

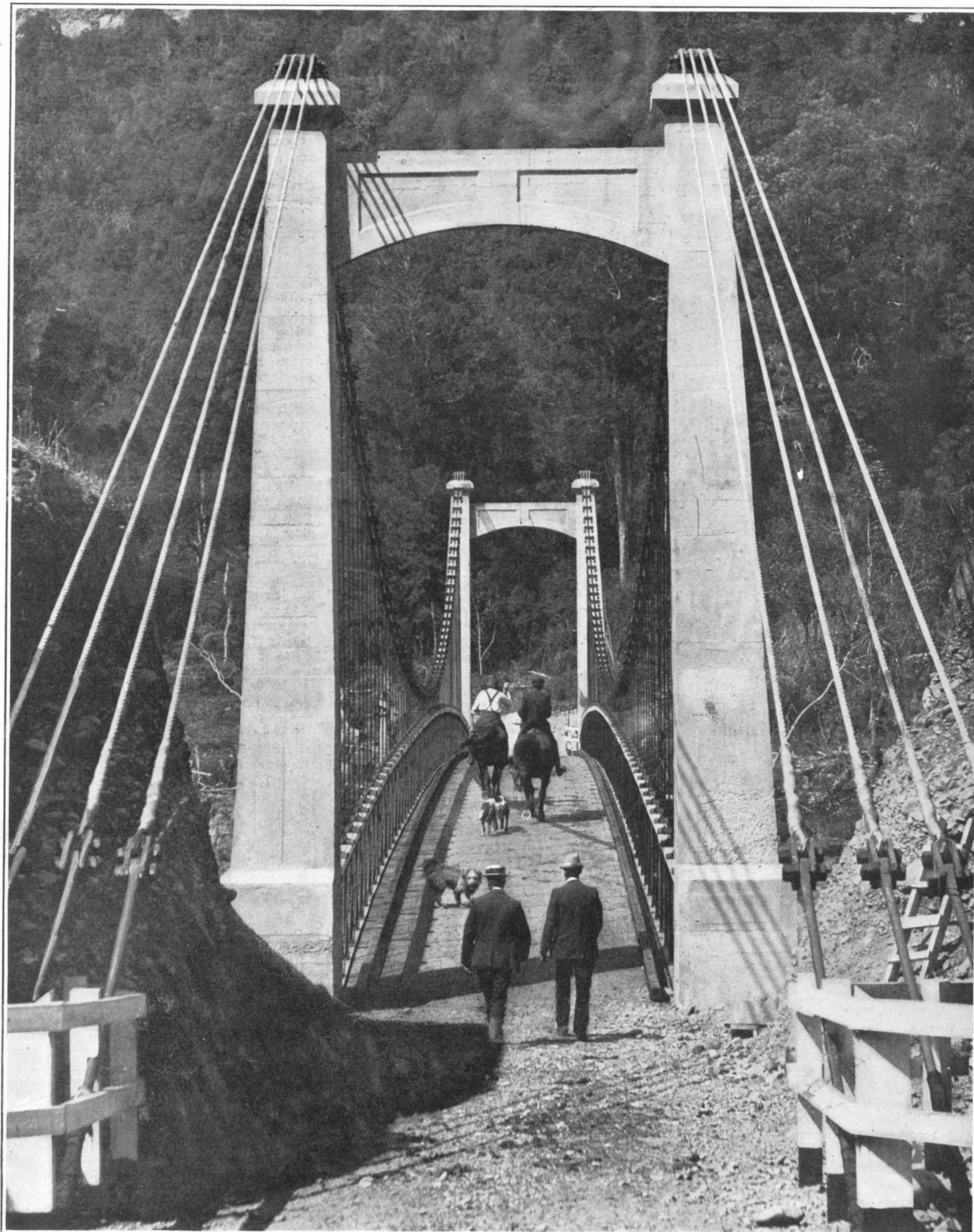
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An attractive suspension bridge of simple design that spans a chasm 170 feet deep.

BRIDGE BUILDING IN NEW ZEALAND.—[See page 152.]

Extension of the Spectrum Beyond the Schumann Region—I*

Difficulties Encountered and Methods of Procedure Followed

By Theodore Lyman, of the Jefferson Laboratory, Cambridge

I HAVE recently published a brief statement of the result of my investigations on the extension of the spectrum.¹ Since the appearance of that article my researches in this field have been directed toward clearing up certain doubtful points. Although these experiments have not resulted in pushing the spectrum beyond the limit already announced, and although the investigation is by no means at an end, it now seems time to make a fuller statement than was possible in a preliminary notice. Such a statement is all the more desirable since an understanding of the difficulties which have been encountered is necessary if one is to estimate the probability of future progress. The first part of this article, therefore, will be found to contain substantially the same material as the earlier notice, while the later parts are devoted to a rather detailed description of the experimental procedure.

The violet limit of the spectrum determined by direct eye-observation lies in the neighborhood of λ 4000; with a glass prism and lenses, the spectrum may be followed photographically to λ 3000 or thereabout; with a quartz system or with a reflecting grating, the limit may be pushed to λ 1850. Victor Schumann showed that the absorption of the air and of the gelatine of the photographic plate were responsible for the abrupt termination of the ultra-violet spectrum near λ 1850. By employing a vacuum spectroscopic and a special photographic plate, the emulsion of which was very poor in gelatine, he was able to push his observations to λ 1230. At this point he was stopped by the opacity of the flourate of which his lenses were made. I have employed a concave diffraction grating arranged in such a manner that the lightpath from the source to the photographic plate is wholly in gas. Briefly, the containing apparatus may be described as a brass tube about 11 centimeters in diameter and rather over a meter long.² This tube is closed at each end by brass plates ground to fit suitable flanges. In my most recent experiments the light is generated electrically in a discharge tube of quartz provided with tungsten electrodes. This discharge tube fits air-tight on one of the two brass plates just mentioned; light from it, having passed through a slit, traverses the length of the apparatus and falls upon the diffraction grating by which, having been analyzed into its component colors, it is brought to focus on a special photographic plate placed in close proximity to the slit.

As the discharge tube is in no way separated from the body of the spectroscopic, it is obviously necessary to choose for the experiment some gas which will not only yield radiations in the region under investigation, but which will be transparent to these radiations. My earlier experiments were conducted with hydrogen, since it had shown the necessary characteristics in that part of the spectrum investigated by Schumann. With this gas at a pressure of 2 or 3 millimeters and by employing a strong disruptive discharge, in May, 1914, I was able to extend the spectrum³ to λ 900.

A rather tedious investigation having convinced me that nothing more was to be expected from the use of hydrogen, at least in this neighborhood, I turned my attention to helium, being guided by some of my earlier experiments which had proved that this gas possesses the necessary transparency.⁴ At the same time I made some improvements in my apparatus which, though they left its general form unchanged, resulted in making it far more air-tight than ever before. The success of this improvement may be judged by the fact that I have been able recently to leave the spectroscopic for over fourteen hours at a pressure of about 3 millimeters without being able to detect any leak, either by a McLeod gage reading to 0.007 millimeter or by the appearance of impurities in the spectrum of the gaseous content. I also took particular pains to purify the helium which I employed.

I have been rewarded for my trouble by a very considerable extension of the spectrum, for with helium free from nitrogen, at a pressure of 2 or 3 millimeters, by the use of the disruptive discharge, and with an exposure of about 10 minutes, I have repeatedly ob-

served a number of new lines, the most refrangible of which has a wave-length of 600 \AA . All this has been accomplished with a grating ruled on speculum and with photographic plates prepared exactly as recommended by Schumann. The line λ 600 represents an extension beyond Schumann's limit greater than that which Schumann himself achieved beyond the region of λ 1850.

The relations of the spectra of hydrogen and helium have recently come into prominence through the theoretical researches of Bohr, Nicholson, and others. It so happens that the region on the more refrangible side of λ 1250 offers an important ground for the study of these relations. In order that the conclusions may be of value, however, it is necessary that the gases under observation should be free from impurities. In the best form of closed discharge tubes the difficulties, arising from the contamination of the gas by the material of the tube or by the electrodes, are very considerable, especially when a disruptive discharge is used. In my apparatus, where the brass spectroscopic and quartz discharge tube communicate directly, these difficulties are considerably increased. I trust in time to overcome them, but for the present I must confine myself to the following statements.

Prominent in the spectrum of hydrogen is the line at λ 1216 which forms the first member of a series predicted, on theoretical grounds, by Ritz.⁵ I have also found the two next members near λ 1026 and λ 972. With pure hydrogen, λ 972 is not visible and λ 1026 is best seen when a disruptive discharge is used, but singularly enough, with helium containing a trace of hydrogen, both lines occur quite strongly with a simple alternating current from a 60-cycle transformer. This may be an illustration of the curious behavior of helium, for an atmosphere of this gas seems to facilitate the production of the spectra of other gaseous substances which occur in it as impurities.

In addition to these lines predicted by Ritz there are a number of others of equal prominence which always appear with a disruptive discharge in hydrogen. Two of these are of special interest, for their frequencies may be calculated rather exactly from the formula:

$$\nu = N \left\{ I - \frac{I}{(n + 0.5)^2} \right\}.$$

They persistently occur at λ 1086 and λ 929. Though the matter is perhaps not entirely settled, all the evidence seems to indicate that the two lines in question are due to an impurity.

The radiations from atmospheric nitrogen and from argon have also been examined. With both substances the disruptive discharge is necessary to produce the best results. The spectrum of the former gas with this type of excitation possesses some strong lines between λ 1050 and λ 1250; the spectrum terminates, however, near λ 975. With a simple 60-cycle alternating current, argon shows a spectrum terminating near λ 915. The extent of its spectrum is thus superior to that of hydrogen or of helium when subjected to similar electric conditions. With a disruptive discharge argon gives a strong spectrum of many lines terminating abruptly near λ 800.

As far as I am able to observe, with one exception all the lines seen with helium when excited by a non-disruptive discharge are also found in hydrogen; a disruptive discharge is necessary for the production of the new lines of extremely short wave-length. The intensity of these lines seems to depend in a critical way on the electrical conditions in the exciting circuit, for it is only when the pressure in the discharge tube, the external spark-gap, and the capacity are all nicely adjusted that the extreme lines appear to the best advantage. The nature of the adjustments suggests that the radiations of the shortest wave-lengths require for their production that the atoms or molecules within the gas possess a very high velocity at the moment of collision. Some of the points in the preceding paragraphs are illustrated in the accompanying plate.

Spectrum *a* is the spectrum obtained from hydrogen when a spark-gap of about 3 millimeters is placed in series with the tube and when a capacity of 0.014 microfarad is shunted across the terminals of the transformer. Pressure about 1 millimeter. Time of exposure about 12 minutes.

Spectrum *b* is the spectrum of helium containing hydrogen under the same electrical conditions as for spectrum *a*. Pressure 1.7 millimeter. Time of exposure 8 minutes.

Spectrum *c* is the spectrum of hydrogen excited by a 60-cycle alternating current, there is no capacity in the system beyond that of the leads; current about 15 milliamperes. Pressure 2—3 millimeters. Time of exposure one hour.

Spectrum *d* is the spectrum of helium under the same electrical conditions as for spectrum *c*. Pressure 2.2 millimeters. Time of exposure 30 minutes.

The extreme lines in the helium spectrum are probably not visible in the reproduction. The scales are intended only to give the position of the lines approximately. I crave the reader's indulgence for the blemishes which disfigure the spectra; they are almost unavoidable under the conditions of the experiment.

The wave-length of the X-rays, as determined by the Braggs, is of the order of one angstrom. There is therefore a gap of some 600 units between the region of the ordinary Roentgen rays and the limit which I have reached. Several attempts have been made recently to produce less refrangible X-rays, but there is no satisfactory way of estimating their wave length unless perhaps one relies on the Planck-Einstein formula $Vc = h\nu$. Taking V as the potential drop which gives the cathode particle the velocity necessary to produce a very soft X-ray, e as the charge on the particle, and giving to h the usual value ascribed to Planck's constant, the experiments of Dember⁶ were made to yield a wave-length for the X-ray longer than that which I have determined. Such speculations, though they are very interesting, cannot be given any great weight. There is still a considerable region between λ 600 and wave-length 1 angstrom which must be experimentally explored. My present limit is probably due rather to difficulties of technique than to any fundamental fault in method. Now that we know that a Schumann plate can be used and that the speculum grating is efficient, I see no insuperable difficulty to a still further extension by purely spectroscopic means.

The following pages contain a detailed description of my experimental procedure. A table of the wave-lengths of the lines is given at the end of the paper.

The vacuum grating spectroscopic with which this research has been carried out has been already fully described.⁷ The changes on which the success of the present research largely rest are simple in character, but of fundamental importance. Their object was to improve the air-tightness of the containing vessel and to guard the purity of the gas content. To this end, the plate which closed the working end of the container was of the simpler form used in my earlier work. It was of brass 1.3 centimeters thick, ground to fit the flange which it was destined to cover; of its two windows, one was permanently provided with a quartz disk through which comparison spectra were obtained, the other was fitted with a cup into which a brass cone, destined to carry the discharge tube, was ground. The plate was attached to the flange of the spectroscopic in the following way: A string of pure beeswax, some 2 millimeters in diameter, was bent into a circle of the required size; the flange of the receiver was then slightly warmed and the wax was lightly pressed against it; a photographic plate having been put in place, the face plate, also slightly warmed, was pressed against the wax. On the receiver being exhausted, the pressure of the air forced the face plate against the flange and thus squeezed the wax into a thin gasket. This device was suggested to me by Prof. R. J. Strutt; by its means it has been possible to reduce the leak in the apparatus to a value far smaller than I have been able to attain by any other method. An example of its efficiency has already been given. As a high degree of air-tightness is fundamental to the success of the whole research, the importance of the wax gasket is evident. It is obvious that the nature of the arrangement just described necessitates the removal of the face plate whenever the plate-holder is to be withdrawn from the apparatus. At present there seems no escape from this rather inconvenient procedure.

In order to secure radiations of the shortest wave-

*Lyman, "Spectroscopy," p. 108.

⁷Lyman, *op. cit.*, p. 34.

¹The Astrophysical Journal.

²Proceedings of the National Academy of Sciences, 1, 368, 1915; *Nature*, 95, 343, 1915.

³Lyman, "Spectroscopy of the Extreme Ultra-Violet" (Longmans, Green & Co.), p. 34.

⁴*Ibid.*, p. 78; *Nature*, 93, 241, 1914.

⁵*Ibid.*, p. 69.

⁶W. Ritz, *Gesammelte Werke*, p. 105.

length, it is necessary to employ a disruptive discharge; under these electrical conditions the gas-filling is always more or less contaminated by material torn from the discharge tube. To reduce this cause of error, quartz has been employed in place of glass. A change of form as well as of material has also been made, for the internal capillary type, so well suited to some previous investigations,⁸ cannot be employed when a violent disruptive discharge is used, because the propinquity of the end of the capillary to the inside of the spectroscope encourages a spreading of the discharge with a consequent fatal fogging of the photographic plate. The form of discharge tube finally arrived at was of the simple "end-on" type with a capillary 4.5 centimeters and about 3 millimeters in diameter. The tungsten electrodes, provided by the kindness of the General Electric Company, were in the form of cylinders 1.5 centimeters long and about 3 millimeters in diameter. They were bound with fine tungsten wire to stouter wires of the same material which, in turn, were clamped in brass rods. These rods, covered with quartz sleeves, were contained in legs of the discharge tube and were sealed into these legs with Khotinski cement, the seals being kept hard by baths of mercury. The object of this arrangement was to restrict the electric discharge to the tungsten alone in the hope that thereby the contamination of the gas might be reduced to a minimum. The whole discharge tube thus constituted was sealed into a brass cone which, in turn, fitted air-tight into the cup on the face plate.

It is well known that tungsten if properly treated can be freed from occluded gases; this material, therefore, if employed for electrodes in a discharge tube, affords an escape from the contamination of the gas by the hydrogen which is so freely given off by most metals. In practice, I have found tungsten far more satisfactory than any other material which I have employed, always provided that it has been freshly treated.

Atmospheric nitrogen, argon, hydrogen, and helium have been used in this investigation. I am indebted to my colleague, Prof. Baxter, for the first-named gas. It was free from impurities save for those rare gases whose presence its atmospheric origin rendered inevitable.

I am indebted to the General Electric Company for my sample of argon. They informed me that the gas contained less than 1 per cent of impurity. As judged by spectroscopic observations in the visible spectrum, some hydrogen and a trace of nitrogen were present.

The hydrogen employed was prepared by electrolysis from amalgamated zinc and hydrochloric acid in an automatic generator of special type.⁹ This method was recommended to me as one of the best available. After passing through towers of fused potassium hydroxide, the gas was collected over water. It was found necessary to prepare the hydrogen immediately before it was required for use, for, by standing over water, it is sure to become contaminated with air. Before being introduced into the phosphorous-pentoxide drying system, the gas was passed over platinized asbestos heated to redness in a quartz tube to insure the removal of the least trace of oxygen. A delicate test for the presence of a trace of air in the spectroscope is afforded by the appearance of the nitrogen lines near λ 5005 with disruptive excitation. Judged by the appearance of its visible spectrum the hydrogen seemed free from impurities.

The helium employed has been obtained from three sources. The first sample was prepared from cleveite in the usual way and was purified over charcoal plunged in liquid air; the second was obtained from Professor Cady, of the University of Kansas; the third I owe to the generosity of Professor Boltwood. This last specimen I treated with pyrogallic acid and then passed over hot copper, then over hot calcium, and finally it was exposed to charcoal and liquid air. All the specimens were free from nitrogen and oxides of carbon, but contained a trace of hydrogen. Charcoal cannot be trusted to remove the last remnant of this gas, but as the helium was bound to be exposed to some admixture of hydrogen from the walls of the spectroscope and from the discharge tube, it seemed useless to go into the greatest refinement of purification at the present stage of the investigation. It must be noted that after the gas had been admitted to the spectroscope it sometimes showed a trace of oxides of carbon, but it appeared to be free from nitrogen.

About 100 cubic centimeters of helium are necessary for a single experiment; part of this gas is used in washing the spectroscope and part in the final observations.

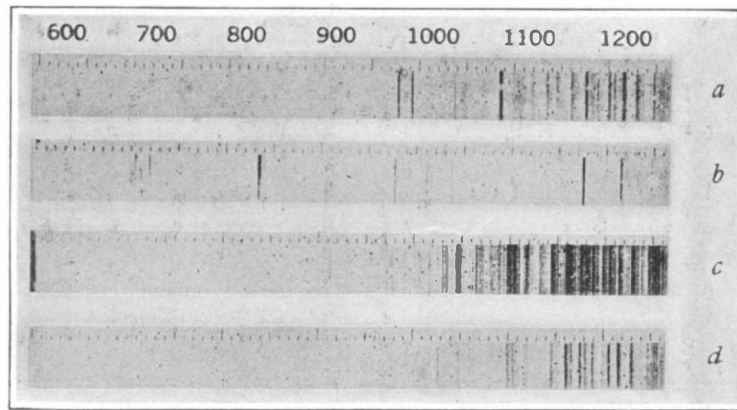
In order to guard the spectroscope from mercury and to reduce the presence of hydrocarbons as far as possi-

ble, a U-tube with legs, each about 35 centimeters long, was plunged in liquid air and interposed between the spectroscope receiver and the rest of the system; this latter consisted of the gas reservoir, the McLeod gage, and the Trimount oil pump.

When a disruptive discharge was required, the current was obtained from a $\frac{1}{2}$ kilowatt Clapp-Eastham transformer run from a 60-cycle, 110-volt circuit. A capacity of 0.014 microfarad was placed across the terminals of the secondary, while a spark-gap of about 3 millimeters was used in series with the discharge tube. Under these circumstances, the equivalent spark-gap between needle-points at the discharge tube was 8.5 millimeters. When the non-disruptive discharge was employed, the current through the tube was of the order of 15 milliamperes.

With the idea of eliminating altogether the difficulties which arise from the introduction of electrodes into a radiating gas, some attempts have been made to use the electrodeless discharge. In this experiment a Chaffee gap¹⁰ was connected in series with the primary of a Tesla coil, the arrangement thus formed being shunted by a condenser which, in turn, was placed across the leads of a 500-volt circuit, one of the lines of which contained a choking coil. The capillary discharge tube was provided with armatures of tinfoil at either end and these were connected to the secondary of the Tesla. Thanks to the regular behavior of the Chaffee gap, a very brilliant and steady illumination resulted.

