fact, the most concentrated, cheapest, and most nutritious of foods, and in feeding, mixing it with bran, middlings, hulls, or other feeds, it produces an ideal cattle food. The tendency of the times is toward more scientific feeding, and the utilization of cottonseed meal, with its high percentage of flesh-forming properties, makes a great advancement over the old method of feeding the whole seed.

The foregoing products are all incidental to the production of crude cottonseed oil. The crude oil is allowed to stand in settling tanks for a number of hours, and is then ready for the refining process. There is obtained from a ton of seed approximately 275 pounds of crude oil. The oil varies in quality considerably, depending upon the condition of the seed and the locality from which it comes. It will vary in color from a light brown to a deep black. It contains varying proportions of red coloring matter and free fatty acids, depending upon the care with which the seed has been handled and the oil produced. The free fatty acids will vary from 0.4 per cent to as high as 30 per cent, but the average is in the neighborhood of 2 per cent.

The real advancement of the last twenty years in the cotton-oil industry has been made by the refinery. While there have been many improvements in the machinery of the crude oil mills, the process is to-day practically what it was many years ago, but when we turn to the refinery, the tremendous strides which have been made in the improvement of the refining methods result in a product so superior to the article produced years ago, that industries utilizing the oil, on account of this improvement, can use greater quantities of the oil than ever before.

Crude cottonseed oil, after its first process of refining, comes out in the shape of a clear, brilliant, yellow oil, known as summer yellow oil, having a specific gravity at 15 deg. Centigrade of 0.92. Owing to the deterioration of the seed and to inferior methods of manufacture, all crude oil does not produce yellow oil of the same grade. The trade has classified summer yellow oil as choice, prime, off, and soap oil, the difference in these grades being in the color and flavor. Choice oil is a light lemon-colored oil, without any suggestion of red, and is mild and neutral in flavor. Prime oil is slightly darker in color and sweet in flavor, without any seedy flavor. These two grades are used for edible purposes. The off and soap grades of oil are reddish in color and the flavor is very poor, due to bad seed, mustiness, etc. This oil is used for mechanical and soap purposes.

As intimated before, the amount of the different grades of oil produced depends largely upon the condition of the seed. It has varied from about 85 per cent to 35 per cent of choice and prime oil, and from 15 per cent to 65 per cent of off and soap oil.

With the improved refining methods of the past ten years has come increased demand and use for refined cottonseed oil. Summer yellow oil forms an important basis for a number of different products after being submitted to various processes, such as bleaching it to make it white and pressing it to extract the stearin.

One of the principal uses and development of cottonseed oil contingent upon the improvements in refining methods in the past decade is that of the manufacture of lard compound—a mixture of lard, oleo stearin, and refined cottonseed oil—making a most palatable and economical food. Another product of cottonseed oil, white cottolene, is a mixture of oleo stearin and specially processed cottonseed oil, marking, perhaps, the highest development of cotton oil as a food product.

Cotton oil is also used in the making of salad oils, packing sardines, in the oleomargarine industry, for miners' burning oil, cathedral burning oil, tempering oil, oil for heavy tool-cutting machines, mixing with putty, and, while not exactly a drying oil, yet for rough painting the crude oil can be and is used to a considerable extent. The cheapness of cotton oil compared with other fats, as well as its excellent soap-making properties, has caused it to be largely used by soap makers, both in America and abroad. It is also used in the manufacture of washing powders. Cottonseed oil is used to-day to a great extent by bakers. It is also used as a substitute for olive oil. Chemists and physicians now recognize cotton oil as a high-class food product.

In the refining process there is produced a loss amounting on an average to about 10 per cent of the crude oil. This forms an important by-product of the cotton-oil industry. This substance is known as soap stock, or foots. It has a fat acid content of from 40 per cent to 50 per cent, and is composed of free oil, coloring matter of the crude oil, and soap caused by saponification in the process of refining. It is used in making wool-scouring soaps and cheap grades of laundry soaps. It makes a most excellent soap. There is also produced from this substance glycerin, candle stock, olein, still pitch, etc. The number of uses of this last, though by no means least, by-product of the cotton-oil industry emphasizes the many uses to which this oil and its various products are put. It is of course impossible here to elaborate upon these, or even to fully enumerate them.

It should be borne in mind in dealing in or describing cottonseed products that in no two seasons are the conditions exactly alike, and the quality and quantity vary so much, that it makes it a constant study and a most interesting business.

(To be continued.)

NOTES ON SOME EXPERIMENTAL RESEARCHES ON INTERNAL FLOW IN CENTRIFUGAL PUMPS AND ALLIED MACHINES.*

By JAMES ALEX SMITH.

INTRODUCTION.

THE purpose of this paper is limited to bringing before the Institute simple means of rendering visible, or recording photographically the course of the fluid current in typical equivalents of hydraulic machines, especially in the rotary parts thereof. It is intended at a subsequent date (probably next month), with the permission of the Institute, to amplify this communication by exhibiting results of various combinations and giving some deductions arising therefrom.

