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FOUNDATIONS.

By W. A. TRUESDELL, PH. B., '67.
Our Oldest Graduate in Engineering Practice.

There is no subject in the whole art of construction more important than foundations, and the student and young engineer should be thoroughly informed on all that is known concerning it.

As the first object of all building is stability, the foundation of a structure should be secure and sufficient. It is by all means the most important part. It should be built with this idea in mind, and on the supposition that it is to last forever. If the foundation is good whatever is built upon it will, under ordinary circumstances, take care of itself. No time, trouble or money should be spared to make it satisfactory.

This is a subject which does not admit the application of mathematical formulas or any other kind of theorizing. Everything of any value that is known regarding it has been derived wholly from experience; theory is of no use whatever. It is only by studying and knowing what has been done in all countries and in all times—what has been successful and what has failed—that we are safe in designing and executing works of this character. All modern methods of building on natural or artificial foundations now used by engineers rest on such observation and the engineer must be guided by his knowledge of what others have done before him and by his own judgment.

A great deal has been written about foundations and much more might be written for it is an extensive subject. This paper is not intended as any valuable addition to what has already been written or as any statement of facts, but what has been long known. It is only an embodiment of ideas and observations gathered during several years of practice and grouped together for the readers of the WISCONSIN ENGINEER. For all rules and principles relating to this subject as laid down by the best writers and for detailed accounts and descriptions of the most noted works the student must consult the standard text books and the various periodicals of engineering literature.

Of Natural Foundations—The supporting power of the different varieties of soils has been a subject of serious study and observation with engineers; for the very first principle of design is to plan and proportion a structure so that its weight on the supporting soil will not be so great as to endanger its safety.

Experiments have been made and rules framed to determine what loads different soils will sustain, but they are of little value. The natural soils which an engineer meets with are so various in their composition and character, that about all he can do is to learn what weight each variety has been successfully loaded with in existing engineering works and what weights have caused failures.

In each particular case, as it occurs in his practice, he must investigate existing successful structures which are built on soils similar to the one he is considering as near as he can determine, bearing in mind the fact that in any variety of soil whatever, the sustaining power is less as the compactness decreases and its saturation with water increases.

To ascertain the character of the soil in a proposed foundation of any magnitude the best method is by borings, but sometimes it is not reliable. Soundings are usually worthless.

Next to solid rock or a bed of boulders, coarse sand and gravel, when free from water, is the best material an engineer ever meets with, and if a structure is planned according to the rules of ordinary construction there is no reason why that structure should not be successful. The supporting power of this material like all other soils varies with its hardness and freedom from water. For ordinary sand and gravel a safe load is three tons to the square foot, but there have been instances where the load was four and even five tons without any settlement, though this depends altogether on the compactness of the material.

The writer once built in this city (St. Paul, Minn.) a pier 6 feet thick and 125 feet long which supported a great weight and proportioned the footings so that the load was 4 tons. The material was coarse sand and gravel.

When sand is of a finer quality and any ways saturated with water its supporting power grows less and the loads must be governed accordingly. With fine sand when dry 2 1-2 and 3 tons is load enough. If saturated to any extent with moisture, or particularly if in that condition commonly called quick sand, any excessive loading will force the surrounding soil upward. In such a case the greatest care is necessary. Material of this character will do for a foundation if loaded to about 1 or 1 1-2 tons per square foot and the whole foundation confined inside of tight sheet piling.

Clay soils are of great variety. Some are hard and compact and free from moisture and incompressible. When found in this condition they have a good sustaining power and are considered reliable foundations, but it is difficult to give the limit of weight with which they should be loaded. In some instances when very hard, so that they yielded only to the pick, they have been loaded with 5 tons per square foot. In other cases hard pure clay has failed with the same load.

As a general rule, soil of this kind, that is, hard clay free from moisture, will bear a load of 2 tons and perhaps 2 1-2 tons with safety. Yet with this as a limit they are unreliable unless kept free from moisture. Instances could be mentioned where buildings have been erected on soil of this character with 2 1-2 tons load and have remained intact for years and then failed, probably because water found access in some way to the foundation.

Clay soils have a great propensity for retaining water when once admitted and in this condition they become yielding and compressible and unreliable, when considered as a foundation. Here the greatest care must be taken. The foundation should be spread over as much area as possible, and then if in ordinary plastic condition, the load is sufficient at 1 or 1 1-2 tons per square foot, provided the whole foundation is confined by sheet piling.

Clay when mixed with coarse sand and gravel is a good soil for building. Its supporting power increases as the sand and gravel increases. Sometimes the clay appears to act as a cement and binds the mass together into a sort of concrete. When in this condition it is commonly called hard pan and is safe for the heaviest loads an engineer would ever think of putting on any kind of soil, say 5 tons or more.

In the various kinds of soil above mentioned, from wet and compressible clay or quick sand, to cemented clay and sand, the loads given as a limit are from 1 ton to 5 tons. Some engineers may disagree with these figures. If so no one will consider the objections more readily than myself.

The Washington monument is built on a foundation of clay and sand, but of what degree of hardness the writer does not know. The weight per square foot is given at 3 tons near the outer edges and 9 tons in the central part of the foundation.

This is the most excessive weight ever known to be placed on any natural foundation. The example should never be imitated and probably never will be. Much was said at the time the monument was completed about it and grave doubts were expressed as to the ultimate fate of the structure. Whether their criticisms were just or not may require a very long time to determine.

From the foregoing we might classify the natural foundations which an engineer meets with in ordinary practice, and which should occasion him no trouble so long as he keeps within the prescribed limits of loading, as follows:

1st. Solid rock, which will maintain any load however great, governed only by the crushing strength of the material and the allowance of a sufficient factor of safety.

2. Boulders and gravel—always a safe foundation to build on—and if the area is well proportioned, no danger of overloading.

3d. Clay and sand. When in a hard and cemented condition this foundation will sustain heavy loads approximating to the softer kinds of rocks. This is considered a good natural foundation.

4th. Dry sand or sand and gravel is another ordinarily good foundation when not in any danger from running water and loaded not to exceed 2 or 3 tons per square foot.

5th. Compact clay, usually a good base to build on and reasonably safe if well guarded from water; one which will bear loads not to exceed 2 or 2 1-2 tons per square foot.

Of Artificial Foundations.—Whenever the soil is too wet and compressible to build directly on, the engineer must resort to some other method which the size of the proposed structure, the locality, and other circumstances only can determine.

The different kinds of artificial foundations now used by engineers are very few in number and might be enumerated as follows: concrete beds, concrete on piling, timber on piling, and timber caissons. Any artificial foundation should be one of these or a modification.

There are other methods recommended by some writers, such as sand piles, compressing a soft soil by short piling, and filling in with sand or gravel, but no practical engineer would ever think of using any of them.

If a wet and yielding stratum is underlaid by a firm and hard one, and is not too deep, the common practice is to remove the softer one entirely and build a bed of concrete, upon which the masonry structure is to rest.

It is sometimes good practice, when the proposed structure is not too heavy, to build the concrete directly on the soft material, giving the bed as large an area as possible. The engineer is governed by the amount of load and the compressibility of the soil when he adopts this method.

Concrete is very often used as a foundation for heavy bridge piers when piling can not be used or is unnecessary. When the river bottom is found to be a bed of mud or silt overlying some hard material such as hard clay, hard pan or rock, it is customary to sink a pier or bed of concrete enclosed in timber, or a cassion filled with the same material, through the soft and changing bottom to a substantial bearing on the hard stratum. This is the common practice and is the best method that can be used whenever a hard and reliable bottom can be reached. The bridges over the Missouri river at Bismark and Plattsmouth are good illustrations of this method.

Concrete is a material which enters largely into engineering and architectural works and its use is still growing. Every practical engineer is expected to understand it and its preparation. Theoretically, or as we read about it in the text books, it is a good material to put in substructures. It is supposed to be an artificial stone, but as contractors are apt to make it, it is not always what is desired in good work. The best concrete the writer ever saw was what he made himself and what he has seen other engineers make—not contract work but by day's labor.

To make the best concrete, where it is essential to have good work done, Portland cement should be used. The additional cost will be money well expended. It is a good method and it is very often followed, where a large quantity of concrete is to be made, say three or four feet or more in thickness, to make the lower portions with American cement and the upper part with Portland.

Though concrete is usually a good foundation when laid on a medium soft soil and the weight above it is not too great, it is unsafe when these conditions are reversed, and it is sometimes difficult for an engineer to decide which to adopt—concrete or piling. If the soil is any ways wet and the superstructure to be of considerable size and weight, then there should be no hesitation about using piling.

Several years ago the Union Depot in this city was built on a bed of concrete where piles should have been driven. The location was on low ground near the Mississippi river and the soil was wet and soft. The fault was soon apparent after the building was completed.

A very unusual and at the same time a very interesting foundation was put in by the writer on the Great Northern Railway bridge over the Columbia River in Washington during May and June, 1895.

