of eight plane mirrors arranged to form an octagonal prism. It was found that a prism having less than eight sides could not be used without producing a very marked distortion of the wave along the time axis. This mirror requires the most careful workmanship in its construction. If it is not almost perfect mechanically, the wave upon the screen will be very unsteady in position, and the image shown will be subject to a very pronounced lateral flickering. The mirror revolves about a vertical axis, being driven by a small synchronous motor through a system of gears (*G*, Fig. 4) at a speed of 75 revolutions per minute, at sixty cycles per second. In the assembled instrument the rotating mirror is protected from dust and injury by a stationary cylindrical shield having a vertical slot just large enough to permit the vibrating beam of light to pass in and out again. A grooved pulley *S* (Fig. 4) allows the mirror to be driven by a belt from a source of power other than the synchronous motor. This method of drive is necessary in telephone work and in many other instances where sufficient or suitable power cannot be obtained from the same source as that from which the vibrators derive their current.

CONSTRUCTION OF MOTOR DRIVING MIRROR.

The construction of the synchronous motor shown in Fig. 4 has been made very simple, but at the same time the motor is very effective. Two coils *MM* are wound upon a U-shaped core *C*. These coils are designed to operate upon a 110-volt circuit at frequencies varying from twenty-five to sixty cycles per second. An iron rotor *R* having six projecting poles *p* rotates between the poles *PP* of this alternating-current magnet. The motor operates upon the well-known principle that the magnetic circuit tends so to conform itself that its permeance is a maximum. When the flux between the poles *PP* is at its maximum value, it pulls the rotor *R* around, so that a projecting pole on the rotor lies directly in front of each of the poles *PP*. However, when the flux is passing through its zero value and therefore exerting no pull upon the rotor, an interpolar space is presented to the poles of the magnet owing to the inertia of the rotating system. This type of motor is very sensitive to the shape and depth of these poles; if they are not correct geometrically, the motor will hunt or fail to develop sufficient power. This particular rotor has six poles, giving it a synchronous speed of 1,200 revolutions per minute at sixty cycles per second. It is started readily by turning the large gear on the mirror by hand until the motor pulls into step.

The multiplier consists of high-resistance, zero-temperature coefficient wire wound doubly in one layer upon a glazed aluminium tube. The resistance can be varied by moving a slider along the scraped portion of the wire on the top of the tube. The slider short-circuits adjacent turns, thus making it possible to vary the resistance between terminals any desired amount. The multiplier has a range of from 250 volts to practically zero volts. This method of varying the resistance allows very rapid and close adjustments to be made.

The shunt is shown in Fig. 5. Two binding posts *BB* are mounted upon a polished wooden base. A resistance wire *W* is connected between the binding posts, passing over a pulley *P*. By means of the thumb screw *T* the wire can be drawn to the desired tension. A bridge *R* designed to slide along the brass guide *G* short-circuits the two sides of the wire *W*, thus changing the resistance between the binding posts *BB*. The circuit wires and the current vibrator leads are both connected to the binding posts *BB*, but to different

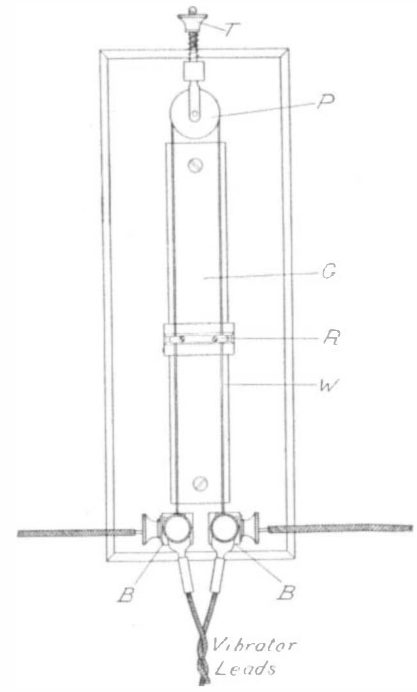


Fig. 5.

thumb screws. By changing the position of the bridge *R* the amplitude of vibration may be increased or decreased as desired.

The shunt is ordinarily designed to carry a maximum current of 10 amperes, but it will produce a full-scale deflection with a current as small as 2 amperes. Intermediate adjustments are, of course, easily obtained. The distinct advantage of a shunt of this type is that if the bridge *R* should make poor contact or even become separated entirely from the wire *W*, the shunt does not become open-circuited, thus causing the entire current to pass through the vibrator, burning it out.