The successful reconnaissance of Saunders¹¹ into the region of extremely short wave-lengths suggested the advisability of trying a calcium arc in quartz. The arrangement was very similar to that described by



Photograph of Spectra obtained by the apparatus described

Saunders except that the lamp was operated from the 500-volt circuit. The chief technical difficulty arises from the rapid deterioration of the quartz. In these experiments magnesium as well as calcium electrodes were employed.

If of the many experimental difficulties of the subject there is one which seems at present more troublesome than the others, and to which the limit of the spectrum may be directly traced, it is a luminosity in the gas content of the spectroscope excited by the disruptive discharge. The phenomenon makes its appearance when the pressure is of the order of 1 millimeter and produces a background of fog on the photographic plate in which faint lines are lost. This luminescence is especially aggravating since the low pressure at which it appears seems particularly favorable to the production of the lines of the very shortest wave-length. As a result of this difficulty long exposures are out of the question. It seems probable that if a window could be interposed between the discharge tube and the spectroscope, the excited luminosity would vanish.

Unfortunately, material for such a window is not at hand. A test with a bit of fluorite 1 millimeter thick, of proved transparency in the Schumann region, showed that this substance was opaque from λ 1230 to the extreme end of the spectrum at λ 600. A similar test with quartz 0.5 millimeter thick demonstrated that this substance shows no signs of transparency in the extreme ultra-violet.

Lyman¹² has interpreted some of his experiments on the ionizing power of light from an aluminium spark as proving the existence of radiations from this source lying on the more refrangible side of the quartz absorption band and transmitted to some extent by air. I have made an attempt to find these radiations by placing an aluminium spark in air outside my spectroscope and about 2 millimeters distant from a quartz window 0.2 millimeter thick which closed the apparatus. The result of the experiment was entirely negative, the adjustment of the apparatus being such that the field covered by the photographic plate extended to λ 250.

¹⁰E. L. Chaffee, *Proceedings of the American Academy*, 47, 270, 1911.

¹¹*Astrophysical Journal*, 40, 377, 1914.

¹²Lyman, *op. cit.*, p. 107.

After this account of the apparatus and the methods employed, it seems important to discuss the various spectra in some detail, paying particular attention to the circumstances under which they were produced.

(To be continued.)

Purification of Running Water by Ozone

THE Prussian city of Königsberg has established an experimental laboratory in water purification, in which there has been developed a process of ozonization at once cheap and effective. The raw water, of yellowish color and often muddy, is first freed of silt and discoloration by treatment with aluminium sulphate in the proportion of 80 grammes per cubic meter, and by gravel filtration. The water is then run from below into a de Frise tower, a small portion being deflected, mixed with ozone in a compressor, and let into the tower on the opposite side.

In order to ascertain the limits of the tower's conductivity, there were introduced into the water enough coli-bacilli to give it a germ content of from 30,000 to 9,000,000 per cubic centimeter; and after each such injection the number of germs still alive after passage through the tower was determined. These tests confirmed the suspicion that the ozone in the tower was not being sufficiently well mixed with the water—that in addition to the many tiny bubbles desired, others were being formed, the size of a cherry, or even larger, which passed through the tower so rapidly that all effect upon the germs was lost.

In order to bring about closer contact of water and ozone, the two lowest celluloid sieves of the tower were covered with a layer of small pebbles and gravel to a depth of 25 centimeters. After this alteration, the bacteriological effect of the tower was excellent; the use of 5.4 grammes of ozone per cubic meter of water reduced the number of germs from nine million per cubic centimeter to ten. Even with a proportion of ozone of only 1.8 grammes per cubic meter, very good results were attained. This was likewise the case even when the water was run through the tower without previous treatment with alum, and without filtration; and also when the bacteria were not single, but in clusters.

It appears that the strength of the ozone is not so much of prime importance as is the reduction to a minimum of the thickness of the sheet of water between two gas bubbles. It is vitally necessary that the ozone shall circulate rapidly through the water, replacing that which has been used up in oxidizing the bacteria and other organic matter.

By simultaneous use of alum and ozone, under this method, it is found possible to convert water of very high organic content into a clear, colorless drinking water with no taste whatever, very free from germs, entirely free, in fact, from pathogenic ones. In every case the result of ozonization is distinctly to be preferred to that of the chlorine treatment; and the increased cost is very slight.—*Die Umschau*.

Behavior of Iron Toward Water and Aqueous Solutions in the Steam Boiler

EXPERIMENTS were made under normal working conditions, at a pressure of 15 atmospheres, in an experimental boiler of about 30 liters capacity, using test plates of mild steel of 400-500 grammes weight suspended from the cover of the boiler. The electrolytic method of removing rust, described by Jakob and Käsbohrer (this J. 1911, 1063), proved useful for determining the amount of corrosion. Freshly-boiled distilled water, free from carbonic acid, produced the least corrosion. Sodium carbonate in small concentrations caused rusting, but in concentrations above 1 per cent showed a pronounced protective effect. Zürich tap water corroded the iron to a greater extent than ordinary distilled water. Sodium hydroxide showed a protective action even at a concentration of only 0.01 per cent, while at 0.1 per cent it prevented corrosion entirely. Sodium hydroxide is formed slowly from sodium carbonate in the steam boiler, and this accounts for the fact that small proportions of sodium carbonate, which produce corrosion at first, exert a protective action after some time. Of the salts which may occur in boiler feed water, chlorides and magnesium salts are specially active in causing corrosion; sodium carbonate at a concentration of at least 1 per cent is an effective protective agent. Sodium hydrosulphite exerts a protective action when added in small quantities, but at a concentration of 1 per cent causes pronounced corrosion of boiler plate even in presence of sodium carbonate.—*E. Bosshard and K. Pfenninger. Abstract from Jour. of the Soc. of Chem. Ind.*

⁸Lyman, *op. cit.*, p. 41.

⁹Cook and Richards, *Proceedings of the American Academy*, 23, 149, 1887.

Monochromatic Photography of Jupiter and Saturn*

Some Results of Experiments With Various Kinds of Ray Filters

By R. W. Wood, Johns Hopkins University

In the *Astrophysical Journal*, 36, 75, 1912, I gave an account of the results obtained by photographing the moon through ray-filters transmitting limited regions of the spectrum. Marked differences in the distribution of light and shade were observed in the different pictures, the most conspicuous being an extensive dark deposit around the crater Aristarchus, which appeared in the picture made by means of ultra-violet light but was quite absent in the one made by the yellow rays. Laboratory experiments on the appearance of various rocks and minerals, when photographed through these same ray-filters, made it appear probable that the dark spot was due to sulphur or usually some sulphur-bearing rock.

It seemed quite likely that results of even greater interest would be obtained if the method of monochromatic photography were applied in the case of planets, but instrumental facilities were not at my disposal at the time.

These earlier experiments were made with a 16-inch nickeled glass mirror of 26 feet focus, mounted on the equatorial of the Princeton Observatory, which unfortunately was not adapted to the very accurate guiding necessary in work of this nature. As it appeared probable that increased definition and magnification would bring out regions of smaller area showing selective reflection, and as there was every reason to suppose that the planets would show peculiarities worthy of study, I determined to repeat and improve upon the earlier experiments. In this work I have been aided by a grant of \$200 from the Gould Fund of the National Academy. The preliminary experiments were made at East Hampton, during the past summer.

The Naval Observatory placed at my disposal a very good Gaertner coelostat, which was used in conjunction with a horizontal reflecting telescope of 56 feet focal length and 16 inches aperture, figured by Mellish and nickeled by the electrolysis of a dilute solution of nickel fluoborate as described in the *Astrophysical Journal* for November, 1915 (42, 365). The nickel deposit was necessary, since silver reflects only about 4 per cent of the light in the ultra-violet region of the spectrum utilized in the work.

A new mirror cell was made for the coelostat, large enough to carry a 16-inch flat, which was also nickeled, and the instrument mounted on a very solid pier of brick and cement, sheltered by a small house with a hinged roof. A double-slide carrier for the plate-holder and ray-filters, with two slow motions and two eye-pieces for following, was made of sheet brass, and mounted on a heavy pedestal of iron.

The photographs made with this apparatus, while distinctly better than those made with the 26-foot mirror, failed to show the very fine details which were desired. This was due partly to bad seeing and partly to the difficulty of following a rather rapid periodic oscillation or drift of the image originating in some small error or errors in the gear wheels which could not be located or remedied.

On this account it appeared best to study the behavior of the various ray-filters, and the spectrum range of the light after reflection from two or more surfaces of silver or nickel and transmission through the filters, rather than to waste time in trying to secure a more accurate drive of the coelostat. These experiments showed that it would be feasible to complete the work with a large reflecting telescope with silvered mirrors, using as an ultra-violet screen a cell filled with dense bromine vapor. Such a cell transmits the entire ultra-violet region below λ 3500, while silver reflects the region λ 3300-3500 sufficiently well to make photography possible in this region with silver-on-glass mirrors.

Photographs were made of the moon and Jupiter with infra-red, yellow, violet, and ultra-violet light, and the times of exposure, with the screen, were determined for both silvered and nickeled mirrors. As a result of this preliminary work, I was able to get satisfactory results at once with the 60-inch reflector of the Mount Wilson Observatory, which was placed at my disposal for four nights in the latter part of October.

With this instrument a very complete set of photographs was made of the moon, Jupiter, and Saturn, by light of the four regions of the spectrum referred to above. Results of very great interest were obtained in the case of the two planets, for dark belts were shown by violet and ultra-violet light of which no trace appeared visually or on the plates made by yellow light, while the infra-red pictures showed scarcely any trace of the belts ordinarily seen. By applying the methods of three-color printing to these plates we can produce a colored positive, in which the belts of selectively absorbing gases appear strongly colored; in other words, we produce an effect somewhat similar to what we should see if our eyes were sensitive to a wider spectral range.

In the earlier experiments, made several years ago, I used for the ultra-violet ray-filter a rather thick deposit of metallic silver on a thin plate of quartz or uviol glass. Silver films are, however, extremely opaque to the selectively transmitted region, which lies between λ 3000 and λ 3200, so much so that an exposure of two or three minutes is required for the full moon. With bromine vapor I found, however, that a fully exposed plate could be obtained in eight or ten seconds, and that if we use in addition a thin cell filled with a very dilute solution of potassium chromate, we obtain

supposedly reliable vacuum cement. The trouble was minimized by applying the wax to the outside of the cell only, after the glass plates were placed against the ends. The wax was rolled into thin cylinders between the fingers, and melted against the seam with a hot glass rod 2 mm in diameters. Cells prepared in this way showed no trace of the deposit for fifteen or twenty hours, and, as they were cleaned every evening and freshly filled, no further trouble was experienced from this source. Four or five drops of liquid bromine were introduced with a capillary pipette, and after vaporization was complete and most of the air expelled, which required a minute or two, the hole was closed with a plug of wax, touched with a hot glass rod.

The cell was 5 cm in thickness, and was clamped in position in front of the plate-holder by means of two brass set-screws. Exposure with the quartz spectrograph showed that such a cell was transparent from λ 3500 to the end of the solar spectrum ($\lambda=2900$), while it cut off completely all of the less refrangible rays capable of affecting an ordinary photographic plate.

If a more restricted region of the spectrum is required we may add a thin cell, say a millimeter or two thick, containing a very dilute solution of chromate of potash; the yellow color should be barely perceptible by daylight.

The correct dilution can be determined by trial only, the quickest way being to use sunlight filtered through the bromine cell, a quartz spectrograph, and a plate of uranium glass. If the solution is not extremely dilute, it removes all of the ultra-violet. If just right, it removes the region λ 3250-3500, the combination transmitting the same region as a thick silver film, but with a much greater intensity (about ten-fold). If the chromate-of-potash cell is used, it is necessary to give three or four times the exposure required with the bromine cell alone.

The infra-red screen transmitted the region above λ 7000, the yellow screen everything above λ 5000, and the violet the region between λ 4000 and λ 4500. These screens were prepared from stained films of gelatine made by the Eastman company, and mounted in balsam between thin sheets of plate glass. They were of such a size that they could be substituted for the thick bromine cell, and were held in place by the same set-screws.

The work at Mount Wilson was commenced on October 22. The double-slide carrier with its attachments for the bromine cell was adapted to the 60-inch telescope, so that the work could be taken up without the construction of any new apparatus. The early hours of the evening were spent in making plates of the moon, which was full at the time, through the four ray-filters, while the rest of the night was given over to the planets.

The telescope was used at the 80-foot focus, and, as the mirrors were silvered, the region of the spectrum utilized for the ultra-violet photography was slightly less refrangible than in the earlier work with the silver film. Preliminary experiments had been made at East Hampton with a quartz spectrograph, on the spectrum of sunlight after three reflections from silver and transmission through the bromine cell (the conditions which obtained with the 60-inch telescope).

The most interesting results were obtained in the case of Saturn. The picture taken through the infra-red screen showed the ball of the planet practically devoid of surface markings, there being only the merest trace of the belts ordinarily seen. Through the yellow screen the planet presented its usual visual appearance, the narrow belts showing distinctly. On the plates made with the violet ray-filter (transmission λ 4000- λ 4500) a very broad dark belt surrounded the planet's equator, occupying the region of the planet which was brightest in yellow light. In addition to this dark equatorial belt, a dark polar cap of considerable size appeared in the pictures. So different were the two pictures that, were it not for the ring, it would have been difficult to believe that they represented the same object. In ultra-violet light the appearance was much the same, but the dark belt was not quite as wide, the bright region between the polar cap and the belt being distinctly broader. Photographs

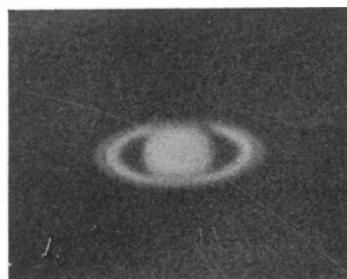


Fig. 1.—Infra-red.

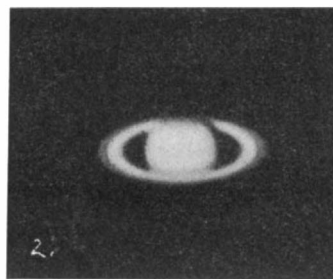


Fig. 2.—Yellow.

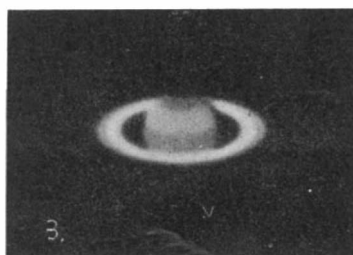


Fig. 3.—Violet.



Fig. 4.—Ultra-violet.

Monochromatic photographs of Saturn.

a transmitted region practically the same as with a silver film, but of about tenfold intensity. The silver film was accordingly abandoned in the present work and the bromine cell used exclusively in its place.

The cell was made by cutting a section from a square glass bottle and grinding the edges flat. A small hole was then drilled through the wall for the introduction of the bromine. The uviol plates (1 mm in thickness) were cemented with beeswax, which was found by Ribaud, in the course of his investigations on the absorption spectrum of bromine, to withstand the action of the vapor fairly well. A piece of asbestos paper, impregnated with a saturated solution of calcium chloride and strongly heated to drive off all of the water, was placed in the cell before the plates were cemented in position. This was necessary owing to the dampness at East Hampton, for, even when the bromine was thoroughly dried, moisture deposited on the inner surface of the uviol plates when the cell cooled off at night. After several hours there appeared also a deposit which resembled a light dew but which did not dry off when the plates were removed. It appeared to be of a greasy nature, and I attributed it to some volatile compound formed by the action of the bromine on the wax. I subsequently found it on clean glass plates which had been standing on my desk for several days, and was quite at a loss for an explanation until Dr. Mees, of the Eastman research laboratory, called my attention to the fact that beeswax sublimates quite rapidly, a circumstance which I had not suspected, as it is one of the constituents of a

*Contributions from the Mount Wilson Solar Observatory. No. 113. Republished from *The Astrophysical Journal*, May, 1916.

made with the four monochromatic filters are reproduced in Figs. 1 to 4.

Two hypotheses suggest themselves in explanation of the dark belt. We may be dealing with a fine mist or dust which forms an extension of the crape ring down to the ball of the planet. This hypothesis appears to be favored by the circumstance that, on the negatives made by the violet and ultra-violet light, the sky between the ball of the planet and the ring is distinctly denser than the region just outside. This would indicate that the region inside of the ring is filled with some material which reflects the short wave-lengths to a slight degree. No trace of this darkening appears on any of the plates made with the yellow screen, even on one that was many times overexposed, which appears to show that the phenomenon is real. This peculiarity was, however, not detected until the work was finished, and I should prefer to verify it or have it verified before recording it as an established fact. The luminosity is much too feeble to show in the prints.

Measurements of the density of the plates between the ring and the ball of the planet and the sky just outside of the ring have been made for me by Mr. Harold D. Babcock, of the Mount Wilson staff, with the Hartmann photometer. His results showed greater density between the ring and ball on both plates (yellow and ultra-violet, but the density was greater in the latter). His values for the densities are as follows:

Yellow Negative.

Sky outside of ring.....1.1
Sky between ring and ball.....1.17

Ultra-Violet Negative.

Sky outside of ring.....1.05
Sky between ring and ball.....1.27

One's first thought is that slight darkening of the region between the ring and ball may be the result of halation. It appears to me, however, that if this were the case we should expect the effect to be more marked with yellow light, which penetrates the film and the glass plate and is reflected back, while the ultra-violet light does not even get through the photographic film, as is shown by the circumstance that the image does not appear on the reverse side of the film with prolonged development, as is the case with ordinary light.

I do not, however, believe that the dark belt is in reality due to the absorption of a dust ring, for measurements made by Mr. Ellerman showed that the belt extended higher up on the ball of the planet than the line of intersection of the plane of the rings. Moreover, it seems highly probable that the belt and the dark polar cap are to be explained in the same way.

The second hypothesis assumes the existence in the planet's atmosphere of some substance capable of absorbing violet and ultra-violet light. This material might be a fine mist or dust, or some gas capable of absorbing the more refrangible part of the spectrum. Such a gas would be of a pale yellow color, and sulphur vapor and chlorine naturally occur to us. I have, however, examined the absorption spectrum of both of these gases in quartz bulbs, with the result that the absorption appears to be much stronger in the ultra-violet than in the violet, which is in disagreement with the circumstance that the band appears wider in violet than in ultra-violet light.

Two spectrograms of the planet have been made by Adams with the 60-inch reflector. In one, the slit of the instrument was parallel to the major axis of the ring and cut through the dark belt shown on the violet and ultra-violet photographs. In the other, the slit cut across the bright region above the belt. The spectra embraced the region between λ 5000 and λ 4000, and we should expect that between λ 4000 and λ 4500 the spectrum of the area occupied by the dark belt would be much darker (lighter in the negative) than the other. No difference could be detected, however, between the two negatives, except at the very end (λ 4000), where there was a very slight trace of the expected effect.

Of course it would be preferable to place the slit parallel to the short axis of the ellipse, and show the spectra of the two regions juxtaposed on the same plate, but the spectrograph available at the time did not permit of rotation. A quartz spectrograph is being planned for a more complete study of the question. The spectra were made in February, 1916, and it is of course possible, though hardly probable, that the ultra-violet belt had in the meantime disappeared.

Another point of interest is the decrease in contrast between the inner and outer ring as the wave-length is decreased. This suggests that the outer ring contains

so much finely divided matter that it shines in part by diffusion. On the infra-red photograph the ball of the planet is much brighter in comparison to the brightest part of the ring than on the violet and ultra-violet pictures. This again suggests a mist or dust in the planet's atmosphere which scatters the shorter wave-lengths. My infra-red photographs of landscapes have clearly demonstrated that we can obtain clear photographs through a blue haze by means of the spectrum region above λ 7200. In these photographs it will be remembered that the blue sky comes out black and the grass and foliage show white. (See *Physical Optics*, 2nd ed., p. 626.)