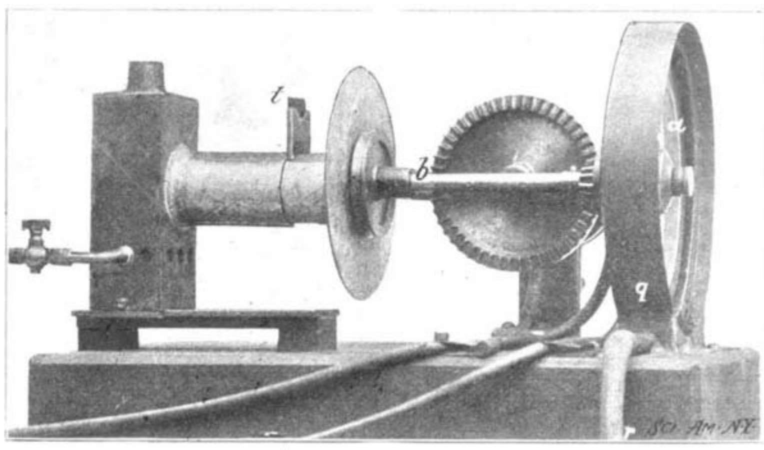


FIG. 1.

It is with diffidence that the writer ventures, in response to a call for a paper, to submit the appended notes. First, because they are, so far as he is concerned, in the nature of a by-product in another field of research, and therefore the adaptation of the instruments to hydraulic analogies, and the revision and elaboration of the rough jottings have not received that special attention and the time the subject properly merits; much must necessarily remain unwritten, much might have been more clearly expressed. Secondly, the problem has been dealt with so extensively—not exhaustively, for finality is not yet—that it would seem none but specialists of wide experience need hope for success. Still, the very importance of the question may justify the publication of any matter, however incomplete, provided it contains the germ of a new method of attack, or affords reasonable hope that in the hands of those competent to grasp the subject and its applications, it may give rise to consideration from a new point of view.

The broad question is of more than abstract or academic interest in general engineering; especially as regards irrigation, it is vital.

Throughout the whole of the variations of prime movers, those yielding the best results transmit energy through a revolving shaft or pulley. The most economical and compact reciprocating steam engines are found under this classification. Gas engines, with their great future, are, according to present design, essentially included. The electro motor and the steam or water turbine are almost the acme of the principle. Logically, a cheap, simple, compact, quick-running rotary pump directly connected and devoid of valves or mechanical complexities, is the complement of the motors referred to. Unquestionably the combination would be all but universal were the efficiency of the centrifugal on high or varying lifts and discharges comparable with that of its reciprocating rival.

It is nothing less than a mechanical barbarism to load a machine with details wholly extraneous to the subject sought if it be possible that the part which renders the complication inevitable, might, by the substitution and judicious improvement of another type, be eliminated. In addition, the advantage of continuity of action, when continuity is not incompatible with the end in view, may be taken as an axiom in mechanics. All deviations therefrom involving changes in velocity must, in practice, be accompanied by a diversion of energy to non-useful ends.

The numerous papers and interesting discussions recorded in the proceedings testify that members are fully seized of the urgency of the problem, but unity of opinion has not been manifested. Clearly the subject is highly controversial, and in what should be the exact science of engineering, controversy as to fundamental truths should have no place. Wide differences of thought imply that actual data are absent or lacking in the range requisite to permit of the crystallization of deductions into laws or formulæ of general and relatively simple application. Unfortunately the available recorded data or statistics of authoritative modern tests bear out this view; even hints serving as finger posts to define paths along which the slow and expensive processes of mechanical evolution might be most profitably pursued, are wanting, and the quality of the procurable machines negatives an inference that, for purposes of individual profit, the information is withheld, though extant. The matter is well worthy of systematic investigation, considering the number of services concerned, and the low efficiency of most, and even the best, centrifugals when judged by an ideal standard not apparently unattainable.

The mathematical treatment certainly has not been neglected; indeed, it is a question whether, in view of the existing stock of facts, it has not been pushed too far. Hypothesis based upon surmise ill supplies the place of theory established upon observed fact.

All seems to indicate the necessity of interrogating Nature—never silent to the earnest seeker after truth—by direct experimental methods, more especially as the ordinary designer, versed in users' requirements, workshop technique and limitations, is much more certain of his results when they arise from the consideration of matters within the category of the visible, or measurable, and not requiring mental translation from mathematical symbolism to the brain images of the concrete facts that symbolism is intended to denote.

The possibility of applying the "stream-line" method to rotors was casually alluded to when Prof. Hele-Shaw's beautiful experiments were yet novel—in fact the extension of the idea from the case of flow in planes at rest to streams in planes in motion was an obvious development—but it does not appear that the suggestion has materialized hitherto, either in actual apparatus or detailed specification.