Fig 1 shows the approximate positions of the oscillograph units when arranged for projection upon the screen. The light projected from the arc lamp 1 in small parallel beams strikes the two vibrator mirrors and the auxiliary or zero-line mirror at 2. It is then reflected to rotating mirror 3, which draws the vibrating beam into a wave and reflects it on the screen. Good results may be obtained if the screen is not more than 12 feet from the rotating mirror. Under these conditions the amplitude of vibration is about 12 inches each side of the zero line. If a sharper and clearer image is desired, the screen may be moved nearer the mirror, but the amplitude of vibration is proportionately reduced.

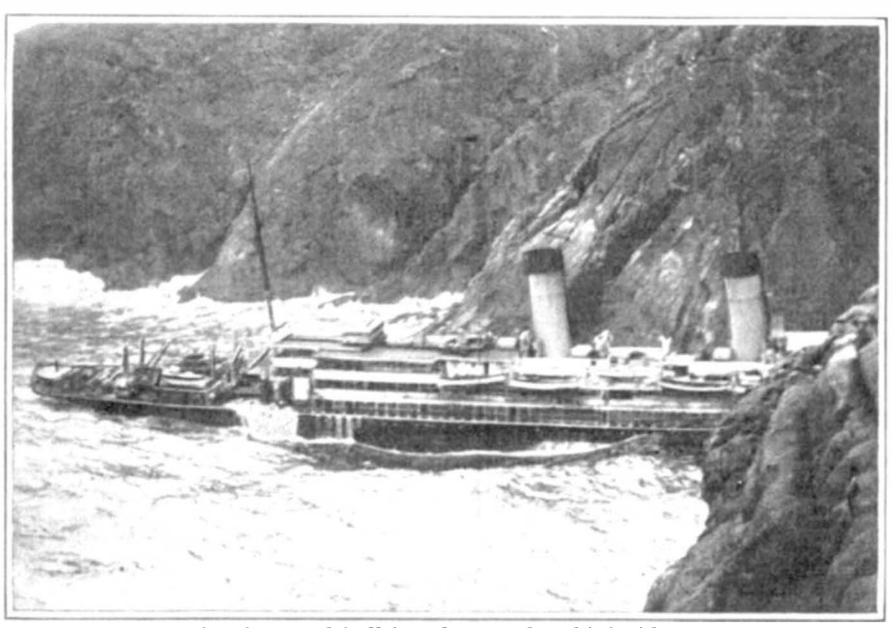
A Marine Disaster on the Coast of China

The steamship "Chiyo Maru," one of the largest Pacific liners, owned by the Toyo Kisen Kaisha, recently went aground off Hong Kong. Her position is shown in the accompanying illustrations of the disaster, a glance at which is sufficient to show that, though the upper works of this fine vessel are apparently intact, the hull of the ship is hopelessly wrecked.

This is apparent in the view taken from the cliffs looking down upon the ship from off her port bow, in which it is evident at a glance that the deck line of the ship from the bridge of the bow, is not in line with the after two thirds of the vessel. In other words, the "Chiyo Maru" is broken in two.

Evidently, when the ship ran aground the fore part of the vessel rested upon a projecting reef or shelf, the after two thirds of the ship being in deeper water. When the tide fell or, possibly, due to the rise and fall of the vessel in a seaway, the bending moment in the neighborhood of the bridge was too great for the strength of the ship, and a rupture occurred. The strength of ships to resist bending stresses is carefully calculated when they are designed, and the maximum stresses occur under certain conditions of loading and when the ship is supported at the ends, or in the center, as she is travelng transversely to the seas. These stresses are large; but they do not compare with those to which a ship is subjected when she is aground and unevenly supported.

We are indebted for our illustrations to Mr. W. Okada, of Yokahoma, Japan.



The shattered hull is submerged at high tide.

Some of the Essentials of Preparation

In general discussion of "industrial Preparedness" at the meeting of the American Society of Mechanical Engineers, it was stated by two members that: It has been shown that the weakest spot in the present war is the lack of ammunition. And in speaking of ammunition, we are not including small arms ammunition, but of the 1-inch to 16-inch calibers which is used by both the army and the navy.

Below are given some statistics of the time that it would take to get prepared and to make ammunition alone.

As a conservative estimate, it would require 50 engineers, designers and draftsmen at least 50 weeks to prepare the drawings for the sizes of shells now used by the United States Army together with drawings for gages, jigs, fixtures and tools. To produce the latter would probably require 800 men, well trained and in well organized factories, at least five years, calculating 300 working days per year.