Photographs of Jupiter made with the four ray-filters showed differences almost as marked as those found in the case of Saturn, though not so striking by casual inspection. The rotation of the planet is so rapid that it was found necessary to make the series of pictures as quickly as possible, if comparable results were to be obtained. Following was accomplished by bringing one of the outer satellites on the cross-hair of the eyepiece in the movable plate-holder. The ex-

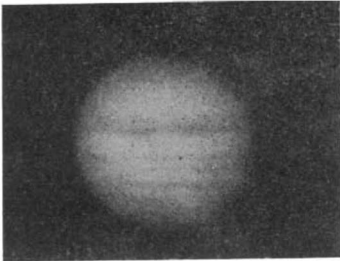


Fig. 5.—Infra-red.

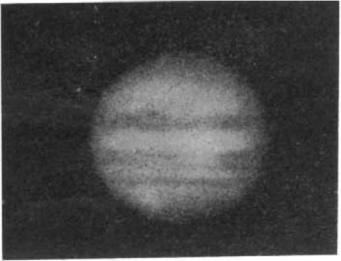


Fig. 6.—Yellow.

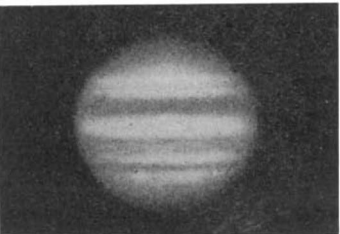


Fig. 7.—Violet.

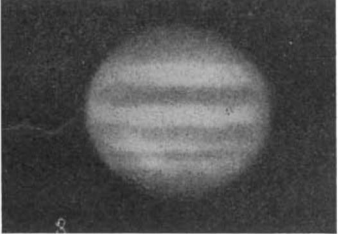


Fig. 8.—Ultra-violet.

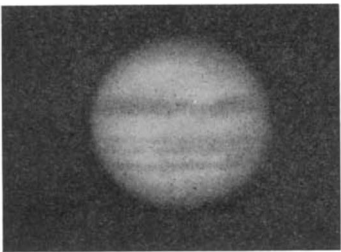


Fig. 9.—Infra-red.

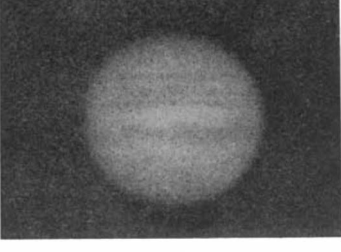


Fig. 10.—Yellow.

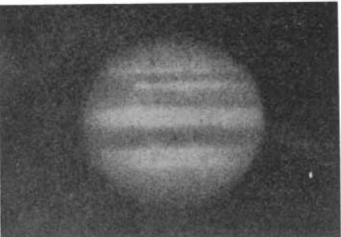


Fig. 11.—Violet.

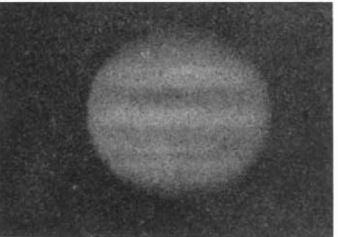


Fig. 12.—Ultra-violet.

Monochromatic photographs of Jupiter.

posure times were two seconds for the violet and yellow negatives, seven seconds for the ultra-violet, and ninety seconds for the infra-red. The dark belts are scarcely visible on the infra-red plates, while the pictures made with violet light show them in the greatest contrast.

This circumstance made it appear probable that very marked color contrasts would appear if the planet were viewed through a screen which transmitted deep red and violet light. The violet filter used in the work has this property, and through it the cloud belts appeared deep red on a violet background. Unfortunately the vivid color contrast obtained in this way is not of much help in the visual study of the planet, as the eye does not focus well for these two regions of the spectrum.

The appearance of the disk in the light of the four spectral regions specified is shown in Figs. 5 to 12. They were all made on the evening of October 24, 1915, between 7:30 and 9:30 Pacific time. The details are given in the accompanying table:

The direction of rotation of the planet is from right to left. On three of the plates slight blemishes have

been noticed which have nothing to do with the surface markings; a light spot on the broad dark belt near the left hand edge, Fig. 8; a small dark spot near the lower edge, Fig. 11; and a small dark spot on the broad edge, Fig. 11; and a small dark spot on the broad dark belt above the bright equatorial belt.

The chief differences between the views of the planet made by light of different wave-lengths may be summarized as follows: The infra-red pictures show less darkening of the disk as we approach the limb, which is what would be expected on the theory that the darkening results from atmospheric absorption or scattering. The cloud belts moreover are very inconspicuous in these pictures. The two dark belts above the bright equatorial belt have a number of still darker spots on them which are most distinct in the yellow picture, less so in the violet, and almost invisible in the ultra-violet (Figs. 10, 11, 12). Above this dark belt, a double bright belt appears in the violet and ultra-violet pictures, which cannot be seen in the infra-red and yellow pictures, or, to speak more accurately, the dark belt between them is visible only in the violet and ultra-violet. The upper dark polar cap shades off gradually in the yellow and infra-red views, but is sharply terminated in the violet and ultra-violet, its lower edge marking the upper boundary of the double bright belt. These are the chief peculiarities. Observers who have made a long study of the surface markings of Jupiter will doubtless find other points of interest, and I shall be glad to lend the original plates to anyone who wishes to study them in greater detail.

TRICHROMATIC PHOTOGRAPHS OF THE PLANETS.

By applying the methods of trichromatic color-photography to the negatives made through the ray-filters, very beautiful and striking transparencies have been made, which represent, in strong color contrasts, the differences which can be seen by comparison of the monochromatic photographs. As is well known, if three negatives are made of an object through red, green, and blue ray-filters, and the positives made from them on bichromatized gelatine are stained with blue, magenta, and yellow dyes, these positives when superposed in register yield a fairly faithful reproduction of the object in its natural colors.

If we apply this same method to pictures made by yellow, violet, and ultra-violet light, we shall obtain a colored picture of the object as it would appear if the region of the eye's sensitiveness were shifted slightly toward the ultra-violet, or, to put the matter in astro-physical language, as the object would appear if it were receding from us with a velocity sufficient to cause ultra-violet to appear violet! Color-photographs of Saturn made in this way show the ball of the planet yellowish in color, with a broad orange-red band (the violet and ultra-violet dark belt) surrounding the equator and a dark-red polar cap. The narrow belts, which can be seen visually and which appear on the negative made with yellow light, come out blue in the picture, the lower one being in coincidence with the upper edge of the dark belt. Owing to the fact that the dark belt is wider on the violet negative than on the ultra-violet one, the upper edge lacks yellow in the finished picture, and the superposed narrow blue belt appears purple in consequence (magenta+blue).

Color contrasts also appear in the ring, as a result of the circumstance that the outer or fainter ring is relatively more luminous in ultra-violet light. The inner ring appears white, and the outer bluish green. Similar colored belts are shown in the pictures made of Jupiter. The photographs as a whole give us a vivid impression that we are really dealing with great belts of selec-

Fig.	Ray-Filter	Time	Exposure	Plate
5.....	Infra-red	7:30	90 sec.	Spect. Panchrom.
6.....	Yellow	7:33	2	Cramer Iso. Inst.
7.....	Violet	8:15	2	Process
8.....	Ultra-violet	7:50	7	Process
9.....	Infra-red	9:20	90	Spect. Panchrom.
10.....	Yellow	9:23	2	Cramer Iso.
11.....	Violet	9:25	2	Process
12.....	Ultra-violet	9:30	7	Process

tively absorbing, and hence colored, vapors or gases. They show us moreover that the absence of strong color-contrasts in the surface markings of the planets results merely from the limited range of the spectrum to which the eye is sensitive.

In view of the interesting results obtained with these two planets, it is my hope that similar observations will be made on Mars, on the occasion of its next near approach to the earth.

The Action of Nitric Acid on Aluminium*

By R. Seligman and P. Williams

IN recent years the use of aluminium in factories making nitric acid and explosives has grown to large proportions, the chief directions in which the metal has found application being the following: 1. For the conveyance of nitric acid in tanks or by pipe lines. 2. For storage and blending in tanks. 3. For carrying off fumes by means of hoods, domes and vapor pipes. 4. For the covers of vessels, themselves not made of aluminium. 5. For the gigantic pipe systems used in the manufacture of nitric acid from the atmosphere. 6. For many small utensils.

It is therefore essential that the interaction of aluminium and nitric acid on the one hand and of aluminium and nitrating mixtures on the other should be fully understood, and as moreover the experience of different factories which have used aluminium has varied within wide limits, it has become a matter of urgent importance to establish as far as possible the causes of these divergencies. The great differences which have appeared in practice are a reflection of the conflicting results obtained by the large number of chemists who have investigated this subject. Thus for instance the following divergent statements may be found in the literature of this subject. (i) Dilute sulphuric acid and nitric acid, both dilute and concentrated, have no effect upon aluminium (H. E. Roscoe, *Proc. Royal Inst.*, 1889, 12, 451); (ii) Sulphuric acid and nitric acid act immediately upon aluminium (G. A. Le Roy, *Chem.-Zeit.*, 15, Rep. 276); (iii) Aluminium is not attacked by boiling nitric acid whether dilute or concentrated (Deville, *Comptes rend.*, 38, 279); (iv) 100 cubic centimeters of 1.35 nitric acid at 100 deg. Cent. will dissolve 1 gramme of aluminium in 30 minutes (Stillman, *J. Amer. Chem. Soc.*, 19, 711). Of all the work done on this subject the most accurate appears to be that of Lunge and Schmidt (*Z. angew. Chem.*, 1892, 7), whose results so far as they refer to similar conditions are confirmed by the present work. Lunge and Schmidt, however, conclude that aluminium "cannot be used in the manufacture of nitric acid." Acworth and Armstrong also seem to have correctly interpreted the facts in their communication to the Chemical Society in 1877 (*J. Chem. Soc.*, 1877, 54).

While in the work described in the present communication the practical bearing of the subject has been continually kept in mind, attention has been concentrated on eliminating the sources of error which have made so much of the earlier work done on this subject misleading, and it is therefore hoped that a true picture of the conditions has been obtained. As in all similar investigations, the complexity of the subject has grown rapidly as the problem has been faced and many conditions influencing the rate of attack have been disclosed which were not contemplated at the outset of the experiments. Some of these minor factors have not been completely elucidated, but as they are of comparatively small practical importance and not likely to influence to any appreciable extent the main conclusions arrived at, it has been thought unwise to defer publication of the results obtained.

During the concluding stages of this investigation there appeared an article by A. Trillat (*Bull. Soc. d'Encouragement*, 122, No. 3, page 547) on the same subject. Many of Trillat's conclusions are identical with those of the present authors. In some cases, however, notable differences occur, while the basis for a comparison is frequently missing, so that it seemed desirable to bring forward the results obtained in spite of Trillat's publication.

The main conclusions reached were the following:

A. Effect of Temperature.—The most important condition affecting the rate of dissolution of aluminium in nitric acid is temperature. Over a considerable range of temperature an increase of 10 deg. Cent. is sufficient to increase the rate of dissolution by 100 per cent. The practical importance of this factor, to which no reference has heretofore been made, is very great. The life of aluminium vessels used for the storage or transport of nitric acid can be greatly increased where it is possible to keep the temperature down.

B. Effect of Concentration.—Next to temperature, concentration plays the most prominent part in determining the rate of dissolution of aluminium in nitric acid. The most active solvents are mixtures containing between 20 per cent and 40 per cent by volume of nitric acid of 1.42 specific gravity, while on the other hand some acids made from the atmosphere and containing 94.7 per cent of true nitric acid were found to be almost without effect on aluminium. A sample of the metal suspended in this acid for 71 days lost only 0.0004 gramme, equivalent to a rate of dissolution of 0.015

milligramme of aluminium per 100 square centimeters per 24 hours. The extreme inactivity of acid of this strength is held to account for the great success which has attended the use of aluminium transport vessels by the Norwegian makers of nitric acid.

C. Impurities in the Nitric Acid.—Contrary to statements made by other investigators (e. g., Trillat, *loc. cit.*, page 553), the presence of up to 0.05 per cent chlorine in nitric acid was not found to affect the rate of attack of the latter upon aluminium. Similarly no acceleration could be noted on the addition of up to 0.01 per cent of iodine. On the other hand, the presence of traces of sulphuric acid was found to promote the rate of attack, 0.04 per cent of sulphuric acid being sufficient to raise the rate of dissolution from 36 to 62 milligrammes per 100 square centimeters per 24 hours.

D. Effect of Oxides of Nitrogen.—The rate of attack is increased by the presence of the lower oxides of nitrogen. If the acid be kept free from such lower oxides the rate of attack on aluminium can be reduced considerably. The effect of the oxides of nitrogen produced by the interaction of nitric acid and aluminium in stimulating the attack is held to account for the fact often observed in practice that dissolution is most rapid in crevices or corners where the acid cannot circulate freely and where such products therefore accumulate.

E. The Effect of Physical State of the Metal.—The effect of the physical state of the aluminium is considerable, the metal being attacked very much more readily when amorphous than when crystalline.

F. The Composition of the Metal.—The composition of the metal is of very much smaller importance than has heretofore been assumed to be the case. Nevertheless the purer metal is generally the most resistant to the attack of nitric acid.

G. Mixed Acids.—Mixed nitric and sulphuric acids attack aluminium very much more readily than pure nitric acid, and the statements to the contrary to be found in the literature of the subject are erroneous (cf. Guttman, *this Journal*, 1896, 15, 850).

H. Uniformity of the Action.—The attack by nitric acid on aluminium sheet of high quality is absolutely uniform and during the present investigation no instance of local action or "pitting" has been observed.

In addition to the conclusions recited above and which are all of technical importance, certain observations have been made which are less of practical than of scientific interest. Only very short reference will be made to these observations here as they will form the subject of separate communications.

I.—It has been stated that in the crystalline form brought about by annealing aluminium is more resistant to attack by nitric acid than in the amorphous or unannealed form. The observation has been made that a partial change to the more resistant form is brought about by exposure for a few hours to a temperature of 125 deg. Cent., but that by a longer exposure to this temperature metal loses its comparative immunity from attack. A similar change to the more resistant form has been observed to commence at a temperature as low as 100 deg. Cent. Moreover, it has also been noticed that metal which has been freshly annealed at 540 deg. Cent. is more resistant to attack than metal which has been allowed to stand for about ten days after annealing. These observations cast some doubt upon the sufficiency of the accepted explanations of the changes which take place on annealing.

J.—During the course of the experiments made the existence has been established of a number of hydrates of aluminium nitrate heretofore unrecorded. The solubilities of these hydrates in nitric acid of 1.42 and 1.5 specific gravity have been determined and found to be extremely small.

Conclusion.

The practical conclusion to be drawn from the experiments is that, as the authors have frequently pointed out, aluminium can be used with great advantage for dealing with strong nitric acid provided that the latter be cold and provided that the plant or apparatus be suitably designed. For hot nitric acid of any concentration aluminium can have but a very limited life. Dilute nitric acid if cold could in many cases be handled in aluminium with success, although the life of the aluminium will not be so long as where the metal is exposed only to the action of the strong acid. Owing to the higher rate of attack by dilute nitric acid, storage and transport tanks after being emptied should either be thoroughly washed out or so sealed that moisture cannot get in and so dilute the acid which remains in the tank. Finally aluminium should only be used with great caution for handling mixed acids, and where aluminium covers and domes are used above vessels containing such mixtures care should be taken to prevent any splashing of the acid contents upon the aluminium.

Oldest American Dated Antiquity Made in 100 B.C.

A SMALL stone statuette found near Vera Cruz, Mexico, which has been in the possession of the United States National Museum since 1903, has recently been identified as the oldest known dated antiquity in America. Its ancient Mayan glyphic inscriptions show that it was made 100 years B. C., which is the oldest date authenticated in the New World.

This unique image was originally found in 1902 by a peon while plowing in the district of San Andres Tuxtla near the Gulf of Mexico, about 100 miles southeast of Vera Cruz, Mexico, and came to the museum through the courtesy of Mr. R. E. Ulbricht the next year. It is composed of very hard grayish-green stone, a variety of nephrite or jade, carved into a rounded conical form, about 6½ inches in height and 3¾ inches in diameter at the base. Its general outlines give the impression of an old Mexican idol or priest in a cape or cassock. The upper part represents a human head with a somewhat pointed bald crown, with well defined though primitively cut features. The lower part of the face is covered with a mask, in appearance resembling the bill of a duck, carved in relief and extending down over the chest like a beard. The cheeks and ears are outlined by a conventional scroll design, which lends a genial expression to the face. The idea of a cassock or other loose garment is destroyed when the figure is examined closely, for the bird-like form is further emphasized by the wings covering the sides of the figure, the lower margins of which are carved to represent feathers. Beneath the wings the outlines of a bird's feet and legs are engraved.

On the front, back and sides of this little figure are the peculiar characters, called glyphs, in which the early inhabitants of southern Mexico and the northern part of Central America, known as the Maya, wrote and recorded their early history and achievements. So far only calendric parts of the ancient inscriptions of the Maya have been deciphered, the chronological skeleton of Maya history, as it were, stripped of the events themselves. Thirty years ago Maya inscriptions were a sealed book, and yet to-day we read of the rise and fall of the several cities in relation to one another, and follow the course of the native development even though we cannot fill in the background. The nature of the several inscriptions is of course similar to more recent writings of this prehistoric race, yet the forms of the particular characters are so elemental that only the date signs or numbers are translatable.

In determining the date on this figure, however, a most valuable clue or index to further research and investigation is gained by students of American archeology, the locality of the find gives a hint to further excavation there in the hope of locating more relics and possibly establishing the location of another settlement of some branch of the Maya race.

The figurine in its conception and execution is well within the range of ancient Mexican or Mayan achievement, and presents no features suggestive of foreign origin or influence.

The general shape was evidently laboriously worked out from a block of irregular conical outline, by pecking with stone hammers, the unevenness of the surface, especially on the front and back, never having been fully removed, although the stone is well polished. The under surface shows the characteristic markings produced by primitive methods of sawing hard stone before the discovery of metals. Broad, shallow lines trace the composite features of the man and bird, and establish the fact that the polishing was done after they were cut. All the glyphs, however, were added after the shaping of the various features of the image was completed and the surface polished. The engraving of the hieroglyphics on the hard polished surface was not easy, as is shown by the narrow and uneven scratches which never received the smoothing and finishing touches.

What is known as the "introducing glyph" of the initial series on the image has been shown by Sylvanus G. Morley, of the Carnegie Institution of Washington, to indicate the length of time in the Maya calendar equal to 8 cycles, 6 katuns, 2 tuns, 4 uinals and 17 kins, which compared to our calendar goes back to about 100 B. C., the oldest definite recorded date known to students of anthropology in connection with the New World.

The people responsible for this little image, known to anthropologists as the Mayas, are now resident principally in Yucatan, Chiapas, Tabasco, and in adjoining Central American republics, but one small group, the Huasteca, is found in northern Vera Cruz. It does not seem unlikely that the entire coast line of the state was at one time the habitat of these ancient peoples, who have left us a key to their history, religion, language and customs in the stone manikin described above.

*From a paper read at a meeting of the London Section of the Society of Chemical Industry, and reported in the *Journal of the Society*.

Goldsmiths' Work in the Dark Ages

A Short History of Its Progress, and the Various Schools of Art

By Sir William Martin Conway, M.A., F.S.A.

THE seventh and eighth centuries B. C. were for the Greeks something like the sixteenth and seventeenth centuries A. D. for the peoples of Western Europe—a great colonizing age. From Marseilles in the west to the Crimea in the east, Greek colonies or trading centers and factories sprang up at all sorts of suitable points on the sea coasts. Several such settlements were made along the north shore of the Black Sea by Milesian colonists in the seventh century. "The Euxine coast," Mr. E. H. Minns tells us, "was the first El Dorado, the first mysterious land, to draw adventurers across broad seas in search of fame and treasure." Thus arose Olbia, Panticapæum (the modern Kerch), and many more once thriving settlements. What they thrived on was trade. By sea they were in communication with the Greek cities; by land with the Scythians of the steppe, which stretches away without break far to the west, north, and east into the heart of Asia. Their wealth and taste are proclaimed by the vast quantities of treasures, made of gold and often set with precious stones, which the graves in this region have yielded. The gold may have come from north or south. In any case, the Scythians loved golden ornaments, and the Greeks provided such for them. Most were of local manufacture. These fall into two classes; the work respectively of Greek and of local artists. The former are sometimes purely Greek, alike in design and in technique, but oftener they bear evidence of the taste of the people for whom they were made. The latter are massive, ugly, and barbaric alike in design and in execution. These two schools existed side by side throughout the centuries. The barbarian school, with its clumsy representations of beasts and fabulous creatures, and its love of colored stones, was Asiatic in character. One of its most prominent characteristics was the inlaying of colored stones, oftenest garnets, in a random fashion into the substance of the gold. The Greeks, after the campaigns of Alexander, under the influence of the inroad of Orientalism that followed, adopted the setting of precious stones in their jewelry as a fashion increasingly popular. The stone most commonly employed was the garnet.