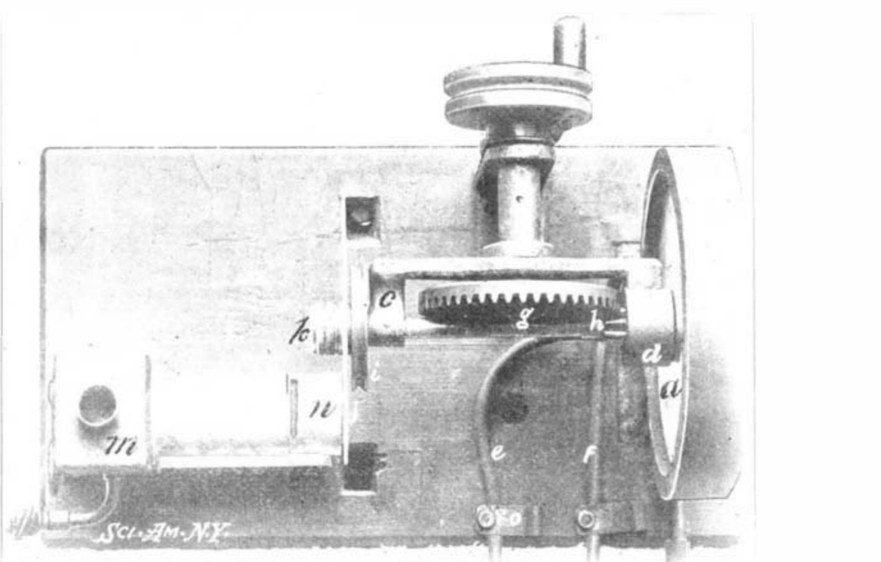


FIG. 2.

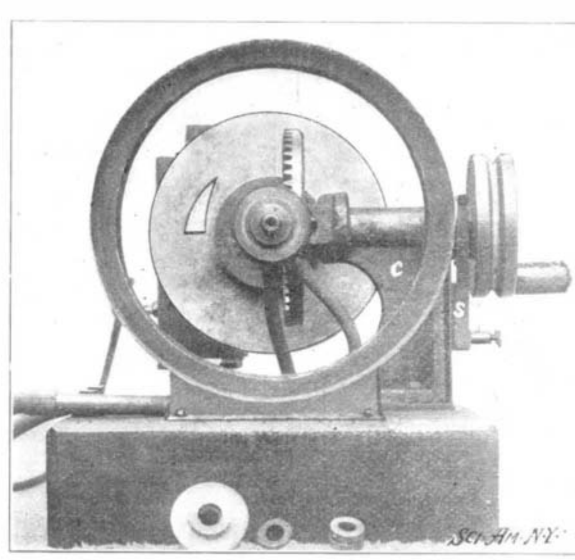


FIG. 3.

It is not to be inferred that the instruments exhibited, and in which that principle to some degree enters, are in conception or in their incomplete state, capable of reaching to more than a partial solution of the many intricate possibilities and combinations. For instance, flow in the apparatus is (sensibly) in two dimensions only; in practice three dimensioned space must be dealt with. The entrance of fluid to the "eye" of the discs may not be in effect strictly analogous to the initial axial flow under actual conditions. In the

* Paper read at Victorian Institute of Engineers, and revised by the author for the SCIENTIFIC AMERICAN SUPPLEMENT.

experiment the discharge from the runners is into the atmosphere freely, in the pump into water under pressure.

Notwithstanding constructive restrictions, possibly removable, it would seem that useful work may be done in observing the *tendency* of the results arising from the forces in action. It may be that the engineer, with a graphic delineation before him, will, by the application of a series of variations, be enabled to some extent at least, to avoid the cumulative losses arising from impact, eddy friction, dead-water, constriction, undue length of path, and so on, all causes tending to dissipate the energy of motion in ultimate useless heat effects.

At least the means are of ready applicability. An idea may be tested or fixed, expeditiously, in miniature, in the laboratory, and at the cost of a little pasteboard and a trifle of time.

GENERAL DESCRIPTION.

Two instruments have been evolved, designated—tentatively—a Vorteximeter and a Volutimeter; the first is designed to analyze vortex or whirl in the runner, the second, the spiral current in a given casing.

In the vorteximeter fluid, or fluids, are supplied through a revolving shaft to a space separating two glass discs fixed pulley-wise upon the spindle. The discs are kept apart by pieces of card representing vanes. When the general stream outline alone is required a single colored fluid suffices; but when in addition the sliding over each other of integral laminæ is to be followed, two fluids must be used; the greater flow then consists of ordinary water, the lesser of filamentary streams of colored liquid injected into the main issue.

To measure the forms and motions of streams resulting from a high velocity of rotation, advantage is taken of the fact that the eye is capable of recognizing objects illuminated for an exceedingly short period—certainly less than 1-100,000th of one second—provided the light is of sufficient intrinsic intensity. Hence, if the rotating discs be lighted for a period so short that the angular motion during that time is negligible as compared with the magnitude of the movements to be observed, it follows that the disc will appear at rest. If, further, it is arranged that successive illuminations shall occur when the vanes are in the same relation to a fixed point, and at intervals of not more than one-tenth or one-seventh of a second, then the disturbance of the retina will continue between flashes, and the brain will receive the impression of a constantly illuminated object at rest, if the phenomena observed be constant. If there be a sequence of phases they will blend into a series giving the effect of change in a non-rotating body.

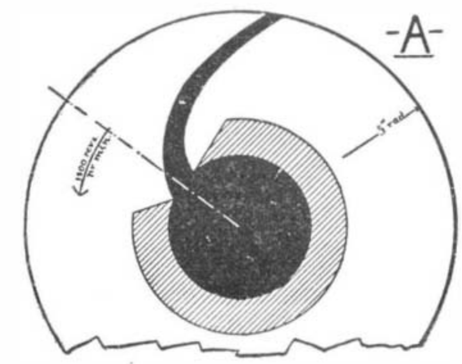
The speed of rotation of the discs is, of course, a quantity dependent upon the hydraulic problems to be treated, but whatever that speed may be with suitable adjustment, the discs seem stationary, although at low speeds the light may flicker.