A timber trestle some 60 feet high and 275 feet in length was to be replaced by a steel structure. The old trestle was in most part built on a bank composed of basaltic rocks and chips mixed promiscuously which had been thrown in when the road was built some three years previously. The embankment rested on solid rock. The new bridge required ten supports besides the abutment at one end. Four of the supports were on solid rock. The others were on the stony embankment where it was necessary to shink shafts or wells each 8 feet by 8 feet with curbing put in as the excavations were carried down through the made bank to solid rock. This was a most tedious operation, and required

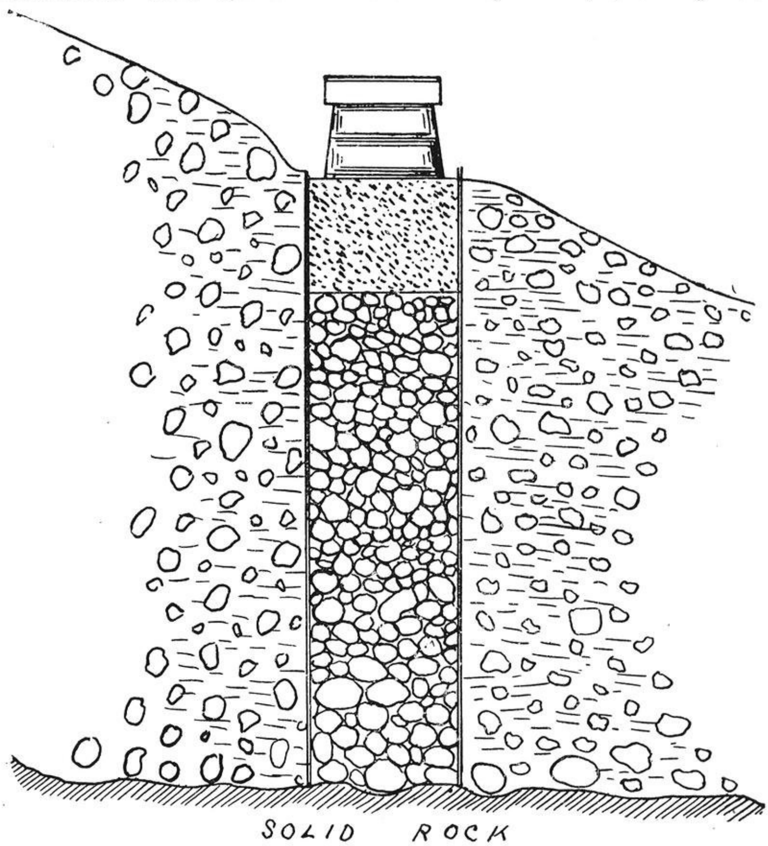


FIG. I.—One of seven foundations, Columbia river bridge.

time and great care, on account of the character of the material removed and the old trestle to be maintained intact. Two of these shafts were 32 feet deep, two others 26 feet. Each well when excavated was filled with broken rock, of different sizes, put in by hand and well rammed and pounded, and each layer of 1 1-2 feet grouted. This filling was carried to within 6 feet of the top. Then came 6 feet of the best concrete and after this a short masonry pier.

When a wet material is too deep to be excavated piles are invariably driven to secure a substantial support. If they are in soft ground only, they depend for their sustaining power on the friction of the surrounding material against their surfaces. If there is a hard stratum below and it can be reached, they are always driven to it, and if practicable into it, to a firm bearing.

Piles are extensively used in all kinds of heavy work, where the location requires it, and have been for ages. It is doubtful if anything cheaper or better will ever be devised. A practical knowledge of pile driving is essential to every engineer. The empirical rules for finding the weight a pile will bear from the fall and weight of the hammer may not have much value. Rankin gives as the safe load for a pile driven to a firm bearing 1,000 lbs. per square inch, and for a pile in soft ground, that depends only on friction, 200 lbs. (*See Civ. Eng., p.* 602.) That writer is cited because he is a very reliable authority. For piles of standard size this would be 50 tons and 10 tons. In all works in this country the loads on piling are between these extremes.

In this city there are a number of buildings five and six stories high and covering large areas of ground which are built on what was originally a swamp. All of them rest on pile foundations with beds of concrete surrounding the piles from two to three feet thick and sometimes a foot above. In some of these buildings the piles were from 25 feet to 30 feet in length and driven to a hard bearing. In others they were 50 and 60 feet long and driven without reaching bottom. In every instance these buildings are solid and stable. One of them is thirteen stories high.

Of course in all localities where pile foundations are put in, there is always sufficient water to insure the preservation of the piles. Wooden platforms on piling are built only when they are to be forever under water. Concrete beds should always be used instead of timber platforms whenever it is possible to do so.

Foundations of whatever kind should be deep. This is a principle of engineering always to be observed, whether it applies to an ordinary dwelling house, a pile bridge or a railroad or highway, or to a large bridge pier in mid stream. In all buildings they should be deep enough to be below the effects of frost if for no other reason. The roadway of a pile bridge will heave and warp out of line and grade if the piles are not driven below the reach of frost. The foundations of bridge piers, if in a shallow stream must be below extreme low water mark and out of the reach of ice, and if the stream is deep and has a stiff current there must be no danger from wash and scour.

During the past year the writer was called to superintend the construction of a steel highway bridge over the Mississippi river at Aitkin, Minn. The contract had been let for some time on plans furnished by the contractor himself. All the men and

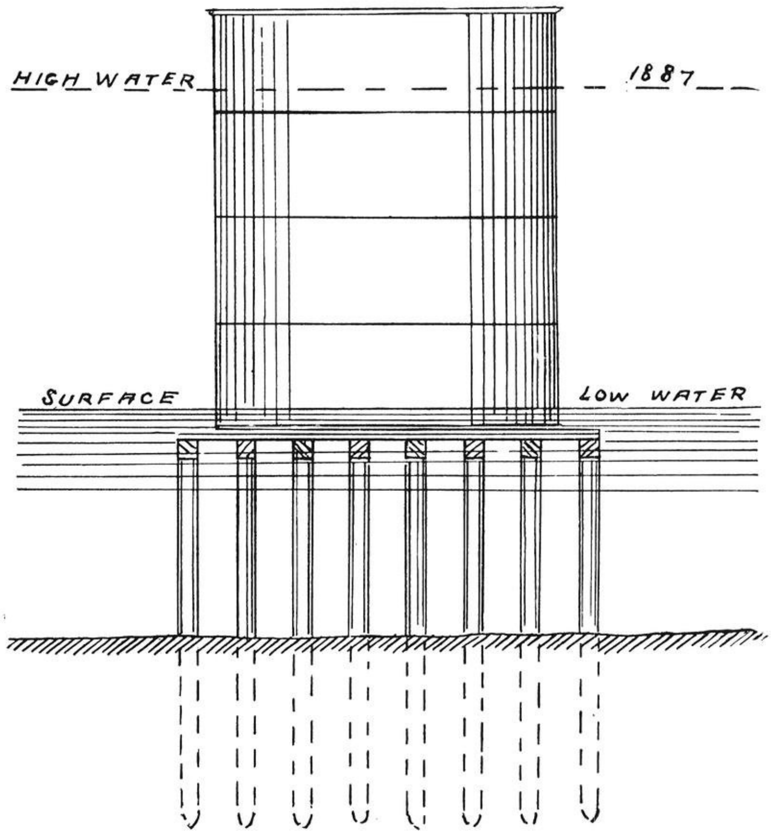


FIG. II.—Pivot pier, Aitkin bridge, as planned.

material were on the ground and work about to commence. The pivot pier to sustain the draw was to be built in mid stream and was to be a cylindrical drum filled with concrete, 18 feet in diameter and 22 feet high. It was intended to build this pier on the foundation shown in figure II.

This absurd piece of work was about to be imposed by the contractor on a board of unsophisticated county commissioners. The foundation was actually built as shown in figure III, which was the best that could be done under the circumstances. Instead of

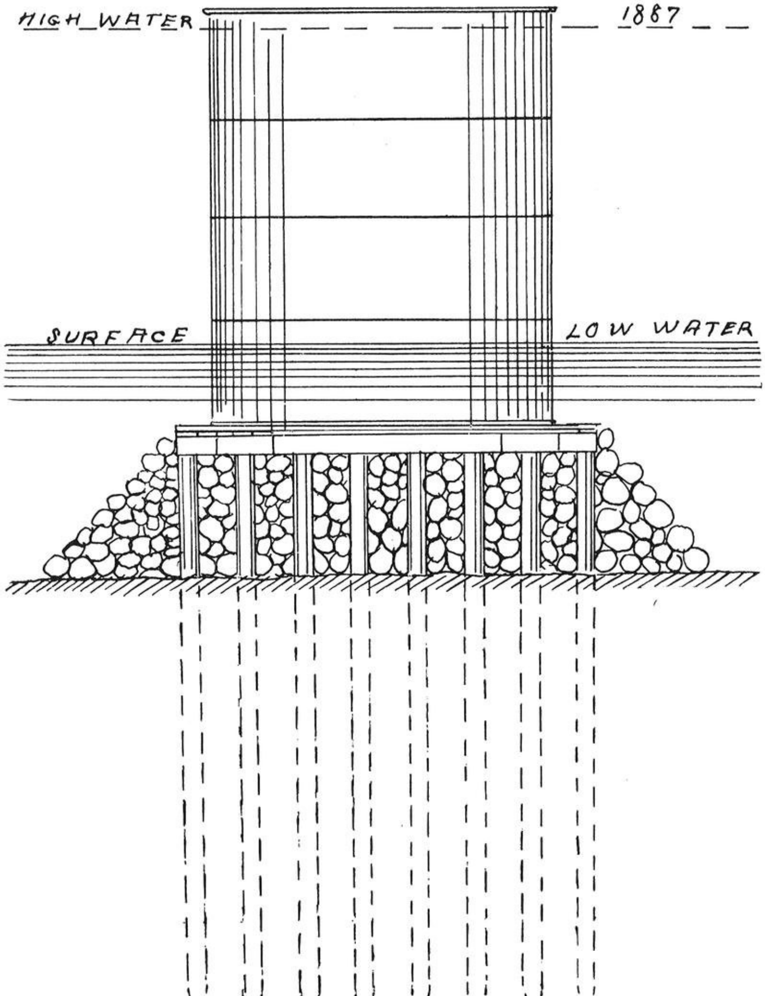


FIG. III.—Pivot pier, Aitkin bridge, as built.

piles 22 feet long, heavier ones 35 feet long were driven through the soft material into a harder one and to a solid bearing. These piles were cut off three feet lower than at first intended and would have been cut off six feet lower if the plan of the bridge above had not been governed by high water mark. Finally after the cut off, over 100 loads of boulders were gathered from the surrounding country and placed between the piles and on the outside, after which the platform was sunk and bolted.