In the first century of the Christian era the manufacture of golden ornaments still went forward in the cities founded by the Greeks on the north side of the Black Sea. We may call these works the product of the Bosphoran School. Some treasures were dug up at Siverskaja, in the Kuban district in South Russia. The most striking of these are two Roman glass vessels, elaborately mounted in gold and garnets. One is of simple vase form. The mounts consist of two decorated horizontal bands of gold—one round the shoulder, the other halfway down toward the foot. These bands are connected by a few vertical strips of decorated gold. The strips are set with garnets in a dog-tooth pattern. From the upper band slender gold chains hang at frequent intervals, in all upward of a score in number. Gold balls are at the lower ends of the chains. The other vessel is a two-handled cup, with a broad gold band round the lip, on which cabochons are set, each held by a ribbon of gold closely fitting around it. Between them are knobs of gold, covered with tiny gold balls. Chains, more numerous than on the other cup, hang from this rim, and each ends in a ball of garnet, with a gold ball hanging beneath it. These cups should be compared with certain chalices in the Treasury of St. Mark's at Venice, which were looted by the Venetians in 1205 from St. Sophia and other churches at Constantinople. Eleven of these chalices present one remarkable feature: from the lower part of the lip-rim of each there hang a series of fine wires, each originally furnished at the lower end with a pearl. These pendant pearls are the direct descendants of the chains and balls of the Siverskaja cups, and the jeweled lip-rims of the chalices likewise preserve the ancient traditional mounting of the Bosphoran School. The Siverskaja cups are not later in date than the first century A. D. The Venice chalices may be approximately dated to the eleventh century. Another feature which the South Russian and the St. Sophia vessels have in common is the vertical straps of metal by which the upper and lower rings of the mounts are held together. This trick, if we may so call it, spread over Europe, and did not remain characteristic of Byzantine cups alone; but it is excessively common in Byzantine cups, and was no doubt copied from them by Western craftsmen, who only occasionally employ it, and never until they had fallen under Byzantine influence.

Of contemporary finds farther west in the heart of

Europe, only two call for brief mention. Both were discovered in Hungary. The first is the Osztrópataka find: it consisted mainly of works of Imperial goldsmiths, the most important being an oval fibula formed of a great onyx, framed in a rim of characteristic openwork, such as was fashionable in parts of the Roman world at that time. The necklets, cups, and long fibulas were all of Roman workmanship. Some embossed silver plates formed part of another find close by, but the animals in relief on these had no barbarian connection. The bulk of these objects must be regarded as of Imperial and some of them of provincial Roman make.

The third and fourth centuries were a critical time in the history not merely of goldsmithy, but of European art, because it was at this time that the Goths (who in the latter part of the second century had left their settled abodes in the lands near the mouth of the Vistula and moved southward) were brought in contact with the civilization and art of the region north of the Black Sea. They there acquired a taste for jewelry of the Bosphoran type, and this taste presently spread through the whole Teutonic world and became an important factor in the growth of the mediæval Gothic art that was to arise in the west. It appears to have been the invasion of the Huns about 376 A. D. that set the peoples in movement and so helped to spread the new art style. It is thus of great interest to observe what the Bosphoran style was in the fourth century, and how many of its traditions were directly absorbed by the artists of, or who worked for, the Gothic people. The most important group of jeweled treasures of the fourth century definitely Bosphoran in type belong to the Berlin Museum, and were found in a grave or catacomb at Kerch. Along with a brooch was found a diadem as markedly barbarian as the brooch is Imperial. The famous Petrossa find contains among other treasures two double-handed gold and jeweled cups, evidently Sassanian. In their present condition they resemble open-work baskets, but the open spaces were once filled with plate-set stones. We arrive at exactly the method of mounting stones which is exemplified by the Jelalabad reliquary and the Ardeshir strap-end. So far as we yet know, such work was only made in Persia at this date. The beast handles are likewise characteristically Persian. It is plain enough that these ornaments are not of the Bosphoran school as we have thus far made acquaintance with it. Every indication leads to the conclusion that we have here examples of the best work of third or fourth century Sassanian goldsmiths.

After the third or fourth century there is little, if any, work discoverable done by Bosphoran craftsmen for Scythian patrons. Thenceforward they worked for the Goths, who by war, pillage, and expansion were growing richer from decade to decade. Whether they worked as valued slaves or free craftsmen we cannot tell. As soon as the true folk-wandering epoch set in, golden and jeweled ornaments were the only kind of artistic products for which wandering chieftains had much use. The bulk of the fifth century barbarian ornaments is very poor stuff, but among it we find a few admirable works. One thing is practically certain, the Bosphoran region did not remain an important center of art after the fourth century. The best workmen having gone to more profitable regions (such as Byzantium) those who remained relapsed, so that such works of the school, few in number, as are discovered near Olbia or Kerch, dating from the fifth or sixth century or thereabout, are rude and poor in quality and design.

The sixth century in Western Europe was a period of decadence for barbarian jewelry. If the original impulse toward that art came from the Bosphoran region, and the fine work of the fourth and fifth centuries was made by civilized craftsmen, unless those craftsmen could be reinforced by continued intercourse with the home of their art, or quickened by a genuine artistic impulse in the people for whom they worked, nothing but decadence could occur. Neither of these vitalizing influences arising, decadence took place. To this sweeping condemnation of barbarian jewelry north of the Alps an exception must be made in respect of three kinds of earrings and the hairpins associated with them; but so great is the contrast between them and other objects found with them that it seems necessary to conclude that they were imported from some more artistic center of manufacture.

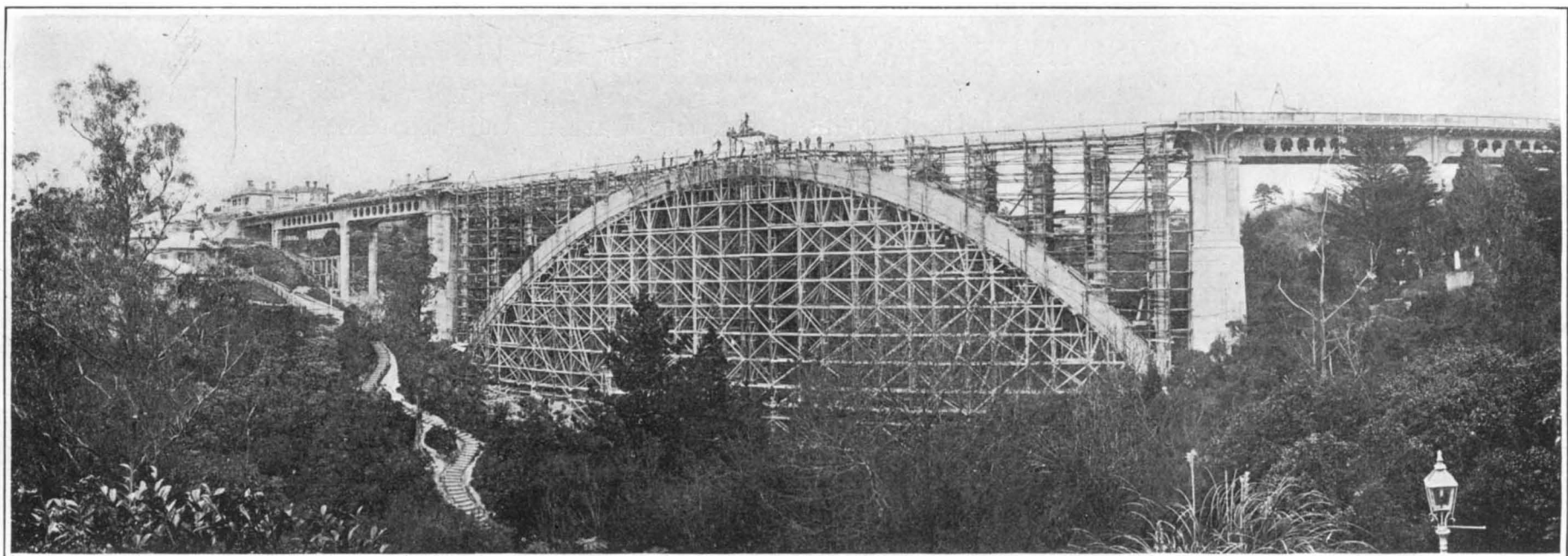
Plenty of instances could be cited of Coptic influence in the west of Europe in the seventh century, but a

digression on that subject here would carry us too far. The jeweled round brooches are of great variety, very numerous, and many of them of a high order of decorative beauty. In type they descend from the roundel of the first century from Siverskaja, described at the beginning of this paper. Though of Bosphoran origin, it was not in Continental Europe, nor at the hands of barbarians, that the type was preserved and developed. That was done somewhere else, and suddenly in the sixth century the form was introduced from elsewhere into the west, and rapidly became popular. In the seventh century local artificers may have imitated it, and many of the surviving specimens may be their handiwork. But barbarian jewelers of the seventh century stood on a very different level from their rude predecessors, and to them we must turn our attention. Now for the first time in barbarian lands we meet with a named artist, and he is not a painter, sculptor or architect, but a goldsmith, nor is he a man of the artisan class, but a bishop and Minister of State—St. Eloy (born c. 588; ob. c. 665). His period of activity was about from 610 to 665 A. D. He started life as apprentice to a goldsmith at Limoges, so that we thus have evidence of a settled manufacture at least as early as the very beginning of the seventh century, and this where we should look for it—in the southern part of France, which had been least damaged by the barbarian infiltration.

At this time in Western Europe, as far north as England, a considerable revival of art took place; but it was not primarily a revival of the older leading arts (architecture, sculpture, and so forth), but of the art of the goldsmith. Art patrons doubtless caused to be erected churches and other new buildings; but what they loved above all else was work in the precious metals and jewels, and these then began to be made for them in great abundance. It is enough to read superficially in the history of the Merovingians to recognize that no works of art could give so much pleasure to the princes of that time as those which could be easily carried about. Hence an intense demand for goldsmithy, which from the seventh century onward till the tenth became and maintained itself as the leading art in all the barbarian lands. We may therefore conclude that from about the latter part of the sixth century goldsmiths became settled, active, and presently important craftsmen, rising in a few decades to the position of the leading artists of their day in the kingdoms of the west.

The last great seventh-century goldsmith was the craftsman who seems to have worked in Kent for the Royal Court there, perhaps at Faversham. This man or school is best represented by the wonderful Kingston brooch—as fine a jewel as any produced in Europe in its day. It was found on Kingston Down, Kent, and is now a principal—perhaps the principal—treasure of the Liverpool Museum. Certain it is that the art of this craftsman did not arise in Kent; but in Kent it received a new application and was wedded to a markedly local style of design. It is impossible to mistake the works of this atelier for those of any other. To it we may unquestionably assign a whole group of round brooches and inlaid buckles, all of finest quality. It is safe to assume that the head of this school of goldsmiths was no obscure artisan, but a man probably like St. Eloy, of high and influential position.

We thus reach the end of this rapid purview of the history of the rise of the goldsmith's craft among the barbarian peoples who poured into the Roman world and overwhelmed and destroyed so much that was precious. It has of late been customary to assign to them artistic gifts of their own of too high an order. That they brought a new spirit and much new blood into the west is obvious enough; that this new spirit ultimately gave birth to new and glorious kinds of art is likewise clear. But it is not true that they carried from the borders of the Black Sea the germs of an art which they themselves developed into something great. It was not until most of their moving and fighting and pillaging was done, and they had settled down in their new homes, that they turned to the lands of ancient civilization and found among the wrecks of its population enough survivors who still cherished the craft traditions of their ancestors to be able by them to create for the new men of power and wealth works of art incorporating indeed the new ideals, but expressing them by aid of a long-standing technique of ancient development.—*Abstract of a paper read before the Royal Archaeological Institute.*



The Grafton bridge, Auckland, New Zealand, under construction.

Bridge Building in New Zealand

Interesting Designs That Have Been Successfully Erected

By Oliver Johnson

IN several parts of New Zealand what are known as Dawson suspension bridges are being erected of which Joseph Dawson, of Hukunui, Paliatua, is the designer and builder. At the official opening of the bridges in the Marlborough Province a thirteen-ton traction engine was driven on to one of the structures and only the very slightest oscillation was visible while the engine was moving. It stopped in the center of the bridge when a test of the deflection was taken. With over 150 people on the structure, besides the engine, the deflection registered was under $1\frac{1}{4}$ inches, which in itself is an eloquent testimony to the stability of the bridge, especially when it is taken into consideration that the deflection of an ordinary truss bridge is anything up to 4 inches. The deflection on the shorter bridge was under 1 inch.

The bridges, which span a yawning ravine about 170 feet in depth, are situated on the Seddon-Molesworth road, and are about twelve miles from the township of Seddon. The structures are spectacular and the practical test given them should dispel any doubts as to their efficiency. It was admitted by practical men at the function that the bridges were all that Mr. Dawson claimed for them—the acme of solidity, durability and cheapness.

The bridges are of similar design and are respectively 104 and 94 feet in length. The anchors and towers are of concrete, which gives the structures a solid appearance. The anchor rods pass through iron pipes embedded in the concrete and are fixed at the back of the concrete with large iron washers and double nuts, which can be replaced should necessity arise. The rods are two inches in diameter and upset two and a half inches at the threads. They are fixed to the cables which have a solid thimble spliced in each end, with strong iron straps and bolts. The clips on each side of the thimbles have $1\frac{7}{8}$ -inch bolts passing through them and firmly screwed up. There are four cables, which have each a breaking strain of 85 tons, or collectively, 340 tons. Each anchor has a breaking strain of 66 tons, and the eight rods together are capable of sustaining a weight of 588 tons. The cables are 5 inches in diameter and pass over the towers on cast iron saddles with six strong iron wheels to each cable. The suspending rods that carry the bridge from the cables are composed of steel, 1 inch in diameter, and are spaced at intervals of 5 feet and fixed to the cables with strong clips. They each have a breaking strain of 14 tons. The steel channel that holds the concrete decking is double with a space left between to receive the suspending rods which are screwed to the bottom. From the flange of the channel curved corrugated iron is put at 5 feet centers to receive the concrete deck, forming a series of arches throughout the bridge, which has a camber of from 1 to 8 inches. A top dressing of 4 inches of concrete is put on making a solid deck. The trusses or chords are double—that is, there are two chords on either side of the bridge, spaced 1 foot apart, so that the cables

can go between the double trusses, which are 5 feet high and have a 5 x 4 timber top and bottom, with galvanized iron pikes between spaced to 5 feet centers. The truss bolts are $\frac{3}{4}$ -inch iron and the only timber in the bridge is the top and bottom chords and the wheel guards. Over a space of 10 feet there are six rods with a breaking strain of 84 tons. With the weight of the bridge taken from the rods there are 79 tons over a space of 10 feet, upon which a traction engine rests. The crushing strain of the towers is 2,000 tons, the breaking strain of anchor rods 528 tons, and the suspending rods 532 tons. One of the bridges fully loaded would have a weight of about 65 tons, but it would have a margin of safety five times that weight. One cable would sustain the whole weight and leave 20 tons to spare.

A COMPARISON.

To the layman it would appear that a wooden bridge could be erected at a cheaper rate than one of ferro-concrete, but this is not so. The bridges at Upton Downs cost, with commission added, £7:12:9 per foot, while a wooden suspension bridge erected at Mt. Bruce cost £11 per foot.

TAIHAPE BRIDGES.

Two lofty massive ferro-concrete towers of enormous strength and solidity stand as sentinels on either side. From these the eight steel cables support the bridge, being attached at each of the approaches to anchor rods embedded in concrete and capable of taking a strain of 1,000 tons. The combined strength of the cables is 672 tons, while the bridge itself weighs but 60 tons. There are 124 suspending rods $\frac{7}{8}$ of an inch in diameter, and these are capable of bearing a strain of 1,036 tons. Compared with the bridge built by the Government at Mt. Bruce, which weighs 70 tons and has a span of only 220 feet, the Taroa bridge is vastly superior in weight carrying capacity although 10 tons lighter in weight.

THE HUTT BRIDGE.

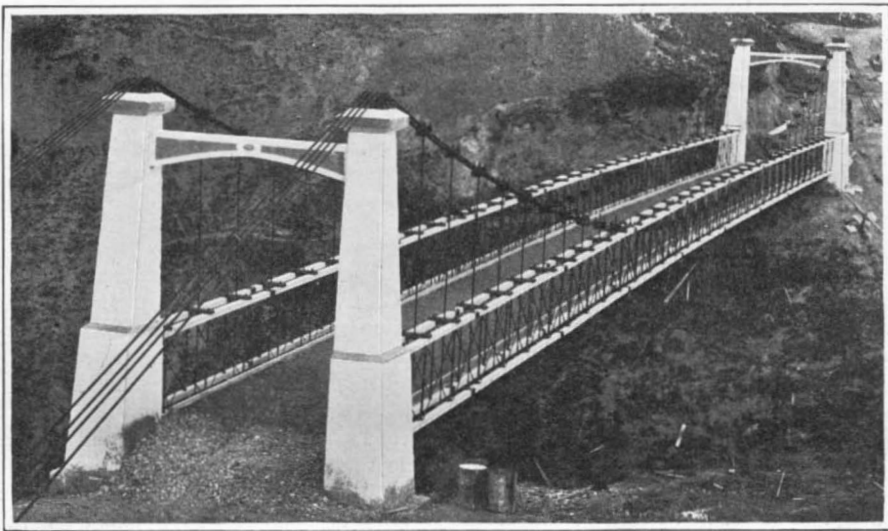
The length is 175 feet, width 12 feet, weight of bridge empty 65 tons. About 30 tons of cement have been used. The four towers are of reinforced concrete connected by arches between the piers. There are twelve wheels on each tower—forty-eight in the whole. There are eight cables connecting and supporting the bridge; each has a breaking strain of 72 tons riveted together at 5 feet center; the arches of corrugated iron between channels are filled with reinforced concrete deck. The channels form a series of arches right through the center of the bridge. The camber of bridge is 18 inches from tower to tower. The truss is 5 feet over all and is composed of iron and steel—no wood whatever being found in final structure. The suspending rods are of $\frac{7}{8}$ -inch thick iron. All the rest of cord bolts $\frac{5}{8}$ -inch thick; $1\frac{3}{4}$ pipes are put at every 5 feet to convey the strain of the bolts. The blocks that support the suspending rods from the cable are of reinforced concrete. The cables are all attached to substantial concrete anchors let into the bank; each cable is 280 feet long.

THE GRAFTON ARCH BRIDGE, AUCKLAND.

The most interesting feature of the bridge, from the engineering point of view, is the 320 foot arch span. The adoption of an arch of that span was unique in the history of reinforced concrete work, inasmuch as the largest known span was 280 feet, that over the Rocky River, U. S. A. Another unique feature is the length and depth of the main girders in both approach spans. These girders range from 75 feet to 80 feet in span, and at one approach these spans form one continuous girder of 306 feet, which is considered to be the longest in the world. The span is supported by sets of piers. The deepest point of the gully is 147 feet from the road level. The roadway is 24 feet wide, and is covered with Neuchatel asphalt. The footways are each 6 feet wide, and are finished in concrete. The balustrades are in reinforced concrete, and the kerbing in Coromandel stone. The bridge is illuminated by twenty-six electric lights, in each of which are two 25 candle-power incandescent lamps.

A very large quantity of material was used in the construction of the bridge—over 5,200 cubic yards of concrete, and 330 tons of steel. In the mixing of the concrete, 1,130 tons of cement were used, and 2,100 cubic yards of broken blue-stone, as well as 4,050 cubic yards of shingle, 60 cubic yards of sand for rendering, and 230 yards (cubic) of stone boulders. The timber used in the arch span, centering and falsework, totaled 400,000 superficial feet.