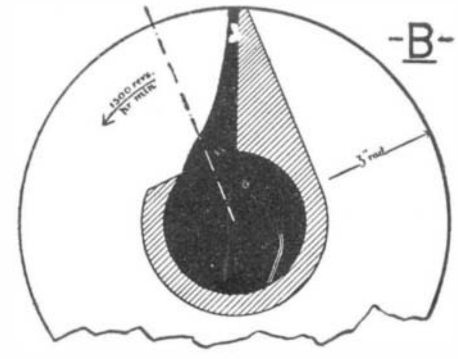
In the volutimeter it has not, so far, been found expedient to rotate the runner. The instrument consists of glass planes separated by paper templets representing the casing to be tested, but the equivalent of the runner is fixed, and with orifices of efflux so designed that the effluent, supplied under pressure, shall at exit pursue a path as nearly as possible coincident with that of the discharge from an actual given runner. Flow is rendered apparent by mixed streams, but special illumination is not requisite.

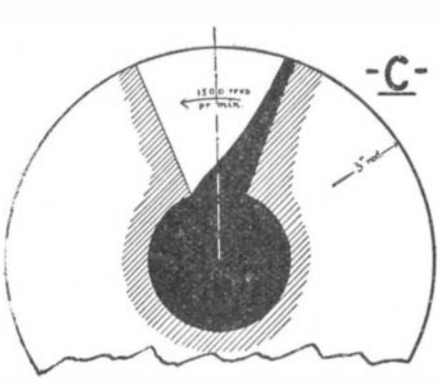
The arrangement gives approximations, and is an application of stream line demonstration.

The scale of the instruments is arbitrary, but if the effects occur within a three-inch square, photographs —lantern-slide size—may be taken direct without a camera, and the derived positives enlarged by the optical lantern to any desired extent. In the case of the volutimeter direct projections may be made if the instrument itself be utilized as a slide.

as a broad annular flow, the latter discharges through fine perforations. Motion is imparted to the axle by a bevel wheel (g) and trundle pinion (h), geared 6:1 or, alternatively, by a belt over a grooved pulley (i) on the shaft. For steady running either method may be used in connection with a motor or heavy flywheel, but when studying change of velocity effects, manual driving, with the intimate correlation of eye, brain and







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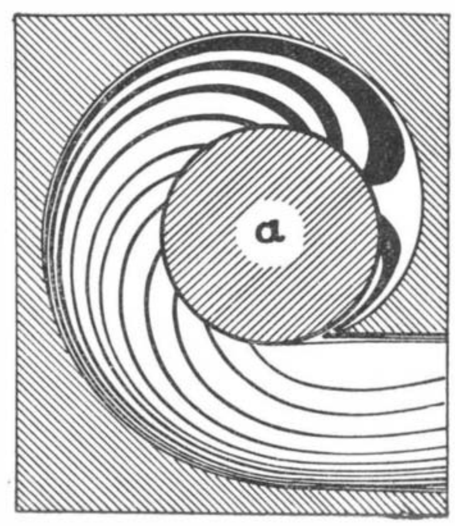

hand is preferable. Hand driving is effective up to 1,800 revolutions per minute.

Light is transmitted periodically by the rotating shutter (j), consisting of two plates of thin metal, fitting loosely on the shaft, until nipped in any position relative to each other or the glass discs, between the threaded pulley (i), and a milled nut (k). That plate nearest the light is furnished at a radius of two inches, with various holes and slots, the other has one horn-shaped aperture only, designed to cut out all those in the first plate save the one in use, and if required to reduce the length of that. Three slots, each half an inch long, and respectively 1-120th inch, 1-50th inch, and 1-10th inch wide, meet all requirements. The first used in a well-darkened room for fine markings, the second for general work, the third for photographic work or rough determinations. Light is derived from an acetylene flame (from a "ceetee" half-foot burner) inclosed in the lantern (m), collected and concentrated upon a slot in the cap (n) on the nozzle by a compound condenser consisting of two 1½ inch diameter,

6,000 and that, or 1-6000 of unity represents the feeble illumination reaching the eye.

Illumination is a function of the factors named, not of the speed of revolution.

The electric arc or mixed gas jet would, under certain circumstances, be advantageous.

For visual work a sheet of finely ground glass placed immediately behind or before the glass discs, greatly helps vision; without such aid only those parts of the discs immediately between the eye and the slot would be seen. Pot opal is too dense as a diffuser; flashed opal cannot be obtained in Melbourne. Much the best method is that finally adopted, viz., fine grinding of the back surface of the disc next the light. Clear glass is retained for photography.

