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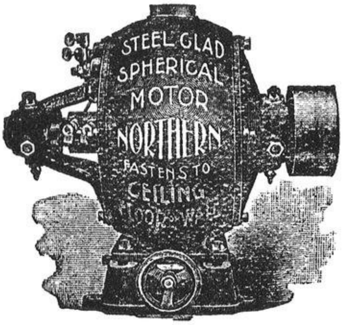

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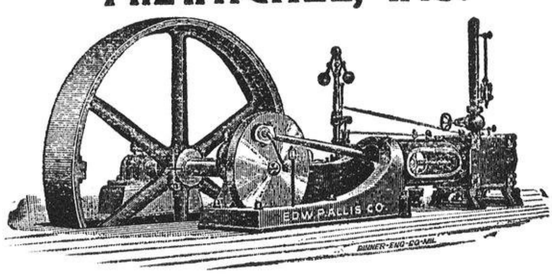

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THE CAST WELDED JOINT.

BY GEO. A. MEAD, B. S., '95.

With the inroduction of elecricity as the motive power on street railways, many of the difficulties which had already been overcome again confronted the street railway manager together with new ones. Many of these difficulties were the result of putting in new construction based upon the requirements of former modes of traction. Street railway managers were not long, however, in discovering their faults and correcting them and more solid construction in both track and rolling stock was the result; the greater speed and weight of the cars making this absolutely necessary. But of all the difficulties met with in electric traction, none have been given more thought or taxed the skill and ingenuity of the engineer than the question of rails and rail joints. To those not acquainted with street railway work these may seem points of little consequence, but those actually engaged in such work know too well the results of poor track construction. I venture to say, that many electric roads which are not now paying a dividend upon the money invested can attribute such to cheap construction, which means a large expense to keep not only the track and joints in repair, but also the overhead construction and car equipment, and a much larger expenditure of coal than would be necessary had a substantial construction been installed at first.

The first requirement of a joint is that it shall present at all times a smooth, unbroken surface to the passage of the car wheel. To do this it must be strong and solid, preventing the adjacent ends of the rails from pulling apart due to contraction, also from bending down and outward due to the weight and

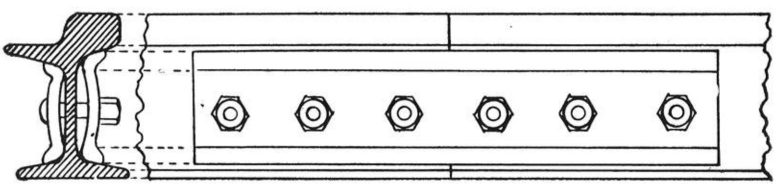


FIG 1.

pounding of the cars. Second, the first cost of construction plus the cost of maintenance shall be a minimum.

The joint in most common use at the present day is that known as the fish plate, channel bar or splice joint; Fig. (1). This joint is too well known to require a description. Experience has demonstrated that for the first year or two this joint gives satisfaction; but about the third year, when the traffic is at all heavy, it begins to give trouble and becomes a source of expense, which constantly increases from year to year, until at the end of the fifth or sixth year, the ends of the rails have reached such a low state, it is found necessary to replace the old fish plates by new ones if it is desired to keep the cost of maintenance of the car equipment a minimum and give to the public a service with any degree of comfort.

But with the utmost precautions which may be taken with this joint, there are conditions detrimental to its life over which the track master has no control. The rails *will* contract leaving a space between their adjacent ends such that a car of ten or twelve tons in weight, when loaded, in passing over this gap is sure to produce a "pound" upon the end of the rail it is approaching. This "pound," although small at first and hardly noticeable is constantly increasing in magnitude and working havoc with the joint. Rust forms between the surface of the rail and plates where contact is made with each other, and the sliding of the rails due to contraction and expansion works this rust out, thus loosening the plates and allowing the rails to give with the weight of the cars. In time the rails become permanently low and upon examining fish plates removed from such joints, one finds the half which come in contact with the rail towards which the car is moving worn down as shown by Fig.

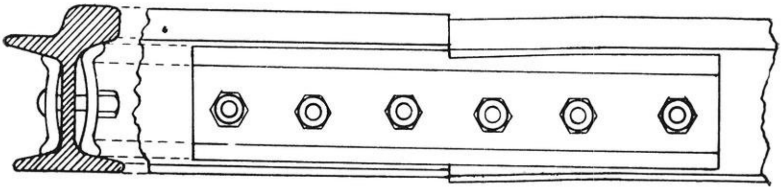


FIG. 2.

2, some plates being worn as much as 1-4 of an inch.

Plates, angle irons, inverted rails, etc., have been used upon the sides and bottom of the rail in connection with the fish plates to give greater strength and support to the ends of the rail, also many improved forms of joints have been devised and placed upon the market which might be called truss or bridge joints, and which involve many good features, but all require bolts or clamps which in time become loose for the same reasons given before. They do, however, increase very materially the life of the rail ends, but not sufficiently to keep us from seeking further for a better way of fastening our rails together.

How are we then to overcome the difficulties experienced with the fish plate joint and its many improved forms, and obtain a joint which shall meet with our requirements, namely—a smooth unbroken passage to the car wheels at all times, small first cost and small cost of maintenance?

An ideal track would be one without joints at all, but until the steel rail manufacturer is able to roll for us rails in a continuous length on reels as we buy our trolley wire, we must be content to take the rails as he can best furnish them and devise some method of joining them which will give the desired results.

We have for this purpose two methods which may be employed, namely—the "electric" and the "cast" welding. The former consists in uniting the rails by electrically welding their ends directly together making what is called a "butt weld," or by welding strips along the web of the rail in such a way as to extend over the joint; a "butt weld," being formed at the same time. This latter is known as a "chock weld" and is the better of the two. But up to the present time the electric welding process has been more an experiment and has had but little practical use as compared with the cast welding process, which consists merely in placing around the adjacent ends of the rails a quantity of cast iron while in the molten state, forming solid and rigid joints which are difficult to detect. This method of joining the rails has been adopted by not a few of the larger roads in this country and is now attracting considerable attention in Europe. Although brought into practical use some three or four years ago the method of making such joints may still be new to some and for the benefit of those I will describe in a few words the process as used by the Chicago City Railway Co.

A small portable cupola together with an engine and blower are mounted upon a truck for convenience in moving along the line as the work of casting progresses. The joints to be cast, if previously used with fish plates, are opened up, the dirt removed from around the rails and the fish plates taken off. The ends of the rails are now brought into alignment. We find that with all old rails which have become permanently low at the joints, there will be a slight depression just back from the end of each rail which it is quite impossible to remove. This, however, is found to be an advantage as the molten metal which is cast around the ends of the rails upon cooling contracts, thus forcing the ends up sufficiently to bring them to a level with the rails proper. Should this bend be entirely removed before casting the joint it would be necessary to strongly clamp the rails from above to keep their ends from becoming elevated through the cooling of the casting, requiring considerable labor in filing down. This is also the case when new rails are cast welded. The sides and bottom of the rails for a distance of six or seven inches back from their ends are now scraped and cleaned with emery or garnet paper, or as is the more recent practice, ground by means of a portable emery wheel. This is to remove all rust, which is absolutely necessary if a thoroughly reliable weld or union between the rails and the casting is desired.

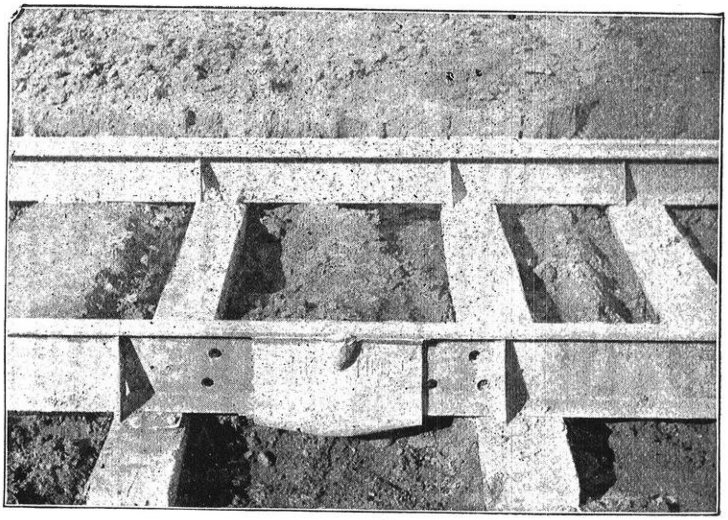


FIG. 3.

The joint is now ready to receive the mould which consists of two cast iron shells about one inch thick, and is so shaped that the bulk of the casting is formed about the base of the rail, Fig. 3.* The inner surface is coated with a mixture of linseed oil and plumbago to prevent the molten iron from adhering to the mould. In order to take up part of the strain which comes upon the weld, also to prevent the rails from working back and forth in the finished joint from contraction and expansion, should a weld not be formed between the rail and the casting, a pin is placed in the end hole of each rail and extending on each side of the web from one-half to three-fourths of an inch. These pins make it almost impossible for the rails to pull apart at the joint unless

*By courtesy of Street Railway Review.

the casting gives away. A metal shim is now driven between the ends of the rail in order to fill any opening which may exist and the mould clamped in place. A ladle of molten iron is now brought from the cupola and poured into the mould, that coming in contact with the mould cooling almost immediately, while the interior remains molten for a considerable length of time at a temperature of about 2400 degrees F., thus softening the metal of the rail about the base and tending to amalgamate with the same. This tendency of the cast iron to unite with the rail thus forming a weld is greatly assisted by the contraction of the iron in cooling, which forces the molten metal strongly towards the center, pressing it tightly against the sides and bottom of the rail.

After cooling for a short time the moulds are removed, carried forward and placed on other joints. This process is continued until the desired number of joints have been cast. After the casting has cooled thoroughly the ball of the rail is filed down until it is perfectly smooth and level. Joints thus made are difficult to detect by the eye after the paving has been replaced, and equally as difficult when riding over them. An average number of joints cast on a 4 1-2 inch rail during a run of 5 hours with a single cupola is 140, but as high as 168 have been cast in the same time under favorable circumstances. A run of five hours is about the maximum limit to which these small cupolas will work satisfactorily, as the slag which forms chokes them up, thereby increasing the time required to melt the same quantity of metal as at first, also increasing the amount of coke required and decreasing the quality of the metal for casting. The mixture used consists of two-thirds pig and one-third scrap iron, but with an abundance of old scrap of a good quality on hand, one-half scrap and one-half pig gives excellent results.

The question of the contraction and expansion of the rails is an all important one, and has no doubt raised an objection in the minds of many as to the practicability of the cast welded joint, but let me assure those who have taken this view of the process that up to the present time no serious trouble has been experienced due to the change in length of the rails with the change in temperature from summer to winter months. In order to overcome as much as possible, at the start, any trouble from this source, the casting is done at a time when the rails are at a medium temperature (about 50 degrees F.), thus making the change in length due to contraction about equal to that due to expansion. The most difficulty will be experienced during the early part of the first winter after casting the joints, for those which are imperfect—from blowholes usually—and were not detected while casting, are pretty sure to give way to the enormous strain which comes upon them through the contraction of the rails. The breakages are very few, however, averaging from 0.1 per cent. to 0.2 per cent. of the total number cast. These are repaired as soon as the weather will permit by sawing a piece of rail of the same section as that laid and sufficiently long to completely fill the gap. The old casting is removed, the short piece of rail inserted and another joint cast exactly as described before.

The cross section of the casting is eight times that of the rail, and since cast iron is one-fourth as strong in tension as steel we have a joint about twice as strong as the rail. Most of the breakages which occur take place at the joint, but these as a rule we find to be honey combed from blow holes, and escaped detection at the time of casting. In the case of expansion during the summer months but little difficulty has been experienced. The tendency of the rails of course is to bend in one direction or another due to their increased length, but owing to the assistance of the pavement and dirt in holding them in place, whatever variation in gauge, alignment, etc., of the track there may be, is so equally distributed its magnitude is not realized.

Upon examining joints which have broken it is generally observed that a weld or union has taken place between the rail and the casting, not all over, but in spots of sufficient size to cause one to investigate this point still further as to whether or not the cast joint can be depended upon for carrying the return current across from one rail to the other without the use of copper bonds. As the carrying capacity of the rails on many roads is equal to, or greater than that required for the return circuit, should the cast joint be found to be such that full reliance could be placed upon it to make a *perfect weld at every joint,* then the copper bonding could be entirely done away with and the money which would be thus expended used to help pay the cost on the cast welded joint. In order that a weld shall take place between the rail and the casting it is absolutely necessary that every particle of rust or oxide be removed, and this in turn depends upon the honesty of the one in charge of the work and the care he takes in inspecting each joint before being cast. Care should also be taken that the molten iron is at a sufficiently high temperature to produce a weld. Any defects as regards blow-holes of a serious nature can as a rule be detected with a hammer, and those found defective removed and cast again. Cast joints which are alone depended upon to serve as bonds should from time to time be tested for conductivity by sending through

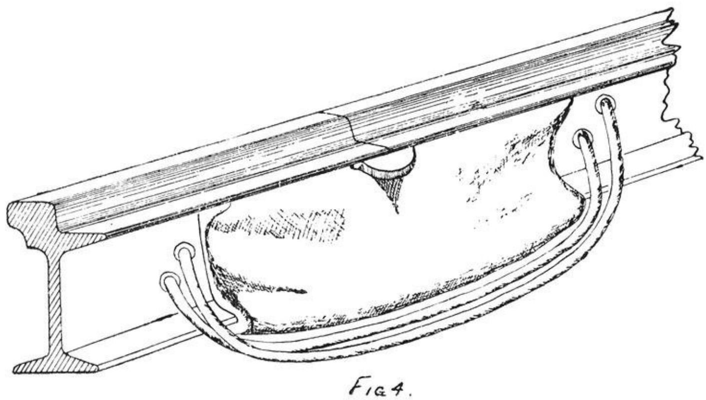


FIG 4.

the joint as large a current as possible, and measuring the drop by means of a very low reading volt meter. This seems quite necessary, as a joint which today has a perfect weld may at some future time break the weld due to the strains of contraction and expansion and still not be noticeable to the eye, as the pins cast into the rail will keep the ends from pulling apart. This does not destroy its efficiency as a joint, however, but does destroy its use as a bond, offering a path of high resistance to the return current.* If one depends only upon the cast welded joint as a bond, he is not positive at all times that his return circuit is com-

*"Notes on Electric Railway Return", G. W. Knox. St. Ry. Rev., Dec. 15, '96; Track and Track Joints—Construction, Maintenance and Bording; M. K. Bowen. Trans. Am. St. Ry. Ass., 1896-1897.

plete, but let him place a copper bond around the joint and his return circuit will be equal to the best that our present methods of bonding will permit of. When copper bonds are used in connection with the cast welded joint the method of applying them is shown in Fig. 4.

One question in my mind as to the durability of the cast welding process is, whether the severe strains upon the rails and joints due to their contraction and expansion will not in time result in the crystalization of the metal, thus causing a large number of breakages of both rails and joints long before they have paid for themselves and the time for track reconstruction is arrived. Our experience with this joint has not been of sufficient length as yet to determine what the results will be as regards this point.

In the use of the cast welded joint we have a method of joining our rails together which gives absolute satisfaction as regards strength and rigidity—a method which prevents their ends from separating, from bending down, producing low joints, and from bending outward. Three years of service on lines having as heavy traffic as can be found, has done much to prove its practicability. The cost of maintenance for the three years has been almost nothing and to all outward appearance they seem to be as strong and rigid as when first cast.

PERMANENT RAILWAY CULVERTS.

By W. A. ROGERS, B. C. E., '88.

Assistant Engineer Bridge and Building Dept., C. M. & St. P. R. R. Co.

When a railway is first built the bridges, especially the less important ones, are usually constructed of wood. This is a wise policy aside from considerations of economy and speed of construction for the reason that the conditions of rainfall, the size of the streams and the velocity of their currents is not well understood, therefore making it impossible to properly proportion the bridges to suit the requirements. They are therefore as a rule larger than necessary for the amount of water which is to pass through them. As the business of the railway increases and the line becomes of more importance the wooden bridges are replaced by the more permanent structures of masonry, iron or steel. This latter class of construction is usually designated as "permanent bridge or culvert work." By the term culvert we mean any opening through an embankment having a solid top, which is covered with dirt and ballast and has the track rails laid on ordinary track ties. The designing and constructing of iron bridges is treated of in our ordinary college text books. Descriptions of the larger and more important bridges built during recent years have been published in current engineering literature, but the ordinary culvert, its description and methods of construction is seldom discussed. A large proportion of the money spent on permanent work by the western railroads, however, is spent in constructing culverts of the various kinds, and in their construction a great opportunity of exercising skill and economy in designing and good management is offered to the engineer.

The writer has chosen in this article to describe the practice in designing and building this important class of permanent work as adopted and in use by the railway bridge and building department with which he is connected.

Permanent work culverts may be divided into the following classes:—

Iron pipe culverts.

Masonry culverts:

(*a*) Box culverts—Stone top, rail top, and I beam top.

(*b*) Arch culverts.

IRON PIPE CULVERTS.

The smaller openings, ranging from 20 in. to 4 ft. and 5 ft. in diameter are usually made with cast iron pipe. This is cast in 6 ft. and 12 ft. lengths and of various diameters from 18 inches to 60 inches. The smaller size is rarely used from the fact that a man can not crawl through it to clean it out. Twenty inches in diameter is the smallest customary size. Fifty-four and sixty inch pipe are going out of use because they are frequently cracked by the weight of the fill placed above.

Iron pipe culverts are commonly used to replace two kinds of structures: pile bridges and timber culverts. The building of an iron pipe culvert through a pile bridge is a simple matter. The sections of pipe are unloaded near the site and are rolled and pulled into place by means of bars and tackle. Building one through a timber culvert where the opening is still intact is not much more difficult but when it is not large enough to admit the pipe the operation becomes more complicated and expensive. If the fill is of a material which stands well, tunneling through the bank is often resorted to. This process is quite simple. The dirt slope is cut straight down as close to the track as may be, in order to shorten the length of the tunnel and then the opening is commenced, of a size a trifle larger than the pipe. If necessary to prevent caving the roof is supported by means of a row of posts through the center. After the tunnel is cut through the fill, the pipe is immediately pulled into place before the earth caves in. In a fill of soft material, sand or gravel which will not permit of tunneling, it is usually necessary to build a temporary bridge to carry traffic while the entire fill is being excavated.

In all cases it is necessary that the pipe shall have a firm foundation to prevent undue settlement and also that after being placed in position the earth shall be well tamped around the lower half of the pipe. If the soil is soft a platform of old bridge timbers, 6 feet or more wide, is often placed under the pipe to distribute the load over a wider area. A moderate amount of settlement in the culvert is not considered objectionable unless it is uneven, having the effect of unjointing the different sections of pipe. This is often provided for by laying the center of the culvert slightly above a line drawn between the two ends. Formerly pipe culverts were built almost universally with a masonry wall at each end. By this means they were shortened, thus saving one or more lengths of pipe. The cost of the pipe saved was more than the cost of the masonry ends and this was therefore true economy. During the last few years, however, the cost of cast iron pipe has decreased very materially so that now it is cheaper to put in the extra lengths of pipe than to build the masonry ends. The masonry is therefore usually omitted unless there are other reasons for its use. There are places, however, where it is necessary by this means to protect the fill at the end of the pipe from the action of the water. The pipe culvert fills a very important place in the construction of the permanent openings of a railway, taking the place of the more expensive small stone culverts.

Among its valuable features are the ease and economy of its construction and its smooth interior offering no obstruction to the flow of water.

When a permanent opening exceeding about 12 sq. ft. in area of cross-section is desired, some form of masonry culvert is usually constructed. The masonry culvert may be divided into two general classes: Box culverts, whose inside section is rectangular; and arch culverts, whose inside section has a curved top. In any case the question, whether to use a box culvert or an arch, is one of utility and economy. The box culvert is at present limited to a maximum span of 16 feet, although it is neither impossible nor impracticable to build a box culvert of a 20 foot span.

In general the arch culvert requires a firmer foundation than the box culvert as a slight settlement of the walls of the arch has the tendency to destroy its equilibrium and wreck the structure. A settlement of the walls of a box culvert unless very unequal has little effect except to cause more or less unsightly cracks. It is therefore necessary to take greater precautions against settlement in the case of an arch than of a box culvert, and in general it may be said that wider footing courses are necessary and the foundation is more expensive in the case of the former than in the latter. The walls of the arch are usually made heavier than those of the box culvert because of the somewhat uncertain action of the stresses induced by the earth filling. Those induced in the walls of the box culvert, due to the same cause, are only the vertical, due to the weight of the material on the cover and the horizontal pressure of the earth on the sides. For the same grade of masonry at the present prices there is little difference in cost between the arch and the box culvert of the same area of cross-section up to about a 6 foot span, but as the span increases above this amount the cost of the arch becomes increasingly greater than the box culvert as we build them.

With this brief note of comparison between the two different classes of masonry culverts, we will pass to the points of construction which are common to both. The first consideration in any case is the foundation which is dependent upon several things: the soil and the weight to be imposed on it, the size and kind of structure to be built and the manner in which the water flows through the culvert.

Foundations ordinarily used in culvert work may be divided into natural, in which the masonry rests directly on the natural soil; grillage, in which it rests on a timber platform used to distribute the weight over a greater area than that of the footings; and pile, in which the load is transmited by means of piles either to a hard strata lower than it is practicable to go with the masonry or to the surrounding soil by means of its friction against the piles.