Mr. R. F. Wood, C.E., was chief engineer to the Ferro Concrete Company, of Australasia, Limited, at the time tenders and designs were asked for by the City Council, and he decided to submit a design of a very bold nature, taking as a model the bridge which crosses the Isar River, near Grünwald, Bavaria, built by the firm of Wayss & Freytag, Neustadt. This bridge consists of approaches with 30 foot span girders and two three-hinged arches 230 feet clear span. The general appearance of this work is very graceful, and he decided that a design after this bridge would be very fine if it could be carried out at the cost, or for the money available, £35,000. After making a careful survey of the bedrock that would have to support the foundations of the big arch, and measuring carefully the angle of thrust and the stratification of the sandstone rock, several preliminary sketches were made, and he finally decided after careful investigation to design one arch over the gully of 320 feet clear span, this being the distance giving the best result, keeping in view the angle of thrust of the arch and the sweep, which would all be regulated by the proportion of rise of arch from its springings to the crown to the span, which worked out very nearly as four of span to one of rise, and which formed a curve closely approximating a parabola, but which is not generally considered by engineers to be a curve possessing any beauty. The approaches consist of one small span, 41 feet at one end, and two large spans, 80 feet each, straight girders, hollowed out for the purpose of lightening and the gen-



Ashley-Clinton suspension bridge.



Bridge across Upton Downs gorge.

eral appearance. One end consists of two spans of 35 feet each and four spans of 75 feet each. The ends of each end girder are free to slide when expanding or contracting, but are continuous over their pier supports in between, and in the calculations were treated as such in each case. The large girders are three in number in each bay, and measure 9 feet, 3 inches deep by 15 inches wide, carrying the proper amount of steel reinforcement to take up all the necessary calculated stresses. The secondary beams and decking are more or less just the ordinary type of reinforced concrete.

The main piers are more for architectural effect, and in no way carry any portion of the main arch. These piers are 100 feet high, 50 feet by 25 feet at the bottom, tapering to 16 feet by 36 feet at the top; are hollow from top to bottom, and only support the end of each girder from the approaches. The main arch has a span of 320 feet between the hinges, and a rise of 87 feet, and consists of two arch rings, braced together by heavy wind ties to prevent racking. The size of the rings, or ribs as they are termed, vary from 6 feet by 4 feet 6 inches at the skewback hinge to 9 feet 6 inches by 4 feet 3 inches at the haunch and 5 feet by 4 feet at the crown hinge. The arch was built on Oregon pine false-work centering, which amounted to 400,000 superficial feet in all, and the ribs were built in blocks weighing from 15 to 35 tons, placed alternately from the crown downwards to the abutments, the column blocks being the first moulded; the alternate, or filling, blocks, being the wind bracing blocks, being also moulded from the crown towards the abutment. The crown hinges were put in last. The whole of the concrete work for the arch ribs and wind-bracing took fourteen days. The columns rising from the arch ribs are T shaped, with T-shaped bracing or tie beams. The reinforcement in these columns is very heavy, to prevent any possible lateral bending of the column.

The arch ribs are hooped with $\frac{1}{4}$ -inch steel rods every 12 inches apart, but more heavily at the fourth or toward the skewback hinge. The longitudinal reinforcement beyond, being of material assistance, was really never seriously taken into consideration, the arch being designed to act entirely in compression, and is consequently truly a masonry arch, with three hinges to allow the proper movement to take place for expansion and contraction. Had the true reinforced or elastic arch been designed, the shape would have been entirely different, and the reinforcement considerably heavier. The pressure due to thrust of the arch is taken up by the hinges and distributed throughout the concrete by means of steel H girders, riveted together to form grids, which were buried in the concrete. The height of the arch above the bottom of the gully is 147 feet, the span 320 feet, the width of roadway 24 feet and two pathways, each 6 feet, making a total of 36 feet between parapets. The weight of the arch and superstructure is about 3,700 tons. The pressure upon the abutments at the rock base is two tons per square foot when loaded. The total length of the bridge is 951 feet, being one of the largest masonry structures in the world.

X-Rays and Crystal Structures, With Special Reference to Certain Metals

ON THE occasion of the sixth annual May Lecture of the Institute of Metals, at a meeting of the Institute in London, Prof. W. H. Bragg, D.Sc., F.R.S. (Nobel Prize-man), gave an interesting account of the new method of applying the properties of X-rays to the study of crystal structure, including the structure of certain metals.

The method, it was shown by the professor, results in the determination of the exact relative positions of the

atoms of which the crystal is composed. It is not successful in every case as yet, because of the lack of practice and experience of the experimenters in the new field and because some of the interpretations are not fully understood. There is no lack of indications; but we are not yet fully aware of the meaning of all of them.

It is natural to attack first such crystals as have no obviously simple structure and consist of few elements associated in simple proportions. It is also of great advantage if the crystals belong to a group of isomorphous members, such as the rock-salt series. This series, in fact, has everything to recommend it to the experimenter—its form is simple, that of the cube; its symmetry is high; it contains two elements only, in equal proportions, e. g., sodium or potassium associated with chlorine or iodine; and there are several members of the series, so that we can watch the effect of changing one element at a time. The constitution of this series was, therefore, one of the first to be examined and made plain.

The constitution of the diamond, which has also been determined, presented a rather more difficult task, because the arrangement of the atoms is not so simple as that of the rock-salt series: although its form is cubic, its symmetry is high, and it contains atoms of one kind.

Of the metals which will naturally be of special interest to the Institute of Metals, silver and copper, and by inference gold, have been shown to possess a very simple structure, in which the atoms are arranged as in the piling of shot. Bismuth and antimony have a distorted arrangement; but these two, as well as zinc, have not been completely determined. A beginning had been made with iron. The war has, however, stopped all work of the kind on this metal.

This new field of research, according to Prof. Bragg, depends on a principle already known. When a regular train of waves falls upon a surface separating two media, part is reflected and part goes on. If the part that goes on meets another separating surface, a second portion is reflected and some of this emerges from the second medium in the same direction as the beam reflected from the first surface. It will happen in general that the two reflected beams are out of phase and to that extent destroy one another. Whether they do so or not depends upon the relation between the wave-length, the angle of the inclination of the beam to the reflecting surfaces, and the distance between the surfaces. In this way are explained the colors of the soap film, of the thin layer of oil on the surface of a liquid, of the colors of steel when being tempered, and so on.

If the reflecting surfaces are many in number, not two, the effect is made more intense and at the same time more precise. It occurs in the beautiful colors of potash crystals as shown by Lord Rayleigh. These crystals are formed of alternating layers, twinned across their surfaces of separation, and for some obscure reason the thickness of all the layers is the same though it varies from crystal to crystal. When white light containing all wave-lengths is incident upon such a crystal, at a certain angle, then only that wave-length is reflected for which the proper relation between the wave-length, angle, and spacing holds good. If the angle is altered the wave-length which is reflected is no longer the same. Hence the play of colors which the crystal shows.

It is an essential cause of the success of this wonderful effect that the wave-length and the spacing are not very different in amount.

We now pass on to the case of the X-rays. These consist of waves—so, indeed, these very experiments tell us—which are something like ten thousand times shorter than the wave-length of light. To obtain the parallel effect we must look for reflecting surfaces which are ten thousand times closer together than the twinning surfaces of the chlorate of potash crystals, and these are separated from one another by only the forty-thousandth of an

inch or thereabout. These also nature has provided in the layers of atoms in the crystals.

It may seem curious that a layer of atoms should act as a reflecting surface: but after all it is not necessary that such a surface should be continuous. A row of iron railings, for example, can act as a reflector of sound waves. A natural face of a crystal contains, no doubt, a layer of atoms arranged regularly; and behind the natural face are other layers all similar, and placed at regularly increasing distances behind it. Thus, all the conditions for this peculiar reflection experiment are present, and we actually find that when a pencil of X-rays of a definite wave-length are allowed to fall upon the face of the crystal, and the crystal is gradually turned round so as to alter the angle of incidence, the reflection of the beam as a whole is non-existent, except when the angle is right. Then it flashes out strongly. When this angle is observed, the relation of the wave-length to the spacing is known.

The instrument used is called the X-ray spectrometer. It has no lenses because X-rays cannot be refracted, and the rays are invisible, so that in place of the telescope appears a chamber containing gas, which is ionized by the X-rays. The resulting electrical effect is observed in an electroscope. It is important that the measurement of the result is quantitative, so that in this respect the new spectrometer has an advantage over the old.

In this way, if we use always the same X-ray, we can compare the spacings between the layers parallel to one after another of the natural faces parallel to the crystal; and in this way we arrive finally at the crystal structure. The instrument is not at all difficult to use, and the observed effects are large and precise, so that it is quite easy to get numerical results. The interpretation is not always quite so easy. One part of it comes readily, viz., the number of molecules to each unit of the pattern of the crystal—the unit being the smaller part, which, being reflected again and again without alteration of orientation or distance from its neighbors, forms the complete crystal. For instance, the unit of pattern of potassium sulphate contains four molecules; the unit of pattern of antimony contains two atoms.

The far greater difficulty lies in the determination of the way in which the atoms are arranged in the unit. These data are sufficient, but the interpretation is hard. To understand how it is attempted, and in some cases achieved, is best explained by models.—*Chemical News*.

Mysterious Swarm of Moths

IN the report of the South African Museum for 1915, just issued, Dr. L. Péringuey, the director, relates a very extraordinary occurrence. While the troops of the Union were camped in the wide sand-belt of Luderitzbucht and Swakopmund, waiting to advance inland, there appeared, suddenly, after heavy rains—a thing almost unheard of in those parts—all along the line, immense swarms of moths. The fact is the more extraordinary and mysterious since these sands are almost void of visible vegetation. That they were brought by the wind from inland Dr. Péringuey considers improbable. They disappeared as rapidly as they came. Samples which were sent to the museum proved to consist of no fewer than twenty species of Noctuidae. In this report mention is also made of the fossilized skull of the "Boskop" man found in the Transvaal, and of fragments of limb-bones, probably of the same skeleton. This skull, which seems to be remarkable for its great length, has not yet been described in detail. It is much to be hoped that this will soon be done. A mandible found in the river-gravels at Harrismith, and stone implements found in another locality in the Orange Free State, are also mentioned among the acquisitions for the year deserving special mention.—*Nature*.

Spinning and Weaving in Early Times*

Primitive Methods, Some of Which Are Still in Use

By H. R. Carter

THE spindle for twisting fiber into thread and the loom for interlacing these threads at right angles into cloth are prehistoric tools, and older than the history of mankind. In the remains of the lake dwellings of Neolithic man have been found pieces of thread spindles, and spinning wheels, proving the spinning of fibers, and weavers' weights and remnants of cloth, some of them twilled, proving the existence and skill of the weaver.

The primitive spinning and weaving implements still used by the natives of India and China are almost identical with those used in the most ancient times, while those abandoned by the Scotch, Irish, and Welsh peasantry within the memory of the present generation are almost as primitive. In the country parts of Japan, too, the spinning wheel is still much used, although rapidly giving place to factory methods.

Very early examples of the spinner's art are extremely rare, owing, of course, to the perishable nature of the fibers used. Most of them are contained in shreds of textile fabrics, such as the linen cloths unwrapped from Egyptian mummies; for the Egyptians of old were expert spinners and weavers, and did a large export trade with Europe and distant parts of Africa and Arabia in textile fabrics, the fine linens of Egypt especially being unrivaled in the ancient world for evenness and fineness of texture. In Exodus we read: "And all the women that were wise-hearted did spin with their hands," an art the Israelites no doubt learned from their captors.

The Egyptians regarded the spinning of a single thread as so wonderful that they ascribed the invention of the art to the goddess Isis.

In one of the lake dwellings of Switzerland, discovered in the bed of the lake at Robenhausen, in 1882, were bundles of raw flax fiber, fine and coarse linen threads, twisted strings of various sizes, and thick ropes as well as netted and knitted fabrics and fragments of cloth, sometimes rudely embellished with needlework. There were also found spindle whorls, fragments of wooden wheels, which probably formed parts of spinning wheels, charred spindles with thread wound upon them, and toothed combs, which were probably used for preparing the raw fiber.

Primitive man discovered that various vegetable and animal fibers, even short ones, could be twisted together and joined up into threads of any required length and thickness. He likewise found out, by experience, no doubt, that fine filaments produce the finest and level threads, and that some comparatively coarse fibers might be split up by combing, carding, and hacking.

From the evidence at our disposal it would appear that it was during the later Stone age that mankind selected the principal textile fibers and acquired the art of spinning and weaving proper. It is obvious that these efforts of the weaver's craft would be as primitive as man himself. His demands were of the simplest description. He would only need clothing and something for shelter, and for these purposes he would use such fibrous materials as came to his hand easily, such as grasses long enough in their natural condition for interlacing or plaiting; but each step in the progress of man from the state of savagery to civilization would be marked by a corresponding advance in the manner in which he clothed and sheltered himself, and, as culture dawned, the simple demands of mere necessity would be developed by the need of variety or by the desire for color and ornament. The use of multicolored threads provided ornament for the simple structures in use, but the demand for variety would extend far beyond the limits of color, and different materials were employed, either separately or conjointly, and different schemes of interlacing were evolved.

The Egyptians were probably the first skilled weavers of civilization, for as early as 1800 B.C. the arts of spinning and weaving were extensively practiced. The Bible records that Pharaoh arrayed Joseph in vestures of fine linen (Genesis xli., 42). This occurred in 1716 B.C. It was undoubtedly in Egypt that the Israelites obtained the skill in weaving which enabled them to execute the hangings of the Tabernacle and other artistic textures in 1491 B.C. (Exodus xxxv., 35). Pictures found at Beni Hassan of pre-Theban origin, 1500 B.C.,

show flax workers engaged in linen manufacture. Tanahquill, wife of Tarquinius Priscus, in 613 B.C., is said to have been the first to weave a straight tunic on a perpendicular loom. This form of tunic was worn for many centuries under the white toga by the younger Roman citizens.

Cotton spinning and weaving are known to have existed in India for upward of three thousand years. Herodotus mentions the cotton drawers worn by the Indian contingent of Xerxes' army. The same writer also mentions hemp, saying that Thracians made garments of hemp, which closely resembled linen.

Pliny, in his great work, *Historia Naturalis*, published in the year A.D. 77, gives interesting notes on flax and hemp cultivation and manufacture. In his account of flax, he gives the reason why flax is not a favorite crop with farmers. "It has the property," he says, "of scorching the ground where it is grown, and of deteriorating the quality of the very soil itself."

Egyptian weavers were men, for Herodotus assures us that the women of Egypt were employed abroad in trade and business, but the men were left at home to spin and weave.

In the *Chronicles*, the writer, speaking of the families of the house of them that wrought fine linen, bears out the idea that the trades of spinning and weaving were carried out by a particular tribe or family.

Syria was early noted for its cloths. As to the celebrated Syrian purple, it is estimated that it cost £32 to color one pound of wool.

Felt was probably manufactured before yarn was woven into cloth, the method of producing it being accidentally discovered. Felt manufacturers take St. Clement for their patron saint, because, they say, the saint, before starting on a long pilgrimage, put soft wool inside his shoes, and found at the end of his journey that the layer of soft fibers had been converted into cloth by the action of his feet. Be this legend true or not, felt cloth was manufactured at a very early date, such cloth being sometimes of such a texture as to form a protection against the bows and arrows of that day.

The Israelites were forbidden to wear a garment made of a mixture of flax and wool. It is said that this was to prevent idolatry, as heathen priests wore such mixed garments in the hope of a lucky conjunction of the planets bringing down a blessing upon their sheep and flax. Furthermore, no man could enter the temple with garments having any wool fiber about them, and no man could expect a resurrection from the dead whose body had been buried in woolen clothes.

In olden times, as in some countries and places today, women took a pride in boasting that their husbands and children were solely clothed by the labor of their hands.

A passage from the Proverbs gives the character and occupation of an industrious housewife among the Hebrews: "She seeketh wool and flax, and worketh willingly with her hands. She layeth her hands to the spindle, and her hands hold the distaff. All her household are clothed with scarlet. She maketh herself a covering of tapestry, her clothing is of silk and purple. She maketh fine linen and selleth it."

The art of spinning was also once popular in the homes of the great. Homer represents some of the most distinguished maidens as so employed. Penelope plied the spindle and loom, and tasked her maidens. The fairy tale of King Crotchet's wife may also still be fresh in the memory of some. All these legends go to prove, then, that—

"To spin with art in ancient times was seen,
Thought not beneath the noble dame or queen;
From that employ our maidens took their name
Of Spinsters, which the moderns never claimed."

Our maidens are still "spinsters." In heraldry and genealogy one talks of the "distaff" side of a family, the female side, the side which spun the thread from which the cloth was woven in which the "spear" side went forth to fight; and, although the distaff and the spinning wheel no longer find an active place in any ladies' boudoir, we still depend upon the distaff side for much of the clothes we wear.

The spindle for twisting fiber into thread is, as we have said, a prehistoric tool. It is essentially a short

stick with a weight or whorl at one end and a hook or notch at the other, the thread, when spun, being wound between these two. The primitive spinner carried a bundle of fiber to be spun upon the end of a stick, "rock," or distaff, carried under the left arm. She first drew out a few fibers, and, twisting them in her fingers, attached them to the hooked end of the spindle, which she then rotated with one hand, while she continued to draw out fibers with the other. When a convenient length was spun it was wound upon the spindle, and a fresh length commenced. Homer, describing Ulysses following Ajax, employs the following figure:

"As when some dapper, gerald wife
Near the bosom holdeth
The spindle, whence she draweth out
The rove beyond the sliver,
So near Ulysses kept and trod
The very prints of Ajax."

One great advantage this primitive spindle had over modern machines was that it could be carried about by the spinner without her having to discontinue the work. An ancient story by Herodotus illustrates this point. King Darius chanced to see a Phoenician woman, who was carrying a pitcher on her head, leading a horse and spinning, all at the same time. He sent spies after her, and they reported that she filled the pitcher, watered the horse, and returned, continuing all the time to spin with her spindle. Darius asked if all the women of Phoenicia were so industrious, and, being told that they were, ordered that all the Phoenicians—men, women, and children—should be removed from their own country into Persia.

Whether this reward of merit was appreciated by the Phoenicians or not, Herodotus does not say.

The spinning wheel was the next development in spinning machinery, and is still in use in China, Japan, and various Eastern countries, as well as in remote parts of Ireland, Scotland, and Wales, where home industries still linger.

In its most perfect form it is an ingenious arrangement, by means of which the two operations of twisting the thread and winding it up are done simultaneously.

We have mentioned that Penelope and her maidens plied the loom. A Greek vase-painting, dated about 500 B.C., shows us that this loom was arranged in a similar way to those in which Oriental carpets are woven by hand to-day, i. e., the warp threads hang vertically downwards, and the woven cloth is wound upon a roller above, the fabric and pattern being produced by interlacing the weft threads in various ways and order. On a small vase in the British Museum there is a sketch of a lady weaving on a small frame supported on her lap.

The character of still earlier looms, and the process of weaving, can only be inferred from incidental notices. The Bible does not notice the loom itself, but speaks of the beam to which the warp was attached; for example (1 Samuel xvii, 7), 1063 B.C.: "And the staff of his spear was like a weaver's beam;" also of the pin to which the cloth was fixed, and on which it was rolled. For instance (Judges xvi, 14), where Delilah fastened Samson with the pin: "And he awakened out of his sleep, and went away with the pin of the beam, and with the web."

We also have notice of the shuttle, which is described by a term significant of the act of weaving (Job vii, 6), 1520 B.C.: "My days are swifter than the weaver's shuttle."

The "thrum" or threads which attached the web to the beam are taken notice of in Isaiah (xxxviii, 12): "I have cut off like a weaver my life; he will cut me off" from the thrum.

Ovid writes:

"The web enwraps the beam, the reed divides,
While through the wid'ning space the shuttle glides,
Which their swift hands receive, then, poised with lead,
The swinging weight strikes close the inserted thread.
Each girds her flowing garments round her waist,
And plies her feet and arms with dexterous haste."

The Egyptian loom was usually upright, and the weaver stood at his work, the cloth being fixed sometimes at the top and sometimes at the bottom of the

*From *Knowledge*.

loom. Pictures of primitive looms in many cases exhibit no feasible shedding apparatus, while the implements found to be used for carrying the weft lead us to believe that the operation of weaving in those days partook largely of the nature of darning. Probably the oldest representations of looms existent are those to be found on ancient Egyptian tombs. Several of these have been found at Thebes, on tombs fixed by the best authorities as belonging to the period about 3000 B.C. It is probable that the Egyptian form of loom was carried first to Greece, and thence to Italy, without suffering much change in its migration.