Water, preferably boiled to expel air, is used as the colorless fluid, supplied per the tube (e) under a head of about 12 inches, and regulated by a pinchcock (o). The colored fluid under a head of about 20 inches flows by the tube (p). As coloring matter, permanganate of potash, logwood and iron salts, aniline "acid black," inks, etc., have been used, but as a good non-actinic, distinctive color aniline, "scarlet R.R." in a strength of about 30 grains per pint has been adopted. The splash guard (q) and waste pipe (r) collect and convey the discharge. Full view of the discs is afforded at all times.

If outlines alone are under consideration; one—a colored—fluid is used, but in that case escaping centrally,

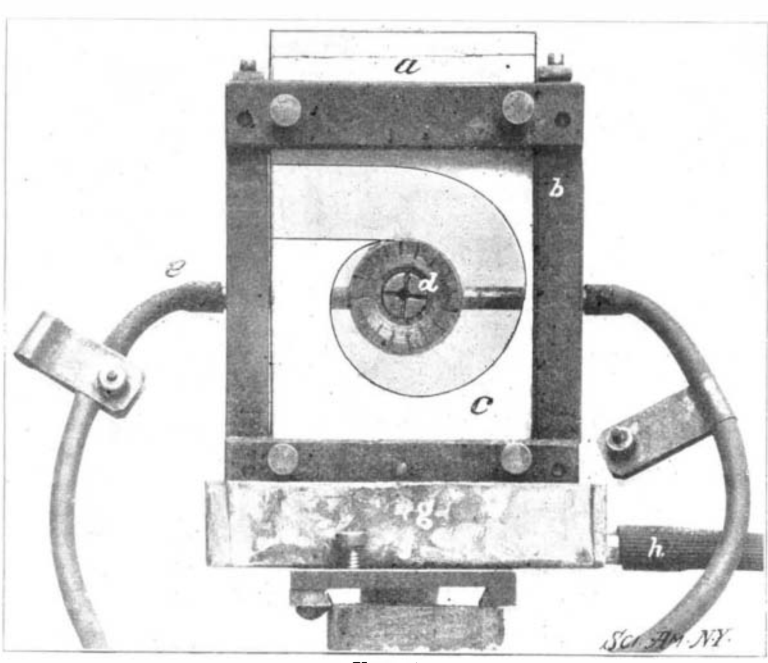

Fig. 4.

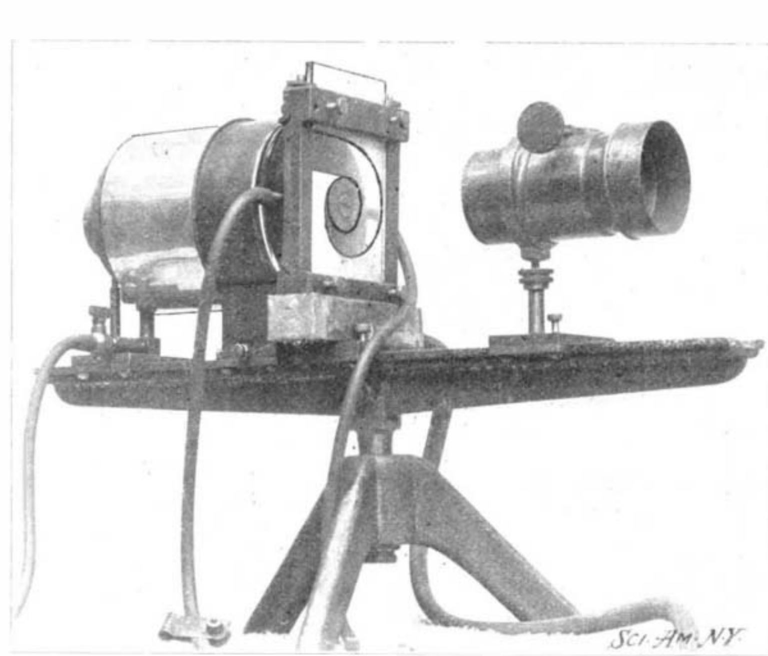

Fig. 5.

Optical enlargement will be found to much facilitate study.

DETAILS OF CONSTRUCTION AND USE.

Similar letters denote similar parts in related figures:

Vorteximeter, Figs. 1, 2 and 3. The disks (a) are of plate glass three-sixteenths of an inch by six inches in diameter, perforated centrally with three-quarter inch holes. They are carried and rotated by a shaft (b) running in bearings in a bracket (c); the front bearing (d) is coned and fits watertight in its bush, and by means of suitable ports and grooves provides two separate channels to the space between the disks for the clear (e) and colored (f) fluids. The former escapes

by 2 inch focus biconvex lenses, and a third similar focusing lens. The slot in the cap (just clearing the revolving plate) corresponds with that in the shutter. Interchangeable caps are preferred to a variable slit.

The optical problem is to pass as much of the available light through the slit as possible, and at such an angle that none of it shall be wasted by falling without the useful area of the glass disks. It must be remembered that only a fraction of the light finally reaches the eye. First it is cut down by the shutter in the ratio of the time of opening to time of eclipse, say 1: 300, then the proportion of light from the flame reaching the slit is in the inverse ratio of the whole area of the flame mantle to the area of the slit, say (assuming the 1-50 inch slit) 1:20, hence the final ratio is 1:

not through the fine perforations, it may be caught and re-used indefinitely.

Speed of rotation at any particular phase is noted chronographically by electric contacts on the floor and driving mechanism (s).