Of the natural foundations rock is of course the firmest we have, although it is not always the cheapest. It rarely ever lies in just the shape desired, the bed is not level, or it is rough and uneven, or there is a rotten layer on the surface which has to be quarried off. In any case it is necessary to remove the loose rock to make the top surface of fairly level planes if stone masonry is to be started directly on the rock or to level up the surface with a layer of concrete. The surface must be cleaned and washed carefully to remove any dirt which will interfere with the adhesion of the mortar. Where concrete is used it is well to drill holes in the rock bed and put in iron dowels allowing them to project into the concrete in order to prevent any sliding of the concrete on the bed.

Hard pan, gravel and clay each furnish excellent culvert foundations with no danger from settlement if the footing is properly proportioned. Ordinarily sand if not exposed to scour and quicksand if confined make good natural foundations. Three feet is about the usual depth to which we go for this class of foundations, for the moderate sized culverts provided the soil is firm enough. In deciding on the depth of foundations necessary the question of erosion is to be considered as well as the firmness of the soil. Where the current is strong it may be necessary to increase the depth materially under the point where the soil is of a sufficient firmness, in order to be below where the current will cut. A culvert washes out by undermining the foundation, beginning usually at one of the ends and this is usually at the lower end. The water in discharging digs a hole just at the lower end of the culvert. This gradually grows deeper and larger until it reaches far enough back under the masonry to cause a section to fall. The next bad rain is apt to "eat" back farther and take another section or complete the destruction of the culvert. This is the frequent operation especially when the water discharges through the culvert under a head at times of severe storms. The writer has in mind a large culvert which probably failed in this way and of several arches which were damaged in the same way during the last two springs.

Occasionally an arch fails by the undermining of the walls near its center. A small arch on one of the divisions of the railway on which the writer is employed was partially washed out in this way this past spring. To prevent this injurious effect of strong currents we build masonry cross-walls level with the floor and of the same depth as the footings at right angles to and between them. They are placed from 6 feet to 10 feet apart from one end of the culvert to the other, the number being varied to correspond to the danger apprehended from erosion. Stone paving is placed between these cross walls as an additional precaution. In exceptionally bad places a concrete floor is built between the lower wings as well. These cross walls serve as struts to keep the pressure of the earth from crowding the walls together as well as to prevent scour.

Where the soil is of a yielding nature and still is not soft enough to require a pile foundation, or where there is a thin firm strata overlying a soft one and there is danger of breaking the crust; and it is not practicable to broaden the footing courses enough to spread the weight over a large area and prevent injurious settlement, a timber grillage is used. It is usually made of stringers, caps or ties taken from bridges which have been renewed. This material is as good as new for this purpose and will last as long. It should be placed low enough so that it will always be wet. The grillage usually consists of a single course of timber laid at right angles to the direction of the wall and of a width great enough to spread the load over a sufficient surface. For the smaller box culverts in moderate fills this class of foundation usually suffices for even very soft soils. A pile foundation adds very materially to the cost of a culvert and is to be avoided where practicable. From the consideration of bridge masonry we get the idea fixed in our minds that the settlement of all masonry, either bridge or culvert, is something to be prevented at any cost, but in reality the settlement of an unimportant box culvert is of slight consequence if the amount is small and uniform throughout. As an example of this class of foundations, a rail top culvert built several years ago, may be mentioned. It was 10 feet wide and 5 feet high inside and was in an 8 foot fill on a peat swamp which was almost bad enough to be called sink hole. To have attempted a pile foundation would have been very expensive.

A grillage consisting of a single course of second-hand bridge stringers 10 inches thick and 14 feet long was laid with the timbers at right angles to the walls. The masonry was built on this platform with the expectation that it would settle and the grillage used so that it would be uniform and of a moderate amount. It did settle somewhat, but was not at all injured in so doing.

There are places where the soil is very soft and yielding or where there is great danger from scour, at which pile foundations are necessary. Pile foundations for culverts are much the same as those built for ordinary piers or abutments, consisting of two or more rows of piles driven hard, cut off below low water mark and either capped and a floor of timber put on or else cut off and surrounded by a mass of concrete for one or two feet below and above their tops. In culvert work it is rarely the case that all of the piles can be driven by means of the track driver on account of the distance from the center of the track to the ends of the culvert being frequently greater than the reach sideways of the pile driver. This necessitates the use of a land driver.

In places where the soil is very soft and the distance to the hard bottom is considerable, there is danger that the top of the foundations of the two walls may be sprung towards each other by the pressure of the earth filling. This is prevented by placing a number of timber struts between the foundations. The cost of a pile foundation averages from $10 to $15 per pile under ordinary conditions; i. e., where there is little delay in driving the piles and the water, is not very troublesome.

After the foundation is completed the next operation is to build the walls of the culvert. There are three general classes of masonry used in ordinary culvert work: stone masonry, concrete masonry, brick masonry. These three general classes are frequently combined in the same structure.

There are three kinds of stone masonry used in culvert work. Our bridge stone masonry consists of regular horizontal courses of huge stone laid in cement mortar, the courses varying in thickness from 14 inches to 24 inches, decreasing in thickness from the bottom to the top of the wall. The stones are dressed to parallel beds and laid with joints not exceeding 1-2 inch in thickness. This class of masonry is very little used in culvert work except in large arches. It necessitates the use of a derrick in its construction and the cost per cubic yard is considerably more than that of the other classes. With present prices for wages and material it costs from $6 up per cubic yard, depending on the stone used and the amount of cutting required.

The next class of stone masonry used is block rubble. It differs from bridge stone only in the thickness of the courses and in the size of the joints allowed, the former varying from 8 inches to 14 inches, and the latter not more than 3-4 inch. This class of masonry has been used for walls of box culverts and bench walls of arches. The writer is not in favor of its general use. The pieces of stone are of such dimensions that they are too heavy to be economically handled by hand and too small to be economically handled by derricks. The cost of labor in building is practically the same as in bridge stone masonry. The use of a derrick is very objectionable where the boom has to be swung across the track as it necessitates more or less hindrance and danger to traffic. This is to be avoided as in these days of fast trains bridge departments are expected to do their work without the slightest interference with passing trains. Its cost differs from that of bridge stone practically only in the price paid for the stone of the two qualities.

Common rubble masonry is the class most used in our culvert work, although the use of concrete is increasing each year. The cost of the concrete is a little less per cubic yard than that of common rubble and the decision whether to use concrete or common rubble in a given case is made in part by the distance the materials have to be hauled. What we designate common rubble masonry in our culvert work is in reality a better class than the name indicates. It is made of stone not less than 6 inches thick, 16 inches long and 10 inches wide, laid in beds approximately horizontal with cement mortar joints about 1 inch in thickness. The ends of the walls, steps and top of the wall are built of stone which are large enough to extend clear across. The stone in the wall is laid with only enough cutting to make proper joints between adjacent face stone and to square up the front edge of face stones. The work is generally coursed for the reason that the stone which we principally use lies in strata with parallel beds and of very even thickness, varying from 6 inches to 9 inches so that it is easier and cheaper to course the work than to build it broken range. The main consideration in this class of work is to have good stone and to use a first class mortar, to fill the joints and beds full, leaving no holes unfilled. The strength of a common rubble wall is dependent on the quality of the mortar and the way the latter is used. The qualities which make this class of masonry adapted to culvert work are several. It is economical, costing in the neighborhood of $4 per cubic yard, varying with the cost of the stone and the price of labor. It can be built without the use of derricks, therefore doing away with any interference with the track. Culvert walls are only used to resist the steady, even pressure of earth filling for which this class of masonry is well adapted.

The use of concrete in culvert work is increasing each year. It is seemingly an ideal form of masonry for certain classes of this work where proper broken stone can be economically obtained. It has not been in general use long enough to say positively what the results will be when subjected to the freezing and thawing of water as in a culvert in which water stands throughout the year. The probabilities are that if properly made and protected by a facing of good mortar that it will resist the action of the frost as well as the ordinary stone masonry. The requisites of a good concrete are, good materials and thorough mixing. The cement used should be of a good quality and adapted to the work for which the concrete is intended. For ordinary culvert work a first class material cement such as Milwaukee, Louisville, Rosendale, and others of like quality, may be used. Each shipment of cement should be properly inspected and none but first class used. The sand must be clean, sharp, coarse and free from all dirt. A sand with grains of uneven size is preferable for the reason that the small and large grains fit together, leaving fewer voids.

The broken stone should be hard, angular, free from dirt and dust and varying in size from that of a hazel nut to that which will just pass through a 2-inch ring. The hard, blue limestone found in the vicinity of Milwaukee and Waukesha, Wisconsin, makes an excellent crushed stone.

Having the requisite materials, the next thing is to decide upon the proper proportions of the different ingredients, bearing in mind that first the cement must be in excess of the voids in the sand, then that the mortar must exceed the voids in the broken stone. We find, using Milwaukee cement for our concrete and with a good coarse sand and broken stone similar to that described, that a proportion by volume of about one part of cement to 1 1-2 parts of sand to 3 1-2 parts of broken stone is about right, the exact proportion to be determined in each case by examination of the materials used. Great care should be exercised in mixing the concrete, using an amount of water which will permit of ramming it well.

The writer was formerly an advocate of a very dry mixed concrete, but he has changed his views somewhat on finding that better work can be done with a moderately wet mixture, in culvert work, in which the mass is moulded in comparatively narrow walls between wooden frames which absorb more or less of the water of mixture before it has completely set. If the soil is hard the ordinary method of procedure is to dig the foundation of the exact size desired for the footing course and then fill the hole with well rammed concrete.

Then a frame of plank, the shape of the wall is built. The plank on the exposed face of the wall is surfaced so to give that side a smooth finish.

The concrete is deposited in the interior of this frame in layers from 6 inches to 8 inches thick and well rammed to place. A facing of Portland cement mortar from 1 inch to 2 inches thick is built in the following manner. On all exposed faces of the wall a board is placed about 2 inches from the side of the frame which it is desired to face, and the concrete is deposited back of it.

The space between the board and frame is filled with Portland cement mortar of the proportion one part of cement to two parts of sand, and then after removing the board the concrete is rammed well into the mortar, forming so intimate a mixture of the two that the facing will not peel off. This facing forms a protection against the action of the elements. Concrete work, when properly faced, has a very pleasing appearance and will undoubtedly prove durable. The cost of this class of concrete work under like conditions is about 50 cents less per cubic yard than common rubble. It is done with a crew of about 10 laborers and a foreman. The cost, of course, varies with the price paid for labor, cement, sand and broken stone. The large item in the cost being that of labor, it alone amounting to nearly 50 per cent. of the whole.

Brick masonry has been used for culvert work to some extent in building arches, but we do not use it at present except in building the ring of arch culverts. For this purpose we use a paving brick of about a No. 2 quality, set in either Portland or natural cement mortar of the proportion of one part of cement to two parts of sand. The cost of brick masonry where paving brick is used is considerably more than that of either concrete or common rubble. The cost of the brick in a cubic yard of masonry about equals the total cost of a cubic yard of either common rubble or concrete. It is therefore but little used from economical reasons if from no others.

Having described the different classes of masonry used in our culvert work, the distinctive features in the construction of the different forms of culverts will now be touched upon.

The box culverts may be divided into different classes according to the covering, as follows:

Stone Top Culverts,

Rail Top Culverts,

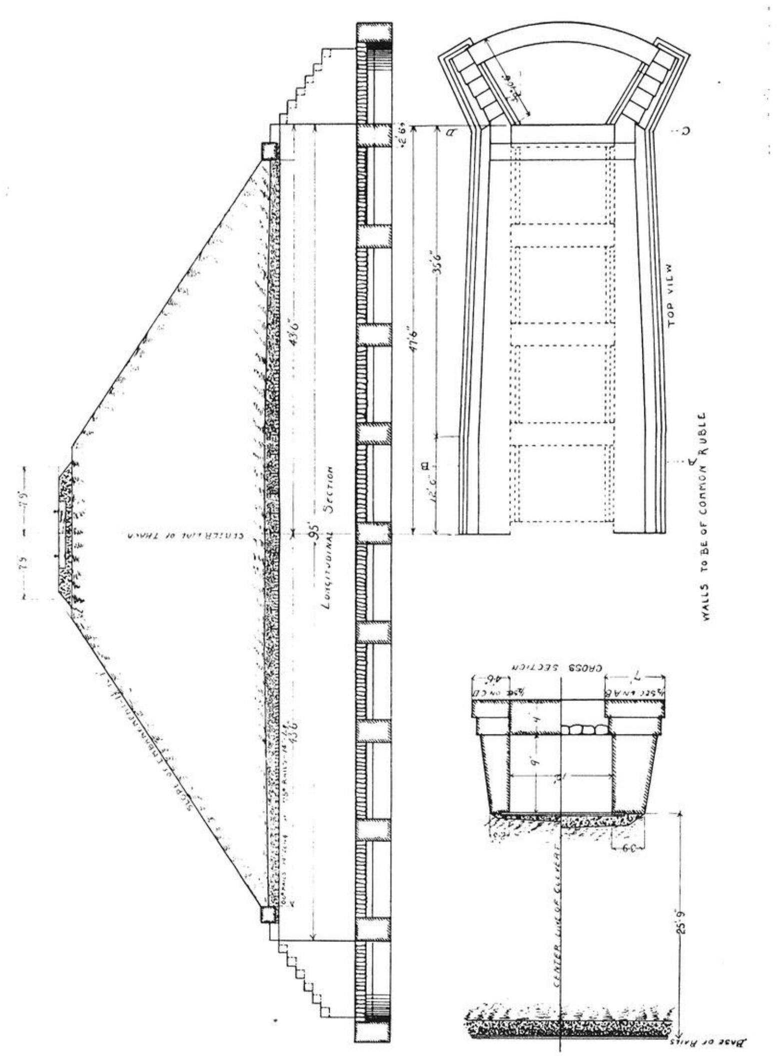
I Beam Top Culverts.

The stone top culvert has side walls of masonry with a covering consisting of large, flat stones, spanning the opening and bearing at least one foot on each wall. The thickness of the cover stone varies with the distance spanned. Stones without flaws and imperfections are required for this purpose. Stone boxes vary in size from about 2 feet wide and 2 feet high, to 4 feet wide and 5 feet high, although they have been built 5 feet wide. This was a very popular form of culvert until a few years ago, but the cheaper cast iron pipe has taken its place to a large extent. They have, however, served a very useful purpose in the development of the western railways. The writer has, during the past few years, examined many of this class of culverts which have been built from 20 to 40 years and are still in good condition. The weak point is, however, in the top. The cover stones, especially in the wider spans, are apt to break in time, causing considerable expense to repair, if the fill is a high one.

The rail top culvert is an outgrowth of the stone top culvert. Until within a few years, in places where openings too large for the stone box were required and where a bridge was not desirable, an arch of some form was built.

The idea of using scrap rails of various lengths was suggested and from that starting point a distinctive form of culvert has been developed. Economy is the watchword in all branches of the railroad service and any idea which has merit and is truly economical is eagerly sought after. The use of rails for the covering of culverts serves the double purpose of furnishing a use for short pieces of old rails which are of no value except as scrap and it also permits the building of culverts, other than arches, of a larger span than formerly. As at first used, the rails, sometimes in two layers, were simply placed on the top of the walls and the earth filled over them. From this by gradual improvements a culvert has been evolved in this bridge department, which is unique in many particulars. It is built in 5, 6, 8, 10 and 12 foot spans through fils of any height, provided only that there must be at least 2 feet 6 inches from the top of the opening to the base of the rail. This is to provide room for ballast over the covering. The height of the opening is, in general, less than the width; but may be of any amount as the requirements of the place may dictate.

The walls of our rail top culverts are built of either common rubble or concrete. The covering is made with rails laid on the flange parallel to the track across the opening between the two walls. Over and between the rails and extending to the back of the wall, concrete is placed to serve a double purpose; to form a tight covering and to prevent in a measure the rusting of the rails. In the case of common rubble walls a smooth bearing is cut for the rails on the top of the walls and a shoulder of about one inch is left in the masonry against the end of the rails so that they will act as struts to prevent the crowding together of the walls of the culvert by the pressure of the earth filling. Where concrete walls are used a smooth bearing of Portland cement mortar is made for the rails and the concrete back of the ends of the rails is left rough so that the concrete covering and the walls will join together, forming one mass and acting together in the same manner as in the case of the common rubble walls. The strength of the rail covering is proportioned roughly to the load that is to be borne. Its exact proportioning is for many reasons impossible and unnecessary. The strength of the rails is impaired through the reduction of the section by use in the track and will be further impaired by corrosion. The manner in which the earth pressure acts and the way in which the load due to the passing trains is distributed is not well understood, making it impossible to tell what the load is in any given case. An assumption as to the earth loading and the action of the train load is made which is on the safe side and the rail covering is proportioned roughly according to this assumption. This is done by varying the size of rails used from the 56 lb. to the 75 lb. section, and also by the spacing of the rails. They are either laid close together, the flange of each rail touching that of the next one or else they are spaced about 9 inches center to center and the space between filled with brick, placed side by side on their flanges to keep the concrete covering in place till set. In the case of large spans and high fills I beams are also added in the part of the covering directly under the track. The concrete covering varies in thickness from 6 inches to 1 1-2 feet above the top of the rails and is made of either Milwaukee or Portland cement. The former is used in the case of the narrower spans and the low fills; and the latter, in the case of the wider spans and the higher fills. The thickness of the concrete is increased



as the height of fill increases. The strength of the concrete is disregarded in proportioning the covering.

A parapet either of stone or Portland cement concrete resting on rails is placed at either end of the cover to catch the earth slope.

A plan of a rail top culvert, now under construction, which is typical of this class as built by the Bridge & Building Department, of which the writer is a member, is shown. The arrangement of the rails and the spacing with brick may be seen. The plan shown is of the widest span we build and as will be noticed, is in a high fill. The rails are therefore of a heavy section and laid close except towards the ends where the height of filling is less and an I beam is placed between every 4 rails directly under the track.

The rail top culvert is proving of immense value in the construction of the smaller permanent openings, and this company has built more of them during the last two years than of all other masonry culverts.

The I beam top culvert is an adaptation of the rail top to wider spans.

I beams of various sizes being substituted for the rails with this difference: that the I beams are not laid close but are always spaced by means of brick. It has been used for spans of 15 feet and 16 feet, but may be used for 20 foot and even 25 foot spans.

Arches are built of spans varying generally from a minimum of about six feet. The smaller sizes are usually built of common rubble and brick or concrete, while the larger are commonly built of bridge stone.

The common rubble arch ring is built of stone of the same quality as the ordinary common rubble work, except that an attempt is made to select stones of a size which are wide enough to extend the full depth of the ring.

The face of the stone is roughly hammered to a line. The joints at the inside are about one-half an inch and are wider toward the outside.

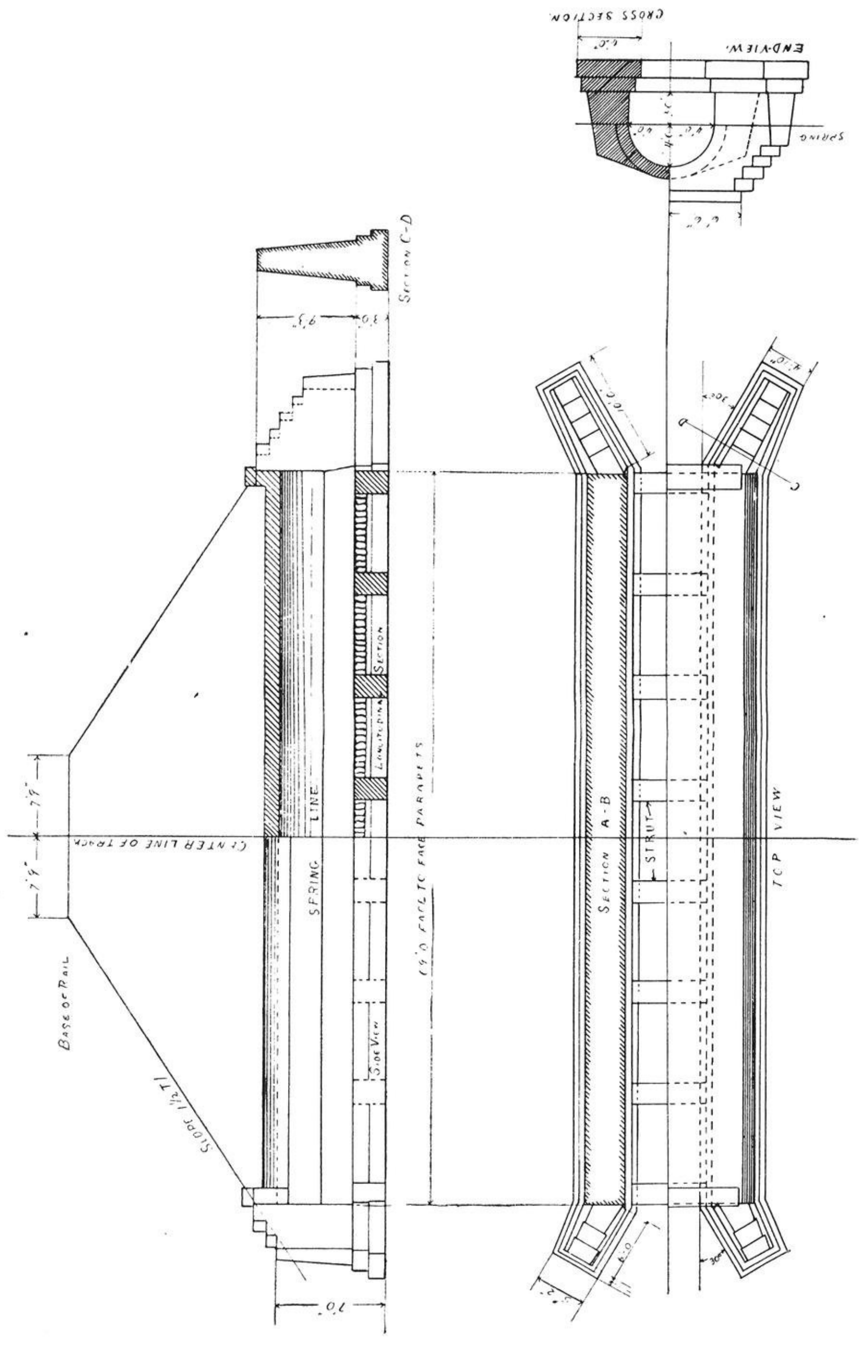
We have been using Portland cement mortar to set the arch ring.