This would equip 100 factories, each employing 2,000 men, capable of producing a total output of 200,000 rounds per day. Twice this amount has been used in a single day in the present war by one of the combatants.

We have not mentioned the question of aeroplanes, rifles, battleships or a large number of other important parts of equipment which must also be provided for in great numbers and which require a long time to build.

The Reform of the Man of Science

SOME correspondence has recently appeared in the *Morning Post* under the title that stands at the head of this article. Lt.-Col. J. W. Barret, of the Australian Army, a Melbourne doctor, well known for his active participation in the educational world there, writing respectfully of British men of science, laments their exclusiveness. They are, he implies, too much dominated by the idea of studentship; they regard the sphere of science too much as that of the laboratory and the academy; they do not acknowledge brotherhood with men in the greater world, who, in the spirit of enterprise and with the kind of method that prevail in conventional science, are solving great problems of industry, commerce, and national development. Another writer goes further, and would hail as a brother in science the man who elucidates the authorship of Shakespeare's plays or the technique of an old master.

It is not proposed here to enter upon a discussion of the legitimate use of the term science. We may be all for brotherhood, but the circumstances of life compel us largely to separate into groups for purposes of action, and there can be no real complaint if the word science is used in a restricted sense for what is perhaps better called natural science. This should not prevent men of science from recognizing their kinship with all faithful workers for the elucidation of truth, in whatever sphere of action.

Let us avoid a controversy about mere words. Lt.-Col. Barret's complaint is a more substantial one—not one of terminology. It is essentially this, that when operations relating to the forces of nature transcend a certain scale they are no longer recognized as science, and that men of science in the limited sense thus lose a great companionship and an invaluable link with the greater world. He gives as an illustration the work of a railroad president whose operations "involve the placing of towns and even cities in new positions, the reorganization of the agricultural education of districts, the estimation of future markets, and other complicated actions involving scientific imagination of the first order."

It is probable that most men of science would readily admit that some solid advantages would be gained by having in their camp these great operators, with all their intellectual energy, their enterprise, and their influence, and perhaps many would admit their claim to inclusion. There is undoubtedly a tendency for an increased scale of operations to remove a man from the scientific class if he was once in it, or to prevent his accession if he did not originally enter through the usual portal. The case may be well illustrated from engineering. A scientifically trained engineer who betakes himself to great problems of engineering, constructing some almost impossible railway or irrigating a whole parched province of India, seems to be moving away from science. An engineer who has acquired such powers without having received the hall-mark of formal scientific training, will find it hard to get his place acknowledged in the ranks of science.

We may ask, What is really at the bottom of this? Is it merely narrow-mindedness, or is there something more excusable? It is pleasant to think that there may be. Scientific men in their most august society are banded together "for the improvement of natural knowledge." They are by implication a body of students working in the temple of Nature for truth's sake alone, heedless of the world and its rewards. What they garner is their gift to the world: they fill another page in the Revelation that brings men nearer to the angels. Let a man wander into the world with his science as wares to sell for money profit, and he has passed from the true brotherhood. Surely this idea, perhaps here rather fancifully stated, is at the bottom of much of our exclusiveness. It is certainly expressed very often in the privacy of small deliberative councils and in personal intercourse, and it is strongly, though silently, operative in the outer world.

If this were the chief reason for the detachment of men of science we should have to ask whether it be really good and sufficient. That it has elements of good in it, no one would deny. There should be much strength in the union of disinterested people, and the flame of disinterested—that is, unworldly—study is the most sacred light of knowledge. But there is this great fact of history and actuality against an austere brotherhood: natural science has had its roots in the practical avocations of mankind, and from them it has received its chief stimulus. The application of science to the practical arts has not more benefited them than it has benefited science. In this place it is unnecessary to illustrate or amplify the argument. It is therefore not only not unbecoming, but it is vitally necessary that the improvement of natural knowledge should be bound up with solving the problems of the busy world, and the man of science who looks with any kind of disdain on those who are engaged in solving these problems, be they labelled brewer, baker, or candle-stick maker, and be they incidentally making fortunes, is despising his best friend and declaring himself a pedant.