Templets are cut from thin "three-sheet card," or enameling board, about 1-70 inch thick. Ribbon brass, lead foil, gutta percha, etc., have been tried; also variations of thickness through a considerable range, but 1-70 inch card is most satisfactory.

The general method of using the volutimeter, Fig. 4, is shown in Fig. 5, but it may be placed in any other suitable projection apparatus or used alone without lantern enlargement.

Two glass plates (a) with a paper templet (c) between them, are secured in a frame (b). The back plate is perforated with a one inch diameter hole, countersunk on the inner side. Within this opening is secured a brass plug and plate (d), permitting the entry of clear and colored streams through the tubes (e) and (f). The water is collected by the tray (g) and pipe (h).

It will not be found advisable to use paper more than 1-100 inch thick for the templets; these may be affixed permanently to loose strips of 26 ounce selected window glass (plate is theoretically better) by bichromated glue, and retained for reference.

RECORDING RESULTS.

Photographs are simply obtained. In the case of the vorteximeter, pieces of any smooth, thin, rapid bromide paper—Kodac glossy white "A" for instance—are cut to appropriate forms and sizes. Moistened with water they are squeegeed gelatine side to the glass by the fingers, the paper will adhere at all ordinary speeds. This simple method was arrived at after much more complex means had been tried. A slot of a third of an inch or more in width may be used. Crispness is here dependent, not upon speed of eclipse, but chiefly upon the parallax introduced by the thickness of the glass, a negligible quantity.

The preceding adjustments are made by ruby light, filtered through a strip of glass in the slot (t) in the lantern nozzle.

When adjusted, the machine is started, run until the correct phase is visible through the wet paper, and exposure made by raising the ruby glass slip. Exposure may be at discretion; with steady running a quarter of a minute may be given, for incipient cavitation, and with a special appliance to use concentrated sunlight a very small fraction of a second suffices.

The volutimeter effects may be dealt with as in ordinary photographic enlarging; this and development, etc., need not be dwelt upon.

The flow, located by lines etched (and darkened) in one of the discs, may be sketched, or it may be traced upon ground glass, gelatine or tracing paper. The results (the ground glass first varnished), or photo transparencies from negatives made as described and waxed, may be enlarged by lantern or camera.

VARIATIONS.

The discs need not necessarily be of glass nor planes. Glass may be worked to forms other than flat discs by the opticians' methods, or it may be turned in the lathe as though it were hard cast iron, by maintaining the tools keen and lubricating with turpentine. A sufficient finish may be given to the surface by grinding with pieces of copper or brass, then with wood, using emeries (with water) down to washed grades. Special channels of varying depth may be etched with hydrofluoric acid. Celluloid pressed, or non-absorbent marble worked to form may be utilized, in the latter case observing from the back by reflected light.

Photography by quick flash powders and the electric spark have been tried but are wanting in simplicity, and prevent attention being concentrated on main issues.

Eclipsers running 8,000 revolutions per minute have been used, but such high speeds were not found to be warranted by results.

Many other modifications were, in the course of the work elsewhere alluded to, tried, but they would more fittingly form the basis of notes on stream-line methods, and need not be further alluded to here.

Much small detail has been given above, because in the writer's experience the absence of minutiæ has frequently caused him wholly unnecessary labor in repeating other published experiments.

APPENDIX.

Figs. 1, 2, 3, 4 and 5 have been explained. The other illustrations are from effects to be shown to-night, although more fittingly they should be deferred to a future time.

A negative of a stencil between the glass discs when *at rest*; and one made when they were *running* at a speed of 35 revolutions per second prove conclusively that photographs may be implicitly relied upon to record the phenomena occurring between the discs when in motion.

A, B, and C are diagrams sketched from negatives taken at a speed of 1,500 revolutions per minute using one fluid.

A is the path (in the space between the glasses) of a fluid after discharge through a thin-edged aperture in an annular runner.

B is the same class of discharge restrained by a radial vane on the "trailing" side.

C is similar to B, but with a second radial vane added on the "leading" side.

Diagram D reproduces the result of a *radial* flow from the "runner" (a) into an Archimedean spiral casing.

DISCUSSION.

Mr. Smith, by the use of photographs and the instruments used, illustrated his paper.

The Chairman (Mr. Higgins) complimented Mr. Smith for his very interesting and instructive paper and experiments. He said we are on the eve of great advances in centrifugal pumps. When in Glasgow he saw pumps which were said to lift water 300 feet or so. The representatives of the firms did not feel free to give full particulars, but he understood that they were on the successive system, i. e., one pump feeding another. From their catalogue he ran out a few figures, and had found that instead of these pumps giving an efficiency of 70 per cent or 80 per cent they fell back to 30 or 40 per cent. He was not quite clear as to the truthfulness of the assertions made at the exhibition, that a pump lifted to the efficiency of 80 per cent. Another reason for his saying that we are on the eve of great advances in centrifugal pumps was that the well-known firm of C. A. Parsons & Co. had a skilled designer constantly employed in designing centrifugal pumps and their variations, and they were giving effect to the experiments performed. Dr. Hopkinson was giving almost his whole time, together with several assistants, to the question of centrifugal pumps. Another well-known firm, Messrs. Guinn & Co., were interesting themselves deeply in the subject. Coming nearer home was found the design of Mr. A. G. M. Michell, whose nomination paper was before the meeting, and he (Mr. Higgins) hoped that Mr. Michell would be at the next meeing. His design was for utilizing the kinetic energy of the water as it leaves the runner, and so far as he (the speaker) knew it was the most scientific yet out.