The face stones are larger and selected from block rubble.

The spandrel backing is built of the smaller stones, which have been left after selecting those for the sheeting.

The ends, the steps of the wings, and the coping of the parapet walls are made of block rubble.

The ring is often made of brick and the rest of the arch of common rubble


CROSS SECTION
END VIEW
SPRING
SECTION C-D
SPRING LINE
CENTER LINE OF TRACK
LONGITUDINAL SECTION
SIDE VIEW
BASE OF RAIL
SLOPE 1½ TO 1
19'0 FACE TO FACE PARAPETS
SECTION A-B
STRUT
TOP VIEW

A few years ago a number of arches were built on this railway entirely of brick.

It is a question, however, whether the well built rubble arch is not fully as durable as the brick

The concrete arch for railroads is in a more or less experimental stage. A disadvantage in the use of concrete for arch culverts is the fact that, as a rule, it is desirable to fill over the culvert shortly after its completion, but the fact that the concrete takes more or less time to set prevents this. Where there is sufficient time for it to properly set, there is little doubt but that it is suitable for arches.

At present there is under construction on this railway a semicircular arch 18 feet in diameter with 7 foot bench walls through a 26 foot fill. The wings are of common rubble, the footings and bench walls are of Milwaukee cement concrete with a common rubble facing and the ring is of Western Portland cement concrete with a single inside ring of Galesburg paving brick. This culvert will be filled over this fall.

An 8-foot rubble arch and a 10-foot arch with a brick ring and the rest of common rubble has just been completed.

The plan of the 8-foot rubble arch is shown.

Larger arches are usually built of cut stone and are quite expensive.

Where economy is a consideration some form of bridge, such as a steel trestle or a girder span on masonry abutments, is usually preferable, even though the arch may be the more esthetic structure and even the more desirable from the standpoint of operation.

In the foregoing the writer has touched upon some of the points to be met with in the construction of an important part of the work of a Railway Bridge Engineer.

The practice in this work, as in all other engineering work, is constantly changing and improving.

What is considered good practice at one time is not so considered a few years later on account of changed conditions. A few years ago the question of first cost was not as important an item as at present.

In these late years every plan must be weighed in the balance of economy and if found wanting, rejected.

He has tried to treat the points which are of interest to the young engineer and has undoubedly gone more into detail for this reason than would otherwise have been necessary.

THE ELECTROLYTIC DECOMPOSITION OF THE CHLORIDES OF SODIUM AND MAGNESIUM.*

BY M. C. BEEBE, B. S., '97.

The enormous quantities of bleaching powder which are consumed yearly in various industries and for various purposes has been the incentive for the numerous applications for patents on various forms of apparatus for decomposing sodium or magnesium chloride by electrolysis, their object being to produce a substitute for bleaching powder at a lessened cost. The matter has received much more attention abroad than in America.

It has long been known that by electrolysing a sodium chloride solution that the result was a liquid which possessed excellent bleaching properties. The primary elements liberated are sodium and chlorine, but these immediately recombine and form sodium hypochlorite (Na Cl O) unless special provision is made to prevent this. By placing the electrodes in separate compartments of the electrolytic cell, the products of electrolysis may be kept separate and it is on special forms of diaphrams and partitions for this purpose that most of the patents have been granted.

As early as 1851, Charles Watt attempted to decompose sodium chloride on a commercial basis, using primary batteries as a source of power. Since the perfection of the dynamo the matter has received fresh impetus and several plants are now operated on a commercial basis. In this article only the apparatus in which no attempt is made to keep the products separate will be considered.

The solution formed owes its bleaching properties to compounds which are the result of secondary reactions in the cell. It is said that it possesses greater antiseptic powers than corrosive sublimate, and as a bleach has the advantage over other

*Abstract of a thesis submitted for the degree of B. S. in Electrical Engineering, received special honors.

bleaching agents that it is slightly alkaline or neutral and owes its bleaching action to a hypochlorite and not to a mixture containing an excess of a base which is harmful to the articles to be bleached. The principal commercial apparatus for the production of electrolytic hypochlorite is one developed by Hermite, a Frenchman. His apparatus has been tried experimentally at Worthing, England, for the disinfection of the sewage of that town, and tests at this plant have shown it capable of doing much toward the solution of the sewage problem. It is also being used to some extent as a substitute for bleaching powder in the bleaching of paper pulp and textile fabrics.

His apparatus consists of a galvanized iron tank in which the decomposition takes place. The anodes are made by mounting platinum gauze in an ebonite frame, these anodes being fastened to a copper bar by a leaden lug. Between each pair of anodes is a zinc cathode. The cathodes are discs mounted on a revolving shaft, each being provided with a scraper which cleans it as it revolves. While running, a white deposit adheres to the cathode which, unless removed, increases the resistance of the cell greatly. This white deposit is probably hydrate of magnesium formed according to the following equation:

$$Mg\,Cl_2\,O_2 + 2\,H_2\,O = Mg\,H_2\,O_2 + 2\,H\,Cl\,O$$

Hermite's process is a continuous one. The electrolyte enters the tank through a well perforated pipe which runs along the bottom of the tank and after passing up between the electrodes it overflows into a trough which surrounds the top of the tank. From here it is conducted away for use. After being used in bleaching vats it is returned to the electrolyser and regenerated. Sea water is used for the electrolyte where available, but a solution containing 5 gms. $Mg\,Cl_2$ and 50 gms. Na Cl per litre is used where sea water is not obtainable.

The resistance of the electrolyser is about .00122 ohms. It is claimed that the sodium chloride is not decomposed during the process but merely serves as a conductor. This seems rather improbable since the E. M. F.'s of polarization of the two salts ($Mg\,Cl_2$ and Na Cl) are so nearly alike.

It has been shown by experiments at Worthing, Eng., that the electrolysed solution containing .25 gms. of available Cl per litre is an excellent deodorizer, but to effect sterilization of sewage a solution containing at least 0.75 gms. Cl per litre is necessary.

Dr. Ruffers found further, that solutions containing .5 gms. per litre lost 90 per cent. of their strength in 24 hours, but stronger solutions were more stable, one containing 1.05 gms. per litre lost only 7 per cent. in 24 hours. The greatest loss seems to take place during the first twelve hours.

As to the power required it is said that a common size of Hermite's electrolyser requires 1,200 amps at 5.5 or 6 volts. This electrolyser is capable of producing 2.2 pounds (1,000 gms.) available Cl per hour. The theoretical amount liberated per amp hour would be 1.32 gms. Hermite himself says, 10 H. P. acting for 24 hours will produce the equivalent of 100 Kg. of dry chloride of lime.

Mr. A. E. Woolf of New York has given the matter considerable attention and has installed several experimental plants under the name of the Woolf system. The system used by him is very similar to Hermite's and what is true of Hermite's solution is true of Mr. Woolf's. He uses tanks of about 500 gallons' capacity for his electrolysers and his electrodes are of platinum containing about 5 to 10 per cent. of iridium. The current density used is about one ampere per square inch of anode surface. He says regarding the power used, that in a practical operation about 15 grains (.97 grams) of available chlorine are produced per ampere hour, the applied E. M. F. being about 6 volts.

It is customary to rate the bleaching power of a bleaching liquor by the number of grams of available chlorine it contains per litre, and the value of electrolytic bleach has usually been estimated in the same way. It is claimed, however, by many who have made comparisons experimentally, that in the case of electrolytic bleach the arsenious acid test (which is the one generally used) shows nothing as to its real value as a bleach. Electrolytic bleach, they say, possesses greater power than ordinary bleaching powder of equal chlorometric strength, and this seems to be especially so in the case of electrolysed magnesium chloride. This is generally accounted for by the presence of some additional bleaching agent in the solution which is not taken account of by the arsenious acid test.

It has been observed that in the electrolyses of the alkaline chlorides that the volume of oxygen liberated is less than half that of the hydrogen. Some unknown oxygen-chlorine compounds may be formed which have bleaching properties. Others credit the bleaching action to hypochlorous acid and not all agree as to whether the solution is acid, neutral or alkaline. Dr. Schoop's investigations recently made show that no free chlorine was ever formed during the electrolysis.

Messrs. Cross & Bevan, who have had considerable to do with the Hermite solution, made some comparative tests and found that in bleaching powder, instead of being a simple oxidation only, there was also a combination of chlorine with the fibre constituents. They carefully compared the hypochlorites of calcium, sodium and magnesium formed by chemical processes with those formed by electrolysis. They found that 26 per cent. of the calcium and sodium compounds was used up in the chlorination effect, and with magnesium hypochlorite 14 per cent. of the total amount was lost. With the electrolysed solutions there was no chlorination at all. In bleaching with the electrolysed solution there is a complete reversion to the chloride and therefore its bleaching action is an oxidation pure and simple.

Electric bleaching was well known in Russia in 1883. Ltdoff and Tikcomroff, seeking to find the liquid of maximum bleaching power, electrolysed various solutions of chlorides. They gave the preference to chloride of potassium. Representing the bleaching power of electrolysed potassium chloride by 100, they found that of sodium to be 73 and of calcium chloride 24. In the case of the electrolysed solution the chlorine is present in a weakly combined state whereas with bleaching powder no action takes place until the chlorine is liberated by the addition of acid.

A series of comparative investigations by M. G. Saget into the action of Hermite's solution, electrolysed sodium chloride (Gebauer & Knoeffler's solution) and ordinary bleaching powder upon cellulose are very interesting.

Two series of experiments were made. In the first series the tissue was completely immersed in the liquid and exposed to the sun; under these conditions oxycellulose was not found with Gebauer's solution provided the available chlorine was less than .25

gms. per litre, or with Hermite's solution if the chlorine did not exceed .2 grams, but with ordinary bleaching powder as much as .54 grams available chlorine might be present before the oxycellulose was formed. In the second series of experiments the tissue was partly immersed and placed in the shade, the liquid being drawn up into the fabric by capillarity. In this case, chloride of lime was the most active, oxycellulose being distinctly formed even with less than .3 grams available chlorine per litre, while the Gebauer and Hermite solutions formed none. As a bleaching agent he found Hermite's solution the most active, Gebauer's next and chloride of lime least.

Really very little has been done to determine the relative values of bleaching solutions formed in different ways. It is of prime importance because the cost of replacing the use of chloride of lime hinges directly upon this question.

As to exactly what takes place when a solution of a chloride is decomposed by electrolysis, as in the Hermite system, there is some difference of opinion. The following reactions probably take place simultaneously:

First: The electrolysis of Na Cl with formation of Na O H, H, and Cl.

Second: Electrolysis of Na O H with formation of H and O.

Third: Formation of Na Cl O, by the action of Cl on Na O H.

Fourth: Formation of Na Cl O_3 by the oxidation of Na Cl O.

Fifth: Electrolysis of Na Cl O, with the formation of Na O H, H, H Cl O and O.

Sixth: Electrolysis of Na Cl O_3 with formation of Na O H, H, H Cl O and O.

Seventh: Reduction of the Na Cl O found at the cathode to Na Cl.

Eighth: Reduction of the Na Cl O_3, found at the cathode to Na Cl.

That the temperature of the electrolyte is an important factor in the amount of available chlorine produced there can be no doubt. At temperatures above about 20° C. the output of Cl per ampere is considerably smaller than at lower temperatures, other conditions being the same. It is generally believed that the decreased efficiency is due to the formation of chlorates in the bath instead of hypochlorites or that the hypochlorites are easily changed to chlorates at higher temperatures. It is important then to keep the temperature of the electrolyte low, either by artificial cooling or better by circulating the liquid.

Mr. Fitzgerald in a discussion of Mr. Swinburne's paper entitled "Commercial Electrolysis," stated that he had devoted much time to the electrolysis of magnesium chloride and had come to the conclusion that the selection of magnesium chloride by Hermite was an unfortunate one because of its strong tendency to form magnesium chlorate, even at ordinary temperatures.

The difficulty of obtaining a suitable anode for use in the electrolytic production of hypochlorite has been a serious one. A good anode should be a good conductor, cheap and not attacked by the products of the electrolysis. Platinum was finally adopted by Hermite after failing to find anything cheaper which would serve the purpose. It seems that it has served admirably, yet for the production of a cheap product some cheap anode is essential. Hermite at first used platinum foil but found it poor mechanically. By using it in the form of a gauze he reduces the cost and obtains results, with the same weight of platinum, as good as when used in the form of a sheet.

Carbon has been tried in a variety of forms and the general experience has been that all forms of moulded carbon disintegrate rapidly. From the researches of Bartoli and Papasogli it is known that carbon is attacked when used as an anode in any solution which evolves oxygen at the anode. Retort carbon has been most generally used, since it is cheap and quite durable, especially when prepared by soaking in paraffin or tar and heating very hot. The carbons are attacked and disintegrated much more rapidly in a dilute electrolyte than in a concentrated one. Hermite tried carbon in his electrolyser but was forced to adopt platinum because it was the only substance he found which would not disintegrate in his weak electrolyte when used as an anode.

Lithanode is a substance invented by Mr. Fitzgerald, and is made by mixing ammonium sulphate with litharge and compressing into the desired form by great pressure. It is then oxidized to lead peroxide by immersing in a bleaching solution. Since it is incapable of further oxidation, it is very durable.

It is said that phosphide of chromium and also an alloy of iron and titanium are indestructible anodes.

The cathode is not nearly so troublesome as the anode but for the sake of economy one should be used which does not give off hydrogen, not only because the hypochlorite would be reduced but also because a considerable amount of power is wasted when hydrogen is given off. Mr. Fitzgerald gives the E. M. F. of polarization as 2.3 volts when both hydrogen and chlorine are given off. When the hydrogen is absorbed it is 1.61 volts and when both hydrogen and chlorine are absorbed in the electrolytic tank, 1.09 volts.

Since the cost of the power required for the production of hypochlorites by electrolysis is almost entirely the determining factor in the cost of the product, the writer performed some experimental work with the following objects in view:

First: To find the power required to produce hypochlorites by the electrolytic decomposition of magnesium and sodium chlorides.

Second: To find the effect of different current densities upon the amount produced and power required.

Third: To find the effect of the density of the electrolyte upon the amount produced and the power required.

Fourth: To find the effect of temperature upon the efficiency of the process.

Fifth: To find how strong a solution could be obtained economically.

The apparatus used for the purpose consisted of several glass tanks 6 in.x9 in.x8 in. high. The electrodes were pressed carbon plates 6in.x10 in.x3-8 in. thick, made by the Solar Carbon Co. To ensure good electrical connection with the carbon electrodes two holes were drilled in the end of each plate. The end of the plate was then copper plated, and after being well tinned, a leaden lug was cast around the top of the plate. The distance of the electrodes from each other was one inch in every case. They were generally immersed in the electrolyte to a depth of six inches.

The method of getting at the results was to connect six tanks in series, all having different densities of solutions in them. The anode surface, being the same in all the tanks and the same current traversing each, enabled observations to be made by which the effect of a certain current density upon the different densities and kinds of solutions could be determined. Several runs were made with the conditions similar, only using a different current value. From the data taken the effect of different current densities upon a certain strength of solution are easily compared. During a run the following data were observed at regular intervals.

Applied electro-motive force.

Current.

Temperature.

Amount of available chlorine per litre.

The test used to determine the amount of available chlorine contained per litre was the arsenious acid test generally employed for this purpose. This test takes account only of the chlorine existing in the solution in a free state or in a hypochlorite.

In order to compare the results obtained, conveniently, curves were plotted from the data. These curves show the relation of the chlorine produced per ampere to the time the current was flowing, the chlorine per ampere being calculated from the chlorine per litre at any time by multiplying the amount of Cl per litre by the number of litres electrolysed and dividing by the current flowing. Typical curves are shown in figures I, II, III, IV, V, VI. Fig. I shows curves obtained by electrolysing a 13 per cent. solution of sodium chloride. In this run no attempt was made to keep the electrolyte at a low or constant temperature. A current density of approximately 50 amperes per square foot (see curve *e*) gives the best efficiency for over four hours, then on account of the rise in temperature of the electrolyte the curve slopes off rapidly.

Curve (*a*) was obtained from a current density of 10 amperes per square foot. It is the lowest current used here, and undoubtedly the Cl per ampere reaches a higher final value than any of the others in Fig I, because of the small C^2 R loss and consequent small rise in temperature of the electrolyte. Fig. II shows similar curves obtained by electrolysing a mixture of sodium and magnesium chlorides. In this case the low current density is the most efficient, even at the start. This is true not only of this one test but of several others, using different proportions of magnesium and sodium chlorides.

Curves (13) and (17), Fig. III, were obtained from a 25 per cent. sodium chloride solution which is nearly saturated. The current density for curve (13) was 24 amperes per square foot, and for curve (17) was about 90 amperes per square foot. The tempera-

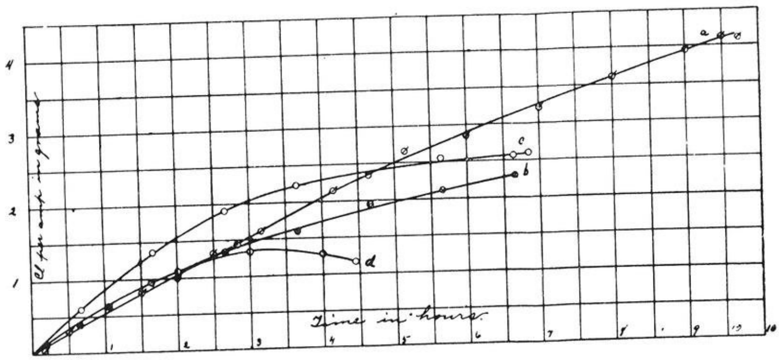


FIG. I.

ture for curve (13) was kept constant at 11°C. Although (13) slopes off more rapidly than (17), yet to obtain a certain strength of solution the high current density is fully as efficient as the low one.

The curves, Fig. IV, were obtained by electrolysing 20 litres at a time instead of 4 litres as in the previous tests.

To obtain curves (20) and (22) a 20 per cent. sodium chloride

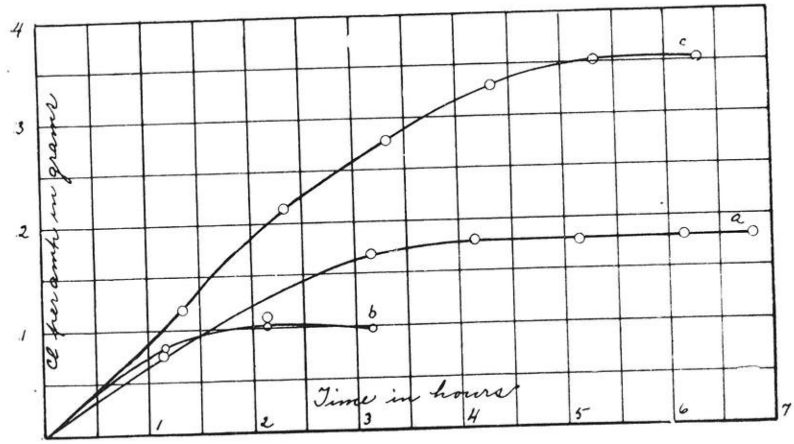


FIG. II.

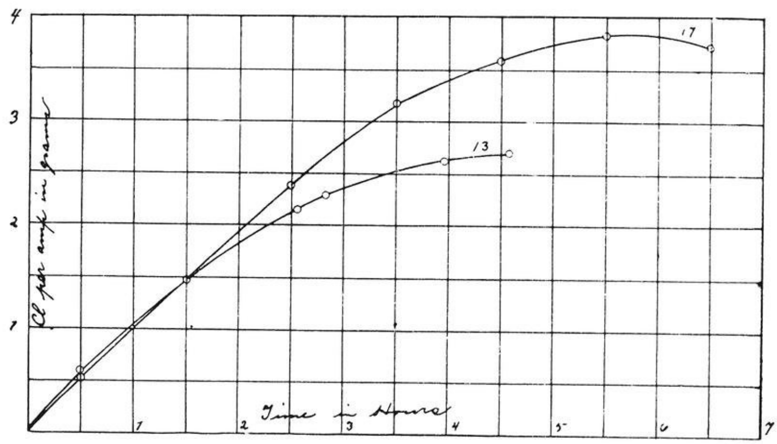


FIG. III.