This change was a vast improvement on what was at first intended. It brought the timber platform below the reach of ice and gave more stability to the pier. Perhaps this foundation is not a model one but it is safe and substantial enough for an ordinary highway bridge where there is no scouring or wash. The whole load on each pile is about 10 tons.

A foundation to be stable, should be uniform throughout its whole area. One of the greatest difficulties an engineer ever has to contend with is when the soil is of variable character and of unequal hardness, as for example, rock or compact earth in one position and common earth or a yielding soil in another. So long as a foundation is of equal compressibility whether it is hard or soft the settlement is equal and no damage is liable to occur, but if the underlying soil varies in this respect then whatever is built upon it will settle accordingly. Any structure on such ground is bound to settle unequally and unequal settlement causes cracking.

In my opinion, a foundation in a swamp is preferable, for in such a case an engineer knows just what to do, but when the soil is of different supporting power he is sometimes uncertain how to proceed. About all he can do is to make it as uniform as possible, and take extra precautions in that part where the soil is softest. He should always endeavor to make a foundation to a uniform plan as near as circumstances will admit, that is to say, it should be all earth, all concrete or all piling, and not part one and part the other.

The east abutment of the Seventh Street Improvement Arches, built by the writer in this city in 1883, was a long piece of masonry about 225 feet in length, and supported on piles. At the south end the ground was very hard and piles were driven with difficulty. At the north end every thing was different, wet and soft. After the whole work was completed, unequal settlement took place and a slight crack vertical in direction occurred through the whole abutment from bottom to top, exactly at the dividing line between the hard and soft ground.

There is a large wholesale building in this city, which was built with one end on sand rock and the other on piles. This building shows the same result from the same cause.

Foundations should be spread and the superstructure so designed that the weight will bear equally throughout the whole area. This is another principle to be followed. It is the only safe way to build on a bad foundation, and the principle holds good whether the foundation is bad or not. A long paper might be written on this subject alone detailing how this principle should be carried out in all structures and giving interesting illustrations, but time and space will not permit. The writer is now (July, 1896) engaged on the foundation of a large office building which rests on piles from 20 feet to 30 feet in length and driven to a hard bottom. The foundation is so planned that together with the outside walls and interior supports the load per pile will be from 10 to 11 tons.

Foundations should never be built on made ground. This is another principle of good engineering, though it is not liable to be violated in works of large magnitude. When made ground is sand and gravel it will come to rest in a comparatively short time, but if clay, it may be years before it reaches a final rest. Anything built on made ground is liable to settle and usually does. When a soft stratum rests on a hard one, some of our text books advise excavating the soft material and filling in with sand or gravel as a base to build on. This is bad practice whether the deposit of sand is rammed and puddled or not. One of the worst failures that ever occurred in this city was a wall built on such a foundation. This rule is not laid down because that particular failure is in mind, but because it is a well known fact with builders that made ground is not reliable.

To an engineer well posted in his profession the practice of foundation work should present no difficulty. Engineering science has made rapid strides in this country during the last 25 or 30 years, and many celebrated works have been constructed, which have been fully described and illustrated and are accessible to study and inspection. The engineer now about to commence his profession will find that so much has been done by others before him that his work is, in a great measure, only a process of imitation and very little opportunity is left for originality. It is well perhaps that this is so. Foundation work from its very nature and importance must necessarily be a question of experience.

It is too hazardous to attempt any original and untried methods, and no engineer who has his reputation at stake would think of doing so. He must let experiment and theory alone. It is far better to follow the old beaten paths which heretofore have always lead to success.

ABRASIVES.

By A. L. GODDARD, B. S., '96.

During the last few years there has been a remarkable development in the manufacture and use of abrasives. The multiplicity of the applications of the various kinds of abrasives makes a general knowledge of the methods employed not only useful, but necessary to engineers.

Formerly the grindstone was used almost altogether for grinding. The stone was a soft, even standstone. For shop-tool grinding it was run slowly, but for heavy grinding and grinding cutlery a fast speed was used. The stones were quarried and roughed out with mallet and chisel, then mounted and turned up with an old file or chisel or with a piece of soft iron gas-pipe. A slow speed was generally used for turning up and for trueing up in the shop; but if this was not easily obtained, the high spots were first marked with a piece of chalk or charcoal held against the revolving stone, and then the stone was stopped and these spots were picked with a pick or old chisel, after which they could be more readily turned off. The turning was always done dry except the finishing when water was sometimes used. If the stones were to be used for grinding tempered steel as axes or other edged tools, the surface of the stone was picked with a tool shaped like a small adze. This made it cut more rapidly with less likelihood of drawing temper. Hard or soft spots are very likely to occur in grindstones and cause much trouble as the wheels soon wear out of true and beside this hard spots will draw the temper of tools unless much care is used. Grindstones are not much used in this country now; the best ones here come from Ohio. In England, however, they are still used. Mr. Paret, president of the Tanite Emery Co., in a visit to Sheffield in 1892, found the workmen in about all of the shops grinding razors and other cutlery on grindstones with the same methods that were used fifteen years ago. And this seems the more remarkable when we remember that these workmen have about as hard, dirty, disagreeable work as skilled workmen are obliged to do.

Corundum is an oxide of aluminum, having the formula $Al_2 O_3$. The gems, oriental amethyst, sapphire, garnet, oriental ruby and oriental emerald, are corundum crystals. The corundum which is used for grinding is mined principally in Georgia and Pennsylvania. The crystals are dark and very hard. Corundum having impurities, usually oxide of iron, is called emery. This occurs massive, sometimes in veins between other rock and sometimes it is found in large granular masses in the soil. That which occurs in veins splits easily with flat sides, but that which occurs in masses in the soil is amorphous and massive and is broken with difficulty. Corundum is much harder than emery. The hardest corundum is a light colored variety mined in Georgia. Emery is mined in Turkey, in the Island of Naxos, Greece, and in several places in this country. A very good emery is mined in Chester, Hampden Co., Mass. Westchester Co., N. Y., furnishes a somewhat softer emery than the Chester emery, although it has about the same composition. Westchester county emery is used by the Tanite Co. About three-fourths of all the emery that is imported comes as ballast. It is purchased at the ports of Turkey and Greece, not in proportion to the demand for it in the western nations but as it is needed for ballast, and when it reaches England or America it is sold to a broker. It varies widely in quality, and one must use his judgment in buying from the brokers as no guarantee can be given with the emery, for nothing is known about it. It is crushed in an ore crusher and graded to fineness by screens. The numbers 10, 20, 30, 100, etc., indicate the number of meshes to the inch in the screen. It is graded still finer by decantation. This is called "washed flour" emery. A number of reservoirs have water flowing through them in succession at a fixed rate and the emery which is held at first in suspension is deposited in these reservoirs. Of course the coarser particles settle in the first reservoir. It is marked F, FF, etc.

While corundum is essentially an oxide of aluminum, commercial corundum is far from being a pure oxide. The purest specimen of aluminum oxide on record was a sapphire gem which was 98.5% $Al_2 O_3$. Commercial corundum has from 20% to 40% of impurities, mostly silicates. Emery has from 30% to 50% or more of impurities, mostly oxide of iron. This oxide of iron is frequently magnetite. Corundum is the harder, but as stated before, this is not the only essential to a good abrasive in a grinding wheel. Where the abrasive is to be used as a loose powder, hardness is more to be desired.

There are two general methods of making emery and corundum wheels. One is that used in making "chemical" wheels as they are often called, in which the bond that unites the grains hardens of itself or at a comparatively low heat. The other is that used in making vitrified wheels. In this method the bond is composed of a silicate, usually feldspar (a silicate of aluminum) with litharge, gum copal and japan and sometimes other ingredients, different proportions being used to give different degrees of fluidity when hot and of hardness when cold. The emery and corundum, after being mixed with the bond, is molded into wheels and subjected to a heat of about 1,800°, which melts the bond and there firmly embeds each grain in the wheel.

Wheels known as "hard" have more of the bond than "soft" wheels and hence the grains are held in place longer. But "hard" wheels do not cut as freely as "soft" wheels; that is, when the corners of the grains have become rounded off in use the grain does not break off and allow other sharp grains to operate. This is obviated more or less by using a mixture of emery and corundum in the wheel. The emery is softer and more brittle than corundum and splits off, thus keeping the wheel sharp. Since emery is massive in structure it always leaves sharp, ragged edges when it breaks, so that it keeps the wheel sharp by breaking itself and exposing fresh particles of corundum. While some emery has greater crushing resistance than corundum, it does not necessarily follow that it will not break more easily on the wheel as this depends upon its brittleness.

It is claimed by the makers of vitrified wheels that they are stronger than the chemical wheels, but this assertion is disputed. In the larger chemical wheels a mesh of brass wire is imbedded in the wheel to add to its strength. This cannot be done in the vitrified wheel as the high heat required for vitrifying would melt the brass. But the makers of vitrified wheels say their wheels do not need any such device to strengthen them.

In a wheel known as the "tanite" wheel, the bond is principally or entirely tanite, which is a hard, black substance formed from waste leather by a secret process. This tanite becomes plastic, and may be molded when subjected to heat and pressure; but what process it undergoes in the manufacture of emery wheels is not made public. It makes a very strong wheel. Where a wheel must be very thin compared to its diameter a composition of gutta percha is sometimes used as a bond. Rubber wheels, as these are called, 16 inches in diameter and from one-fourth inch to one-half inch thick, are often run at a periphery speed of more than a mile a minute. Such wheels gum up very quickly, however, if anything oily is used on them.

The average cutting speed for emery wheels is from 4,500 to 5,000 feet per minute. The usefulness of a wheel is much impaired by having the belt too loose or too small. This causes the belt to slip when heavy pressure is brought against the wheel and the wheel then wears away very fast and unevenly.

Wheels are made either of emery or of emery and corundum mixed, the mixture never containing more than one-half corundum, because the corundum is so hard that it will not split off when it becomes dull and the whole grain will not readily break loose as the bond, for safety, must be strong enough to hold it fast. That the face of an emery wheel wears away by splitting of the grains can be readily seen by comparing the size of the grains on the face of a wheel that has been used with the size of the grains on the side. The grains on the face will be of about half the size of those on the sides.