Montfaucon, a French monk, writing in the early part of the eighteenth century, refers to a work, believed to be of the fourth century, in which a Grecian loom is shown, which differs very little from the Egyptian.

The process of inserting the rod carrying the weft alternately over and under the warp, as a woman does her needle in darning, is obviously a tedious one, and would decidedly limit production. The necessity, therefore, for some means of separating the warp would soon assert itself.

The most ancient type of heddles, or camb, known, is also traced to Egypt, and consisted of a rod over which a number of simple loops of twine were passed through which the warp threads were drawn. For plain cloth two of these would be required to act upon alternate threads. An ancient Indian loom shows this. There is no reed—just two heddle shafts which are actuated by hand. The weft is brushed into the fell of the cloth, and then beaten up by a stick.

In the Egyptian form of loom, the weft seems to have been drawn through the shed by a hook fixed on the end of a rod. It would then develop into passing the stick, with the weft wound upon it, through the shed, and from this would develop a piece of wood, or shuttle, specially shaped for the purpose of conveying the weft through the shed, and into which fresh supplies could readily be passed. When heddles for shed-forming were invented, this piece of wood became quite short and pointed, and was thrown by one hand from one side of the loom, and caught by the other hand at the other side when the web was a narrow one. Upon broad looms two weavers had to be employed, one at each side, to throw the shuttle in turn to each

other. The task of the weaver of that day is thus described by Dyer in verse:

"He chooses some companion to his toil.
From side to side with amicable aim,
Each to the other darts the nimble bolt,
While friendly converse, prompted by the work,
Kindles improvement in the opening mind."

Thus, in the course of centuries, the ancient handloom was gradually improved. Probably the first step was the winding of the warp upon a roller, and the finished cloth upon another.

Next heddles were invented, and the warp was placed horizontally. Then the reed for pushing up the weft into its place was fixed in a swinging sley, upon which the shuttle slid as it was pushed or thrown across, and through the shed formed by the warp threads and heddle.

The title of our article forbids our following the development of the shuttle and the loom any further, although the history of and the opposition offered to the inventions of Paul Arkwright, Hargreaves, Crompton, Kay, and Cartwright, resulted in the modern spinning frame and power loom, make interesting reading.

Gasoline and Oil Engine Exhausts*

Methods of Determining Efficiency of Combustion

In the more elaborate tests on internal-combustion engines, it is becoming the practice to analyze samples of the exhaust gases, with the object of determining the completeness of combustion and the probable strength of the air-fuel mixture supplied to the engine. The mixture strength, however, cannot be estimated from a partial exhaust-gas analysis alone, but the estimation becomes possible in conjunction with an "exhaust-gas chart." By that is meant the set of curves obtained by plotting on a strength of mixture base, the percentages of carbon dioxide (CO_2), carbon monoxide (CO), and oxygen (O_2), which are found in the exhaust gases, the strength of mixture being expressed as the ratio of air to fuel, by weight. Thus if an engine is supplied with fuel mixtures of different but known strengths, and the exhaust from each mixture analyzed to determine the percentages of CO_2 , O_2 , and CO contained in it, and these percentages are then plotted against the ratio of air to fuel in the mixture, a chart is obtained which shows that the amounts of the CO_2 , O_2 , and CO constituents bear a definite relation to the mixture strength. That being the case, a partial analysis (for CO_2 , O_2 , and CO only) of the engine exhaust, together with an exhaust-gas chart for the fuel used, are sufficient for the estimation of the ratio of air to fuel in the mixture supplied to the engine, and a complete gas analysis (which is a rather troublesome matter) is not required. In his paper, read at the Institute of Mechanical Engineers on March 17th, under the title of the Composition of the Exhaust from Liquid Fuel Engines, Lieut. R. W. Fenning, R.E. (T.) shows further that the typical "exhaust-gas chart" for any fuel can be constructed without using an engine. In the course of his paper he also sets out the results of numerous experiments as to the composition of exhaust gases, especially with reference to the combustible products obtained when using strong mixtures. Several exhaust-gas charts have been prepared. In the paper those for hexane and benzene, gasoline (Bowley's Special) and commercial benzol will be found. It must be noted that such charts cannot be applied directly to cases in which the engine exhaust is diluted with unburnt charge or air, as in some types of 2-cycle engines.

Mr. Fenning's paper, then, consists largely of curve diagrams and comments on them, and may fairly be said to defy summary. It also contains a description of the apparatus used, and of the precautions which have to be adopted. Shortly, the air and fuel were mixed in a glass flask and subsequently passed from the mixing flask into the burette of a Macfarlane and Caldwell gas-analysis apparatus (mercury displacement apparatus being used). After measurement in the burette, the mixture was passed into a glass explosion-vessel (in which mercury displacement was also used). The mixture was next ignited by the passage of a high-tension spark, and the gaseous products of combustion drawn back into the burette and measured. The products were then ready for analysis. In doing this it was found that some details were important; thus the presence of rubber was found to have a weakening

effect on all the air-fuel mixtures, benzol mixture being largely effected, gasoline considerably, and hexane slightly. The employment of rubber was therefore limited to one connection only—that between the abutting capillary tubes of the flask and the burette or the explosion-vessel and burette—and in this case the inside of the rubber tube was coated with soap. The pressure of the mixture before explosion varied from a few centimeters of mercury above atmosphere to a few below, its amount being regulated to suit the strength of the mixture. With weaker mixtures the higher pressure was employed to secure satisfactory ignition. Further, in some cases the explosion took place at constant volume, the lower cock of the explosion vessel being closed, whereas in other cases this cock was left open to limit the risk of bursting the vessel. Under the conditions of explosion several of the weaker mixtures would not fire without the addition of a small quantity (from 6 to 14 per cent) of oxy-hydrogen gas. Mixtures weaker than about 16 or 17 of air to 1 of fuel seem to require this addition. The oxy-hydrogen gas, of course, entirely disappears on explosion, and therefore has no influence on the subsequent analysis. Some of the processes in the analysis also required the production of combustion, and for this purpose oxy-hydrogen was again employed, the quantity being regulated according to the amount of combustible gas already present. The (oxy-hydrogen) electrolytic gas has to be used with discretion, since too much causes a high temperature explosion, with the possible formation of oxides of nitrogen, and the resulting contraction in volume cannot be interpreted, while, on the other hand, too small a quantity gives incomplete combustion and equally misleading results. In the gas analysis, the Macfarlane and Caldwell apparatus was used throughout, and found to give satisfactory results. Caustic potash solution was used as the absorbent of carbon dioxide, alkaline pyrogallol for oxygen, cuprous chloride in hydrochloric acid solution for carbon monoxide, and fuming sulphuric acid for heavy hydrocarbons. Hydrogen was estimated by fractional combustion in a glass tube containing a palladium sponge. (It will be seen that even a partial gas analysis is not just as easy a job as reading a thermometer.) Altogether about eleven pipettes were required for a complete analysis. As a matter of fact the products of combustion of strong mixtures contain combustible gases, and it is the estimation of these gases which make even the "partial" analysis so elaborate. The paper gives full details of the procedure and subsequent calculations, but these are rather for the chemist than the engineer. The point of the matter is this: One might proceed by a direct calculation of the mixture strength instead of by the employment of an "exhaust-gas chart," but the former course presupposes a complete analysis of the exhaust gas, which would take from 2 to 5 hours, whereas the latter requires only a partial analysis, taking from 35 minutes to 1¼ hour. The important thing in the paper, then, is that the author shows that mixture strengths calculated from the exhaust are more accurate than have generally been supposed. The ratios by volume of hydrogen to carbon in the exhaust and in

the fuel should agree if the analysis has been sufficiently complete to reveal all the constituents containing carbon and hydrogen. As a matter of fact he finds that they do so agree (very fairly).

One may pass then to some general conclusions that appear to come out as the result of Mr. Fenning's experiments. The first is the somewhat surprising fact that with volatile fuels there is very little difference in the composition of the products of combustion (at atmospheric pressure) or air-fuel mixtures in a small explosion-vessel and in an engine cylinder, when all the conditions are so dissimilar. It is only because the agreement between the CO_2 , O_2 , and CO values in the engine and the explosion-vessel tests is so close that an exhaust-gas chart prepared from explosion-vessel tests can be used to estimate the strength of mixture supplied to an engine. In general only a very small quantity, if any, of unsaturated or saturated hydrocarbons is present in engine-exhaust gases. (To take a particular instance, methane is almost entirely absent.) The hydrogen constituent in exhausts from strong mixtures is an important item, and increases in value rapidly with increase in mixture strength. The ratio of air to fuel in the original mixture can, as has been said, be calculated with a considerable degree of accuracy from the composition of the exhaust gases, and the reliability of Dr. Watson's method and apparatus for measuring the air and fuel supplied to an engine is once more demonstrated. The author adds: "It has been shown by Dr. Watson and others that mixture strength has a considerable influence on the thermal efficiency of an explosion-engine. Given an exhaust-gas chart for the fuel, the strength of mixture can readily be found from an analysis of the exhaust gases. Why not adopt this method when setting carburetors and thus promote fuel economy, lessen carbonization, and minimize the pollution of the atmosphere by such poisonous gases as carbon monoxide?" Mr. Fenning also acknowledges with gratitude the facilities given by the Governors of the Imperial College of Science and Technology for the purpose of carrying out his experiments.

As may be supposed, the discussion of a paper of this kind was very select. Prof. Callendar (of the College of Science) said the paper showed that the phenomena were extremely simple if only the combustion was really complete (which ought always to be sought for by a respectable engineer and a decent driver). Dr. Dugald Clerk referred to experiments made by the Royal Automobile Club with about forty different cars and real engines. The main thing there was the amount of CO found in the exhaust under certain conditions. That really meant too little O_2 . Using too much gasoline in this way one might lose 30 per cent of the heat of complete combustion. The weaker the mixture (i. e., the more air) the higher the thermal efficiency, so that omitting dead waste like that of incomplete combustion as above, just enough oxygen to burn all the carbon and hydrogen to CO_2 and H_2O was really the least economical mixture that could be used. (Dr. Dugald Clerk's argument is based on specific heat, but Mr. Fenning's "charts" show the same result arrived at experimentally. The mechanical and other limitations to very weak mixtures are obvious.) One might, however, have too weak a mixture for complete combustion and find CO and free O_2 in the exhaust. The best ratio would appear to be about 16 air to 1 of fuel, and 80 per cent efficiency (indicated) was apparently quite possible.

*The Practical Engineer.

The Giant Salamander of Japan

Notes on a Great Batrachian Little Known in This Country

By Dr. R. W. Shufeldt

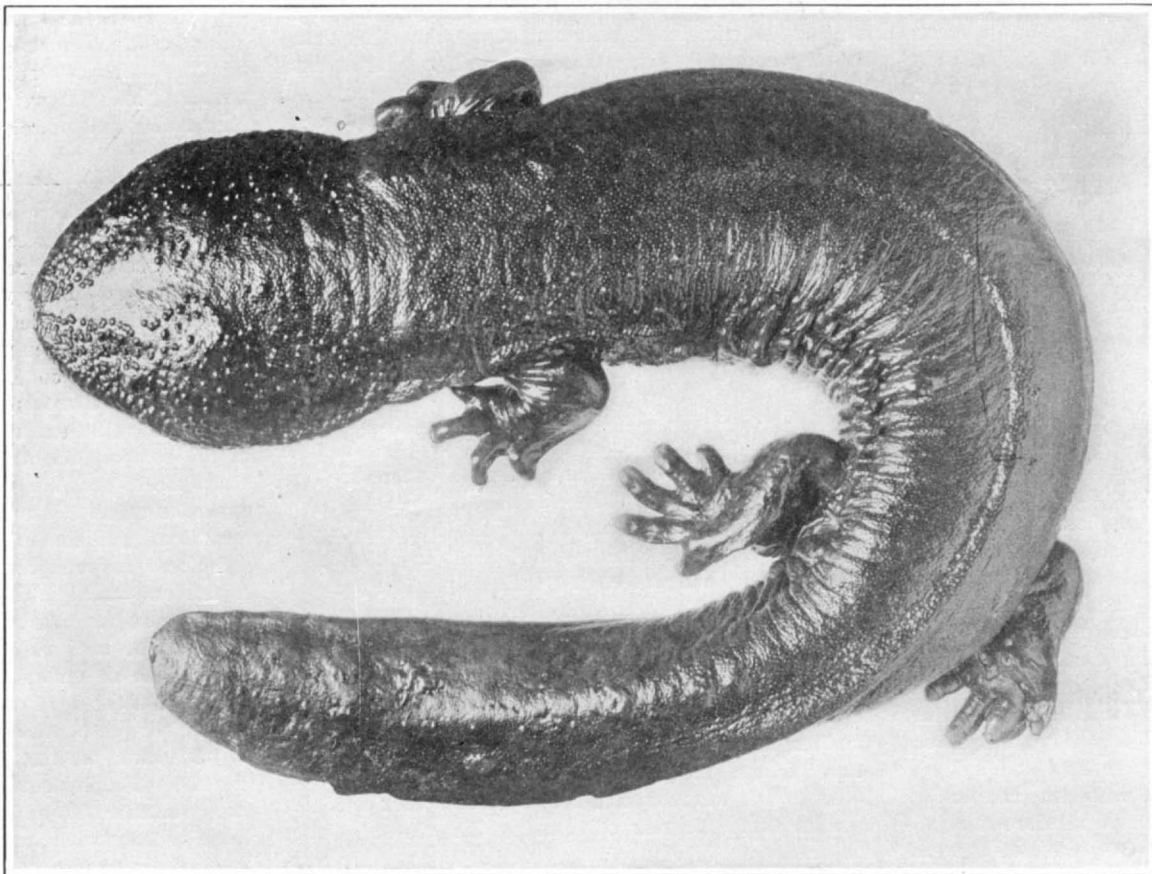
LIVING specimens of *Megalobatrachus giganteus*, that ponderous urodele of Japan and some parts of China, very rarely reach this country; and, in so far as I am aware, no photographs of live examples of this great, tailed amphibian have, up to the present time, been made, certainly not published. This being the case, I must believe that the reproduction of such a picture will be welcomed by our herpetologists, and it affords me pleasure to offer the same as illustration to the present brief article. The specimen shown in the figure was obtained, in fine condition, by Mr. Edward S. Schmid, of Washington, who kindly loaned it to me for the purposes of examination and photography on the 22d of April, 1916, on which date I succeeded in making several fine negatives of the animal.

This specimen was nearly two feet in length, and these salamanders rarely exceed three and a half feet. It appeared to be in excellent health, though, for some cause or other, a kind of ulcer had destroyed one or two of its toes, and two or three spots of the same disease were in evidence on the under parts. The tail of this great salamander is much compressed from side to side, while the body is flattened in the opposite direction. A sticky and abundant secretion exudes from all

parts of the animal's body, as clear as water and quite odorless beyond a very slight fishy smell. In color it is of a dark tan or earthy brown superiorly: all the under parts are somewhat lighter, with a sparse spotting of darker spots. On the upper surface of the head and fore neck are numerous minute tubercles, which are absent in the median area, being thickest in

the facial region and disappearing in the cervical area.

As in nearly all salamanders, it has four toes on each foot of the anterior limbs and five on the posterior ones. Laterally, the integuments are corrugated, the sulci being vertical. I was not able to determine the sex of this specimen, nor its age. Its eyes were remarkably small for the size of the animal, and there were no eyelids. It is said that this salamander lives entirely in the water, and is possessed of both gills and lungs. What it subsists upon is not known to me, though it is probably a carnivorous species, as most salamanders are. Small, clear mountain streams is where it is usually found, at an elevation of 700 to 5,000 feet above the sea. In these narrow streams, often not more than a foot in width, one finds this great batrachian hidden among the thick vegetation, and usually curled about some stone below the surface. The smaller individuals commonly creep into crevices among them, or into holes formed by the current of the stream. It is greatly to be desired that the National Zoological Park should secure this specimen, place it in some suitable aquarium, and exhibit it where it may be studied by naturalists and others visiting our beautiful Zoological Gardens at Washington.



The giant salamander of Japan.

Silica in Retort Settings

THE problem of the most suitable type of refractory material for the various portions of the retort setting is still far from being solved, but papers such as that recently communicated to meeting of gas engineers in Manchester by Mr. John West (the co-inventor of the well-known system of vertical retorts) are paving the way towards some understanding of the vagaries of these substances.

Refractoriness, *per se*, may now be said to give the manufacturer but little trouble, for even with the present-day combustion chamber temperatures of about 2,600 deg. Fahr. failure by fusion is a very rare occurrence. When subjected to heat, however, the various descriptions of fireclays have different habits as to the change of dimensions which they undergo. The ordinary aluminous variety, which is used in this country to a greater extent than any other type, contains about 65 per cent of silica, and has a tendency when heated to undergo contraction. Silica bricks or blocks containing up to 97 per cent of silica, on the other hand, show very considerable inclination to swell. It may, in fact, be said that as the percentage of silica in the material increases the coefficient of expansion rises in direct proportion. Midway between the aluminous clays which contract and the silica clays which expand is the intermediate product—siliceous clay—which is said to be devoid of any tendency towards change in dimensions.

LABORATORY AND WORKING RESULTS.

It is believed, however, that this reputation has been acquired solely as a result of laboratory investigation, for in practical working there are evidences that not even siliceous clay is free from expansion. Mr. West in his paper emphasizes the fact that in this direction laboratory results must, if they are to be relied upon, be backed up by further investigation on a working scale. A case in point is the behavior of clays when heated under stress. When playing the part of a single unit in a retort setting all bricks or blocks must be subjected to a certain amount of compression, which,

in addition to influencing refractoriness, must have an important effect on the ability to expand. As regards the effect on refractoriness, Dr. Mellor has shown that a compressive stress of 54 pounds per square inch is followed by a decrease in this property amounting to from 12 to 13 per cent. So far as expansion is concerned tests made on the laboratory scale by Dr. Mellor with Derbyshire silica showed that there was neither expansion nor contraction. Mr. West, however, has put the same material to a test on a much larger scale, and finds that the material swells to an amount equal to nearly 1 per cent. The method he employed is certainly ingenious. A column of bricks 100 inches high was built inside one of the kilns in which the bricks are burned off. The column was put up just under the cooling hole of the crown of the kiln, and the measurements were taken by fixing an iron bar some distance above, and clear of the kiln, over this hole. By means of the bar accurate measurements were taken from time to time under varying temperatures. The results indicated that the column of bricks expanded to 100 $\frac{1}{8}$ inches at a temperature of 2,600 deg. Fahr. It is also noted that in the case of a silica vertical retort 21 feet in length a total expansion of 2 inches was registered.

METHODS OF COMPENSATION.

It being known that some swelling does occur, although it is practically impossible to gauge exactly what it will amount to, the problem resolves itself into one of determining the most satisfactory means of dealing with this change of dimensions. Some allowance must be made, otherwise the expansion may give rise to such heavy stressing as to cause collapse of some portion of the setting. Probably one of the most scientific methods is that of so disposing the various materials throughout the setting that any expansion of the silica work is compensated for by a corresponding contraction in the aluminous portion. One London gas company which can point to extraordinarily long working periods of its retorts has adopted this principle of construction for some years. A good deal can, of

course, be done by avoiding the very fine joints which are often found, and when much expansion is to be expected a $\frac{3}{8}$ inch joint will prove none too wide. A less usual but nevertheless entirely trustworthy method of compensation is that of laying round the retorts wooden battens about an inch thick, and at a pitch of about 3 inches. These are bricked up in position and the setting is put under fire. As the heat increases the battens gradually char away and provide expansion room for the brickwork.

As regards the effect of load on the refractoriness of fireclays, it is of interest to note that Dr. Mellor, in company with Lieut. Moore, has succeeded in elucidating a general law for the relationship between the ability of the material to resist high temperatures and the loading to which it may be subjected. In applying the law, however, the main difficulty will be found in arriving at a reasonable figure for the amount of stressing which does take place.—*Engineering Supplement of the London Times.*

Why Water Pipes Burst

WHEN closing a water faucet a dull thud is frequently heard in the adjoining pipe, but few people give the matter any attention. This sound, however, has a decided significance, for it tells of a severe pressure and strain put upon the pipe, which is liable to be ruptured unless it is very strong. When a faucet is opened the water flowing through the pipe acquires a considerable momentum, and if the valve is closed suddenly this momentum reacts on the pipe, its force depending on the normal pressure and the speed with which the water flows. With a normal pressure of 125 pounds in the main, and only 20 pounds at the faucet, a pressure of 550 pounds has been encountered in the pipe immediately behind the faucet, when the latter is suddenly closed, and the pressure in the main increased to 220 pounds. Under such conditions it is little wonder that the pipe bursts. This can be easily avoided if the faucet is closed slowly, thus gradually reducing the speed of flow in the pipe.