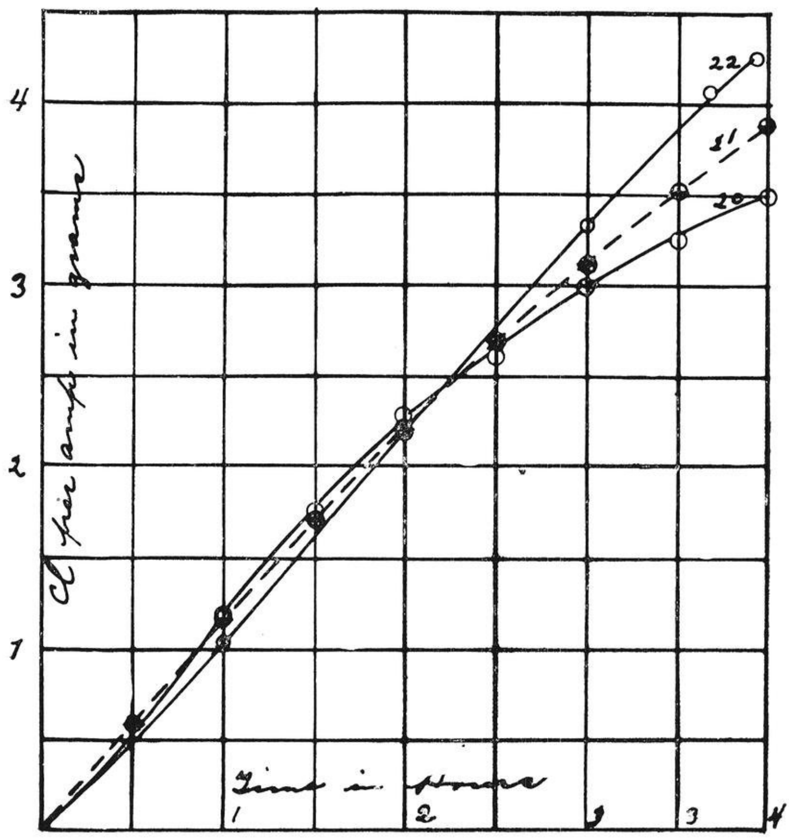


FIG. IV.

solution was used. With (20) a current density of 60 amperes per square foot, and with (22) 30 amperes per square foot was employed, while for curve (21) a 12 per cent. solution of sodium chloride was used and a current density of 30 amperes.

These curves slope very little, and at first thought it would seem that better results are obtained by electrolysing a large quantity at one time, however, to obtain a certain strength of solution it is no more economical to decompose a large quantity than a small one. Here, too, there is very little difference between the efficiency of high and low current densities.

Curves, Fig. V, were obtained by electrolysing mixtures of

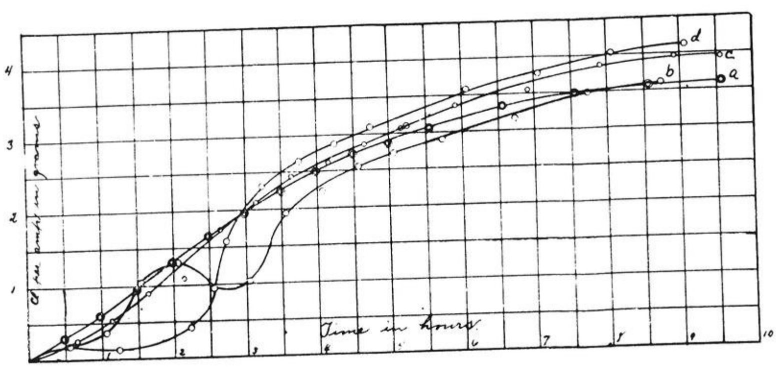


FIG. V.

magnesium and sodium chlorides in approximately the proportions used by Hermite. However, they were obtained in a slightly different manner than the preceding ones. Four tanks containing the same solution were connected in series, and a current of 9.9 amperes passed through them all. The current density was varied by varying the amount of anode surface exposed, and in (*a*) it was 40 amps per sq. ft., in(*b*) 60, in (*c*) 95 and in (*d*) 135. These curves obtained in this way indicate that the highest current density is the most efficient, which disagrees with the results obtained by Dr. Schoop in some recent investigations.

The power required for the electrolytic decomposition of the chlorides is made up of:

1. C^2 R loss in conductors and electrodes.
2. C^2 R loss in the electrolyte.
3. Energy necessary to decompose the electrolyte.

The first of these is easily calculable and can be made of any value desired.

The second may be easily calculated by knowing the specific conductivity of the electrolyte to be used. This loss may be made quite small by bringing the electrodes quite close together.

The heating of the solution decreases the resistance and the consequent $C^2 R$ loss in the electrolyte, but as explained before it is very essential to keep the temperature of the electrolyte quite low. The power required for the decomposition may be calculated from thermo-chemical data. Oettel calculated it and found it to be 2.3 volts for all chlorides, and his results obtained experimentally were very near this value. It may be obtained experimentally by measuring the voltage of the cell immediately after breaking the circuit, by means of a high resistance voltmeter,

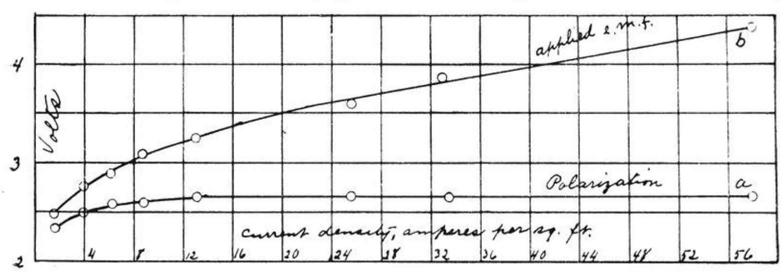


FIG. VI.

or more accurately by charging a condenser at the instant of breaking the current and then discharging through a ballistic galvanometer.

The curves, Fig. VI, were obtained by this condenser method, and it is there shown that the E. M. F. of polarization is entirely independent of the current density. The curve of applied E. M. F. is a straight line of constant slope, as we should expect, knowing the counter E. M. F. of polarization to be constant. The calculated E. M. F. and that obtained experimentally vary by at least .5 volts, depending upon the solutions used. It was also found to vary at least .2 volts, depending upon the time the current had been flowing.

Experiments in which zinc was used as a cathode showed that the polarization E. M. F. was practically the same as when carbon was used. Dr. Schoop found in experimenting with a 3 per cent.

Na Cl solution that the output of bleaching material decreased with increasing current density. My results on a similar solution certainly seem to indicate rather the opposite.

My experimental work seems to justify the following conclusions:

First, that the amount of available chlorine in the solution is not proportional to the power expended. Second, that the amount of available chlorine per ampere is largely dependent upon the temperature of the electrolyte. Third, that the amount produced is also dependent upon the amount of the products of decomposition already formed in the solution. Fourth, that at fairly high temperatures (50° C.) there may be an actual decrease in the amount of available chlorine per ampere hour expended. Fifth, that the amount of available chlorine per ampere hour is dependent largely upon the density of the electrolyte and that dense solutions produce more chlorine per ampere than dilute ones; also that it is possible to obtain solutions having a higher value of available chlorine. Sixth, that the effect of the current density upon the efficiency of the operation can not be stated definitely since in some cases a high current density seemed to be more efficient than a low one, while in other cases the reverse held. Seventh, that if the temperature of the electrolyte be kept below 15° C. it is possible to reach a concentration of 9.7 grams per litre at an efficiency of .9 grams per ampere hour, using Na Cl solution of a density 1.100. Using the Hermite solution or one which had approximately the same proportions, using carbon electrodes, and at a low temperature it is practicable to obtain a concentration of 8.8 grams of available chlorine per litre at an efficiency of .58 grams per ampere hour. Further, it is practical under the same conditions to obtain a concentration of 6.8 grams per litre at an efficiency of .7 grams per ampere hour. Andreoli claims that the highest strength obtainable is 3 grams per litre, using the Hermite solution. Eighth, that a dilute electrolyte disintegrates carbon anodes much more rapidly than concentrated ones. Ninth, that reversing the current frequently, as has been proposed, to lessen polarization and resistance due to deposit upon the cathode, greatly reduces the efficiency of the process and is therefore useless. Tenth, that the polarization for a given density of electrolyte and a given temperature remains constant, regardless of the current density.

Time did not permit of making any quantitative determination of the disintegration of the anodes, but contrary to Hermite's statement, the anodes were eaten away most rapidly at the bottom and along the edges instead of at the water line.

The conditions for producing the electrolytic hypochlorite and the power required are fairly well known but the cost of this bleaching agent cannot be fairly compared with others until reliable data are obtained in regard to its relative value as a bleaching and disinfecting agent.

The following is a list of some of the more important articles which have appeared on this subject recently:

London Electrician—Vol. 26, pps. 16, 45, 90. The Electrolytic Preparation of Bleaching Agents. A. Rigaut. Vol. 30, pp. 709, 745. Some Applications of Electricity to Chemistry. Swinburne. Vol. 30, p. 151. The Cost of Electrolytic Alkali and Bleach. Vol. 32, pp. 381, 442. The Electrolysis of Salts of the Alkali Metals. Blount. Vol. 35, p. 186. The Cost of Production of Electrolytic Alkali and Bleach. Vol. 32, p. 633. M. Hermite's Electrolytic Sewage Process at Worthing. Vol. 35, p. 759. The Hermite Process of Deodorizing Sewage. J. Napier; abstract of paper read before the British Association at Ipswich. Vol. 37, p. 798. Applied Electro Chemistry. Swinburne.

Journal of the Institute of Electrical Engineers—Vol. 24, p. 375. Electric Disinfection by the Hermite System. Vol. 21. The Problems of Commercial Electrolysis. Swinburne.

Journal of the Franklin Institute—Vol. 139. The Application of Electricity to the Bleaching of Textile Fibres. Louis J. Matos. Vol. 139, p. 351. Recent Advances in Electro Chemistry. Richards.

London Electrical Review—Vol. 35, p. 395. The Electrolytic Production of Chlorine and Soda. Andreoli. Vol. 34, p. 10, Hermite's Electrolytic Process. W. Webster. Vol. 32, p. 128, Electrolytic Bleaching. Vol. 31, p. 626. Chlorine and Soda by Electrolysis. Andreoli. Vol. 39, p. 846. Electrolytic Bleaching. Vol. 34, p. 653. Hermite's Electrolytic Sanitary Process. Vol. 35, p. 65. The Electrolysis of the Alkaline Chlorides. Fitz-

gerald. Vol. 35, p. 43. A Point in the Electrolysis of the Alkaline Chlorides. Vol. 35, p. 249. The Electrical Treatment of Water, Sewage, and Garbage. Vol. 35, p. 257. The Hermite High Tension Electrolyser for Electrolysing Sea Water.

Engineering and Mining Journal—Vol. 61, pp. 568, 592. The Electrolysis of Chlorides. Andreoli. Vol. 62, p. 224. A Contribution to the History of the Electrolysis of Alkali Chlorides. George Lunge.

Engineering News—Vol. 30, pp. 41, 65, 105. Sewage Purification in America.

Industries and Iron. (London.)—Vol. 20, p. 187. Sewage and Zymotic Poisons. The Electrical Generation of Chlorine. James Hargreaves. Vol. 16, pp. 290, 258, 323, 358. The Hermite Electrolytic Sanitary Process. Vol. 16, p. 644. Dr. M. A. Ruffer's Report on the Hermite Sewage Scheme. Vol. 14, p. 235. The Valuation of Bleaching Liquors. Vol. 12, p. 619. The Electrolytic Production of Bleach and Alkali. Fitzgerald.

Dingler's Polytechnisches Journal—Vol. 299, p. 96. Electrical Bleaching.

Mineral Industry—Vol. 2, p. 121. Electrolytic Processes of Alkali Mfg. Vol. 3, p. 103. Electrolytic Processes of Alkali Mfg. Vol. 4, pp. 73, 809. Electrolytic Processes of Alkali Mfg.

THE COMPARATIVE EFFICIENCY OF THE STEAM ENGINE UNDER CONSTANT AND RAPIDLY VARYING LOADS.*

BY J. E. DUTCHER, B. S., '97; W. P. KIEHL, B. S., '97; AND F. J. SHORT, B. S., '97.

A great many tests have been made which show in a general way the performance of the steam engine over a wide range of conditions of operations; while but little has been done which shows directly the effect of variable loads upon their consumption of water.

It is quite generally accepted that engines working under variable loads are less efficient than when working under constant loads.

*Abstract of a thesis submitted for the degree in B. S. in Mechanical and Electrical Engineering.

This is borne out by numerous tests made on engines operating street railway generators.

Mr. F. M. Rites, in speaking of the universal failure of electric light and railway stations to realize even a moderate degree of efficiency says, "There seems to be but one general explanation applicable to lighting and railway stations which can account with any degree of probability for such extravagant fuel consumption, and that is the excessive wastefulness of the steam engine under varying conditions of load."

Although many tests have been made of engines under varying loads and at all percentages of their rated capacities, very few have been made which show the actual increase of water consumption when working under such loads, over that consumed when working under constant loads.

Believing that some definite results on this particular point may be of value we made a series of tests on a compound engine. This series was divided into two parts, each consisting of a set of tests. One set was made under a constant load, and consisted of five tests, ranging from twenty per cent. of the rated capacity of the engine to full load. The second part consisted of a similar set but was made under a varying load.

It was thought that if a means of taking an indicator card for each stroke of the engine for a given length of time could be obtained, this would enable the operator to compute the actual work done within the cylinder during that time. This would be entirely impossible with the ordinary method of drum indicator.

An investigation of previous tests showed that very little had been done along this line. In "Power," October, '96, was found a description of a test made on a passenger elevator engine by Messrs. McGregor & Kingsford, where they took continuous indicator cards. Their method was to draw paper strips past the indicator pencil point by running them through rollers belted from the engine.

This moved the paper with a motion proportional to the speed of the engine and as the ordinary card from the indicator is produced under practically harmonic motion it was necessary to make a correction for this which was done by ruling a piece of tracing cloth into ordinates (they used 10 for each stroke) and spacing them so that they came where they would if the paper had been run with harmonic motion. This was done by projecting equidistant points on the circumference of a circle upon its diameter.

They took the average of these ten ordinates as the mean ordinate of the card.

This is at best only an approximate method and would prove very tedious if many cards were to be measured, so it was thought best if possible to obtain a method for moving the paper harmonically, thus obviating the correction above mentioned.

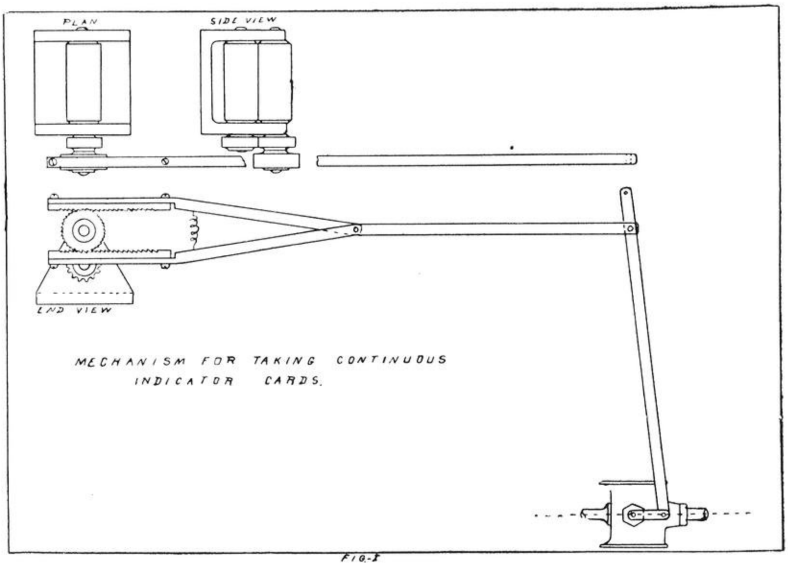


FIG. I

Accordingly the mechanism shown by Fig. I was designed and built. Two of the machines were built, one for each cylinder of a cross compound engine.

The device is similar to that used by Messrs. McGregor & Kingsford, except, where they used a belt and uniform motion, a double-acting rachet, connected directly to the reducing mechanism on the crosshead was used.

This gives the rollers the same motion that the drum of the indicators would have under ordinary conditions except that it is always in the same direction. The racks working on the rachet were made with some end adjustment so they could be set to reduce the lost motion to a minimum.

Both racks and rachet were made from mild steel and case hardened thus making a tooth which would wear well and not be liable to nick.

These machines worked very satisfactorily on the engine tested as it ran less than 100 revolutions per minute.

For a much higher rate of speed they might not work as satisfactorily.

The cards taken with a continuous indicator have exactly the same form of curve as the ordinary indicator card, except that where the exhaust line and compression curve return in the ordinary card they are continued and are reversed in the continuous card.

A continuous card will look the same as the full lines in Fig. IIA. From A to B, represents one revolution of the engine. The area E F C represents the positive work, and it is desirable to determine this area without constructing the compression curve F E, each time. This was accomplished by setting the ordinary planimeter with the points a distance apart equal to A B, and by going around the part B H D, in the opposite direction. This is equivalent to subtracting the area E A F.

Setting the points in this manner gives half the mean effective pressure when the ordinary planimeter is used, as the card is twice as long as an ordinary one, hence the result must be doubled.

However, this is a convenient and quick method.

In about 1889 Mr. F. R. Low (Trans. A. S. M. E., Vol. 15) had an indicator manufactured by the Ashcroft Manufacturing Company in which the pencil was replaced by a planimeter wheel, the angular position of which with reference to the drum, was varied by the movement of the indicator piston. Instead of taking a diagram the indicator drum revolved the wheel an amount proportional to the area of the diagram which would have been taken had a pencil been used.

By a train of recording dials the revolutions of the wheel were counted and it could be run for a minute, or an hour if need be, and give at the end of that time the same result that would be obtained by taking a diagram for every stroke, and measuring and adding the areas.

This worked very well at low speed, but high-speed engines ran

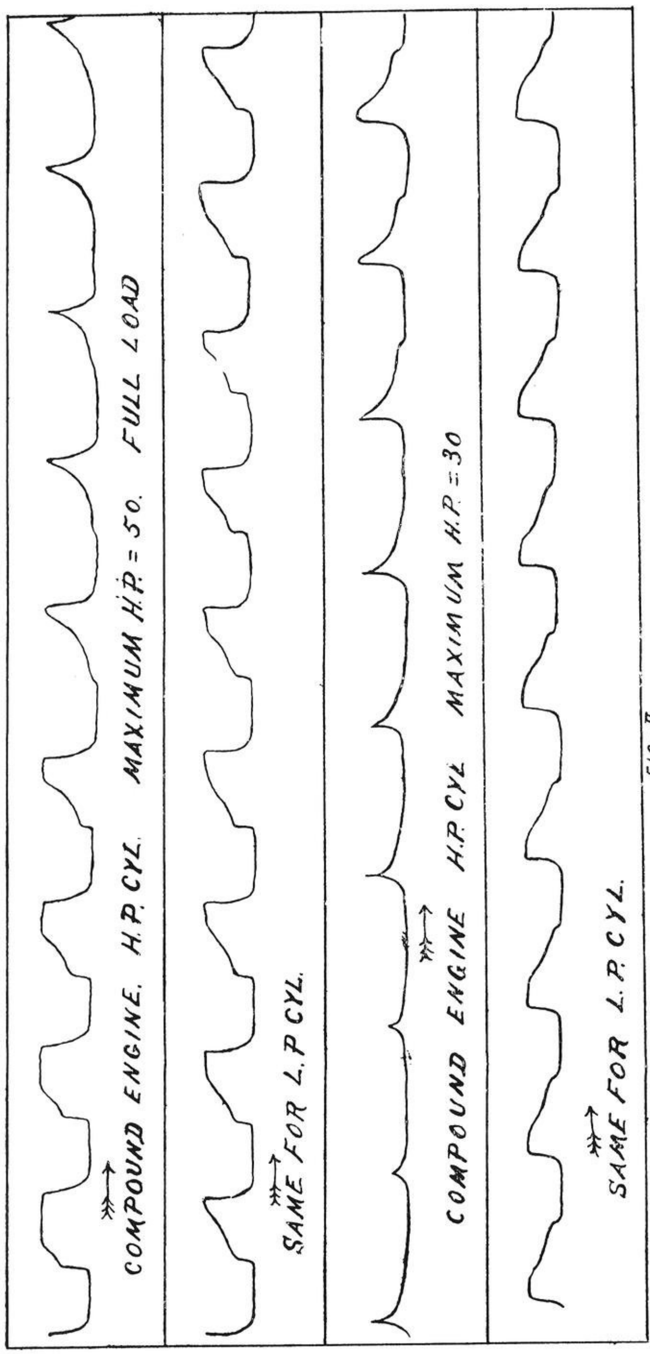

COMPOUND ENGINE. H.P. CYL. MAXIMUM H.P. = 50. FULL LOAD
SAME FOR L.P. CYL.
COMPOUND ENGINE H.P. CYL MAXIMUM H.P. = 30
SAME FOR L.P. CYL.

FIG. II

away with it. This gives the integration of the work done by the engine provided there is no slip, but furnishes no means of telling how the load varied, or to what extent.

Prof. Thomas Gray of Rose Polytechnic Institute, has made quite a number of experiments on engines where he used devices for taking continuous cards.

In The Rose Technic, for May, 1896, can be found an illustrated article giving a description of a continuous indicator device which was used under his direction in testing gas engines, locomotives, etc. His means of moving the paper ribbon past the pencil point is simple and accurate; consisting of cords wrapped around each end of the feed-roller in the same direction and passing around a wheel which was operated in one direction by a cord from the reducing mechanism and was pulled back by a spring.