Polishing wheels, or buffing wheels, as they are sometimes called, are made up of wood to any convenient diameter, usually from six to twenty inches, and covered with leather pegged on. Generally this leather is sole-leather, but sometimes it is walrus hide, when the wheel must be somewhat yielding or must be turned or grooved to some special form on the face. To "set up" the wheel, the leather is given a good coat of hot glue and then is quickly rolled in a trough of emery. This imbeds the emery in the glue and when dry the wheel is carefully balanced. It is then ready to be mounted on an arbor and used for polishing. For a finishing polish, a wheel that has been used till it is dull is still more smoothed off by holding a piece of smooth quartz against it and then a greased rag is applied. The wheel will then give an oil polish to the work which makes it less likely to rust. Polishing belts are leather or cotton belts of suitable width, coated on one side with glue and emery. They are stretched over two pulleys and run at a high velocity. They are used for polishing irregular forms and hollow corners and grooves which cannot be reached with a wheel.

Where the abrasive is to be applied in this manner—by means of glue—there is no advantage gained by using corundum, as corundum costs twice as much as emery and the glue does not form a bond strong enough to hold it till it becomes dull.

It should be remembered, in the use of emery and corundum, that hardness is not always proportioned to purity, and abrasive quality is not necessarily proportional to hardness. The abrasive should be suited to the work to be performed. However, perhaps the following general statement may be made: For hardened tools use a rather soft, free-cutting wheel with moderate pressure, while for softer steel and iron use a harder wheel. For tool grinding in machine shops hard corundum wheels are used with a shower of water falling on the tool to prevent drawing the temper. These wheels have almost entirely supplanted grindstones in machine shops, though some shops keep grindstones in addition for finish grinding.

Carborundum, which is being more and more generally used, is a silicide of carbon with the formula, Si C. It has been manufactured but a few years and was patented in 1893. It is the invention of Mr. E. G. Acheson, who attempted to crystallize carbon by dissolving it in melted silicate of aluminum and then allowing it to cool. Instead of getting crystallized carbon he got crystallized silicide of carbon, which is so hard that it may be used to polish diamonds. It is prepared by mixing 20 parts of crushed coke, 25 parts quartz sand and 5 parts of salt, and subjecting the mixture to the heat of an electric arc. The furnace is about six feet long, eighteen inches wide and twelve inches deep. The core of the charge is a layer of coarsely crushed coke twelve inches wide and one inch thick. Four carbon electrodes, each two inches in diameter, are used at each end to bring the current into the charge. The charge is placed around the coke core, and covered with fire brick. The furnace produces about fifty lbs. of carborundum at each heat. It requires a current of about two hundred amperes a good share of the time. The time required for a heat is seven and one-half to eight hours. When the furnace is taken down, three degrees of the charge are found. That next the core is crystallized carborundum, that next this layer is amorphous carborundum and is of no use, and on the outside is found the unchanged portion of the charge. Actual tests of hardness of carborundum compared to diamond have not been made or at any rate not publicly recorded; but when finely powdered it apparently works about as well as diamond dust for polishing gems. The coarser crystals are too brittle to be used for this work so that it is only for finishing that carborundum can be used in polishing gems. It is, however, used extensively for grinding glass, in dental wheels for dentists' use and wherever extreme hardness is desired. It is also used considerably for grinding brass valves. It is also made into wheels for machine-shop grinding, but whether or not these wheels are better than emery and corundum wheels is a disputed question. It is held by corundum wheel manufacturers that if corundum is so hard that wheels are usually made with less than half of the abrasive of corundum, then it is useless to make wheels of anything which is so much harder than corundum, unless a much stronger bond can be made than any now in use. But the objection to the use of all corundum in a wheel was the toughness of the crystals and emery was put in to split away and keep the wheel sharp. The brittleness of the coarser carborundum crystals may make the use of this material in grinding wheels quite practicable, but the results of tests made with carborundum wheels in machine shops seem contradictory; some shopmen favor carborundum wheels and others object to them very decidedly. Possibly as the material becomes better known its use in this line may increase by reason of different treatment in manufacture and use.

At present the comparatively high cost of carborundum limits its use but this objection will doubtless be removed by improvements in the methods of manufacture. If anything approaching a continuous process of manufacture could be obtained the material could be sold at comparatively very cheap rates.

Bort or black diamond is a form of carbon found massive, that is, not crystalline and having no cleavage. It is very hard and tough. In color it varies from gray to black. When powdered it is used for polishing diamonds and other gems. It is set in a soft metal setting and used for trueing up emery wheels. As it is tough enough to withstand the shocks of the emery wheel without splitting, the corners in time become rounded off. Then to resharpen it is best to chip off a small fragment.

There is a great difference in bort; the preference is usually for the darker variety. Though this is not always a sure test it is often used and leads to the practice of blackening poorer and lighter grades.

Crushed steel and steel emery are other new abrasives which are now coming into prominence. They are about the same thing, differing only in the degree of their fineness. The coarser grades are used for sawing stone and the finer grades for rubbing down and polishing stone and metal surfaces.

For sawing stone it is usually mixed with mud and fed to the saw, which may be either a revolving metal disc or a strip of soft steel stretched tightly in a frame and moving backward and forward horizontally. Stone saws usually run in gangs of varying numbers, depending upon the size of the work and the machine. The crushed steel is manufactured by tempering, crushing and hardening. It is in the shape of coarsely crystalline grains which are able to resist great crushing force and retain their cutting qualities for a long time. It is used over and over again in working stone. The sharp crystals charge into the saw and thus save much wear on the saw, and at the same time it insures their having to take the full force of the cut, and allows moderate pressure to be used on the saw.

Crushed steel is made from a poor grade of steel, probably with tungsten or something else besides carbon to harden it.

Chilled iron shot have been used for sawing and grinding stone to some extent. The name describes the abrasive. Different sizes of shot are used together. It cuts the stone by crushing it away. The balls have little more than point contact, owing to the practice of using different sizes together. Of course considerable pressure is required and this is a serious drawback for it is likely to make the saws buckle and run out.

Crocus is an oxide of iron, usually calcined. It is much softer than emery or even than sand, and is used for polishing brass and other soft metals. It is sold in powder or in sticks and is applied to a rag wheel with oil or tallow or a similar substance to make it stick on.

Rouge is a softer oxide of iron and is used in the same manner for polishing plated ware and the like.

French chalk, powdered pumice-stone, lime and other soft powders are used for similar work, depending upon the metal and its softness.

Water stones or razor hones are sometimes of a soft clay stone but the best ones are of white petrified wood.

Oil stones are of a fine grade of quartz. Good oil stones, whether hard or soft, must be even. A stone with either hard or soft spots will soon wear uneven in use and must be trued up. This is best done by rubbing upon a grooved iron block with coarse sand and emery. It may also be done more slowly by rubbing upon sand paper. Oil stone powder is used by jewelers for polishing steel.

COMPARATIVE COMMERCIAL QUALITIES OF ALTERNATING CURRENT MOTORS.*

By W. H. WILLIAMS, B. S., '96, AND J. H. PERKINS, B. S., '96.

The possibilities of long distance transmission and the demands of large central stations for a day motor load have resulted in the development of the alternating current motor, of which the most successful types have been either two or three-phasers. So urgent have been the demands, that although these motors are scarcely yet beyond the experimental stage, thousands of horse-power have already been installed. Thus far little exact data has been published in regard to them,—what has been given out coming mainly from the manufacturers, who, as interested parties, cannot

* Synopsis of thesis submitted for the degree of Bachelor of Science in Electrical Engineering.

be expected to speak impartially of them. Since a 500 volt, direct current motor service can be installed in cities where the distances are not excessive, the station manager wishes to know in considering the possibilities of alternating current motor service, first, if they can be operated from lighting circuits, and second, how their performance compares with that of direct-current motors.

A careful and impartial series of tests, which shows the comparative performance of alternating current motors with each other and with standard direct-current motors would therefore be of great value to station managers and other prospective purchasers of such apparatus. With this purpose in view we therefore ob-

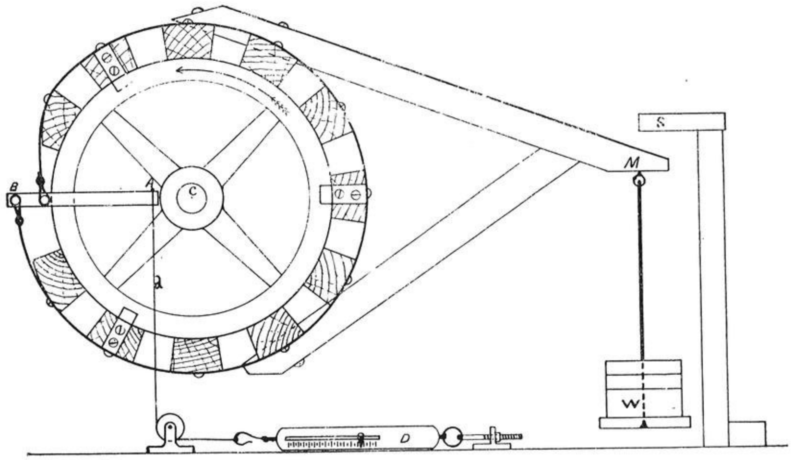


FIG. I.—Self-regulating Prony brake.

tained 5 H. P. alternating current motors of the following makes:

Westinghouse Electric & Manfg. Co., two-phase. Stanley Electric Manufacturing Co., two-phase. Fort Wayne Electric Corporation, self-starting, synchronous. General Electric Company, three-phase. Allgemeine Elektricitäts-Gesellschaft, three-phase. Reliable data was also obtained of recent tests on an Oerlikon three-phaser, and a two-phaser made by C. E. L. Brown. A 10 H. P. Westinghouse two-phaser was also tested.