Mr. Higgins said that as most of the members present would no doubt like to read Mr. Smith's paper before discussing it, he thought it would be well to postpone discussion on the matter until next meeting.

Mr. Smith said that he proposed to supplement the results. Those just shown were merely to demonstrate the action of the machine.

Prof. Kernot said this question was one of the greatest problems of the present time. Statements occurred frequently in many books with reference to the efficiency of centrifugal pumps. There appears to be great difficulty in getting at simple facts. He had had no experience in the matter. What he wanted to know was, what was a fair expectation of the efficiency of a centrifugal pump of fairly good make in our present state of knowledge? Some books put it down at 60 per cent. Could we depend upon that? The chairman had mentioned that 30 or 40 per cent was about the usual thing. If that is all that could be obtained it was no wonder that the application of the centrifugal pump was so limited; but if 70 per cent could be attained, it had a very wide field. The whole question was a most tantalizing one. As to Mr. Smith's apparatus, he was immensely interested; it is a most ingenious and clever arrangement, and it is one that may be of very great value in clearing this subject. Mr. Smith had not taken anything for granted, but had proved everything.

Mr. Seitz said Mr. Smith deserved great credit for his apparatus, which would prove helpful not only to members of the Institute, but to persons all over the world. Respecting Prof. Kernot's query he said the efficiency could be taken at 65 per cent for centrifugal pumps of best makes.

Prof. Kernot: For what lifts?

Mr. Seitz: I consider that the height will not diminish the efficiency; 63 and 65 per cent could be obtained with a 12 inch pump on the brake horse power.

Prof. Kernot: Then if we can rely on the centrifugal pump giving 63 per cent efficiency the great majority of the plunger pumps should be thrown on the scrap heap.

Mr. Fyvie did not think that the results obtained from experiments could be altogether relied upon, owing to engine troubles, etc., and unless they could be absolutely relied upon they were worthless.

Mr. Seitz proposed, and Prof. Kernot seconded, that the paper be printed and the discussion postponed until next meeting.

THE CONTACT PROCESS FOR THE MANUFACTURE OF SULPHURIC ACID.*

I. HISTORICAL.—The production of sulphuric acid is a matter of the greatest importance, as it is not only the foundation of the inorganic heavy-chemical industry and is used for many other purposes, but also has lately become a most important material in the organic dye-stuff industry, especially in the production of alizarine colors and of synthetic indigo. The contact process is causing a complete revolution in the methods of manufacture of sulphuric acid; hence an account of its historical development and present status should be of great interest. The historical development of this process may be divided into four periods.

First period: Phillips, in 1831, discovered the catalytic action of platinum in hastening the union of SO_2 and O to form SO_3.

Second period: Wohler and Mahla, in 1852, showed that many other substances besides platinum possess catalytic properties, and explained the character and course of the reaction.

Third period: Winkler used definite gas mixtures for the production of sulphuric anhydride, as it was then considered that only in this way could good quantitative yields be obtained.

Fourth period, the present one, is noted by the successful use of the furnace gases directly.

The investigations of the third period were directed toward the production of fuming sulphuric acid, which was then very expensive, while the investigations of the first and second periods had the same end as the work of the present time; that is, the replacement of the chamber process by improved methods.

The catalytic action of platinum was discovered by Humphry Davy in January, 1818, who showed that platinum wire, when warmed and then introduced into a mixture of oxygen (or air) with H, CO, ethylene, or cyanogen, became incandescent, and that the gas mixture oxidized, usually gradually, but often rapidly.

Edmund Davy, in 1820, discovered that finely divided precipitated platinum, when moistened with alcohol and exposed to the air, becomes incandescent and the alcohol burns.

Doebereiner, in 1822, found that finely divided platinum, obtained by heating ammonio-platinic chloride, acted in the same manner, and, in 1824, that such platinum could ignite a stream of hydrogen, when this impinged upon it in contact with air, and utilized this discovery in his celebrated "lighting machine."

The honor of having first utilized this catalytic action, for the production of sulphur trioxide, is due to Peregrine Phillips of Bristol, England, who, in 1831, took out an English patent for his discovery, and, in 1832, Doebereiner and Magnus each confirmed the observations of Phillips. Although this discovery attracted much attention, nothing practical followed until 1848, when Schneider exhibited a working model of an apparatus, which produced sulphuric acid through the contact action of a specially prepared pumice. This alleged discovery was presented with great claims, but never was able to show a success, although wonderful results were confidently predicted. The same may be said of the method of Richard Laming, who also used a contact mass of pumice, prepared by boiling it in concentrated sulphuric acid, washing it in ammoniacal water, drying, and then impregnating it with about 1 per cent of manganese dioxide, finishing by heating the mass in a retort to 600 deg. and allowing it to cool out of contact with the air. Here we note for the first time, the use of another contact substance which, like platinum, can exist in various grades of oxidation, namely, manganese.