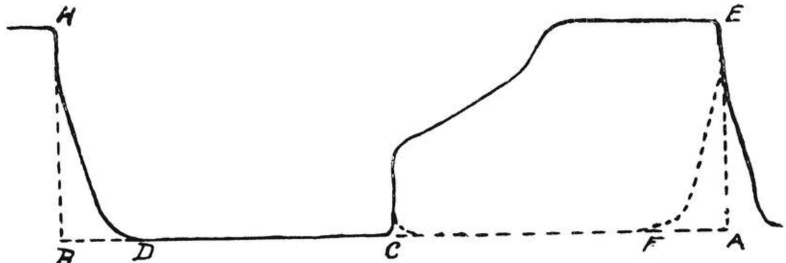


FIG-IIA

These cords pass around small pulleys and are connected by a spring to keep a constant tension in them.

On the forward stroke the top string pulls and the bottom one is released allowing the cord to slip on the drum. The opposite takes place on the return stroke.

Prof. Gray also used a pawl inside a hollow drum to act as a rachet in place of the cord method just described. This is an improvement over the other in that the cord need not slip and hence will not wear out so soon. It would also probably be more accurate at high speeds.

The engine tested was built for the University of Wisconsin by the Nordberg Mfg. Co. of Milwaukee, Wis.

It is a 50 horse power, horizontal, cross compound, quarter crank, condensing engine.

The cylinders are 8 and 13 inches in diameter with a stroke of 20 inches.

Each cylinder is provided with four poppet valves operated by a shaft running at right angles to the crank shaft and driven by a pair of level gears.

The cut-off on the high pressure cylinder is automatically regulated by a Proell governor.

The number of revolutions of the engine may be varied at will from 50 to 125 by changing the weights on the governor.

In the low pressure cylinder the cut-off is regulated by a hand regulator and when once set remains constant.

The walls of the cylinders are steam jacketed, but these jackets were not used, as the object of the tests was only to obtain comparative results.

There is, however, a lagging of mineral wool around each cylinder to prevent condensation.

Steam was supplied directly from the mains leading from the boiler house. The pipes were conducted through a tunnel and were well protected from condensation by a mineral wool covering.

The steam was of a very good quality as may be seen from the table.

The ordinary method of loading this engine is by a Prony brake, but as the brake is suitable only for constant loads, the varying loads were obtained by belting to a dynamo.

The flywheel of the engine is 7 feet in diameter and the pully on the dynamo 3 feet. A 10 inch 5 ply rubber belt was used for transmitting the power. The dynamo was run at a constant pressure of 500 volts by separately exciting the fields from a small dynamo run by a small upright engine in the laboratory.

This dynamo, a four pole machine, was designed and built for a direct connected, gearless street car motor, by the Short Electric Co. of Cleveland, Ohio.

The efficiency of the machine had to be determined, as the brake was used for part of the load on the high loads.

The efficiency of the dynamo was obtained as follows: After the armature had been run during a test and got well heated up, its resistance was found. From this the C^2 R losses were com puted. The machine was run with the fields unexcited and cards taken on the engine. They were then excited and cards taken again. This operation was repeated several times and from the difference of I. H. P. on the engine the Foucault and Hysterisis losses were found. They amounted in this case to .88 H. P. The friction loss was not found as the machine ran during all the tests and, the results being comparative, this loss would be the same in both cases.

An integrating wattmeter was placed in the external circuit of the dynamo so as to determine the out-put. By means of a water rheostat the load could be varied at will. The fields were separately excited for the reason that in varying the load rapidly the excitation would also change rapidly and hence the pressure would vary in a complex ratio. Separately exciting the fields enables the voltage to be kept comparatively constant. The dynamo used for exciting the fields was a 3 1--2 K. W. Prael machine and was run by a 10 horse power upright New York Safety engine, which is used for general purposes in the laboratory.

The current from this machine was regulated by a small water rheostat. It was found that 50 volts and 5 amperes would excite the fields so that 500 volts were obtained at the armature terminals when the engine was run at its normal speed.

All instruments used during the test were calibrated and due allowance for errors made in computing the results.

A 75 horse power integrating watt meter was put into the external circuit but it was found unreliable so a 600 volt Weston Voltmeter and a 150 Ampere Weston Ammeter were substituted and a man stationed to take these readings every minute during the variable load tests and every two minutes during the constant load tests.

We believe the results from the readings to be very near the true results.

The tests were made as nearly as possible according to the methods heretofore described. In the constant load tests with the exception of No. 1 (see summary table), the brake alone was used for the load, the dynamo being allowed to run idle.

Indicator cards and gauge readings were taken every 10 minutes.

Calorimeter tests were taken every half hour. The exhaust steam was condensed in a surface condenser, and was weighed. The indicator cards were taken simultaneously by electomagnets which pressed the pencil points against the paper on closing an electric circuit. This current was obtained by shunting off the exciting machine previously described and putting an incandescent lamp or two in the circuit to control the current. This makes a very convenient and sure means when available.

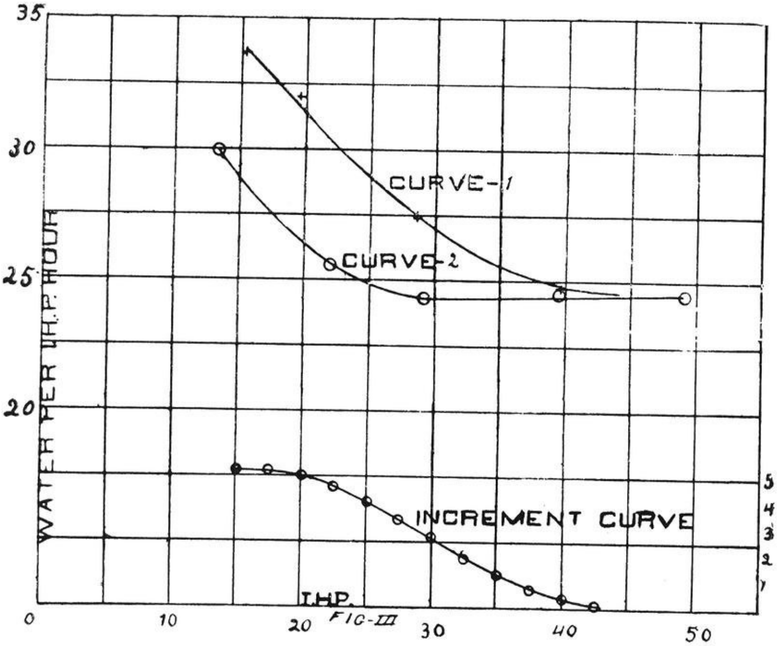


FIG-III

In the variable load tests the rheostat used for load consisted merely of a barrel partly filled with water and two pieces of boiler plate 8 inches wide and 3 feet long, separated by blocks of wood two inches thick, to which the plates were screwed. The terminals of the machines were soldered to these plates and the whole plunged up and down in the barrel by means of a rope over a pulley.

One man stood by this plunger and varied the load from maximum to minimum every 30 seconds. Volts and ammeter readings were taken every minute and indicator cards every 10 minutes.

When the cards were taken the paper was allowed to run for 15 or 20 revolutions.

At the end of 3 hours we then had 18 or 19 sets of cards of 15 or 20 each, and taken every 10 minutes. The first ten consecutive cards of each were figured up and recorded so that what we really have is a set of 10 tests similar to what we would have if the ordinary method were resorted to.

The curves in Fig. III. show the water consumption per indicated horse power hour both for constant and varying loads. In the constant load, Curve II, it will be seen that the water consumption became practically constant after the load had reached 60 per cent. of the rated capacity of the engine, while for the varying loads (curve I) it did not approach the low values till nearly full load had been reached. At the low loads the difference in water consumption is greatest and becomes less toward the higher loads and at full load it is practically the same. We think that the conditions under which the engine was run do not justify its being rated at 50 horse power as the available steam pressure was seldom above 85 pounds and it was necessary to fire above that pressure when the 50 horse power test was made in order to keep the speed up to normal. We think that the pressure should be at least 110 pounds to make economical water consumption for 50 horse power.

The results just mentioned correspond favorably with those found by R. C. Carpenter, and a curve has been plotted showing this relation (Fig. IV). Owing to the difference in horse power of the two engines it was necessary to plot per cent. of rated capacity as abcissae and per cent. that actual water consumed bears to that consumed at rated capacity, as ordinates in order that they might be compared.

It will be noticed that the curves are similar in all respects, but the curve obtained in our test is higher than that of Carpenter's. This is due for the most part to the difference in size of the engines and to some extent to the lack of boiler pressure previously mentioned and to a low vacuum which could not be remedied.

Fig. II shows two sample series of cards as taken by the continuous indicator attachment.

The two upper cards were taken simultaneously on the high and low pressure cylinders when running on the full load variable test, i. e., from 30 to 50 horse power.

The lower cards were taken simultaneously on the variable test between ten and thirty horse power.

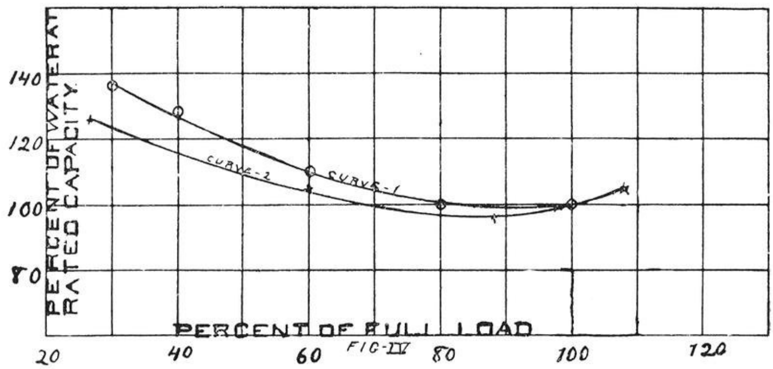


FIG-IV

From these cards a very marked difference in the I. H. P. developed may be noted (between successive cards) and in the upper or full load test the M. E. P. of the high pressure cylinder fell from sixty-five to fifteen pounds in seven revolutions; while in the lower test the M. E. P. fell to zero (in the high pressure cylinder) in some cases as is shown by the cards although there was in both cases a load on the brake.

This is due to the fact that when running at full load both brake and dynamo, the dynamo load woud be all thrown off, this would cause the engine to speed up quickly to considerably beyond its normal speed, causing the governor to act and cut off the entire steam supply in the high pressure cylinder in some cases, as shown, and leaving the engine to work on the receiver, pressure and vacuum of the low pressure cylinder until the load had again reduced the speed to the normal.

A series of these cards also shows quite plainly the sensibility of the governor on the engine tested.

In the tabulated results as found on the average sheet, tests Nos. 1, 2, 3, 4 and 5 were made under constant loads, while 6, 7, 8 and 9, were made under varying loads.

In the first five tests, the cards were taken in the ordinary manner so that the I. H. P. is the average of single cards taken every 10 minutes for three hours.

In the remaining tests the cards were taken with the continuous mechanism so that the I. H. P. is the average of ten cards taken every ten minutes for three hours.

CONSTANT LOADS. AVERAGE SHEET. VARYING LOADS.

No.	I. H. P.	Water Used per I. H. P. Hour.	Water Used per D. H. P. Hour.	Pressures. Boiler.	Pressures. Receiver.	Pressures. Condenser ins. Hg.	Quality of Steam.	No.	I. H. P.	Water Used per I. H. P. Hour.	Water Used per D. H. P. Hour.	Pressures. Boiler.	Pressures. Receiver.	Pressures. Condenser ins. Hg.	Quality of Steam.
1	13.5	30	43.4	79.5	0	21	98.8	6	15.7	33.8	59.6	83	0	21.3	99.5
2	21.9	25.6	31.5	86.3	4.25	21.2	98.4	7	19.4	32	36.6	84	3.01	19.6	98.5
3	29.2	24.4	26.7	84.1	5.23	21.1	98.9	8	28.3	27.4	28.5	85.5	9.5	19.4	98.3
4	39.3	24.6	26.8	82.7	13.9	21.2	98.9	9	39.4	24.7	27.1	85	20.3	20	98.7
5	49.2	24.5	26.5	90.1	23	20.9	98.8								

INTERNAL COMBUSTION ENGINES.

BY C. W. HART, B. S., '96, AND C. H. PARR, B. S., '96.

IV.

Regulation.

Regulation of speed in the internal combustion engine is effected in a great variety of ways. The methods of governing in most common use are the following: Cutting out entirely charges of oil, vapor or gas; varying the quantity of oil, vapor or gas; and varying the quantity of the explosive mixture.

The first method is usually carried out by some hit and miss device which, when the speed is above normal, fails to open the gas valve, the oil injector, the pump, or whatever means is employed to get the gas, oil or vapor into the cylinder, or the exhaust valve is held open or shut. We find the great majority of

American engines using a centrifugal shaft governor with the weights moving in a plane with the shaft and thus moving a sleeve on the shaft. To this sleeve is attached the hit and miss device. In those engines using an oil injector, the injector is operated by a knife edge, and when the speed is unduly increased, the governor weights fly out and the knife edge is drawn to one side so that it misses the rod of the injector. No oil enters, and only pure air is drawn into the cylinder. With this method the work imposed upon the knife edge is small, which is a very desirable feature. It is open to the objection that with almost any mixing device a slight quantity of the oil or vapor remains in the pipes leading to the cylinder. In case the oil is cut off and air allowed to enter through the same channel, this is of course wasted when an explosion is missed. This waste can be lessened by having the oil injector work during the early part of the suction stroke only, so that considerable air is drawn through the pipes after the oil or vapor is cut off. Since, while the engine is governing cool air is pumped through the cylinder, its walls become cooled, and when the next explosion is required a greater radiation of heat through the walls takes place. This loss, however, is about made up by the air acting as a scavenger charge to cleanse the cylinder of burned products so that the next explosion gives out more work.

When the exhaust valve is operated on to remain closed, the knife edge is used to move the valve, and, being deflected to one side by the governor, misses the valve stem. In this case the work of the knife edge is severe and it does not act with the certainty of the above method. The pressure remaining in the cylinder prevents the admission valve from opening and no charge is taken into the cylinder. The burned charge is compressed and expanded till the speed falls and the exhaust valve again opens. This method is open to the objection that a continued radiation of heat takes place through the walls and the work of expansion of the residue is thus not equal to the work necessary to compress it, and a loss of economy results.

The method which has found most favor is to have the exhaust valve pushed open positively, and when the speed increases have the knife edge interposed behind the exhaust valve stem so as to hold the valve open. The exhaust is then sucked into and expelled from the cylinder until the speed again falls blow normal. There being no great suction, the admission valve does not open. We have found, however, that unless the opening of the exhaust valve is large that the spring on the admission valve necessary to keep it closed must be rather strong, and we believe that for the best results in governing in this way the valve mechanism should be such that the admission valve be held shut while the exhaust valve is held open.

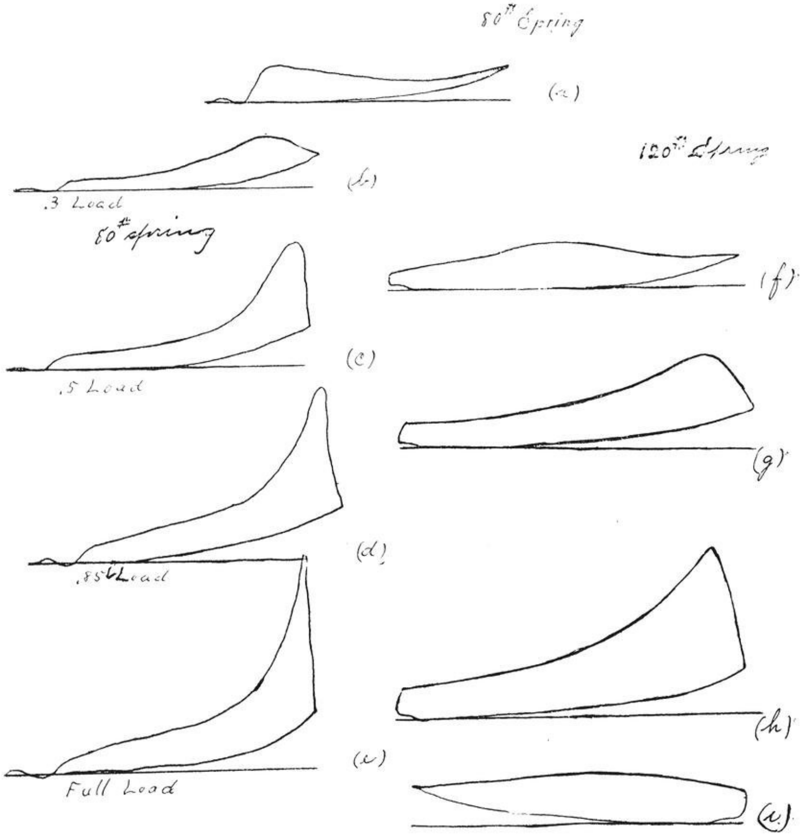
For ordinary work where slight fluctuations of speed do no harm the method of governing by cutting out the entire explosion, either by cutting off the gasoline, vapor or gas, or cutting off the mixture by holding the exhaust valve open so that none enters, is good and economical and can be used easily in engines of moderate speeds. Of these two methods of governing, we prefer that of holding the exhaust valve open, as when worked out in design it is found as easy of accomplishment as any method. It keeps the cylinder at normal constant heat and has proven to be as economical in the cycle of four strokes as any method.

Governing by varying the quantity of oil, vapor or gas has been used to a limited extent. Otto, in his engines for electric lighting, used a sliding step cam in connection with a centrifugal governor. A higher or lower step was brought to act on the gas admission valve, and in case the load was very light the cam missed entirely the admission valve movement and no gas entered.

Early in our experiments we decided that changing the mixture could not be utilized for governing with any degree of economy as slight changes in the proportions would cause missing entirely of the explosions with consequent loss of the charge. Another feature developed especially in the Sintz type of engine. If the proportion of air is large, slow burning takes place as is shown by card (a) taken from one of our engines with a cycle of two strokes. This is also shown by card (i) taken from one of our engines with a cycle of four strokes when running with an insufficient supply of gasoline. The flame will often hang so long in the cylinder that it will ignite the next incoming charge.

The third method of governing, that of varying the quantity of the mixture without materially changing its proportions, has in it the possibilities of close regulation for such work as requires it and a fair degree of economy.

In an experiment with one of our engines with a cycle of two strokes and a mixing valve such as is described on page 340, we accomplished the governing by means of a fly wheel governor,



acting by swinging an eccentric across the shaft. The eccentric rod was attached to a walking beam which held down the transfer valve between the cylinder and base. When the engine was below speed, the beam just touched the valve at the time when the suction of air would open it and a full charge would be taken into the cylinder and exploded. As speed increased, the eccentric throw was made longer and, while the valve was touched by the beam at its natural time of opening, the beam pressed down and kept it open for a longer or shorter time as required. Thus a full cylinder of mixture would enter and part would be returned into the pipe leading to the base. This method gave excellent results as far as keeping a steady speed was concerned. When the spring on the governor ball was properly designed and adjusted a load could be thrown on or off the engine with little variation in speed. When the engine ran with no load an occasional miss of explosion would occur, but very slight load, about 15 per cent., would keep the engine exploding regularly but lightly. Cards (b), (c), (d) and (e) show well the governing in this way.

Theoretically, this method is good for it is known that in the average engine expansion is incomplete. The mechanism can also be made very simple and compact, but it will work better the higher the compression used in the engine. With the common run of engines having a clearance of 40 to 50 per cent. of the stroke it would not work satisfactorily.

Another method, which we have tried and which with proper adjustment works well, is to place in the pipe leading to the inlet valve and between the inlet and mixing valves, a wing valve operated by a shaft governor whose balls move in a plane with the shaft. If too high speed exists the wing valve is closed more or less and not so much mixture enters. With the mixing valve such as we have used a head for the gasoline was found such that the regulating valve remained at one point for all loads and no explosions were missed even when the engine ran without load. Cards (f), (g) and (h) are taken from an engine with a cycle of four strokes governed in this way and show the variation of load from one-third to full load. On this engine when a load of 8.46 B. H. P. was applied the consumption of gasoline per B. H. P. hour was .116 gallon, and with a load of 5.13 B. H. P. the consumption was .113 gallon. With smaller loads than this the consumption of gasoline increased considerably as the load decreased.

In order to obtain close regulation with the internal combustion engine, a high rotary speed is desirable so that the time between explosions is short. And, as the effectiveness of a balance wheel varies as the square of the velocity, it is seen that a high rotary speed will obtain a more uniform motion without excessive weight of balance wheel.

For all ordinary work not requiring close regulation we conclude that the best and most economical governing is obtained by holding the exhaust valve open and the inlet valve shut. Where very uniform motion is desirable even at the expense of economy, we believe it can be obtained by using a small clearance space or explosion chamber and varying the quantity of mixture.

(To be continued.)

EDITORIAL NOTES.

Graduate Work.

It is appropriate at this time of the year to consider the advantages of graduate work. To some of the present seniors the idea of doing more work in college seems to have so little chance of ever being carried out that they have given it little consideration, while others would like very much to take at least a year of graduate work.

The question at once arises as to whether it is better to take work in one's previous course or to study in some other department. A decision here depends so much on circumstances that no definite answer can be given. There is no doubt that, other things being equal, a much higher grade of work can be done by continuing in one's specialty, the necessary ground work having been laid. In engineering, like in other sciences, graduate work is likely to be of the nature of an investigation of quite an original nature. You will be alone; in a few months you ought to know more about this one subject than any of your professors, and you must have confidence in your own resourcefulness to go ahead. If you lack this confidence, unless you have perfect faith in your own conclusions, in your ability to discover your own mistakes, you had better not work for a higher degree.

Work in another department has many advantages though the study must necessarily be of a lower order. You will be confined here to the routine of class work intended rather to develop the mind than to broaden an already mature intellect and will be

Wisconsin Engineer Index

To Current Engineering Periodicals.