Photogenic Substance in the Firefly

Experiments Made to Ascertain How the Insect Produces Light

By E. Newton Harvey

PREVIOUS research on the subject of biophotogenesis has shown that at least three factors are necessary for the production of light, namely, water, oxygen, and a photogenic substance. A fourth factor is probably also involved, an oxidizing enzyme, as in other organic oxidations. Concerning this enzyme nothing is known, at least nothing definite in the case of the firefly. Indeed, Kastle's observations indicate that in the firefly no direct oxidizing enzyme (oxygenase) but small amounts of an indirect oxidizing enzyme (peroxidase) and a catalase are present. (Hygienic Lab., Washington, D. C., *Bull.* 59, 1910, 92.)

The old observation that many luminous tissues can be dried and ground up and will phosphoresce, when water containing oxygen is again added, gives us a simple chemical method of investigating the nature of the photogenic material. The dried material may be extracted with water-free solvents (since the photogen does not oxidize in absence of water), and extracted material as well as the residue from evaporation of the filtrate tested for phosphorescence by adding water. Or the dried material may be extracted with oxygen-free aqueous solvents (since the photogen does not oxidize with light production in absence of oxygen), and filtrate and residue tested as before by admitting oxygen. The first method is satisfactory, and has indicated that a large number of fat solvents will extract nothing from the dried tissue and yet leave the photogenic material unharmed. Indeed, the material may be extracted with boiling ether for twenty-four hours without impairing its power to phosphoresce. Boiling alcohol does destroy the power to phosphoresce, and the nature of its action is discussed below. These results, as well as the previous results of McDermott (*Journ. Am. Chem. Soc.*, 1911, xxxiii., 1791; *Smithsonian Report*, 1911, 345) and Dubois (*Orig. Comm. 8th Intern. Congr. Appl. Chem.*, 1912, xix., 86), using fresh watery material, show that the photogenic substance is not a fat or fat-like body of any kind.

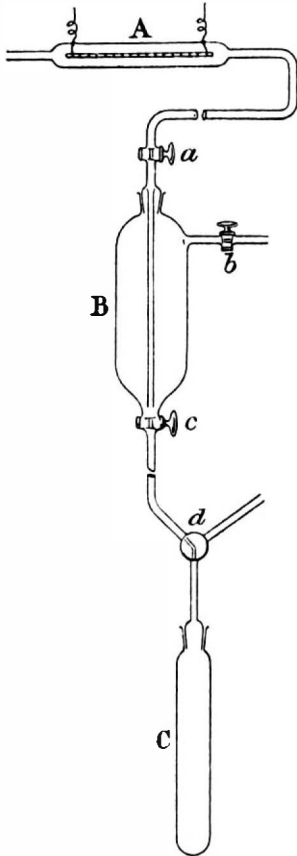
The second method—that of extraction with oxygen-free water solutions—is not satisfactory because the photogenic substance breaks up, or at least loses its power to phosphoresce, on standing in contact with water for any length of time *even if no oxygen is present*. Many attempts were made to extract the dried material with aqueous solvents, and filter the extract in absence of oxygen before it was recognized that such attempts were futile because of the instability of the photogenic substance in oxygen-free water.

My experiments were begun in the winter of 1913 on firefly material collected at Princeton, N. J., and dried over CaCl_2 in a vacuum. (See preliminary note, Harvey, *Science*, 1914, xl., 33.) I am greatly indebted also to Mr. F. Alex. McDermott, of the Mellon Institute, University of Pittsburgh, for an additional supply of material with which the work was continued. Mr. McDermott has been making experiments along similar lines with a somewhat different apparatus, and his results are likewise published in the *Journal of the American Chemical Society* (*loc. cit.*) As luminous material may be found which does not disintegrate in water the apparatus used for oxygen-free extraction is described below.

The material to be extracted is placed in the vessel C (in the drawing), provided with a ground-in stopper connected with a 120-degree stopcock. The water to be rendered free of oxygen is placed in B after passing hydrogen through stopcock C, and closing it. B is connected through A with a hydrogen generator. The hydrogen is passed through potassium hydroxide to remove acid, and then over a glowing platinum wire (in A) to remove the last traces of oxygen, a much better method than passing the gas through alkaline pyrogallol. By alternately exhausting B through b, connected to an air-pump, and refilling with hydrogen several times the water can be quickly rendered free of oxygen. C is then connected to B through c, and one of the arms of the 120-degree stopcock (d) whose other arm is connected with an air-pump. C and the arms of d are then exhausted. The 120-degree stopcock is then turned to connect C and B, and c is opened, allowing the pressure of the hydrogen to drive the solvent on the material in C. The proper amount of fluid for extraction should be placed in B so that the hydrogen may follow it through and fill the chamber C. Then d is closed, when C can be disconnected and shaken during extraction. To filter the extract it is only necessary to connect one of the arms of d with a desiccator fitted with funnel and filter rack. When the desiccator is exhausted, C and the desiccator are connected, and the pressure of the hydrogen in C

drives the extract onto the filter-paper. The firefly photogen begins to phosphoresce when the atmospheric pressure reaches 5 to 6 millimeters, which means an oxygen pressure of 1 to 1.2 millimeters. Consequently, it is necessary to use a good vacuum pump and make connections air-tight. I found small bore lead tubing sealed with Khotinsky cement the best for the purpose.

If one extracts with distilled water for a short time (fifteen minutes) and then filters, on admitting oxygen the filtrate is found to be dark while the residue on the filter-paper shows the bright points of light characteristic of the power of the firefly. But if the extraction be carried out for an hour or more, neither the filtrate nor the residue will phosphoresce when oxygen is admitted. All of my experiments have been carried out in the dark, and the material observed at critical stages (as when the oxygen-free water was added) to make sure that no light appeared, and always with negative results. But to make sure that no very slow leakage of oxygen into the filtering chamber occurred, I have carried out the extraction in a special tube provided with a capillary sealed off during the extraction. After extracting in this tube for one and one half hours and admitting oxygen no phosphorescence appeared. Thinking that possibly the pho-



togen dissolved in the extracting fluid did phosphoresce, but only so faintly as to be invisible because distributed through a relatively large volume of extract fluid, the unfiltered extract was evaporated *in vacuo* to a small volume. This can be very easily done by placing the rubber tube from the vacuum pump over the capillary onto the special tube, exhausting, and then breaking the capillary through the walls of the rubber tube to connect with the air-pump. Even when concentrated, the extract gave no light on adding oxygen.

The photogen is therefore destroyed in distilled water without oxidation. The search for a watery solvent for photogen becomes then a search for a solvent in which the photogen is stable. The following solutions were tried in addition to distilled water. Extraction was allowed to proceed for from 1 to 1.5 hours.

1. Ringer's solution (as representing fairly accurately the concentration and composition of the firefly's blood).
2. 0.125 M NaCl.
3. Sea-water (a mixture of chlorides and sulphates of Na, K, Ca, and Mg).
4. Five per cent NaCl.
5. 0.05 M NaOH and 0.01 M NaOH. The dried powdered firefly organs will phosphoresce strongly if sprinkled on the surface of 0.1 M NaOH.
6. 0.02 M HCl. Dried firefly powder will phosphoresce on 0.0125 M HCl and on 0.025 M HCl, but less brilliantly. Only one or two bright dots appear on 0.05 M HCl, and no phosphorescence occurs on 0.1 M HCl. If neutralized within two minutes after contact with the acid, the light does not appear in the 0.1 M HCl treated material nor

become brighter in the 0.05 M and 0.025 M material.

In each case after extraction, oxygen was admitted and the solution shaken, yet in no case did light appear either in the undissolved residue or in the solution. The 0.02 M HCl extract was also neutralized as it is well known that the acid prevents biophotogenesis. The conditions of phosphorescence in the firefly are therefore more complex than at first supposed. Either the photogen, the enzymes, the enzyme activators, or all three, undergo changes which are not oxidative in nature, when the material stands in contact with water for a time sufficient to dissolve out the luminous material. Both McDermott's results and mine agree perfectly, and while negative and disappointing they are deemed worthy of publication as indicating that water, oxygen, and a photogenic substance are not the only factors involved in light production, and also as showing the instability of the photogen.

My work with water-free solvents has been confined to those listed in Table 1, which gives also the time of extraction, temperature, and results.

TABLE 1.

Substance.	Temperature, Degrees.	Time, Hours.	Extracted Material.	Extract Evaporated in Vacuo.
Ether (cold).....	20	72	+	—
Ether (hot).....	55	24	+	—
Chloroform (cold).....	20	72	+	—
Chloroform (hot).....	61	8	+	—
Ethyl alcohol (cold).....	20	24	+	—
Ethyl alcohol (hot).....	78.4	24	—	—
Ethyl alcohol and ether (equal parts) boiling.....	44	10	+	—
Carbon tetrachloride.....	20	48	+	—
Carbon disulphide.....	20	48	—	—
Acetone.....	20	48	+	—
Toluol.....	20	48	+	—
Amyl alcohol.....	20	48	Very faint*	—
Ethyl butyrate.....	20	18	Very faint*	—

* The material was washed with ether to remove the amyl alcohol and ethyl butyrate.

A plus sign indicates phosphorescence when water is added, and a minus sign indicates no phosphorescence. Both the original extracted material and the residue of the filtered extract evaporated to dryness were examined. The results indicate that the photogenic substance is not a fat or oil, and also not a lecithin. I am aware that the lecithins are difficult to extract *in toto* from the cell, but this can be accomplished by a mixture of hot ether and alcohol, and yet a mixture of hot ether and alcohol will extract nothing which will phosphoresce from the firefly powder. We may safely say that the photogen is not a lecithin.

Of all the solvents tried only hot alcohol and cold amyl alcohol and ethyl butyrate gave results that would indicate a possible solution of the photogenic substance. And yet there is nothing in the filtrate residue that will phosphoresce when water or a neutralized 3 per cent solution of H_2O_2 is added. Thinking that oxidizing enzymes might be necessary, and that these had not been extracted by the fat solvents although the photogen had, the filtrate was also tested by adding a water extract of firefly organs, fresh or preserved with toluol or chloroform, and also by potato-juice which contains considerable quantities of oxidizing enzymes. In no case was phosphorescence observed. The boiling ethyl alcohol (see Note), cold amyl alcohol, and ethyl butyrate must therefore break up the photogen. It is the alcohol itself and not the temperature (78.4 degrees) of boiling alcohol which is responsible for the destruction of the photogen, as the dried powder will withstand this temperature for twenty-four hours without any appreciable diminution in its power to phosphoresce. McDermott finds that liquid sulphur dioxide and liquid ammonia also destroy the photogenic power.

(NOTE.—The 99.8 per cent absolute alcohol was distilled over metallic calcium and collected in a receiver protected from the air by CaCl_2 in order to remove the last traces of water.)

The powder obtained by drying cultures of luminous bacteria behaves similarly to the firefly material.

These results indicate that it will be a vastly more difficult problem to isolate and identify the photogenic substances than might at first be supposed.—*Journal of the American Chemical Society*.

Fluxes for Oxy-Acetylene Welding*

Methods Used In Welding Cast Iron, Wrought Iron, Steel, Brass, Bronze and Aluminum

By S. W. Miller

Those who are familiar with oxy-acetylene welding are aware that fluxes, scaling powders, etc., are used; but it is not generally known why the use of these fluxes is necessary. They are sometimes used in the shape of powders into which the welding rod is dipped, thereby transferring the flux to the weld; or they may be incorporated in the welding rod itself. Also a special welding rod containing certain elements may be used in connection with a powdered flux. Inasmuch as each metal has different characteristics and requires different treatment during the welding process, the nature of the flux varies with the metal. Therefore, it will be well to consider each metal separately, first explaining the nature of the difficulties encountered and then describing the remedies which are applied, including, as far as possible, the materials used for making the fluxes. It should be stated here that the manufacture of satisfactory fluxes requires considerable chemical knowledge and, in the majority of cases, should not be undertaken by a welding shop because of the difficulty of getting the proper amount of the necessary elements and mixing them properly, and because it is cheaper, as a general rule, to buy the fluxes from the manufacturers than to attempt to make them.

CAST IRON.

Melted cast iron has a great affinity for oxygen, which combines with it to form an oxide of iron or slag. This affinity which molten iron possesses for oxygen is well illustrated by the amount of slag produced during the cutting of steel, this slag being nothing but oxide of iron. In the case of cast iron, the oxide is lighter than the melted metal and does not melt at quite so low a temperature. Being lighter, it rises to the surface which makes it easier to dispose of. Many kinds of fluxes for cast iron are furnished by the manufacturers of welding apparatus, or by manufacturing chemists, which vary considerably in their composition, but as far as the writer's experience goes, they differ but little in efficiency. The principle of all of them is to provide some chemical which, at the high temperature involved, will break up the oxide into its component parts. For cast iron the writer has found that a mixture of equal parts of carbonate of soda and bicarbonate of soda makes a very satisfactory flux. Ordinary washing soda is the name commonly given to a somewhat impure carbonate of soda. Bicarbonate of soda is ordinarily baking soda. The carbonates can be obtained in a chemically pure condition from the manufacturers of chemicals, but the writer finds no particular advantage in their use. A good way to prepare the flux is to grind the washing and baking sodas together in an ordinary meat grinder, passing the material through the hopper two or three times in order to be sure of securing a thorough mixture. Somewhat more of this mixture will be used in welding than would be the case if one of the high priced fluxes was used; but as both ingredients are obtainable at any grocery store at five cents per pound, the difference in cost more than offsets the difference in the amount used. The action of the carbonates is to combine with the oxygen in the slag, reducing the iron, and allowing the oxygen to pass off in the form of carbon monoxide or carbon dioxide gas.

It will be noticed in the use of a cast iron flux that as soon as a small portion of it is put on the melted iron, the surface of the metal becomes clear and mirror-like, and that under such conditions the union of the metal in the piece and the metal from the welding stick is easily made. The necessity of using a flux for cast iron may not be thoroughly appreciated, but if any one tries to weld cast iron without it, they will at once experience difficulty. In addition to the use of a flux, it is necessary in the case of cast iron to use a special welding rod which has a large percentage of silicon and a low percentage of manganese and sulphur in it.

When oxy-acetylene welding first became a commercial process, great difficulty was experienced in welding cast iron on account of the hardness of the welds, which prevented their being machined in any way except by grinding. This was due to the use of ordinary cast iron for welding rods. Such cast iron has comparatively little silicon and considerable manganese and sulphur in it. Silicon promotes the formation of graphite in iron, which makes it soft, while manganese and sulphur have

just the opposite effect; so that it will be seen that the use of ordinary cast iron tends to produce white iron or chilled iron containing no graphitic carbon, and which is intensely hard. The increase of silicon and the decrease of manganese in welding rods overcomes these objections and makes possible the production of a soft weld. The manufacturing of such welding sticks cannot be carried out in an ordinary foundry as the iron is not suitable. Therefore, it must be left to those who make a specialty of this work. There are several foundries in the country who do nothing else, and the material can be obtained from them, or from the manufacturers of welding apparatus.

STEEL AND WROUGHT IRON.

In welding these metals, a flux is not ordinarily used, although there is a certain amount of oxide formed which may be removed by the use of a cast iron flux. The melting points of both soft steel and wrought iron are higher than the melting point of the oxide, and while the oxide is lighter than the melted metal, there is more or less tendency for it to sink into the body of the weld. The judicious use of a small amount of flux will help this difficulty. In welding steel, however, the principal thing to guard against is burning the work, which no flux will overcome, and which ruins the weld beyond repair. While it is not necessary to use a flux in making ordinary steel welds, it is absolutely necessary to use the proper kind of welding rod or wire. The higher the percentage of carbon in the steel, the greater is the danger of burning. The writer does not believe it possible to burn wrought iron, which is simply steel with an exceedingly low percentage of carbon, the only difference between the two metals being due to the method of manufacture, which, in the case of wrought iron, naturally produces a metal with less carbon. Inasmuch as the welding wire is generally of considerably smaller section than the weld, there is a greater liability of burning the wire than the weld. The proper manipulation of the torch will help to overcome trouble from this source, but the necessity of having a welding rod that is not easily burnt is obvious, and therefore iron wire is used.

Ordinary iron wire of the kind purchased in a hardware store is quite impure, containing a considerable amount of slag and other impurities which affect the strength of the weld, because phosphorus and sulphur, which are known to be objectionable impurities in steel, are not eliminated from such wire. These impurities, passing from the welding rod containing them into the weld, seriously impair its strength and ductility. The purest wire that can be found is none too good for use in welding, and wire made from pure Norway iron stock has been found to give the best results. This wire can be obtained from wire manufacturers who make a specialty of its production. Much of it is also imported from Norway, and is handled by manufacturers of welding apparatus. It is foolish to attempt to use an inferior grade of wire in welding steel, as the unsatisfactory results obtained more than offset any slight saving in the cost of the wire.

It should never be forgotten that any weld is a casting, no matter what the metal may be, and that it is impossible to produce as strong a structure in the weld as in the original metal, even with the best welding material and fluxes, unless the weld can be given the same rolling or forging treatment as that to which the original metal was subjected. In the case of alloy steels, which are largely used in automobiles, proper heat-treatment must be given in addition to forging of the steel. These results are not often possible to obtain, because the piece cannot generally be forged; nor does it contain the necessary elements for successful heat-treatment, since the joint is not a truly autogenous weld. In addition, no welding shop with which the author is familiar has facilities for conducting such heat-treatments. Therefore, in such cases, a welded piece will not give satisfactory results. This is not the fault of the welder, of the material, or of the flux, but is an inherent limitation of the process. It is, therefore, wise to avoid welding such steel pieces, except in case of emergency or for temporary purposes.

COPPER.

There is no necessity for using a flux for welding copper, if the surfaces are clean and if the proper welding rod is used. Ordinary copper is quite free from impurities, because traces of such impurities make it impossible to use the copper. This metal, however, has

several peculiar properties. When melted it has a strong affinity for gases, such as hydrogen and carbon monoxide. Oxygen is also absorbed by the melted metal, producing copper oxide which forms a true alloy with the copper, making it brittle and worthless. When the metal solidifies, these occluded gases are given out, leaving the metal a mass of blow-holes. It is, therefore, necessary to provide something which has a greater affinity for oxygen than the copper. This is done by the use of phosphorus, which, instead of being used as a flux, is incorporated in the welding rod. Only a small percentage of phosphorus is required, as none should remain in the weld after it is made, although small traces of phosphorus in copper have no bad effect on its physical properties. It is evident that the production of such welding rods or wire is a matter which should be left in the hands of competent manufacturers. This special copper-welding material can, of course, also be obtained from apparatus manufacturers.

COPPER ALLOYS.

The alloys of copper include the various brasses and bronzes, which are exceedingly numerous and of a great variety of compositions. A brass is an alloy of copper and zinc. A bronze is an alloy of copper and tin. These alloys may have added to them lead, antimony, iron, manganese, nickel, etc., in smaller percentages than the main constituents. Inasmuch as it is impracticable in ordinary repair work to determine the percentage of the elements in copper alloys, it is manifestly impossible to make a truly autogenous weld, i. e., one containing the same elements as the piece to be welded.

Of course, where the process is used in manufacturing and the composition of the alloy is known, some experimenting will probably enable one to determine the most suitable mixture to use for welding rods; but in repair work it is necessary to find some one or two alloys which will apply to all of the metals that are likely to be met with. This is well taken care of by the manufacturers of welding apparatus and welding material, and suitable rods for general brass and bronze welding can best be obtained from them. The writer has found the best all-around welding material to be manganese bronze, although he has also used Tobin bronze with good results. The so-called manganese bronze is really a manganese brass, because the two principal ingredients are copper and zinc, the percentage of tin being quite small. Rolled manganese bronze rod or wire is quite fluid and makes a very good weld. Tobin bronze is somewhat more fluid, and while in many cases it works well, yet if the melting point of the piece that is being welded is high, due to the presence of a considerable percentage of copper, it may be difficult to get it to melt at the same time as the welding rod; manganese bronze not melting at quite so low a temperature is, therefore, found more satisfactory as a general rule. Tobin bronze is really a Tobin brass, as it consists mostly of copper and zinc.