Especially noteworthy in this connection is the English patent of Jullion, 1846, because here, for the first time, the use of platinized asbestos as a contact mass is claimed. In 1849, Blondeau passed a current of a mixture of sulphur dioxide, steam, and air through a highly heated tube containing ferruginous, argillaceous sand and obtained sulphuric acid, while, in 1852, Wohler and Mahla found that oxides of iron, copper and chrome also work catalytically upon a mixture of SO_2 and O, a mixture of cupric and chromic oxides being especially efficacious. These investigators gave, moreover, a correct explanation of this catalytic action; they found, namely, that cupric and ferric oxide, when heated in a current of sulphur dioxide free from oxygen, became reduced to cuprous and ferroso-ferric oxides with simultaneous formation of sulphuric acid which, however, ceased as soon as the reduction of the oxides was completed. On the other hand, chromic oxide, under similar conditions, remained entirely unaltered and no sulphuric acid was produced, while metallic copper, in spongy form, exerts no action upon a mixture of 2 vol. SO_2 + 1 vol. O at ordinary temperatures, but, when heated, cupric oxide is first formed, and then sulphuric acid.

They also call attention to the fact that this union of SO_2 and O can take place in the complete absence of H_2O.

Upon these important discoveries are based the later researches of Lunge and others upon the catalytic action of pyrites cinder in causing the formation of SO_3. Quartz has also been recommended for this purpose, as have also platinized asbestos, platinized pumice, and even platinized clay.

Hundt, 1854, passed the hot roaster gas through a flue, filled with quartz fragments and heated by the gas, expecting to convert the greater part of the SO_2 into sulphuric acid with further treatment of the residue. The work of Schmersahl and Bouk, 1855, followed the same lines, as did also the method of Henry Deacon, which was patented in 1871, and may be considered as closing the second period.

So far, not only had all attempts to supersede the chamber process failed, but also no practical method for the production of fuming sulphuric acid had been devised. In 1875, Clemens Winkler published his celebrated researches upon the formation of sulphuric anhydride, for which industrial chemistry must always be greatly indebted to him, as originating successful methods for the economical production of the fuming sulphuric acid for which, as it has become cheaper, many new uses have been discovered.

Winkler concluded, as a result of his experiments, that the SO_2 and O should always be present in the molecular proportion of 2:1, any excess of either gas having a deleterious influence upon the completeness of the reaction, and he obtained this desired proportion by simply breaking up ordinary hydrated sulphuric acid into H_2O, SO_2, and O, removing the H_2O, and then recombining the SO_2 and O by means of appropriate contact substances, the preparation of which he greatly improved by utilizing the reducing action of formic acid. All subsequent work in this branch continued to follow the lines laid down by Winkler; hence, while little progress was made toward superseding the lead chamber, the manufacture of fuming sulphuric acid became highly developed.

II. Knietsch's Work—Purification of the Gas.—This work was undertaken by the Badische Anilin und Soda-Fabrik to determine if a complete conversion of the SO_2 in roaster gas was as practically feasible as it is theoretically possible.

It is well known that the outgoing gases of the chamber process still contain 6 volume per cent of oxygen, and that the roaster gas employed in the contact work contained a similar excess. Hence it was difficult to understand why, in the latter process, the yields were not nearer that of the former.

Experiments showed that when pure SO_2 was used the yield was close to the theoretical, even when a very large excess of O was present, which was contrary to the accepted views of Winkler.

When roaster gas was used in laboratory experiments it was found that when this was carefully cooled, washed with sulphuric acid, and completely purified before it was allowed to enter the catalytic tube, the results were very satisfactory, nor could any diminution of the efficiency of the contact mass be noted even after several days' use. It was therefore supposed that the problem had been solved, and arrangements were made to carry on the process on full working scale.

It was, however, soon found that in practice the contact mass gradually lost all of its efficiency, no matter how carefully the gases were cooled and purified. Extended laboratory investigations were undertaken to determine the cause of this inefficiency, and it was ultimately discovered that there are substances which, when present in the gas, even in excessively small quantities, injure the catalytic properties of platinum to an extraordinary degree. Of all of the substances which may be found in roaster gas, arsenic is by far the most deleterious, next mercury, while Sb, Bi, Pb, Fe, Zn, etc., are injurious only so far as they may coat the contact mass.

It was also found that as the white cloud of sulphuric acid which was present in the gas contained arsenic, the complete removal of this was necessary, although such removal had always been considered an impossibility. This was, however, finally accomplished after an enormous expenditure of time, labor, and money, so that, in the end, by extended washing and filtration, the gases were obtained in a condition absolutely free from all impurities. (D. R. P. 113,933, July 22, 1898.)

Slow cooling of the gas was found to be absolutely necessary as a preliminary to its purification. It is a fact, the cause of which is not yet clearly known, that the removal of the white cloud is rendered far more difficult if the gas is rapidly cooled.

To insure slow cooling, a system of iron tubes was used because it was supposed that, as the sulphuric acid in the gas was in a so highly concentrated condition, any action upon the metal would yield SO_2 only. It was now found that although the contact mass re-

* R. Knietsch, Ber. d. d. Gesell., 1901, page 4069.