Explanation:—W. words, M. Jan., W. Jan. 4, or E. Jan. 6, at the end of the reference, indicates that a description or digest of the article may be found in the index of the Engineering Magazine of January, in The Electrical World digest of January 4, or in the Electrical Engineer digest for January 6th.

List of periodicals from which articles are indexed:

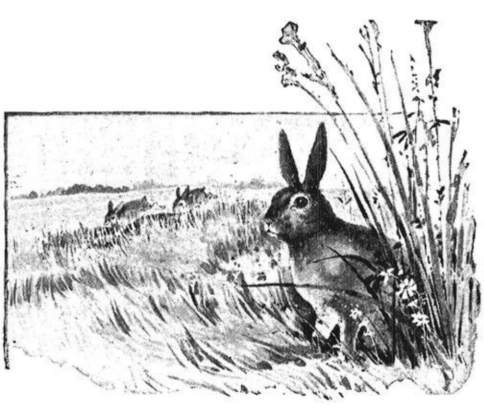
Age of Steel, The. *w.* $3. St. Louis.
American Architect, The. *w.* $6. Boston.
American Electrician. *m.* $1. New York.
Am. Engineer and Railroad Jour. *m.* $2. New York.
Am. Chemical Journal. *b-m.* $4. Baltimore.
Am. Gas Light Journal. *m.* $3. New York.
American Geologist. *m.* $3.50. Minneapolis.
Am. Journal of Science. *m.* $6. New Haven.
American Machinist. *w.* $3. New York.
Am. Manufacturer and Iron World. *w.* $4. Pittsburgh.
American Miller. *m.* $2. Chicago.
American Shipbuilder. *w.* $2. New York.
Am. Soc. of Irrigation Engineers. *qr.* $4. Denver.
Annual Report of Illinois Society of Engineers and Surveyors. New York.
Architect, The. *w.* 26s. London.
Architectural Record. *qr.* $1. New York.
Architectural Review. *qr.* $5. Boston.
Architecture and Building. *w.* $4. New York.
Architektonische Rundschau. *m.* 18 marks. Stuttgart.
Australian Mining Standard. *w.* 30s. Sidney.
Baker's Railway Magazine. *m.* $2. New York.
Board of Trade Journal. *m.* 6s. London.
Boston Journal of Commerce. *w.* $3. Boston.
Brick. *m.* $1. Chicago.
Brick Builder, The. *m.* $2.50. Boston.
British Architect, The. *w.* 23s. 8d. London.
Builder, The. *w.* 26s. London.
Bulletin Am. Iron and Steel Assn. *w.* $4. Phila.
Bulletin of Univ. of Wisconsin. Madison.
California Architect. *m.* $3. San Francisco.
Canadian Architect. *m.* $2. Toronto.
Canadian Electrical News. *m.* $1. Toronto.
Canadian Engineer. *m.* $1. Montreal.
Canadian Mining Review. *m.* $3. Ottawa.
Cassier's Magazine. *m.* $3. New York.
Clay Records. *m.* $1. Chicago.
Colliery Engineer. *m.* $2. Scranton.
Colliery Guardian. *w.* 27s. 6d. London.
Compressed Air. *m.* $1. New York.
Deutsche Bauzeitung. *b-w.* 15 marks. Berlin.
Dingler's Polytechnisches Journal. *w.* 43.60 marks. Stuttgart.
Domestic Engineering. *m.* $2. Chicago.
Electrical Age. *w.* $3. New York.
Electrical Engineer. *w.* 19s. 6d. London.
Electrical Engineer. *w.* $3. New York.
Electrical Engineering. *m.* $1. Chicago.
Electrical Industries. *m.* $1. Chicago.
Electrical Journal. *s-m.* $2. Chicago.
Electrical Plant. *m.* 6s London.
Electrical Review. *w.* 21s. 8d. London.
Electrical Review. *w.* $3. New York.
Electrical World. *w.* $3. New York.
Electrician (Electn.) *w.* 24s. London.
Electricity, (Elec. Lond.) *w.* 7s. 6d. London.
Electricity (Elec.) *w.* $2.50. New York.
Elektrochemische Rundschau. *b-m.* 9.50 marks. Frankfurt.
Electrochemische Zeitschrift. *m.* 18.40 marks. Berlin.
Electrotechniker. *b-w.* 12 marks. Vienna.
Elektrotechnicker Anzeiger. *s-w.* 10 marks. Berlin.
Electrotechnische Zeitschrift. *w.* 25 marks. Berlin.
Engineer, The (Eng.) *s-m.* $2. New York.
Engineer, The (Eng. Lond.) *w.* 36s. London.
Engineer and Contractor. *w.* $1. San Francisco.
Engineer's Gazette. *m.* 8s. London.
Engineering (Engng.) *w.* 36s. London.
Engineering and Mining Jour. *w.* $5. N. Y.
Engineering Magazine. *m.* $3. New York.
Engineering-Mechanics. *m.* $2. Phila.
Engineering News. *w.* $5. New York.
Engineering Record. *w.* $5. New York.
Engineering Review. *m.* 7s. London.
Eng. Soc. of the School of Prac. Sci. Toronto.
Eng. Soc. of Western Pennsylvania. *m.* $7. Pittsburgh.
Fire and Water. *w.* $3. New York.
Foundry, The. *m.* $1. Detroit.
Garden and Forest. *w.* $4. New York.
Gas Engineers' Magazine. *m.* 6s. 6d. Birmingham.
Gas World, The. *w.* 13s. London.
Glasers Annalen für Gewerbe und Bauwesen. *m.* 20 marks. Berlin.
Heating and Ventilation. *m.* $1. New York.
Ill. Carpenter and Builder. *w.* 8s. 8d. London.
India Rubber World. *m.* $3. New York.
Indian and Eastern Engineer. *w.* 20 Rs. Calcutta.
Indian Engineer. *w.* 18 Rs. Calcutta
Industries and Iron. *w.* £1. London.
Inland Architect. *m.* $5. Chicago.
Inventive Age. *s-m.* $1. Washington.
Iron Age. *w.* $4.50. New York.
Iron and Coal Trade Review. *w.* 20s. 4d. London.
Iron and Steel Trades Jour. *w.* 25s. London.
Iron Industries Gazette. *m.* $1.50. Buffalo.
Iron Trade Review. *w.* $3. Cleveland.
Jour. Am. Soc. Naval Engineers. *qr.* $5. Washington.
Jour. Assn. Eng. Societies. *m.* $3. St. Louis.
Journal of Electricity, The. *m.* $1. San Francisco.
Jour Franklin Institute. *m.* $5. Phila.
Journal of Gas Lighting. *w.* London.
Journ. of Inst. of Elect. Engineers. London.
Jour. New England Waterw. Assn. *qr.* $2. New London.
Jour. of Royal Inst. of British Arch. *s-qr.* 6s. London.
Journal of Society of Arts. *w.* London.
Journal of the Western Society of Engineers. *b-m.* $2. Chicago.
Kansas University Quarterly. *qr.* $2. Lawrence, Kan.
La Nature. *w.* 24.50 francs. Paris.
La Revue Technique. *b-m.* 28 francs. Paris.
L'Eclairage Electrique. *w.* 60 fr. Paris.
L'Electricien. *w.* 25 fr. Paris.
L'Energie Electrique. Paris.
L'Gènie Civil. *w* 45 francs. Paris.
L'Industrie Electrique. *b-m.*
L'Moniteur des Architectes. *m.* 33 francs. Paris.

ground down to details the same as are the undergraduates with whom you work. While this attitude may seem and is unbecoming to a student of advanced age, his mature judgment will give him an insight into his subject that the others do not get, and he will come out a broader, better man for the pains. In engineering quite a number of men take up as graduate work the study of another branch of the same science and finish in a year's time with the seniors in the new subject. A mechanical this year may graduate as an electrical or a civil the next, providing he has elected enough work in one or the other of these courses during his undergraduate years. To do graduate work of a literary nature or in fact in any of the other courses "on the hill" is quite uncommon for the reason that most engineering students are too enthusiastic to desert engineering; but it would certainly be beneficial to an engineer could he find time to do work of this kind.

Another question that often arises is whether to study as a graduate the year after one gets his diploma, or to first go into active practice and, after a year or two, return to the university. The latter is undoubtedly the better procedure, for after a year or more of practical work, a person is sure to have a more definite idea of the nature of the study he desires to pursue, and being older is likely to do better work. The great drawback to this in engineering is, that after about a year of hard, often unpleasant, work, at a microscopic compensation, one just begins to see a ray of hope. Perhaps your employer has given you to understand that with a continuation of good services a promotion is near at hand. Already visions of the office begin to float through your mind. At one moment you are sitting before your roll top desk, dictating an important letter, and the nimble fingers of the pretty typewriter fall in a perfect hail storm upon the keys; at another you are giving a few hasty orders to your assistants preparatory to an extended business trip into a new country, and then an old class mate rolls in to ask when you intend going back to the University. Not very much of a place after all, is it? If one is sure he can withstand these temptations to remain at work it is better to go into practical service immediately upon graduation, with a view of returning at a later date for postgraduate study.

Another phase of the question is the advisability of remaining

L'Moniteur Industriel. *w.* 40 francs. Paris.
Locomotive Engineering. *m.* $2. New York.
Machinery. *m.* $1. New York.
Machinery (Mach. Lond.) *m.* 9s. London.
Manufacturer and Builder. *m.* $1.50. New York.
Manufacturer's Record. *w.* $4. Baltimore.
Marine Engineer. *m.* 7s. 6d. London.
Master Steam Fitter. *m.* $1. Chicago.
Mechanical World. *w.* 8s. 8d. London.
Metal Worker. *w.* $2. New York.
Mining and Sci. Press. *w.* $3. San Francisco.
Mining Industry and Review. *w.* $3. Denver.
Mining Journal, The. *w.* £1, 8s. London.
Mining World, The. *w.* 21s. London.
Monatsschrift des Württ. Vereins für Baukunde. 3 marks. Stuttgart.
Municipal Engineering. *m.* $2. Indianapolis.
National Builder. *m.* $3. Chicago.
Nature. *w.* $7. London.
New Science Review, The. *qr.* $2. New York.
Oesterreichische Monatsschrift für den Oeffentlichen Baudienst. *m.* 14 marks. Vienna.
Physical Review. *b-m.* $3. New York.
Plumber and Decorator. *m.* 6s 6d. London.
Popular Science Monthly. *m.* $5. New York.
Power. *m.* $1. New York.
Practical Engineer. *w.* 10s. London.
Proceedings Engineers' Club. *qr.* $2. Philadelphia.
Progressive Age. *s-m.* $3. New York.
Railroad Car Journal, The. *m.* $1. New York.
Railroad Gazette. *w.* $4.00. New York.
Railway Age. *w.* $4. Chicago.
Railway Master Mechanic. *m.* $1. Chicago.
Railway Press, The. *m.* 7s. London.
Railway Review. *w.* $4. Chicago.
Railway World. *m.* 5s. London.
Safety Valve. *m.* $1. New York.
Sanitarian. *m.* $4. Brooklyn.
Sanitary Plumber. *s-m.* $2. New York.
Sanitary Record. *m.* 10s. London.
School of Mines Quarterly. $2. New York.
Schweitzerisches Bauwesen. *w.* 20 marks. Zurich.
Science. *w.* $5. Lancaster, Pa.
Scientific American. *w* $3. New York.
Scientific Am. Supplement. *w.* $5. New York.
Scientific Machinist. *-m.* $1.50. Cleveland.
Seaboard. *w.* $2 New York.
Sibley Jour. of Engineering. *m.* $2. Ithaca, N. Y.
Southern Architect. *m.* $2. Atlanta.
Stahl und Eisen. *s-m.* 20 marks. Dusseldorf.
Stationary Engineer. *m.* $1. Chicago.
Steamship. *m.* Leith, Scotland.
Stevens' Indicator. *qr.* $1.50. Hoboken.
Stone. *m.* $2. Chicago.
Street Railway Journal. *m.* $4. New York.
Street Railway Review. *m.* $2. Chicago.
Technology Quarterly. $3. Boston.
Tradesman. *s-m.* $2. Chattanooga, Tenn.
Trans. Am. Inst. Elect. Engineers. *m.* $5. New York.
Trans. Am. Inst. Mining Engineers. New York.
Trans. Am. Soc. Civil Engineers. *m.* $10. New York.
Trans. Am. Soc. Mechanical Engineers. New York.
Transport. *w.* £1, 5s. London.
Western Electrician. *w.* $3. Chicago.
Western Mining World. *m.* $4. Butte, Mon.
Wiener Bauindustrie Zeitung. *w.* 22 marks. Vienna.
Wisconsin Engineer. *qr.* $1.50. Madison.
Yale Scientific Monthly, The. *m.* $2.50. New Haven.
Zeit chrift des Oesterreichischen Ingenieur und Architekten Vereins. *w.* 53 marks. Vienna.
Zeitschrift des Vereines Deutscher Ingenieure. *w.* 32 marks. Berlin.
Zeitschrift für Beleuchtungswesen.
Zeitschrift für Electrochemie. *s-m.* 16 marks. Halle.
Zeitschrift für Elektrotechnik. *s-m.* 16 marks. Halle, a. S.
Zeitschrift für Instrumentenkunde. *m.* 20 marks. Berlin.



at the same university or of going to another for advanced study. In America university migration is practiced less than in Europe, where it is not uncommon for a man to change universities several times during his undergraduate years. In this country the question of sentiment plays a great part in forming a decision to leave. The ties of fellowship, the class contests, and numerous other things all contribute to make the university so dear to the senior that he is reluctant to leave it. He has yelled the old yell for four years and the thought of going to a strange place, perhaps a rival institution, seems just a little bit degrading. However, there are greater considerations than this. Four years under the directorship of one man moulds you into his line of thinking and it is well to change professors that you may be broadened by other methods of instruction. Again, you may want to specialize in a branch in which Professor B. is better than Professor A. In fact the ideal method of study is to pursue each course under a master. We would say that arguments for postgraduate work at another institution than alma mater seem to have the greater weight.

Should the senior decide that he is unable to pursue a postgraduate course at college let him then decide to take his master's degree as a graduate studying in abscentia. This can be obtained by three years of professional service, one year of which is in a responsible position, and the submitting of a satisfactory thesis.

A Course in Architecture.

Should the university have a course in architecture? After talking with several architects and with some of the university professors, we have decided that the university should have a school of architecture but not until several years to come. There are good schools in architecture at Cornell, Columbia, Boston Tech., and Illinois, also at several other institutions of learning. The large number of poor, unschooled architects practicing the profession is a good indication that there is room for a still larger number of educated men. The College of Engineering offers a splendid opportunity for the architectural student to study engineering principles. The architect of today is becoming more

and more an engineer, as is shown by the work on modern business blocks and other large buildings, where it is often the case that nearly the entire structure is planned by the engineer who turns his work over to the artist to make it pleasing to the eye.

In residence work, however, it is more a question of art than of engineering, and the student of architecture should be educated in an atmosphere of art to be successful from a decorative standpoint. Madison is lacking here and this is a great drawback to the student of architecture. While it is possible to make inspection trips to art centers as do the engineers to engineering centers, still the inspection trip is of more importance to the architect and should be almost continuous if he intends to specialize in the more artistic line of work.

Considering the question from the financial standpoint we are not yet ready to establish such a course. We must first have an engineering building and let it be made large enough to accommodate a school of architecture when the time for its establishment arrives.

Engineering Lectures.

The course of lectures delivered before the engineering students during the past year has been very successful throughout, and that the object of the same has been attained is certain. The students have had the privilege of hearing from men, eminent in the engineering profession, their experiences in the engineering world, and the benefit derived must necessarily be of great value. The attendance at the lectures has in most cases been very good and the audience in each case has been very appreciative. In a previous issue mention has already been made of several of the lectures and those that follow have been delivered since that time.

H. M. SPERRY.

On March 5th Mr. H. M. Sperry, signal engineer of the National Switch and Signal Company, lectured on the subject, Railway Signaling. The lecturer has spent most of his years of practice in this particular branch of engineering and was very conversant with the subject. He illustrated the important points with numerous diagrams and lantern slides, and showed in a clear manner some of the latest improvements in this line. He showed the

advantages of the improved signal system and described carefully the mode of operation of the same. The subject was of especial interest to those who are following the course in railway engineering and was greatly appreciated by them.

J. N. BARR.

Mr. J. N. Barr, superintendent of motive power of the Chicago, Milwaukee & St. Paul Railroad Company, lectured on Friday, March 26, on the subject, "A Screw Loose." This lecture has since been published in the Railway and Engineering Review, May 15, 1897, but several of the important features will here be inserted. It was full of valuable information and suggestion to young engineers and was sufficiently illustrated by blue prints and drawings. He said in part:

"It afforded me great pleasure on receiving a request to address the engineering classes of Wisconsin University to reply in the affirmative. In considering the selection of a subject which ought to be of value to a company of young men spending a few years in special mechanical preparation for the more serious pursuits which they will shortly take up, the difficulty of presenting anything of especial value seems to be almost insuperable. To enter upon a technical discussion of the ordinary problems of mechanical engineering would be too much like carrying 'coals to New Castle.' To consider any of the theories relating to mechanics or physics would probably do more to reveal the speaker's ignorance than any thing else. I have therefore determined to take up a subject which is undoubtedly of vast practical importance to all of you. It is the question of success or failure as influenced by little things."

The lecturer then entered upon this by taking "an object lesson from a journal, box, and bearing of an ordinary car and to follow out in detail its construction and operation, showing the considerations which make and keep it what it is and the reasons for its simplicity and apparent crudeness. A full consideration in this apparently unimportant detail will throw a strong light on the principles and business considerations underlying all successful mechanical designs."

A complete description of the manner of construction of axles, bearings, etc., and the effects of lubrication was then gone into.

In conclusion Mr. Barr said: "I have endeavored to present

AXLES for Railways, Divided—Glaser's Ann, Feb 1—97. 900 w. M Apr.
AYRSHIRE Coalfield, The—Col Guard, Apr 15—97. 1500 w.

BAKERSFIELD Transmission Plant (Ill)—St Ry Rev, May 15—97. W May 29.
BALANCE, Bois Magnetic—Ebeling and Schmidt. Electrotechn Zeit, Apr 8—97. W May 1.
BALDWIN Locomotive Works, Motors at the—R R Gaz, Apr 2—97. 2200 w. M May.
Bâle, The New Church of St. Mathew at—Sweizerische Bauzeitung, Mar 13—97. 1000 w. M May.
BALLARAT West, Quartz Lodges—William Bradford. Aust Min Stand, Feb 11—97. 1200 w.
BALLOON, Static Charge of a—Elektrotechn Zeit, Mar 4—97.
BATH-HOUSE, Brookline's Model (Ill)—Eng Rec, Mar 6—97. 2300 w.
Bath House, Plumbing a Public (Ill)—Met Work, Mar 27—97. 1700 w.
BATTERY, Heat Transforming—Electn, Lond, Apr 23—97. W May 8.
Batteries, Electric Bells and—W. A. Wittbecker. Met Work, Feb 13—97. 1500 w. M Apr.
Batteries, Thermo-Electric—C. J. Reed. Am Electn, Apr—97. 3000 w.
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BATTLESHIPS, Thames-Built—Engng, Mar 12—97. 4400 w.
BEAMS, The Computation of Béton—Zeitschr d Oesterr Ing u Arch Vereines, Mar 12—97. 3500 w.
Beams, The Design of—W. H. Atherton. Mech Wld, Apr 16—97. 1700 w.
Beams, The Efficiency of Built-Up Wooden (Ill)—Edgar Kidwell. Eng News, Mar 11—97. 1500 w.
BEARING, A Roller Center (Ill)—Edward Cliff. R R Car Jour, Feb—97. 500 w. M Apr.
Bearings, Concerning Glass Machinery (Ill)—F. A. Farnsworth. Ir Age, Apr 29—97. 1000 w.
Bearings, Machinery (Ill)—John Dewrance. Jour Am Soc Nav Engs, Feb—97. 6500 w.
BECQUEREL Rays—M. Becquerel. Elec, Mar 31—97. Electn, Lond, Mar 12—97. W Apr 3.
BEETROOT Juice, Purification of—Baudry. Elec Rev, Lond, Mar 19—97. W Apr 3.
BELGIUM, Iron Industry of—Col Guard, Mar 5—97. 1000 w. M May.
BELL Company, Annual Report of—Elec Rev, Apr 28—97.
Bell Telephone Co.—Elec Eng, Apr 7—97.
BELLEGARDE Water Power Transmission Plant (Ill)—Preller. Engng, May 14—97.
BELTING, Notes on—F. W. Taylor. Eng, Lond, Feb 5—97. Serial Part 1. 4500 w.
Belting, Rules for—Engng Mech, Mar—97. Serial Part 1. 1800 w.
BENDIGO Gold Field, The—Min Jour, Mar 20—97. Serial Part 1. 4200 w. M May.
BERLIN Conduit System (Ill)—Elec Eng, Lond, Mar 19—97.
Berlin Tramway, Discussion of the—Glaser's Ann, Mar 1—97. 6000 w. M May.
BERLINER Case, The Probable Decision in the—E. F. Frost. Elec Wld, Apr 17—97. 1200 w.
Berliner Patent, The—Morgan Brooks. Elec, Mar 10—97. 1100 w.
BICYCLE, The Evolution of the Safety (Ill)—Ir Age, Apr 1—97. 2800 w. M May.
Bicycles, Chainless (Ill)—Le Génie Moderne, Feb 15—97. 1000 w. M May.
BILBOA, Electric Tramway at—Elektrotechn Zeit, Jan 21—97. 1200 w. M Apr.
BIRMINGHAM DISTRICT, Notes on the—J. S. Kennedy. Ir Age, Apr 22—97. Serial Part 1. 2200 w.
BISMUTH at Low Temperatures and in Magnetic Fields, Resistivity of—Fleming and Dewar. Elec, Mar 31—97.
Bismuth by Electricity, Refining—Electn, Lond, Mar 24—97. E Apr 21.