It should be understood that the percentage of the various elements in both manganese bronze and Tobin bronze may vary considerably, so that they are not alloys of constant composition, the difference depending on the ideas of the manufacturers; but both contain some iron, which appears to give greatly increased strength and makes the essential difference between the properties of these metals and ordinary brass. As all brasses contain zinc, which readily volatilizes under the heat of the torch, the advisability of having a considerable percentage of zinc in the welding rod is apparent. Theoretically, the fluxes for a copper alloy should depend on the composition of the alloy, but while there are some objections to it the writer finds that for all practical purposes ordinary borax gives very good results. To prepare the borax for use, it should be melted and then allowed to cool, after which it is powdered, because in its original condition the borax does not lie quietly in the weld, but foams up and a good deal of it is wasted. It is the writer's experience that greater success is obtained by using a satisfactory welding rod for copper alloys than by varying the fluxes; and it should not be forgotten that when the composition of the piece being welded is unknown, the use of one flux may be satisfactory while another one is not. Borax seems to be the best all-around substitute. In welding brasses and bronzes, care should be taken not to heat the piece too hot. If carefully observed, it will be noticed that at a certain temperature the prepared surfaces will show little globules rising from them. This is the

*From *Machinery*.

temperature at which the metal from the welding rod should be added. It will be found that if this is done a satisfactory weld will be made, provided the surfaces are clean and a small amount of borax is used as a flux.

ALUMINIUM.

At high temperatures aluminium has a strong affinity for oxygen. At ordinary temperatures, pure aluminium is but little affected, but all ordinary aluminium pieces, which are generally alloys of aluminium and copper or of aluminium and zinc, tarnish more rapidly. The tarnish is due to the formation of a thin film of oxide of aluminium. Unlike iron or steel, where the oxidation or rusting goes on indefinitely, the thin film of oxide on the surface of aluminium protects the metal from further attack at ordinary temperatures. However, when aluminium is melted it oxidizes freely, and as the oxide or slag is heavier than the melted metal and melts at a very much higher temperature, the tendency is for it to become mixed with the molten metal and weaken the weld. This action of the oxide makes it very troublesome for a beginner to weld aluminium.

The chemical inertia of the oxide makes it exceedingly difficult to decompose with a flux, even at the temperature of melted aluminium. Fluxes for this purpose, therefore, have to be very strong and chemically active, and of difficulty with those which the writer has used is the after-action on the aluminium, a large number of pieces having been observed in which the metal for some distance around the weld had been seriously injured by this action, although it took some time for the damage to develop. In some cases, instructions are issued that after the welding is done, the piece must be thoroughly brushed off with boiling water to remove the remnants of the flux and prevent this action. It is also the writer's experience that after a weld has been made with a flux, should a crack develop in it or near it, such a crack cannot be welded without considerable difficulty, if it can be welded at all, unless the surface is thoroughly cleaned and the metal in the old weld has been removed. Also, while it is theoretically advisable to use a flux, and while in the case of sheet aluminium it is necessary to do so, there are other reasons in the case of repairs to such castings as automobile crank cases, transmission cases, etc., why the use of a flux is difficult. The principal ones are the condition of the surface before welding, and the fact that it is not desirable, in the case of thin sections of aluminium, to prepare the piece by beveling it, as is done in the case of iron and steel. There is considerable shrinkage in an aluminium weld, and it is advisable to resist this as much as possible by leaving the full thickness of the section, the thin edge of a prepared piece having less area and therefore offering less resistance. Of course, this will not stop shrinkage entirely, but it helps to do so.

Again, before any flux can be used, the surface must be entirely cleaned. Frequently, it is not possible to do this, although the use of strong acid and alkali, such as hydrochloric acid and caustic soda (applied to the work separately), followed by a thorough washing and brushing in water afterward, will remove the grease and dirt from the exposed surfaces. It will not, however, remove the oxide nor, as a general rule, will it remove the grease and dirt from the crack or break, because they are more or less absorbed by the aluminium, which is porous. This absorption extends in some cases for quite a distance from the break, and unless such metal is entirely cut out the use of a flux will be found unsatisfactory. Of course, in some cases it is possible to spring a piece to allow for contraction, but in other cases this is not feasible and other remedies must be resorted to. The narrower the weld, the less the contraction and distortion of the piece, and so the less metal removed the better.

A number of fluxes are sold by the apparatus manufacturers and the chemical companies which vary in composition, and these firms should be consulted as to the best flux to use, the conditions under which it is to be applied being thoroughly explained. Sheet aluminium work is generally a manufacturing proposition, sheet aluminium being used largely for automobile and carriage bodies and similar purposes. A flux is necessary for the proper performance of the work, but as the surfaces are clean the same objections to a flux do not exist as in the case of broken parts, and a proper flux will make the weld just as tough and capable of standing as much work as the original sheet. A flux which was devised in France in the laboratory of the Autogenous Welding Association has the composition given in the accompanying table. A very small amount of this flux is all that is necessary with clean metal, but it should be remembered that it is necessary to wash the flux off carefully, as previously explained. This flux gives a bright red color to the flame when it is applied, which is characteristic of

lithium salts. The writer has used this flux and finds that, as would be suspected by one familiar with the chemical properties of its ingredients, it is exceedingly active. It is, however, open to the objections mentioned above.

COMPOSITION FOR WELDING ALUMINIUM.

Ingredients	Per Cent.
Lithium chloride.....	15
Potassium chloride.....	45
Sodium chloride.....	30
Potassium fluoride.....	7
Potassium bi-sulphate.....	3

In most cases, a weld can be made without the use of a flux in the time taken to prepare the piece so that a flux can be used. Therefore, for practical purposes, the use of a flux in other than special cases is believed by the writer to be inadvisable, and a resort to the puddling of the weld with a rod made of soft steel about 3/16 inch in diameter and bent to the desired shape appears to be the best way out of the difficulty. It is true that more or less oxide is included in welds thus made, but the fact remains that they are plenty strong enough for service and tests show that they are generally stronger than the surrounding metal. This being the case, it is evidently a question whether it is advisable to resort to the use of a flux. The puddling must be thoroughly done and care must be taken to keep the metal melted while it is going on; but if the proper precautions are observed there will be no serious defects visible in the weld through an ordinary magnifying glass, and the work will last as long as the original part. Acquiring the necessary skill to enable one to make a satisfactory weld in this way takes time, and some men never become good aluminium welders. Close observation and the frequent breaking of test pieces will show whether the necessary skill is being acquired, and what is necessary to do in order to overcome any difficulties that may arise. There are two other points to be considered in connection with the use of an aluminium flux. First, there is no casting made that is not more or less porous, due to the presence of oxide in it. This being the case, the writer does not see any use in trying to make the weld any better than the casting. Second, even by the use of a flux, it is not possible to make a perfectly sound weld, although it is freer from porosity than one made without a flux. Therefore, the question of the use of a flux with aluminium casting is a practical one rather than theoretical, and in the writer's mind the arguments against the use of a flux carry more weight than those in favor of it.

The principal alloys used in this country for aluminium castings that the ordinary repair welding shop meets with are composed of about 93 per cent aluminium and 7 per cent copper; while in England and on the Continent, the general alloy appears to be about 90 per cent aluminium and 10 per cent zinc. In both cases, other elements are present in small quantities. The zinc alloy is somewhat stronger at ordinary temperatures than the copper alloy, but has the peculiar disadvantage of being very brittle at a temperature just below the solidification point. This makes it difficult to cast, particularly if the pieces are of a complicated shape; but while a welder may encounter some of these zinc alloys, particularly in parts cast a number of years ago, at the present time he will find but few of them. This is fortunate and considerably to his advantage, because it is sometimes very difficult to weld an aluminium-zinc alloy on account of the tendency of the shrinkage strains to crack the metal. The writer has frequently found it necessary in such cases to purposely cut the casting at a point where it can be sprung to compensate for the shrinkage, but in several cases has found it impossible, even by doing this, to avoid cracking. A zinc alloy can generally be readily detected by the condensation of the white oxide of zinc fumes on the colder parts of the casting. In such cases, thoroughly preheating the whole piece to the highest safe temperature undoubtedly helps to reduce the shrinkage strains. The writer finds that the welding rod for aluminium is very satisfactory if made of what is known as No. 12 mixture, containing 93 per cent of aluminium and 7 per cent of copper, and which can be obtained from the aluminium manufacturers in pigs. Any good aluminium foundry can cast from these pigs sticks of the desired size, or they can be obtained from any of the manufacturers of welding apparatus.

MALLEABLE IRON.

This metal is a very peculiar one, and on account of its method of manufacture, but little is generally known of its peculiarities and characteristics. Cast iron contains two kinds of carbon, one of them combining with the iron and making iron carbide, which is a true alloy, and the other existing free in the state of graphite. The graphite is in the form of thin plates

or flakes which break up the continuity of the iron, and its presence accounts for the comparatively low strength of cast iron. White iron or chilled iron has no free carbon in it, all of the carbon existing in the combined state as carbide of iron. Malleable iron is manufactured by packing white cast iron in boxes filled with some pulverized material as iron ore, lime or sand and subjecting it to a high temperature for several days, so that some of the combined carbon is partly removed by being oxidized; but it is mostly changed into a third condition which is called "temper carbon." This latter change cannot take place in the presence of any appreciable amount of graphite, which is the reason for using white iron in the process.

It is not necessary to go further into the metallurgy of malleable iron, except to say that the quality of a malleable iron casting depends on the material in which it is packed during the annealing process, on the time to which it is subjected to the heat, on the temperature, and on the original quality of the material from which it is made. If the casting is small, if it is packed in such a material as iron oxide, and if it is subjected for a long enough time to a sufficiently high temperature, a large percentage of the carbon may be eliminated, resulting in the formation of a crude steel. Such castings can be welded with ordinary steel welding wire and very good results obtained. In a thick casting, however, particularly if it is not packed in iron oxide or some similar material, the action is different, and the resulting metal is not a crude steel but a form of cast iron, except on the outside, where there will be a thin layer of the steel formation. A welder who observes closely, will notice that such a casting acts peculiarly. The outside skin is hard to melt and acts as steel does under the torch; while the center part acts more like cast iron, becomes full of blow-holes, and cannot be welded with steel, but will weld readily with cast iron, as in fact the whole section will do. At times such a weld is strong enough, but it has only the strength of the cast iron and will tend to be extremely hard.

A little thought will show why this is naturally the case. The original metal of which the casting was made, was cast iron of such a composition that it chills, even when poured in sand without a chill plate, so that the melting of the malleable iron tends to return it to its original condition of chilled or white cast iron, which is very hard and brittle. This accounts for the hard spots and brittleness of a malleable iron weld made with malleable iron welding rods. Of course, it is possible to eliminate these difficulties by again putting the piece through the malleabilizing process, but this is not possible in ordinary repair work, so that other means must be resorted to for joining the broken parts. It is impossible, therefore, to produce a truly autogenous weld in malleable iron without putting it through the malleabilizing process. Experience has shown that the most satisfactory and practical way of joining broken malleable iron parts is by using manganese bronze of the proper composition. Care should be taken not to heat the malleable iron too hot, and it must not be melted, but only brought to the temperature at which the bronze will alloy with it, and the weld should be somewhat reinforced. Borax used as a flux gives very good results.

It should be remembered in all discussions of fluxes that the flux used depends upon the kind of welding material used and *vice versa*, as well as on the material which is being welded; so that no general rules can be laid down governing all cases. More or less experimenting has to be done by every welding shop, particularly by beginners, because they are not able to reproduce at will the same conditions in the use of the torch; and the variations existing from this cause frequently overshadow or entirely obliterate the results obtained by the use of certain fluxes and welding materials. The preceding outline, however, is the result of the writer's experience during the past five years in welding over 16,000 pieces of all kinds and qualities of metal. That there will be changes in the practice of oxy-acetylene welding is undoubted. That new methods will be discovered is not questioned, as it is not to be expected that any process of so recent an origin as oxy-acetylene welding is fully developed. However, the writer believes that the composition of fluxes and welding materials should be determined in laboratories equipped for accurate work, and that rough experimenting without facilities for properly checking and determining the results is a detriment rather than a benefit to the art. He therefore recommends that, except where it is specifically stated above, fluxes and welding materials be either purchased from the manufacturers or from those furnishing the apparatus, and that time and money be not wasted in making experiments that have probably been made before by others better fitted to interpret the results.

Wave Proportions and Their Effects

By Arthur R. Liddell

Standard writers on naval architecture give us tables showing the lengths and periods of waves of different speeds of advance. Some of them also give sketches illustrating the generally accepted theory of the structure of the waves and state the laws governing a number of their characteristics.

One all-important point on which they leave us without guidance is that of the heights and the relations which these bear to the lengths of the waves. It may be that the absolute heights of full-grown deep-sea waves of a given speed partly depend upon temperature, degree of saltness and similar conditions of the water that are difficult to take into account, and that our only means of determining them is that of direct observation, which is beset with practical difficulties, but the general relation borne by the heights to the lengths of waves traveling at different speeds ought surely to yield in its general terms to mathematical treatment.

Waves are generated by the friction of air moving over the surface of the water. If the surface of the water is oiled, they subside considerably on account of the diminution of the friction. According to the accepted theory, the particles at the crest of a wave are moving forwards and those in the trough rearwards with reference to the general advance. The particles of air sweeping over the water will evidently behave in a similar manner, and will be moving at each point in the same direction as the particles of water adjacent to them. The back slope and the crest of the wave are impinged upon by the air, while the front slope and the trough undergo a reduction of the ordinary pressure of the atmosphere. The air, indeed, is continually sweeping up water from the back slope over the crest, while the front slope and the trough are advancing forwards and upwards trying to fill up the partial vacuum there forming.

Within a given breadth of path the work done in raising a single wave may be represented by $\text{area} \times v^3 \times c$, in which v is the velocity of advance of the wave, and c is a constant. Beyond a certain point the wave subsides as fast as it is raised—that is to say, it ceases to grow higher. This point is reached when the work done in raising the wave is equal to that done in its subsidence. The latter may be represented by weight of water $\times h^2 \times k$, or by $\text{area} \times h^3 \times k$, in which h is the height of the wave and k is a constant. If we now let constants be constants and also disregard area, which is the same in the two cases, we get v^3 proportional to h^3 and v proportional to h . In other words, the height of the wave is proportional to the velocity of its advance. But according to the standard tables the velocity of a wave is proportional to the square root of its length. We therefore get the height of the wave also proportional to the square root of its length.

The general results of observation with regard to proportions of wave height to wave length have been put together by Sir Wm. White somewhat as follows: Some short waves were found to have a proportion of 1 to 6; waves of 500 feet to 600 feet in length had one of 1 to 20, and the very longest waves were credited with about 1 to 50. If we assume that wave height = $1.17 \sqrt{\text{wave length}}$, we get: For a length of 49 feet, a height of 8.19 feet, i. e., about 1 to 6; for a length of 550 feet, a height of 27.5 feet, i. e., about 1 to 20; and for a length of 3,000 feet, a height of 64.0 feet, i. e., about 1 to 46.9. Assumptions here made are the lengths of the "short" and the "longest" waves and the factor 1.17, which is necessary to give the proportion of 1 to 20 for the 550-foot wave. The assumption of wave height = one-twentieth wave length was made by Mr. Wm. John some forty years ago in connection with calculations of longitudinal strength of the Atlantic liners of that day, which had lengths of about 500 feet to 600 feet. Unfortunately, some other naval architects thought they might use it for ships of all lengths, and their results were not always satisfactory.

The theory that the heights of the waves vary with the square roots of their lengths has been advanced by different naval architects, who, however, have not stated their grounds for its adoption. The theory has been received with considerable scepticism. It has been neither adopted nor repudiated by the profession at large. Some evidences in favor of it are the following: The sheer given to a ship is a development of long ages of experience. It is really governed by the proportion borne by the height to the length of the critical wave, i. e., of the wave having the same length as the ship. In consequence of the taper of entrance and run, passing wave crests rise higher at the ship's ends than at her mid-length, and the hollower the wave the greater is the height difference. The sheer given varies in

general about as the square root of the length of the ship, although designers do not go by any such rule, but simply comply with ordinary practice. Again, the minimum ballast draughts of vessels for sea work vary about as the square root of their lengths. A ship of 100 feet in length may have a minimum ballast draught of rather less than 10 feet. If it is much less she will maneuver badly, her propeller will race, and she will pound the water with her forefoot whenever she meets with the waves of about her own length critical for her. Further, the freeboard of a ship, which is likewise a growth of experience, has been shown to bear a definite relation to the square root of her length. As in the foregoing cases, this is governed by the proportion borne by the height of the critical wave to its length. Perhaps the most important practical application of the assumed law would be to the fixing of scantlings. The smallest admissible scantlings of merchant vessels are at present decided by comparison with tables that have been put together from the results of experience with ships of ordinary proportions and build. In the case of an abnormal design the ship is assumed to be at rest first on the crest and then in the hollow of a wave of her own length and of one-twentieth of her length in height. The longitudinal bending moments to which she is then found by calculation to be subjected are compared with those similarly ascertained for an ordinary ship of the same length. For the design the tabular scantlings may then be increased or perhaps diminished accordingly. For similarly loaded ships of any given length this method gives good comparative results, but when long ships are compared with short ones the respective proportions borne by bending moment to moment of resistance of midship section are found to vary very considerably. This would appear to show that long and short ships have widely differing factors of safety. That this is really the case, however, is exceedingly unlikely.

If, now, we make use of a wave height of $1.17 \sqrt{\text{length}}$ instead of .05 length, introduce the Smith correction for pressure differences in crest and trough water, and allow for worst possible longitudinal dispositions of weights, we get a proportion between bending moment and moment of resistance that is fairly constant for all sizes. It may be thought that the rules of practice are sufficient for all purposes, and are even more reliable than the application of the laws of mechanics. But this is not the case, since the guiding numbers used in the tables do not take sufficient account of unusual proportions of length to breadth and depth or of the possibilities of unfavorable dispositions of the weights of ship, machinery and cargo. Here, as everywhere, practice and its foot-rule theory must work together. Fair allowances of material can be made only by taking into account all the principal conditions of each case. To do this with a high degree of accuracy would involve very great labor. But this extreme accuracy is unnecessary. A rapid method that would take rough account of the main weights and moments concerned and give an infinitely fairer distribution of material between ship and ship than the present one could be very well devised. The present tables of scantling could then be held to apply to a set of definite conditions as regards proportions and loading of the ships and could be used as the standard of reference and comparison.

The present method is to apportion scantlings sufficient for the worst set of conditions to which a ship of given size to which they apply might be made liable, irrespective of whether a particular proposed ship of the size could ever be made subject to them. Rough scientific treatment might save the country half the difference between the most favorable and the most unfavorable set of conditions in each case, that are now treated alike. Methods of assessment of scantlings of the kind suggested cannot, however, be relied on with certainty till our knowledge of the proportions and action of the waves has been much further advanced.—*The Engineer*.

What Is Rheumatism

"RHEUMATISM" and "malaria" have ever been two of our most convenient terms with sufficient elasticity to cover almost any symptoms not otherwise easily catalogued. Uric acid for many years was assigned as a causative factor in rheumatism and the lay world and the patent medicine people still gloat over this term. Now we know that uric acid is in a measure innocuous and rather an end product of a complicated process. Neither is dampness and exposure a direct cause of rheumatism, only to the extent that bodily functions are thrown out of balance. Rheumatism should be thought of as an infectious disorder of endogenous origin, in other words it is due to toxin or bacteria found within the organism. In the light of

our best information these seem to be pus-forming germs and their ravages may be very remote from the site where they were produced. The tonsils and gums are now looked upon as arch-offenders in causing rheumatism, since they are so often the hotbeds of bacteria which are so easily dumped into the circulation. Rheumatism is therefore not to be considered as a definite entity but a condition that may be quite diversified in its manifestations as well as its etiology. It is nearly always due to poisons that are leaking into the blood and eventually set on a process in the serous membranes. Look for this source, if it is found and removed the rheumatism is "cured."—*Medical Summary*.

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