A 5 H. P. motor is probably about the average size used in central station service; and the tests may therefore be accepted as representing, for central stations, comparative results between the average motors they are likely to use on alternating current systems; and the results may also serve as a basis for comparison between the performance of alternating and direct current motors.

Prof. Silvanus Thompson has stated as the requisites of a good motor:

First: It shall exert a good torque at starting.

Second: It shall be capable of running at a nearly constant speed at all loads.

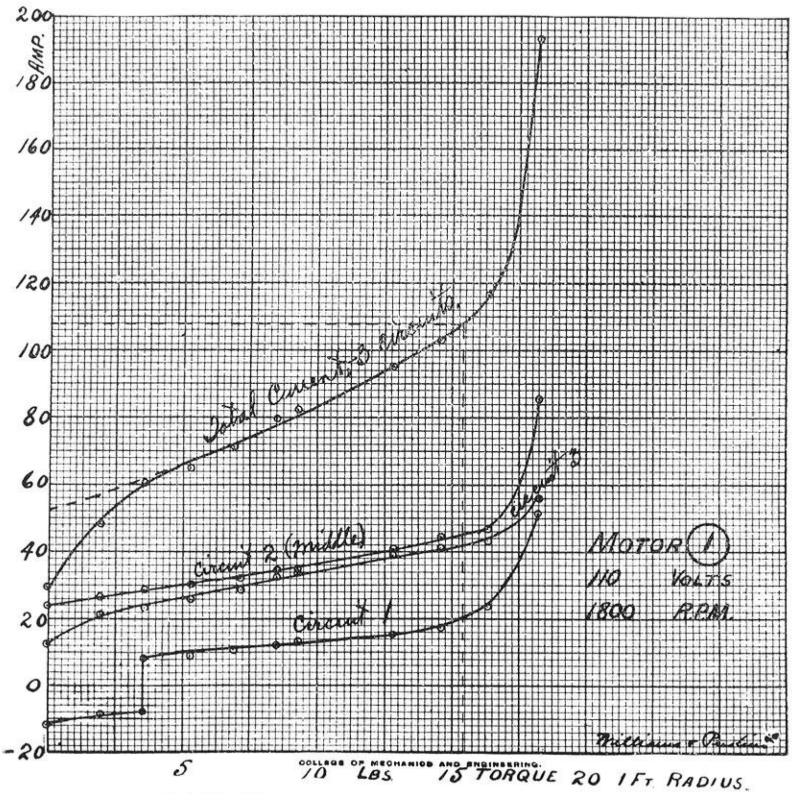


FIG. II.—Three-phase motor on monocyclic circuit.

Third: It shall have a high commercial efficiency.

To these we would add three additional requisites which determine to fully as great an extent the commercial success of the motor:

(a) The motor shall have a high power factor.

(b) It shall not require an abnormally large current from the lines at the instant of starting.

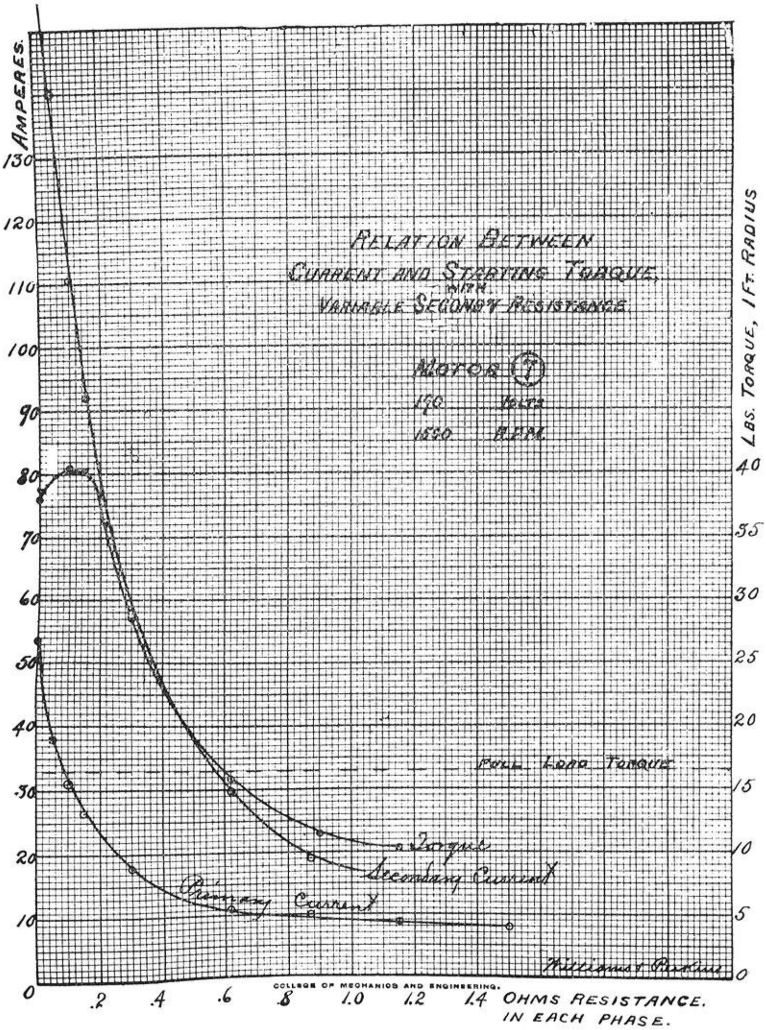


FIG. III.—Effect of variable secondary resistance.

(c) It shall not cause a large unbalancing of the line pressures of a polyphase circuit.

These last three requisites are of vital importance if the motors are to be operated on commercial lighting circuits.

Our tests therefore included:

(a) Starting torque and current.

(b) Speed regulation.

(c) Commercial efficiency at all loads.

(d) Power factor at all loads.

(e) Effect on the line pressures when starting.

The measurements were made by the following methods:

The power absorbed by the motor was measured by direct reading watt-meters, the two watt-meter method being usually employed. Currents and apparent watts were obtained from the readings of ammeters and voltmeters in each circuit.

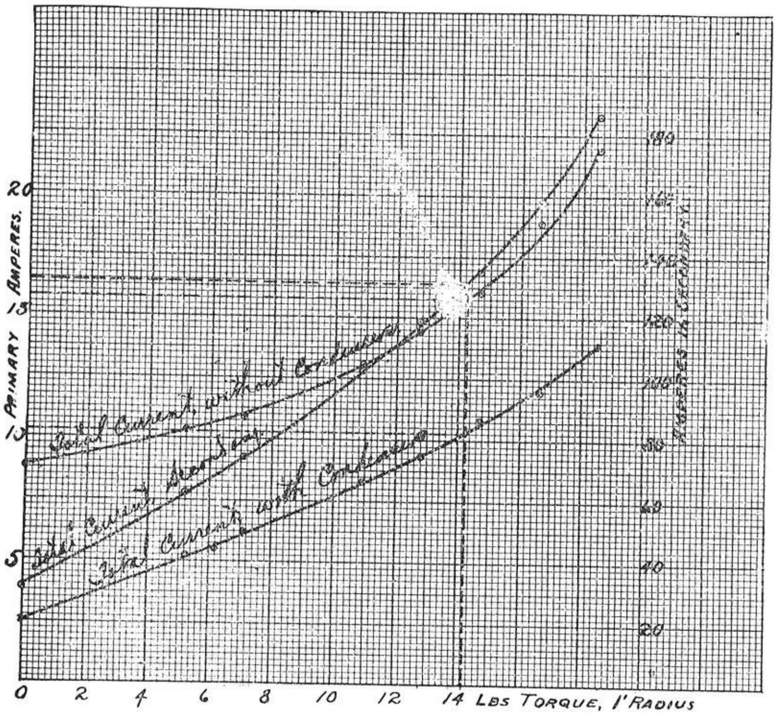


FIG. IV.—Effect of condensers, Stanley motors.

Outputs were measured by a special form of self-adjusting prony brake, shown in the accompanying illustration, Fig. I. This brake is exceedingly sensitive and steady in operation and enables all corrections to be accurately measured. It proved entirely satisfactory, and is by far the most accurate form of brake for this class of work.

Disturbances of the circuits upon starting the motors were determined by observing the effect upon incandescent lamps operated from independent transformers, and by voltmeter readings of the pressures on the lines.

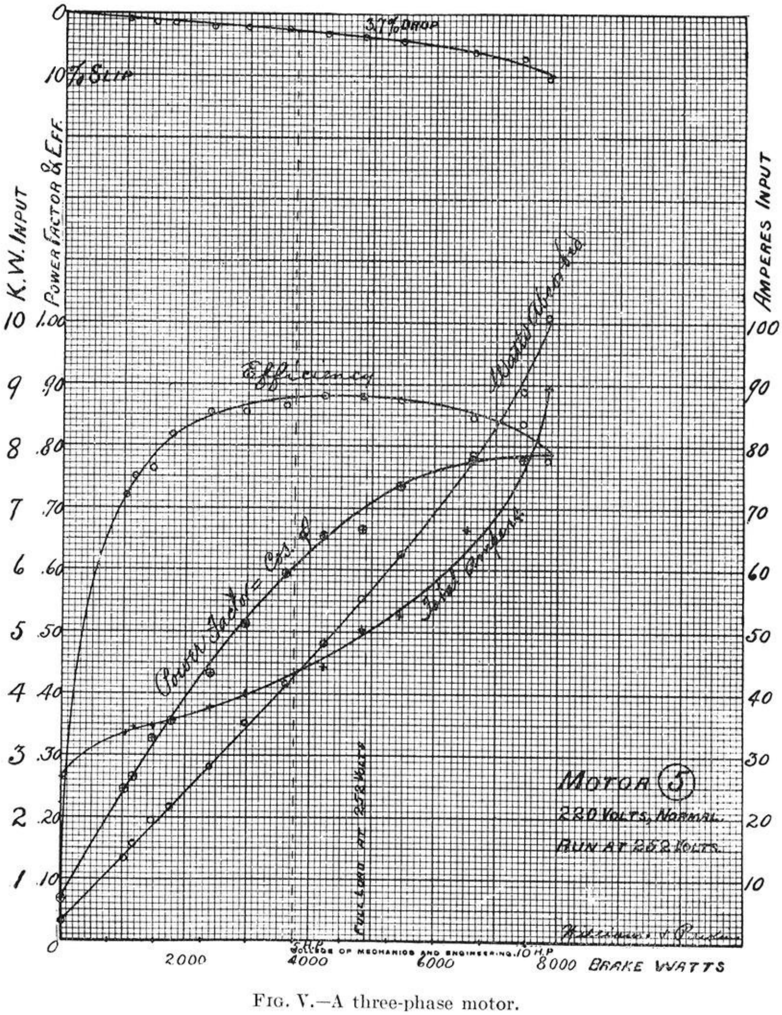


FIG. V.—A three-phase motor.