5—Wis. Eng.

Bismuth, On the Electrical Resistivity of Electrolytic—Dewar and Fleming. Elec, Mar 24—97. E May 12.
BLACK HILLS, Mineral Wealth of—Min Ind Rev, Mar 4—97. 1400 w.
BLACKBURN Power Plant (Ill)—Elec Eng, Lond, Apr 30—97. W May 15.
BLAST FURNACE, Electricity at the—Am Mfr, Mar 19—97.
Blast-Furnace Practice, American and British—J. Stephen Jeans. Eng Mag, May—97. 3300 w.
BOAT, Submarine—Eng News, May 20—97. W May 29.
BOILER, A Gas-Burning Water Heater or Steam (Ill)—Am Mach, Mar 18—97. 800 w.
Boiler Attendants, The Certification of Engine and—Engng, Mar 5—97. 2400 w.
Boiler Construction, Progress in Heating—Hugh J. Barron. Heat & Ven, Mar 15—97. 700 w.
Boiler Explosions and Failures from Hidden Defects (Ill)—Age of St, Feb 27—97. 2000 w. M Apr.
Boiler Explosion at New Bedford—Bos Jour of Com, Mar 20—97. 1600 w.
Boiler Explosion at the Gratweiner Paper Mill, Steam (Ill)—Oest Monatschr f d Oeff Bau, Mar—97. 3000 w. M June.
Boiler Explosions Heat and—James Wright. Can Elec News, Feb—97. 4500 w. M Apr.
Boiler Furnace Gases, The Presence of Hydrocarbons and Nitrogen Peroxide in—R. S. Hale. Eng News, Feb 18—97.
Boiler, The Steam—Stephen Christie. Safety V, Mar—97. 2000 w.
97. 6800 w.
Boiler Water, The Cure for Corrosion and Scale from—Albert A. Cary. Eng Mag, Mar—97. 7400 w. Eng Mag, May—97. 6200 w.
Boilers for H. M. S. "Pelorus," Watertube (Ill)—Engng, Mar 19—97. 1400 w.
Boilers for Mining Purposes, Steam—William Kent. Col Eng, Mar—97. Serial Part 1. 4000 w. M May.
Boilers at Acushnet Mill, New Bedford, Explode—Bos Jour of Com, Mar 16—97. 1000 w.
Boilers, Defects in Steam—Eng News, Feb 11—97. 3300 w. M Apr.
Boilers, Incrustation in—M. Dibos. La Revue Technique, Jan 25—97. 6000 w. M Apr.
Boilers in Warships, Water-tube—C. C. P. Fitzgerald. Engng, Apr 9—97. 5000 w.
Boilers, Limitations of the Efficiency of Steam—Eng News, Mar 1897. 1000 w.
Boilers, Navy—Eng, Lond, Apr 16—97. 1700 w.
Boilers, Proper Construction and Care of—J. M. Allen. Bos Jour Com, Apr 17—97. Serial Part 1. 1200 w.
Boilers, Salt Water in Water-tube—Eng, Lond, Mar 19—97. 1400 w.
Boilers, Salt Water Feed for Express—Engng, Mar 19—97. 1700 w.
Boilers, Suction Draught for Marine—Matthew Paul. Eng, Lond., Feb 5—97. 2800 w. M Apr.
Boilers, Water-Tube vs. Shell—W. Barnet Le Van. Mach, Mar—97. 3500 w. M May.
BOLSTERS, Finding the Stresses in Trussed (Ill)—Ry Mas Mech, Mar—97. 1000 w.
BOSTON and Montana Consolidated Copper and Silver Mining Company—Eng & Min Jour, Mar 27—97. 1800 w.
Boston Fire Company, Station for (Ill)—Eng Rec, Mar 20—97. 1400 w.
Boston's Sewage Handling—Henry G. Young. Bos Jour of Com, Mar 27—97. 1800 w.
BRACING for Wooden Bents, Comparative Test of—Edgar Kidwell. Proc L Sup Min Inst, Aug—96. 5000 w.
BRAKE for Testing Small Motors—Marechal. L'Eclair Elec, Apr 24—97.
Brake Gear for Locomotive Tenders, Foundation—R R Gaz, Apr 30—97. 2200 w.
Brake Rigging for Electric Cars (Ill)—C. F. Ueberlacker. St Ry Jour, Mar—97. 3500 w.
Brakeshoes, Gears, Pinions and Trolley Wheels, Some Statistics on the Life of—St Ry Jour, Mar—97. 1300 w.
BRASS Casting, A Pattern for a Difficult—Chas. H. Allmond. Am Mach, Feb 18—97. 800 w.

to you briefly the complicated considerations involved in such a simple piece of mechanism as an oil box for freight cars, with some of the various attempts at improvement which actual experience has demonstrated to be of no value. The subject has necessarily been treated in a light and sketchy manner as under the circumstances a complete discussion could not be attempted. It is to be hoped, however, that the picture is complete enough to illustrate the fact that the underlying principles involved in even the most simple piece of mechanism are sometimes extremely abstruse and complicated; that many of them are still undefined; that in general, successful mechanism has beneath it a broad bases of experience made up of various degrees of success and failure, wherein failure greatly predominates and is frequently a source of disaster to its author.

If this discourse shall assist in impressing on your minds the importance of avoiding failure, the necessity of keepng in general in the beaten path and of doing a great deal of what is expressively termed 'dish washing,' the object of the speaker will have been fully accomplished."

M. SWENSON.

Mangus Swenson gave a talk, May 8th, on cotton. He described his cylindrical bale and also his cylindrical press. This was given in such a masterly manner in the previous number of the Wisconsin Engineer, over Mr. Swenson's own signature, that we will not dwell on this portion of the lecture. Mr. Swenson further described his new cotton gin which has a much larger capacity than the present form of gin, and is not so damaging to the cotton fibre in its operation. He gave the results obtained with an experimental machine and also showed drawings illustrating its operation. It is expected that this gin will work greater wonders in the cotton industry than his present cylindrical press.

Mr. Swenson further pointed out the need of a machine for "delinting" cotton seed, an operation necessary, not only for the production of oil, but also for the successful storing of the seed. He said, "If any of you bright young men want to work on this problem, I'll provide you with a ton of seed and when you have

decided that your experiments are a success, call on me and I'll do the right thig by you." Mr. Swenson is one of our most enthusiastic alumni. He is a U. W. man from the ground up.

DR. R. H. THURSTON.

A large audience was present on Friday, May 14, when President Adams in introducing the speaker stated that Prof. Thurston was appointed director of the Sibley College the same year that he was called to the president's chair of that university. In the following seven years Sibley College grew from a small department of 20 students until, when President Adams was called from Cornell to fill the president's chair at Wisconsin, there were over 600 names enrolled in the engineering courses.

Prof. Thurston announced as his subject "The Modern Leviathan." He traced the growth of the steamboat from the early forms of Fitch and Fulton to the great ocean steamers of today. He told how naval architects, blindly experimenting with different shapes of hulls, had finally settled on a shape which they could not improve. This was shown to be of the same general form as that of the fishes. The "mid ship" section in both are at a distance from the front equal to one-third the entire length. In the case of yachts this section is at a corresponding distance from the stern, that is the yacht sails backwards. But the yacht is propelled from an outside force while the steamers and fishes are propelled from within. An interesting example was given of the enormous power of the engines in modern steamships in which the power developed by them was compared to that of a number of good draft horses. If the horses were hitched to a beam, side by side, it would require a beam 80 miles long to allow room for the horses.

The lecture was illustrated by a large number of lantern slides and was very entertaining. Prof. Thurston is a leading authority on thermodynamics, but has found sufficient time to make a special study of many of the problems pertaining to the design of ships. He made an exhaustive series of measurements and comparisons of all of the common fishes and of modern ships with the result above noted.

California with Reference to Its Mineral Deposits, Outline of the Geology of—H. W. Fairbanks. Min & Sci Pr, Feb 13—97. Serial Part 1. 1400 w.

CALORIMETRY—C. D. Jenkins. Am Gas Lgt Jour, Mar 22—97. 1200 w.

CAM, Pattern for a Cylindrical (Ill)—Mach, May —97. 1300 w.

Cams, The Draughting of—Louis Rouillion. Mach, Mar—97. Serial Part 1. 1400 w.

CANADIAN Waterways and the Canadian Tariff—Trans, Apr 2—97. 900 w.

CANAL, A Black Sea and Baltic—Eng, Lond, Apr 9—97. 800 w.

Canal and Claiborne Railroad Company, The System of the (Ill)—St Ry Jour, May—97. 10000 w.

Canal Communication from the Midlands to the Sea—Eng, Lond, Mar 26—97. 3000 w.

Canal, Dismal Swamp—J. C. Ranson. Trade, Mar 1—97. 2200 w.

Canal, The Dismal Swamp—Croatan. R R Gaz, Mar 19—97. 1100 w. M May.

Canal Traction—Electn, Lond, Apr 30—97. Elec Eng, Lond, Apr 30—97.

Canals, Electric Traction on—L'Elec, Apr 24—97. W May 15.

Canals, Mechanical Propulsion on—Robinson. Ind & Ir, Mar 5—97. Elec Eng, Apr 30—97. Electn, Lond, May 7—97. Engng, Apr 30—97.

Canals, New York's—C. W. Adams. Sea, Mar 4—97. 6000 w. M Apr.

CANDLE POWER of a Search Light—Amer Elec, Apr—97. W May 1.

CANTILEVER in Bridge and Building Construction (Ill)—Glaser's Annalen, Feb 1—97. 8000 w. M Apr.

CAR, B. & O. R. R., Combination (Ill)—R R Car Jour, Feb—97. 1500 w.

Car Builders' Rules, Master—R R Gaz, Apr 23—97. 1100 w.

Car Design, Railroad—Archer Richards. R R Car Jour, Feb—97. 2500 w.

Car for the President of the United States, A Private—R R Car Jour, Feb, Apr—97.

Car, Inter-Urban (Ill)—Elec Eng, Apr 14—97. Elec Rev, Apr 14—97.

Car, Lincoln's Private (Ill)—R R Car Jour, Apr —97. 1200 w.

Car of 100,000 lbs. Capacity, Steel Hopper (Ill)—Ry Car Jour, Mar—97. Ry Rev, Feb 20—97.

Car, Standard Twin Hopper Gondola (Ill)—Loc Eng, Mar—97. 800 w.

Car Wheel Metal, Transverse Strength of Chilled —Jour Fr Inst, Apr—97. 4000 w.

Car Ventilation—Ry Rev, Apr 10—97. 3000 w.

Cars, Modern Private (Ill)—Duane Doty. R R Car Jour, Apr—97. 2000 w.

Cars, Recent Designs for Steel (Ill)—Eng News, Mar 4—97. 1200 w.

Cars with Filtered Air, The Ventilation of—Glaser's Ann, Mar 15—97. 2500 w.

CARBIDE Industry in Germany—Frank. Zeit f Electrochemie, Apr 5—97. W May 22.

Carbide of Calcium in England, Restrictions Placed on—Pro Age, Apr 1—97. 700 w.

Carbide of Calcium—Electn, Lond, Apr 30—97.

CARBON Brush, How to Make a—Coleman. Amer Elec, Apr—97. W May 1.

Carbon, Contributions to the Investigation of the Crystallization of—Zeit f Elektrochem, Mar 20—97. 3000 w. M June.

Carbon, Electro-Chemical Equivalent of—Coehn. Zeit f Elektrochem, Apr 5—97. W May 22.

Carbon in Electrolysis, Reaction of—Vogel. Elek Tech, Apr 30—97. W May 29.

Carbon Element, Experiments Upon the—Zeit f Elektrochem, Feb 20—97. 3000 w. M May.

Carbon From the Non-Conducting Into the Conducting Condition, The Transmission of—George Brion. Electn, Lond, Feb 5—97. 1800 w. M Apr.

CARBONIZING—Krueger. Elek Anz, Feb 28—97. W Apr 3.

CARBORUNDUM Furnace and Its Operation, Details of the (Ill)—Elec Eng, Feb 24—97. 1200 w. M Apr.

CARIBOO, B. C., The Revival of Mining in—Can Min Rev, Feb—97. 4000 w.

CARNOT Principle to the Theory of the Cell, Application of—L'Eclair Elec, Apr 10—97. W May 22.

CASTING Machine, The Uehling Pig-Iron (Ill)—Ir Age, Apr 22—97. 1100 w.

Casting Pig-Iron, A New Method of (Ill)—Eng News, Apr 29—97. 1400 w.

Castings Direct from the Blast-Furnace, Hints on—W. H. Butlin. Ir & Coal Trds Rev, Apr 2—97. 1600 w.

CATHODE and Lenard Rays—McClelland. Electn, Lond, May 14—97. W May 29.

Cathode Rays—Elster and Geitel. L'Eclair Elec, Mar 20—97. W Apr 10.

Cathode Rays—J. J. Thomson. Elec Eng, Lond, May 7—97. W May 29.

Cathode Rays, Coloring Salt with—L'Eclair Elec, Apr 10—97.

Cathode Rays, Electrostatic Bending of—Jaumann. L'Eclair Elec, Mar 27—97.

Cathode Rays, Experiments with—Swinton. Elec Rev, Lond. Mar 19—97. W Apr 3. Electn, Lond, Apr 23—97.

Cathode Rays in an Alternating Magnetic Field —Fleming. Electn, Lond, Apr 23—97. W May 8.

Cathode Rays, Mr. Swinton on (Ill)—Elec Rev, Lond, Apr 9—97. 1400 w.

Cathode Rays, Mutual Action of the Electrodes and—Deslandes. L'Eclair Elec, Apr 10—97.

Cathode Rays on Diamonds, Action of—Moissan. Comptes Rendus No. 13. Electn, Lond, Apr 9 —97. W May 1.

Cathode Rays, Some Experiments with (Ill)—A. A. C. Swinton. Nature, April 15—97. 3300 w.

CEMENT in Sea Water, The Behavior of Portland—Dr. Wm. Michael. Eng Rec, Feb 20—97. 2500 w.

Cement Industry, European Portland—Frederick H. Lewis. Eng Rec, Mar 13—97. 1600 w.

Cement Manufacturers. The Annual Meeting of the Association of German Portland—S. B. Newburry. Eng News, Feb 25—97. 5000w. M Apr.

Cement, Slag—Moniteur Industrial, Feb 13—97. 1000 w.

Cement Testing, Methods of—Munic Engng, Apr —97. 3400 w.

Cements, Practical Points About Waterproof—Glaser's Annalen, Mar 1—97. 2500 w. M May.

CELL, Acetate Standard—Mauri. Electn, Lond, Apr 30—97. W May 15.

Cell, Iron Chloride-Carbon—Kuester. Elektrochem Zeit, Mar 5—97. Electn, Lond, Mar 26—97. W Apr 17.

Cell, The Lead—B. E. Moore. Phs Rev, Mar—Apr—97. 6000 w.

Cells, Irreversible—Taylor. Jour Phys Chem, p 11—97. Proc Lond Phys Soc, Mar 1—97.

Cells, Standard—Electn, Lond, May 7—97. W May 22.

CHAMPS-ELYSEES, The New Palaces of—La Revue Technique, Mar 10—97. 500 w.

CHARCOAL, On Electrical Properties of Fumes Proceeding from Flames and Burning (Ill)—Lord Kelvin and Dr. Magnus Maclean. Nature, Apr 22—97. 1800 w.

CHARGING for Current and the Competition of Private Installations—Elektrotechn Zeit, Apr 22—97. W May 15.

Charging, Method of—Wilson. Elec Rev, Lond, Mar 19—97. Elec, Mar 24—97. W Apr 3.

CHEMICAL and Metallurgical Industries, Electricity in the—Kershaw. Electn, Lond, Apr 2 —97. W Apr 17.

Chemical Synthesis by Means of the Dark Electric Discharge—Lasonitsch and Jovitschitsch. Zeit f Elektrochem, Apr 5—97.

CHICAGO Street Railway Franchises—West Electn, May 15—97.

Chicago Suburban Company—St Ry Rev, Apr 15—97.

Chicago's Lake Front Parks—Harper's Wk, Apr 3—97. 2000 w.

CHILLED ROLLS, A Method of Casting—Ir Trd Rev, Feb 25—97. 2000 w.

CHIMNEY of Capacity to Suit Plant of 200 Horse Power, On the Construction of a—Robert Kunstman. Brick, Apr—97. 2300 w.

Thesis Subjects.

Now that the members of the present junior class are beginning to think about thesis subjects for next year, a few words about the choice of a subject may not be amiss.

In the first place keep in mind the object of a senior thesis. It is to bring out a man's power of independent thought. The senior thesis is the first and only piece of work which the student carries out by relying entirely upon his own intellectual resources. It is in a degree a test of his power of investigation and in a number of cases the work achieved may be regarded as a forerunner of his success or failure in practical life.

In selecting a subject then, the student should keep in mind the object of the work and should choose something in which he is interested in more than a passing way. There are really three kinds of theses in the engineering departments: The experimental thesis, the thesis of design and the thesis of compilation. Of course a thesis may be, and often is, a combination of any two or even all three of these varieties, but the prevailing subject matter is quite likely to come under one of the above headings.

The experimental thesis is usually of the nature of a test on some piece of apparatus in the laboratory or on some plant or other machinery in actual practical service. The comparative test of commercial apparatus is quite popular because of its practical bearing. The experimental thesis occasions more anxiety on the part of the author than any other, but if the results are good it will help more to make him known to his profession.

The thesis of design generally involves the design and estimate of cost of some practical engineering structure. It is quite sure of a successful termination as a thesis and in rare cases the design may be constructed to the pecuniary aid of its author. On the other hand there is generally the dissatisfaction of seeing no practical test vindicating the results of theory.

The thesis of compilation should involve an enormous amount of library work and the author should have good taste in abstracting the work of others. It requires good judgment but no in-

genuity. As a thesis it is sure of success if the author works hard enough.

After selecting a subject the next question to be decided is, whether to work alone, or with one or more fellow students. The nature of the subject alone will determine this. It might be added that too much care cannot be taken in the selection of a good thesis partner. He should be a man of energy and enthusiasm, of unlimited resourcefulness and indefatigability.

All these things being settled the thesis should have an early start. Work during vacation if possible; by all means have the work under way the first month of the senior year and in calculating the time necessary for its completion use a large factor of safety against delays.

Appreciation of U. W. Graduates.

A glance at our alumni notes will show that, from the responsible positions held by our older graduates and the promotions which the younger ones are receiving, our engineering graduates are thoroughly appreciated by the outside world.

The university is constantly receiving letters of praise for its engineering alumni. Such things are easy to get for the asking but spontaneous plaudits are procured only through excellence of work.

The following may be taken as sample expressions from letters of this kind, hundreds of which have been received:

"I want to say that we expect great things from men out of your class, as all men from the University of Wisconsin seem to be a good deal better than good."

"I am pleased to say I am *very much* pleased with——. * * If he keeps up as he has started out, and I know of no reason why he will not, he will make me a valuable man, and it speaks much credit for you in turning out such articles."

"When we want *good* men in our line I'll let you know."

The fact that we are able to maintain the policy of having the majority of our contributions come from the alumni is another evidence. Some college engineering journals have at least one-half of their reading matter devoted to the faculty. When their professors become written out, they resort to biographical sketches of them until they recover, when another series of faculty articles is commenced. We believe in faculty articles to a limited extent

and would feel that our alma mater was incapable of making a good showing before the engineering world if the faculty did not contribute to our columns; but it certainly speaks better for the university and its faculty, better for the alumni and for the students, when we are able to publish so many practical articles by practicing alumni. The criterion of judgment of a university is the success of its graduates, and their success must be determined from the standpoint of their appreciation by the outer world.

Recognized Abroad.

We are glad to record that some of the Wisconsin Engineer's articles are being copied in English periodicals, due acknowledgment being given.

ALUMNI NOTES.

(*We will be thankful to any of our graduates for material under this heading.*)

'96.

J. H. Perkins is with the Youngstown Electric Light Co. of Youngstown, Ohio. He reports that his company is a progressive one, and likes his position.

L. G. Van Ness visited the university recently.

W. M. Camp is one of the editors of the Railway and Engineering Review. He is at present publishing a continued article on "Track." This article is of an exhaustive nature. It will be remembered that Mr. Camp wrote on this same subject in the Wisconsin Engineer.

'95.

W. J. Bohan is with the C., M. & St. P. R. R., with headquarters at Milwaukee. Electric signaling is his specialty

Wm. H. Schuchardt, ex-'95, recently visited the University. He is with Alexander Eschweilder, a prominent architect of Milwaukee.

W. S. Hanson has secured a position with the Walburn-Swenson Co. in their shops at Chicago Heights, Chicago.

L. W. Golder ought to have been placed in the marriage list of our last issue. He is still in his old position in Minnesota.

A. S. Grover has been promoted from the shops of the Niles Tool Works to their drafting rooms.

A. L. McCulloch is with the U. S. Land Department in southern California.

J. M. Boorse visited the University the lattter part of May. He stills holds the position as electrician at the Alms House in Wauwatosa, Wis. Not long ago Mr. Boorse installed a small lighting plant in that town.

R. C. Falconer is in the New York office of Purdy & Henderson, architects. Word comes that he is at the head of the office force.