As a matter of fact this disdain does linger. It is the inevitable product of the seminary; it is the fatuity of the cloister, arising, no doubt, from the theological beginnings of our educational system—this notion of keeping science unspotted from the world. It has much to answer for. The neglect of applied science—what is it not meaning now in the fortunes of our nation! It is comfortable for us to blame anyone but ourselves. Have we not long proclaimed the vital importance of science for the service of industry and the State? Industry and the State are doubtless much to blame, but surely no fair-minded person would say that the scientific world is exempt. Rather let us acknowledge that Lt.-Col. Barret is in essence right; the scientific world has been too exclusive; it has not bound itself as much as it might have done to great workers in the world, whose tasks, if not the same, are much akin to those of the laboratory, men whose sympathies, already scientific, would be strengthened by association and make broad channels for the flow of science into practice.

Scientific men, we must admit, have often no conception of the real environment and problems of the industrialist; of the accumulated store of empirical knowledge from which he must select what is needed; of the skill and design with which he must apply it under the limitations imposed by men, material, and markets. They, too, often underrate the extent and importance of what may be called technological science and the new horizons that it opens. The technologist is often ignorantly set in the outer courts of learning; he is not quite of the elect, and antipathies arise. How much have we not sacrificed of the acceptance and efficacy of science in industry by offering young men trained in pure science and knowing nothing of manufacture, to employers trained in manufacture and knowing nothing of science, relying wholly on the manufacturer for a most difficult and precarious adjustment?

The management of our applied science has become one of the great problems of the day, and it brings with it great difficulties. Spurious technology is a hateful make-believe that has already wrought much mischief; a man, however scientific, wholly on the make—to use a concise vulgar term for a vulgar condition—is an unedifying spectacle. But it does not follow that because a man is preoccupied with industrial problems he shall lose his scientific virtue or that his achievements, however remunerative, should rank on a lower plane. It is not so difficult to distinguish the genuine from the base among scientific workers wherever they may be engaged.

We must strengthen the bonds between science and industry by something more than an appeal to the pocket. A real sympathy and interest must be created on both sides; we must open our arms wider. There are many men in our world of industry and in the service of the State who, without any list of scientific memoirs to their name, have yet been potent in the service of science, and would be more potent still if they were brought more into companionship with the scientific world. The Royal Society has the power of admitting to its ranks at the rate of one each year "persons, who, in their opinion, have either rendered conspicuous service to the cause of science or are such that their election would be of signal benefit to the Society." Here at least is a limited opportunity of doing something towards introducing into the circle of science the sort of men whose influence might help towards bringing about the reform to which we are bidden by a candid friend. In any of the new associations that are contemplated for giving science its right place in our national life we shall surely do well to cast our net widely and to extend our outlook beyond the conventional circumstance of what have usually been deemed scientific circles.—From *Nature.*

Education and Preparedness

IN a recent address before the Political Economy Club, of London, Sir Hugh Bell, who is prominent in the iron industry of England, made some pertinent remarks that are equally applicable in the United States. He said that the industrial advance of Germany since 1870 has been the fruit mainly of "the German system of education," which "put into the hands of the German manufacturer the means of conducting his operations in a thoroughly scientific way." "Very carefully trained chemists were turned out of the technical schools by hundreds," and the manufacturers "had the good sense to make use of the materials thus provided." "The field of inquiry was quite new, and offered boundless opportunities of research," and it was vigorously exploited, with the result which the war has made only too plainly evident. Alluding to the manufacture of dyes, regret is expressed that a great new branch of industry has passed from British control, but in this matter blame is laid upon the Government, both central and local, in the enactment of unwise restrictions, the effect of which, as, for example, in the instance of alcohol, has resulted in the serious hampering of industrial development. The great industrial prosperity of the country has also produced an attitude of indifference to scientific discovery in this and other countries, which, in the case of the latter, has silently but none the less surely laid the foundation of great industrial enterprises.

SCIENTIFIC AMERICAN SUPPLEMENT

Founded 1876

NEW YORK, SATURDAY, JUNE 24th, 1916.

Published weekly by Munn & Company, Incorporated
Charles Allen Munn, President; Frederick Converse Beach, Secretary; Orson D. Munn, Treasurer;
all at 233 Broadway, New York

Entered at Post Office of New York, N. Y., as Second Class Matter

The Scientific American Publications

Scientific American Supplement (established 1876) per year $5.00
Scientific American (established 1845) . . . . " 3.00
The combined subscription rates and rates to foreign countries, including Canada, will be furnished upon application
Remit by postal or express money order, bank draft or check

Munn & Co., Inc., 233 Broadway, New York

The purpose of the Supplement is to publish the more important announcements of distinguished technologists, to digest significant articles that appear in European publications, and altogether to reflect the most advanced thought in science and industry throughout the world.

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