The *static torque* of the motor was found by clamping the brake up tight and then balancing the pull of the motor. The *true starting torque* was obtained by diminishing the load by successive units until one was found under which the motor would start from rest and pull up to full speed. Starting torque, we found, can be made approximately equal to static torque by using a properly adjusted and subdivided starting resistance.

The accuracy of all instruments used was checked by the laboratory standards.

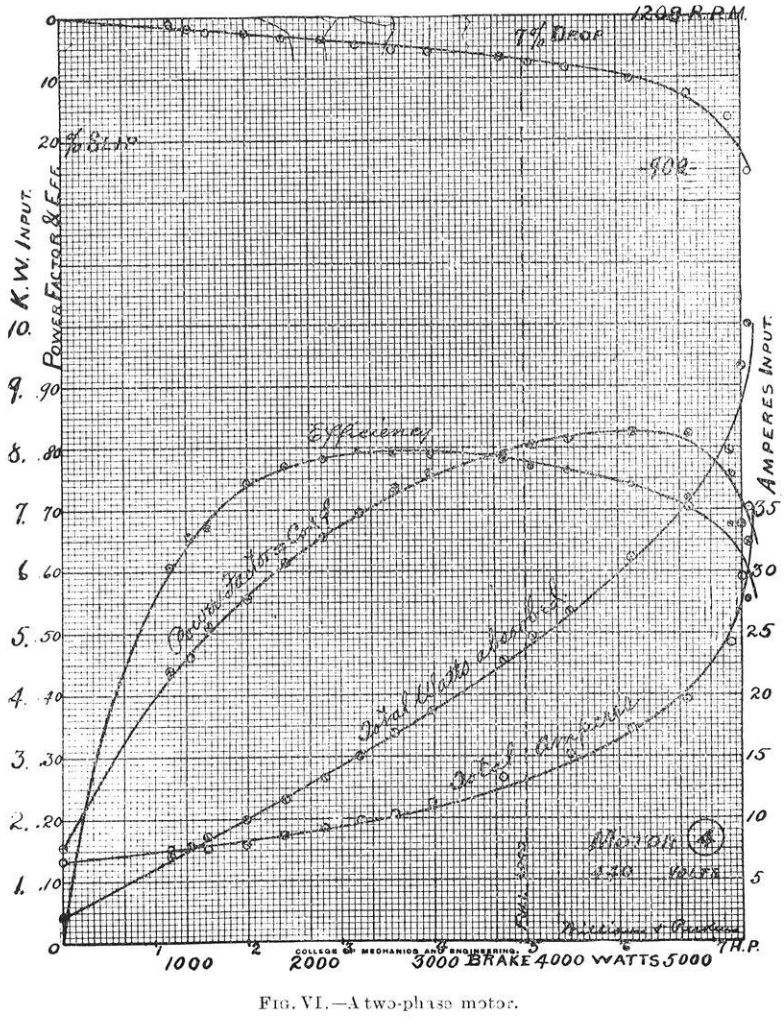


FIG. VI.—A two-phase motor.

The Stanley motor was tested on a Stanley generator circuit, and the Westinghouse motors were run by a Westinghouse generator. Two of the three-phasers were tested on the monocyclic circuit, the two transformers being connected so as to give an unbalanced three-phase circuit. The other three-phaser was tested on a balanced circuit.

Since most of the circuits used were usually slightly out of balance we have used total current (sum of the line currents) in our curves, instead of current in each phase.

The unbalanced three-phase circuit obtained from a monocyclic

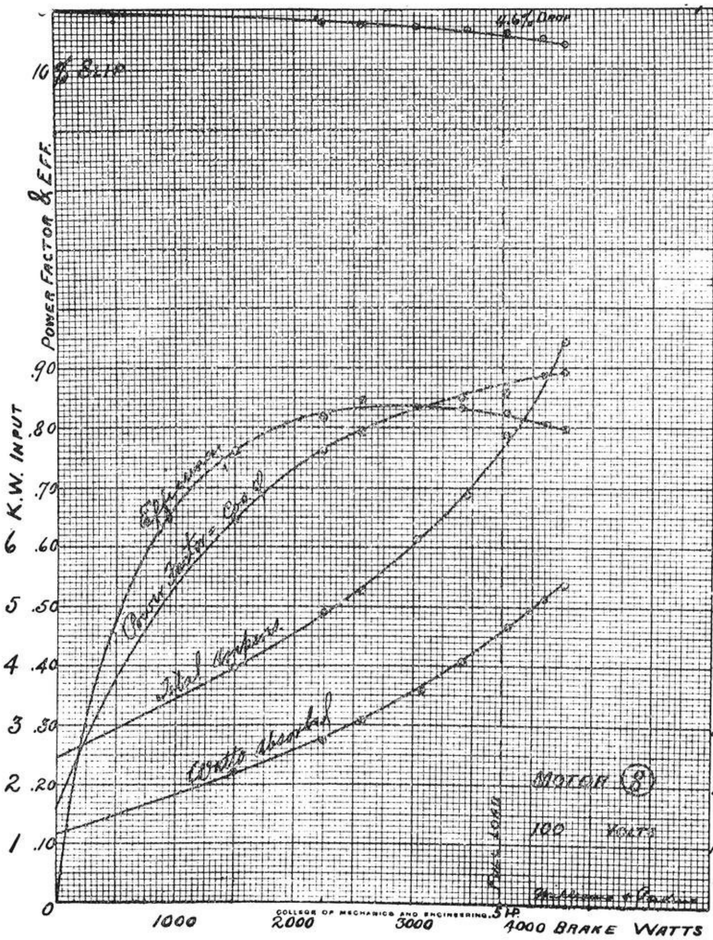


FIG. VII.—A two-phase motor.

generator may cause a peculiar current distribution in an induction motor, which is illustrated in Fig. II. At light loads the lag of current in one circuit of a star wound motor was over 90°,—that is, it acted as a generator.

The relation between starting torque and current is well illustrated in Fig. III. (What is here called *starting torque* is in reality *static torque.*) As will be seen, the use of starting resistance gives a wide range of torque, capable of meeting all service conditions; but *very large* starting torque requires abnormal currents. Kapp has also shown that decreasing the self-induction increases the torque. We also found that subdividing the starting resistance made the true starting torque practically equal to the static torque, since this allows the motor to attain its normal speed by successive steps, and the gradual cutting out of resistance does not lessen the torque sufficiently to cause the motor to slow down. It is evident therefore that with a motor having small self-induction, and a well adjusted and subdivided starting resistance, large starting torque may be obtained without an excessive flow of current. A glance at the table will show that most of the machines tested were not the equals of standard direct-current motors in starting torque; but as indicated above this defect is easily remedied.

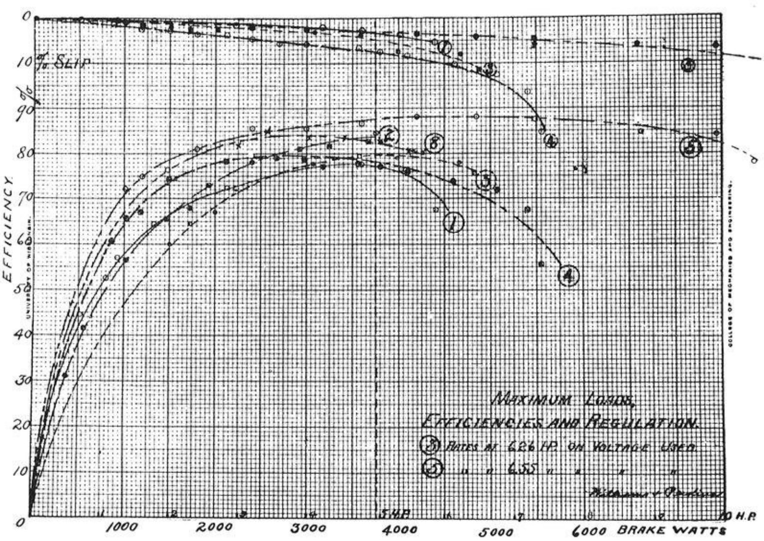


FIG. VIII.—Efficiency curves, alternating current motors.

In regulation and efficiency alternating-current motors are fully equal to the best direct-current motors as will be seen by a comparison of the two sets of efficiency curves.

The matter of power factor is of great moment to central stations; since a low power factor means a larger investment in apparatus, on account of the increased capacity required, hence larger interest charges, and larger line and transformer losses. We found all the American motors, with a single exception, inferior to the foreign ones in power factor. It is our opinion, however, that the two three-phasers tested on the monocyclic circuit would have a higher power factor if run on a balanced system.

The evidence on this point is not conclusive, and the matter will be investigated further. Until power factors of alternating-current motors are improved central stations may well hesitate about using such motors except for long distance service.