A. R. Sawyer visited the University lately in the interest of manual training at the Milwaukee schools.

T. R. Brown is with the Wisconsin Bridge & Iron Co. He has had his salary increased four times in less than two years' connection with that company and was retained in their office during the hard times when they had almost no contracts ahead.

T. L. Gregerson is in the office of Olaf Hoff, consulting and contracting engineer, Minneapolis, where he has been nearly two years.

A. H. Ford, E. E., has been elected Fellow in engineering at Columbia for 1898.

'94.

W. A. Baehr is Superintendent of Distribution of the Milwaukee Gas Light Co.

H. P. Boardman is with the Chicago & Calumet Terminal Ry., with headquarters at Chicago. For three years he was with the Chicago Drainage Canal.

'93.

C. H. Hile, M. E., is Superintendent of Electrical Construction for the West End Railway, Boston.

J. H. Griffith is now in the City Engineer's office, Indianapolis, Ind., in charge of designing structural work. He has been elected Fellow in Engineering at Wisconsin for 1898.

J. C. Haine is in the general office of the C., M. & St. P. Ry. at Chicago, and is well liked by his superiors. His work is partly indoor and partly outdoor work.

J. G. Wray is Superintendent of Construction for the Chicago Telephone Co. This is a position of great responsibility.

'92.

L. B. Worden is Contracting Engineer for the Wisconsin Bridge & Iron Co. He has been connected with this company since graduation and is a vital part of it.

H. F. Hamilton is assistant engineer, C., M. & St. P. Ry. at St. Paul.

'90.

W. G. Potter, C. E., is with the C., M. & St. P. Ry.

In Topographical Work.

Among some of the most successful graduates in topographical engineering might be named David Fairchild, '90, E. C. Bebb, '96, and Harry Tripp, '96. Their superior officers in the topographical branch of the U. S. Geological Survey have spoken of their services in the very highest terms, and have shown their appreciation by giving them substantial promotions.

Both Mr. Bebb and Mr. Tripp took the U. S. civil service examination in April and will be appointed soon upon the permanent force of this important survey.

It is also significant that the success attained by these young men has lead the director of the U. S. Geological Survey to request the topographical department of U. W. to recommend a larger number of topographers the coming season.

LOCAL NOTES.

Senior Theses.

The following are the names of the engineering graduates of '97 and the titles of their theses:

Civil Engineering.

Arnold E. Broenniman, "Experimental Study of Internal Hydrostatic Pressures in Masonry Dams."

Perry F. Brown, "Sewerage System for the City of Janesville."

Edward Coombs, "Sewage Disposal at the State Insane Asylum."

Ross C. Cornish, "Drainage of a Cranberry Marsh."

Fredric Dixon, "Relocation of a Portion of Portage Branch of C., M. & St. P. R. R."

Henry C. Fuldner, "On the Modulus of Elasticity of Stone."

William G. Kirchoffer, "Sewage Disposal of the State Insane Asylum."

Charles M. Kurtz, "Sewerage System for the City of Janesville."

Clinton McDonald, "On the Modulus of Elasticity of Stone."

Harry H. Ross, B. S., "Experimental Study of Internal Hydrostatic Pressures in Masonry Dams."

Spenser S. Rumsey, "Drainage of a Cranberry Marsh."

Merton V. Webber, "Relocation of a Portion of Portage Branch of C., M. & St. P. R. R."

Mechanical Engineering.

Walter Alexander, "A Comparative Test of Simple and Compound Locomotives."

Robert B. Cochrane, "A Comparative Test of Simple and Compound Locomotives."

Nathan Comstock, "A Test of the University Boiler Plant."

James Short, "The Comparative Efficiency of the Steam Engine under Constant and Rapidly Varying Loads."

Benjamin W. James, "A Comparative Test of Gas and Gasoline Engines."

William H. Kratsch, "A Test of the University Boiler Plant."

Emil Lueth, "A Comparative Test of Gas and Gasoline Engines."

Wallace MacGregor, "The Effect of Impurities upon Cast Iron."

Fred Nelson, "The Effect of Impurities upon Cast Iron."

Electrical Engineering.

John S. Allen, "Investigation of Certain Phenomena of a Synchronous Motor."

Murray Beebe, "The Electrolysis of the Metallic Chlorides."

Victor A. Berganthal, "The Effect of Impurities on the Magnetic Properties of Cast Iron."

Leon R. Clausen, "A Comparative Test of Simple and Compound Locomotives."

John Dutcher, "The Comparative Efficiency of the Steam Engine under Constant and Rapidly Varying Loads."

George H. Jones, "A Comparative Test of Electric Meters."

Wallace Keihl, "The Comparative Efficiency of the Steam Engine under Constant and Rapidly Varying Loads."

Otto Lademan, "The Effect of Impurities on the Magnetic Properties of Cast Iron."

Llewellyn Owen, "Commercial Test of Hotel Pfister Power Plant."

Harry W. Reilly, "Commercial Test of Hotel Pfister Power Plant."

Edward Schildhauer, "Investigation of Certain Phenomena of a Synchronous Motor."

Charles J. Schmidt, "Commercial Test of Hotel Pfister Power Plant."

Rudolph F. Schuchardt, "Comparative Test of Electric Meters."

NEW PUBLICATIONS.

The Locomotive, Its Failures and Remedies, by Thomas Pearce, D. Van Nostrand Co., price $1.00, is a new book which has been received since the appearance of the last number of the Engineer. It is a book published with a sincere desire, on the part of the author, to benefit those who aspire to pass the examination now required for the position of engineer on a locomotive.

It takes up the work systematically by asking such questions as any competent engineer should be able to answer or would be likely to get in such an examination and gives the answers immediately following.

The answers are very suitable for each particular condition to which they are applied and show much experience and careful thought on the part of the author.

The book is divided into chapters, each taking up some particular phase of locomotive operation.

Chapter I contains information for overcoming the more elementary emergencies, as, failure of injector, leaky tubes, priming, etc.

Chapter II takes up in detail the technicalities of the valve

mechanism and cylinders, as, lap and lead, admission, cut-off, expansion, etc.

Chapters III and IV take up the testing of valves, ports and pistons, etc., at different relative positions of the same.

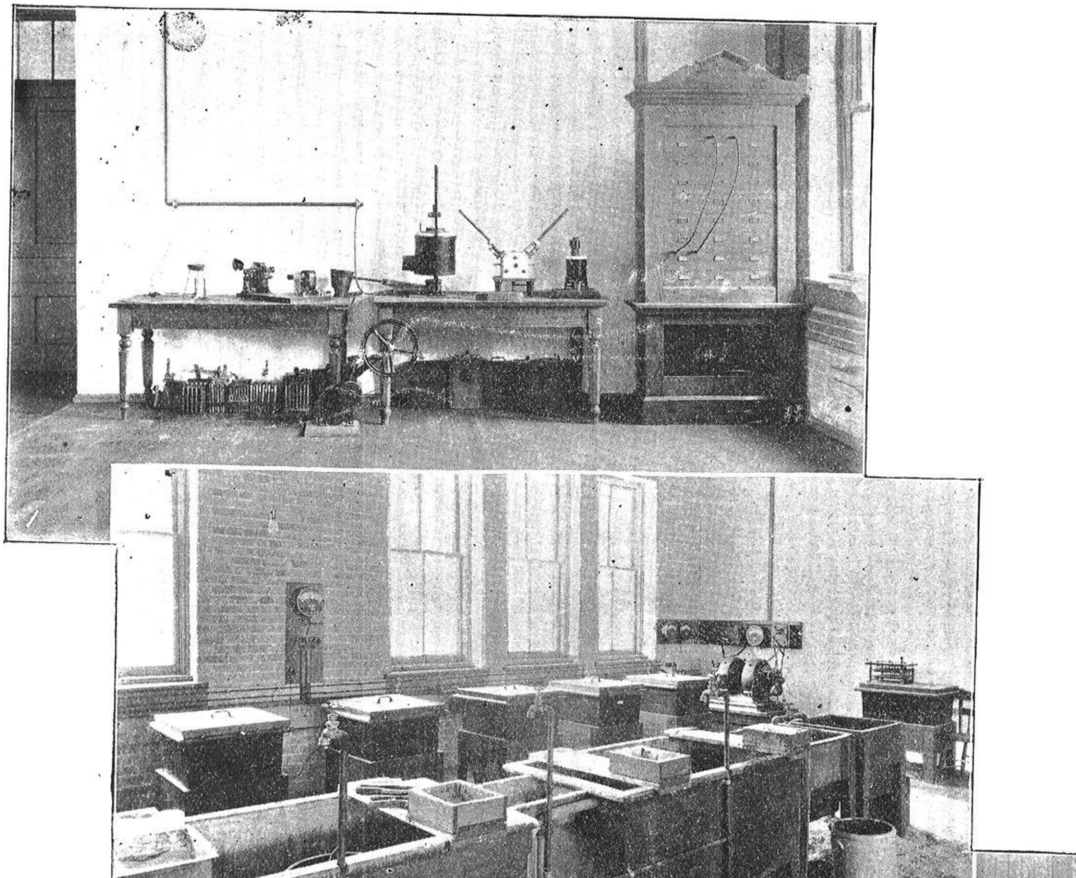
Chapter V assumes certain damages upon the moving parts, and suggests such remedies as will cause the least delay.

Chapter VI takes up the methods of placing the engine for uncoupling or for general repairs.

There is also a very complete set of valve diagrams, showing how the valves should be set for different positions and conditions.

The entire book is typically English and although it might not strike the American engineer as exactly conforming to his ideas for overcoming similar obstacles, yet we believe it to be a production that would be of value to any one interested in locomotive management.

The book contains about 100 pages, besides 16 double page diagrams.



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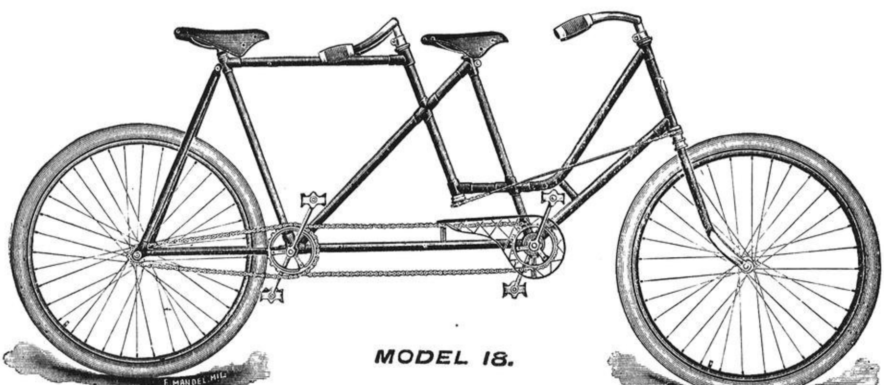

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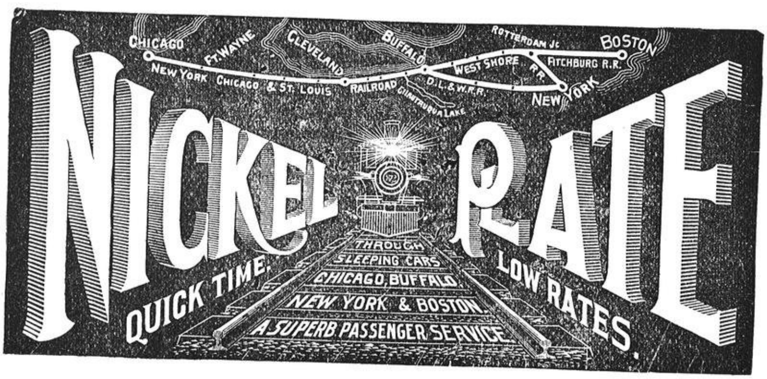

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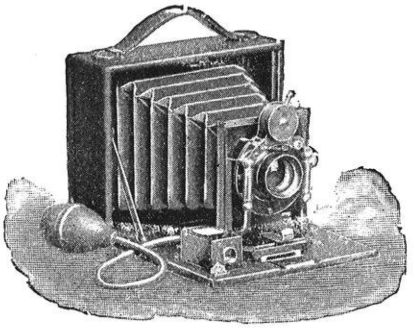

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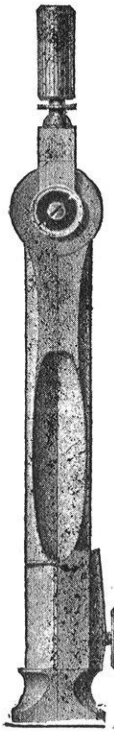

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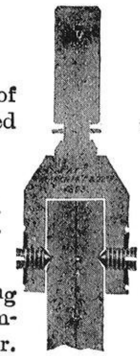

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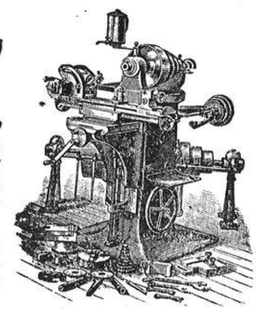

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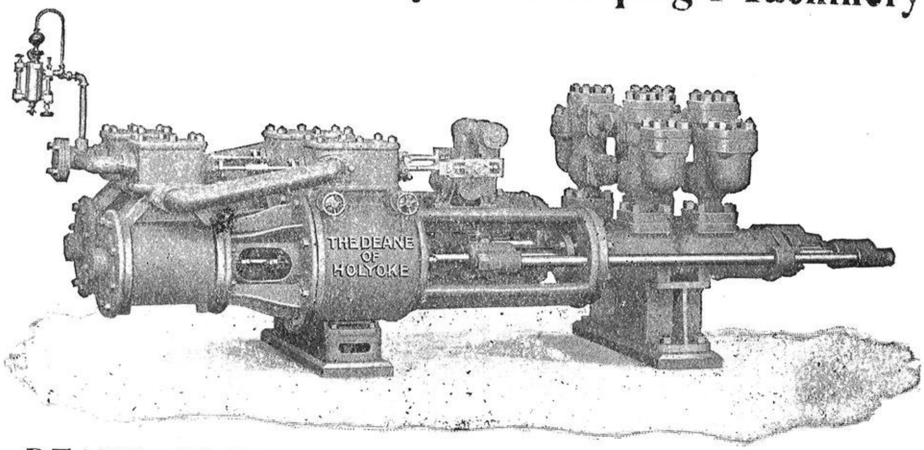

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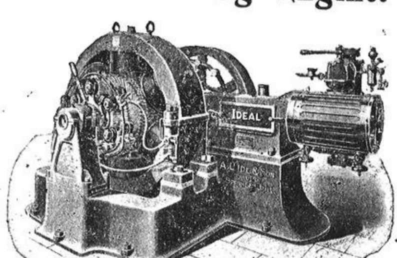

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United States Deep—Eng News, Feb 11—97. 12000 w. M Apr.

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Water Works at Cambridge, Mass (Ill)—Fire & Water. Mar 20—97. 1800 w.

Water Works in United States and Canada, Number and Ownership of—Engng News, Apr 29—97. 2800 w.

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Water Works of Calbe, The—Zeitschr der Vereines Deutscher Ingenieure, Mar 13—97. 3500 w.

Water Works Practice, Present Tendencies in—Eng News, Apr 15—97. 2200 w.

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Water Works Records and Blanks, Prize—Munic Engng, Mar—97. 2000 w.

Water Works, The Financial Management of—E. Kuichling. Proc Am Soc Civ Engs, Apr—97. 7000 w.

Water Works with Electric Driving (Ill)—Zeitschr der Vereines Deutscher Ingenieure, Mar 20—97. 1500 w.

Water Works—See Lighting Station.

WATT and the Measurement of Power—W. H. Preece. Electn, Lond, Feb 12—97. 4500 w.

Wattmeters, Calibrating—Bedell. Sib Jour, Mar—97. W Apr 10.

WELLS at Brookline, Mass., Driven—F. F. Forbes. Jour N E Water Wks Assn, Mar—97. 2300 w.

WEIGHING Machine, A Power-Feed, Automatic (Ill)—R R Gaz, Apr 16—97. 2300 w.

WELSBACH System in Paris, Public Lighting by the—M. Maréchal. Jour Gas Lgt, Feb 16—97. 2500 w. M Apr.

WEST KOOTENAY Mines, The—Wm. A. Carlyle. Min & Sci Pr, Feb 20—97. 1500 w. M Apr.

WHEATSTONE Bridge, Most Sensitive Arrangement of—Child and Stewart. Phys Rev, May, June—97. W May 29.

Wheatstone Bridge, Currents in the Branches of—Crehore and Squier. Phil Mag, Mar—97. W Apr 17.

WHEELS, Axles, Etc., A New Method of Dressing Car—R. Atkinson. Eng News, Feb 25—97. 2000 w.

Wheels, Correct Gaging in Mounting Car—R R Gaz, Feb 26—97. 1500 w.

WIDNES, Copper Works at (Ill)—Elec Rev, Lond, Mar 19—97.

WILLOW Grove Park, Philadelphia, Amusement Features at—Eng News, Mar 11—97. 3200 w.

WIMSHURST Machine, Observations with the—Negreanu. L'Eclair Elec, Mar 6—97. W Apr 10.

WINDING Arrangement with Constant Resistance, New—André Desprès. Col Guard, Apr 9—97. 2400 w. M June.

WIRE—A. L. Orton. Sib Jour Engng, Apr—97. 1800 w.

Wires of Iron and Bronze, Sag of—Dreisbach. Elektrotechn Zeit, Mar 11—97. W Apr 3. E Apr 21.

Wiring—Bonfante. Bul Soc Int des Elec, Feb—97.

Wiring, Calculation of—Amer Electn, Apr—97. W May 8.

Wiring Circuits, Drop in Special Incandescent—Amer Electn, May—97.

Wiring, Inconsistencies in Electric—H. N. Gardner. Elec Eng, Feb 24—97. 2000 w. M Apr.

Wiring, Interior—Hanchett. Amer Electn, Feb, Mar, Apr, May—97.

Wiring Rules and Regulations in Germany—L'Elec, Apr 3—97.

Wiring, Temporary—Bliss. Amer Electn, Mar—97.

Wiring; Uninsulated Pipe for Interior—Zingler. Elec Rev, Lond, May 7, 14—97. E May 26. W May 29.

WITWATERSRAND Gold Fields, Economic Features of Mining on the—E. P. Rathbone. Eng & Min Jour, Feb 13—97. 3800 w. M Apr.

WOODS, Summary of Mechanical Tests on Thirty-two Species of American Woods—U. S. Dept of Agri, Circ No. 15. 4000 w.

WORCESTER Electric Lighting Station, The Extension at the—Elec Rev, Lond, Apr 2—97. 1600 w.

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YEAST, Production of—Elek Anz, Mar 28—97. W Apr 24.

YUKON District, Gold Mining in the—W. M. Ogilvie. Can Min Rev, Apr—97. 4400 w. M June.

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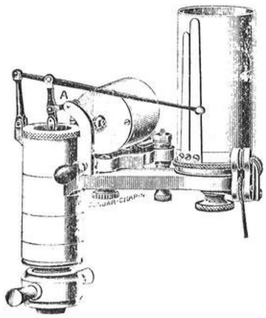

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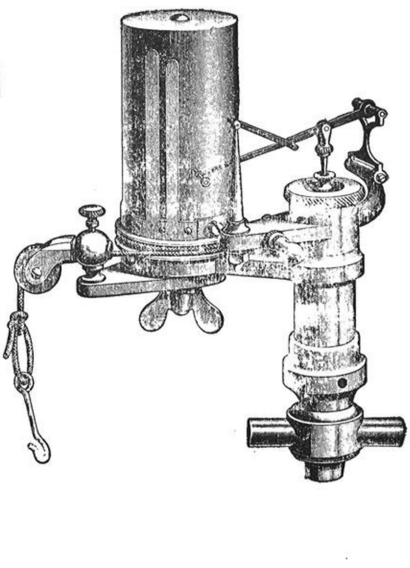

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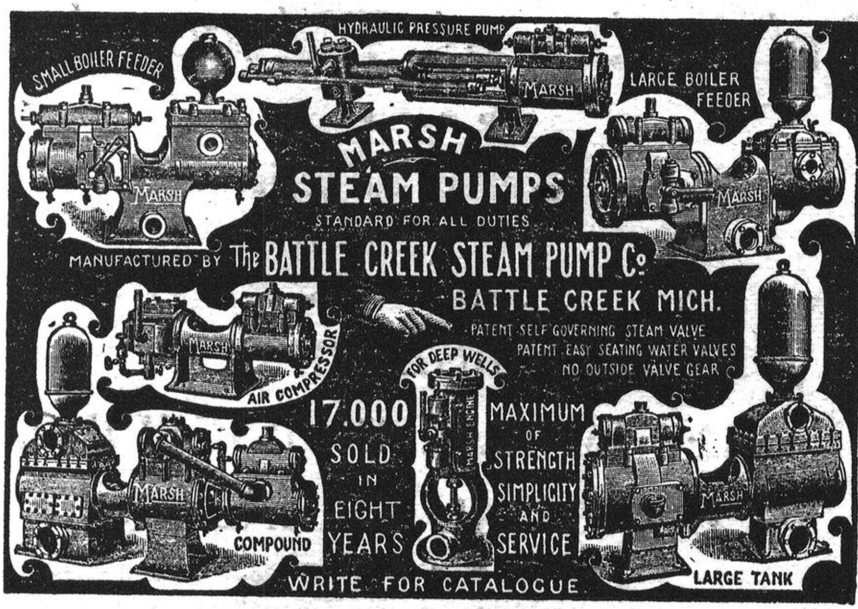

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