Of the six motors tested by us, only two could be started under load without seriously affecting the lights of the system. Both of these motors are of American make and could be thrown on or off with the armatures blocked without visibly affecting the lights. Voltmeter measurements showed practically no unbal-

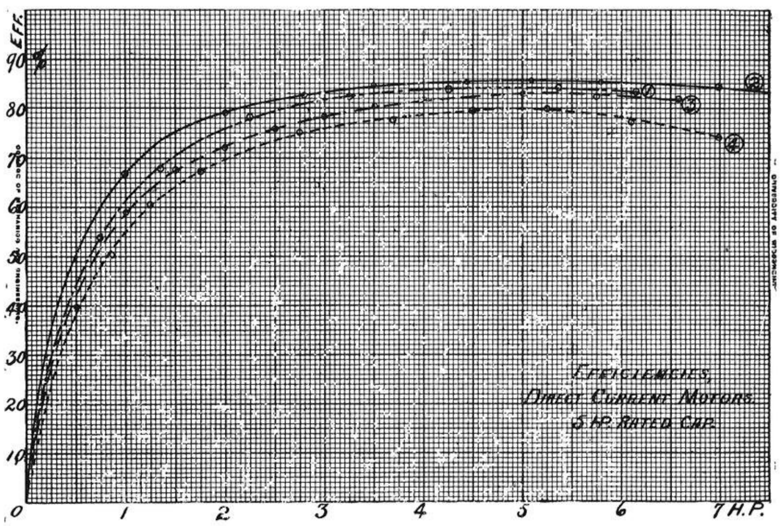


FIG. IX.—Efficiency curves, direct current motors.

ancing of the line pressures. None of the others could be used on commercial lighting circuits where good regulation and the satisfaction of the customers are considered of importance. (It should be noted here that the generators used in these tests were of 75 to 300 K. W. capacity). As evidence of what proper design of motors may accomplish in this respect, the performances of (1) and (5) may be considered. Both were tested on a monocyclic generator of 300 K. W. capacity, running on about one-third load. When started under load a very perceptible winking of all the station lights was caused by (1), while the effect produced by (5) was barely measurable by a sensitive voltmeter.

We noticed also that the line pressures were most seriously

RECAPITULATION — COMPARATIVE QUALITIES.

Number.	Class.	Rated capacity, H. P.	Rating at voltage used, H. P.	Torque, in Per Ct. of Full Load.			Starting current, in per cent. of full load.	Drop in speed, in per cent. at full load.	Efficiencies—Per Cent.					Power Factors—Per Cent.					
				Max. running.	Static.	Starting.			Maximum.	¼ load.	½ load.	¾ load.	Full load.	Maximum.	0 load.	¼ load.	½ load.	¾ load.	Full load.
1	3-P.	5	5	140	131	77	157	3	77.8	55.2	70.6	77	76.6	76.4	13	37.5	50	62.3	71.5
2	Syn.	5	5	100	45	44	153	......	83.8	54.5	72.5	80.5	83 8	67.5	10.5	25.5	58	67.3	64
3	2-P.	5	6.26	104	90	85	114	9.7	79	52	71.9	78.9	77	84	74	81.6	83.3	83.7	84
4	2-P.	5	5	186.5	136	39.4	262	7	79.5	62.2	77.2	79.5	77.8	82.6	15.5	44.7	62.5	73.7	80.3
5	3-P.	5	6.55	171	138.5	86.6	156	3.7	88	75.2	85	87.7	88	78.5	6.8	27.5	45.5	59.8	70.3
6	2-P.	10	10	>147	142	137	194	4.5	82	67	78.4	81.9	81.1	79	15	40.4	59.1	69	73.4
7	3-P.	4.5	4.5	>163	232	......	357	3.7	79.1	61	73.8	78.4	79.1	88.4	22.2	51.3	69.4	80.3	85 2
8	2-P.	5	5	.....	......	......	......	4.6	83.8	65.5	80.2	83.8	82	89	......	52	71.5	81.7	87.2

NOTE.—6, 7, and 8 were not run up to maximum load, on test. 1 and 5 were tested on a circuit badly unbalanced and their power factors have later been found to be larger on commercially balanced circuits.

affected by the induction motors where the generator had a very peaked, irregular electro-motive force curve; and least affected where the curve was practically of the sine form. Our experiments upon this point, however, were not sufficiently extended to make our results conclusive, but we believe they are in harmony with recent theoretical conclusions. An irregular curve of e. m. f. gives rise to harmonics which distort the motor field, thus rendering the motor more of a disturbing element on the line, and also increasing the losses. In two-phase circuits, for instance, the third harmonic, which is the strongest, sets up a rotary field in opposition to the main one, thus also reducing the torque. With a sine curve, all these irregularities and extra losses are eliminated; consequently a generator having a sine curve of e. m. f. should give the most satisfactory service where induction motors are used.

Another fact emphasized by our tests is that central station generators from which induction motors and lights are to be operated should have the smallest possible armature reactions; otherwise when the generator load is light the starting of a motor is sure to affect the lights disastrously.

The reduction of the wattless current and the consequent improvement of the power factor by means of condensers in parallel with each phase of the primary is clearly shown in Fig. IV.

For purposes of comparison, the efficiency curves of several of the latest type direct currrent motors are also here given.

We believe the following conclusions are justified:

First: Induction motors give as good regulation and efficiency as direct-current motors.

Second: They can be made to have, and some of them do have, as good starting torque as direct-current motors.

Third: Their starting torque may be made as high as necessary to suit service conditions without using an excessive current at starting; and only such motors as are guaranteed to do this should be used on commercial lighting circuits.

Fourth: Only generators having small armature reactions, and approximately sine curves of e. m. f. should be used to operate both lights and induction motors for commercial service.

Fifth: Such motors and generators are now furnished by at least two American manufacturers, and therefore it is now possible for central stations to furnish both light and power from the same generators with economy to themselves and satisfaction to their customers.

Sixth: For power distribution the polyphase motor is the ideal motor on account of its simplicity of construction, mechanical stability, sparkless running, and constancy of speed in addition to other desirable qualities already mentioned.

INTERNAL COMBUSTION ENGINES.*

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

I.

The first man to propose the use of explosion to obtain power was the Abbe Hautefeuille, the son of a baker at Orleans. To him belongs the honor of designing the first motor in which heat was used for the generation of power.

In 1678, he planned to explode powder in a vessel in communication with water and utilize the vacuum thus produced to lift the water. Other powder machines were designed and built, but during the next 100 years the attention of engineers was turned to steam and the first to design and construct an actual gas engine was John Barber, who took out a patent for one in 1791. His engine consisted of a pump which forced gas with air into a receptacle where it was ignited and from which, combined with steam, it issued through a nozzle against the blades of a paddle-wheel.

A great improvement in the practical application of gas engines was made by Phillippe Lebon, a French engineer who obtained a patent in 1799 on the production of gas from coal, and a second in 1801 in which he proposed to utilize this gas to drive a piston in an engine very similar to that designed by Lenoir sixty years later. The inflammable gas and a sufficient quantity of air to make it ignite were introduced separately into the cylinder on both sides of the piston, and the inventor proposed to fire the mixture by an electric spark. The machine was double acting,

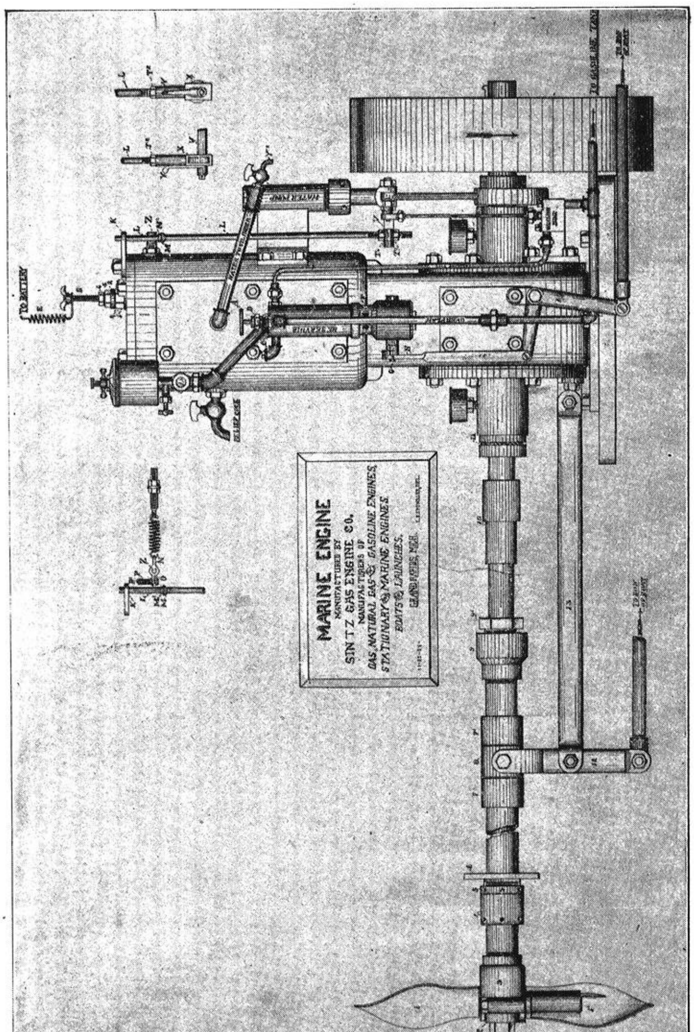
* A thesis submitted for the degree of B. S. in mechanical engineering; received pecial honors.

and the explosions of gas took place alternately on each side of the piston. The piston rod worked not only the motor shaft but through it the two pumps in which the gas and air were compressed before they entered the motor cylinder. Lebon also suggested that the machine generating the electric spark should be driven from the motor shaft. The excellent theoretical principles on which this machine was designed were striking at that early period, and marked a new era in gas engines; but more than sixty years elapsed before the great advantages Lebon had so clearly understood, of compressing the gas and air before ignition, were fully realized.

The next engine of note was that of Barnett, patents for which were taken out in 1838. The first had one working cylinder, single acting. Gas and air were drawn in and compressed by two pumps, and passed into a receiver below the motor cylinder where they were mixed. During the down stroke of the pumps, while the charge was being compressed into the receiver at a pressure of about 25 lbs. per square inch, the return stroke of the motor piston was discharging the burnt gases through the exhaust. All three pistons moved simultaneously up and down. As the motor piston reached the bottom of its stroke, a valve at the side opened communication with the receiver. At the same time a revolving ignition cock immediately above the exhaust fired the charge issuing from the receiver, and, as the crank passed the dead point, the burning gases entered the motor cylinder through the admission port and impelled the piston upward. Barnett may justly claim the honor of having been the first to introduce compression of the gas and air in a practical shape as now used in gas engines.

Up to 1860, the designs for engines were numerous and many were built. Certain conditions came to be recognized. The heat generated was so great that it had to be carried off as quickly as possible, and even with water jackets on the cylinder, parts of the engine somtimes became red hot. It was also impossible, in a double acting engine, to compress the gas and air before ignition, and expansion of the gases was also greatly limited. It was some time before inventors came to know that the discharge of the products of combustion at high temperatures was a great loss of energy.

Barsanti and Matteucci, in England, sought to overcome this



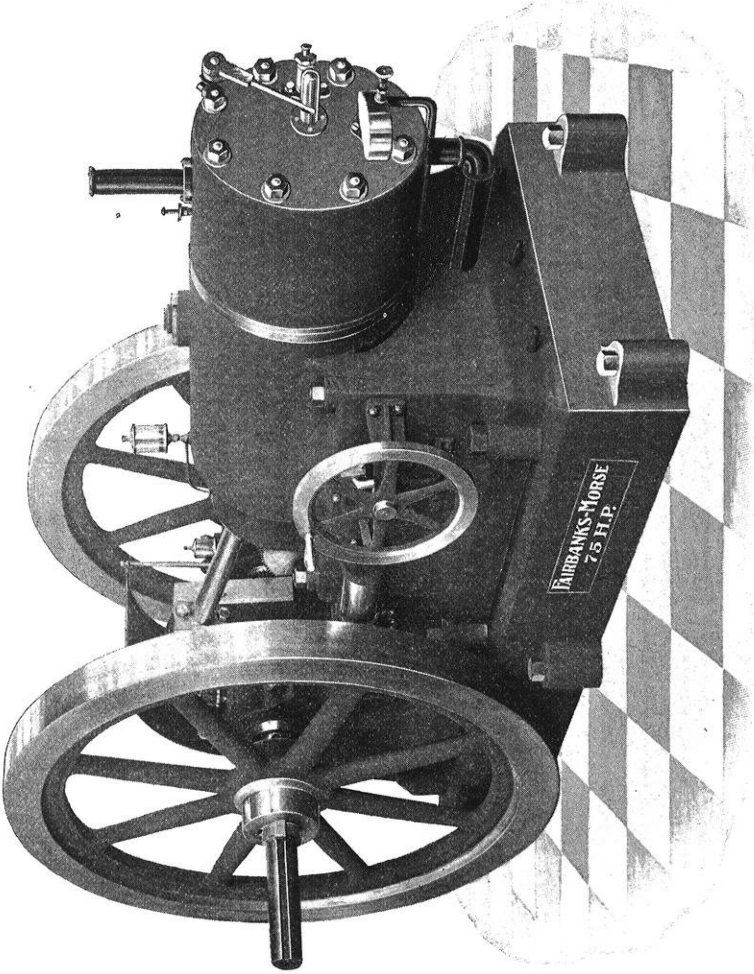
Sintz Gasoline Engine adapted for boat propulsion.

difficulty by their vacuum engine. A long cylinder was provided in which was a piston free to move out, but which clutched the shaft by means of a ratchet and gear on its return. During the early part of the out stroke the mixture was drawn in. At a certain point it was fired by an electric spark and the piston pushed rapidly out until the atmosphere without and the vacuum within stopped it. The vacuum was further increased by the cooling of the gases and the piston, in consequence of this and of its own weight, was drawn forcefully in, doing work on the shaft. While this motor was not a success owing to its mechanical construction, its cycle was good as it utilized to the fullest extent the expansion of the gases.

We have now gone over in brief the purely experimental period of the gas engine and come now to the period of application, which began about 1860. Great as was the perfection to which steam engines had been brought, it was felt that they did not and could not supply all the various requirements for an economical motor. The necessity for some other kind of engine had already been pointed out by Chevarton in 1826. In a letter to the Mechanic's Magazine, he says: "It has long been a desideratum in practical mechanics to possess a power engine which shall be ready for use at any time, capable of being put in motion without any extra consumption of means, and without a loss of time in its preparation. These qualities would make it applicable in cases where but a small power is wanted, and that only occasionally required. They are so numerous, and the consequent saving of human strength would be so great, that the advantages accruing to society would be immense, even if the current expense were much greater than that of steam." No words could better describe the present advantages of the gas engine.

In 1860, much had been achieved by mechanical ingenuity in the construction of the gas engine. All the parts had been designed and the details thought out. Scarcely a single improvement has been suggested in modern engines, which may not be found in the drawings of Lebon, Barber, Street, Barnett, and others. In the words of Professor Witz: "The gas motor had been invented; the problem was how to make it a working success." It is here that we enter on the second period of application.

The first practical working engine was that of Lenoir. It resembled in construction a double acting horizontal steam engine, and the gas was fired electrically. Gas and air were admitted at both ends, drawn in by the piston during the first part of the stroke, and then fired and expanded. Admission of the charge was cut off either at half stroke or a little later. The cylinder, both covers, and the chamber into which the gas was admitted were water-



Fairbanks-Morse 75 H. P. Gasoline Engine.

jacketed, and the circulating water was used over and over again.

Hugon, in 1862, introduced the flame ignition and forced a jet of water into the cylinder in order to keep it cool, lubricate it, and increase the efficiency. The injection of water has since been proven to be of no advantage.

At this time very little scientific work had been done on the gas engine. Those experimenting with the motors recognized the great waste of energy without being able to better their work. They could not tell why one engine worked better than another. Any one who has experimented with the gas engine is able to appreciate their position. About this time (1862) a remarkable patent appeared in France by Beau de Rochas. He pointed out that the reasons for the extravagant working of these engines were incomplete expansion, lack of compression, and loss of heat through the walls. He laid down as conditions essential to good efficiency:

I. The largest cylindrical volume with the smallest circumferential surface.

II. Maximum speed of the piston.

III. Greatest possible expansion.

IV. Highest pressure at the beginning of expansion.

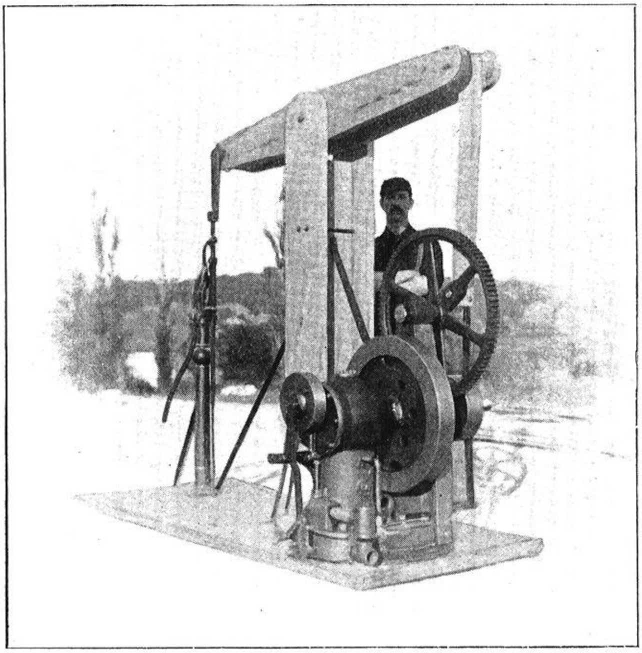
These rules have not been improved upon even to this day; and the intelligent inventor has, since these conclusions were brought out, worked to produce mechanism which would best fulfill these essential conditions. Large cylinders were used instead of multiple cylinders as the cylindrical volume increases as the cube of linear dimensions, while the surface of walls increases as the square. The wall surface exposed being smaller, less heat passes through it. As the absorption of heat by the walls is a function of the time, a higher piston speed is desirable. In order to avoid great waste through the exhaust the expansion should be utilized to the fullest extent. In order to obtain a good range of expansion, and for the best combustion, a high pressure at the beginning of expansion is desirable. This cannot be obtained without previously compressing the charge. Beau de Rochas not only put forth the conditions but proposed a cycle of operations for realizing their accomplishment. He proposed a single cylinder in which was to be carried out in four consecutive strokes:

1. Drawing in the charge of gas and air.
2. Compression of the same.
3. Ignition at dead point, with explosion and expansion.
4. Discharge of the products of combustion from cylinder.

This is the cycle upon which the best modern gas and oil engines are founded.

In 1866, Otto and Langen brought out an engine somewhat along the lines of Barsanti and Matteucci. In an earlier patent they say: "Experience has shown that the interval of time between the heating and consequent expanding of the gases, and the subsequent cooling with consequent contraction, is but a very short one, and therefore, in applying the expansive force of such heated gases as motive power, unless they are allowed to expand very rapidly—immediately after combustion has taken place—a great portion of the heat which should have produced such expansion will be absorbed by the cylinder walls of the engine, and consequently, a great part of the motive power will be lost."

The principle of their engine was to obtain the most rapid and complete expansion possible. In theory their premises were true and their engine realized an economy, 26 cu. ft. of gas per H. P.



Gasoline Engine attached to ordinary windmill pump.

hour, in excess of any engine up to that time, and which compares favorably with engines of the present day. About 5,000 of these motors were built. They were not a mechanical success, but they approached more nearly to being such than did the motors of Barsanti and Matteucci where the principle employed was the same.

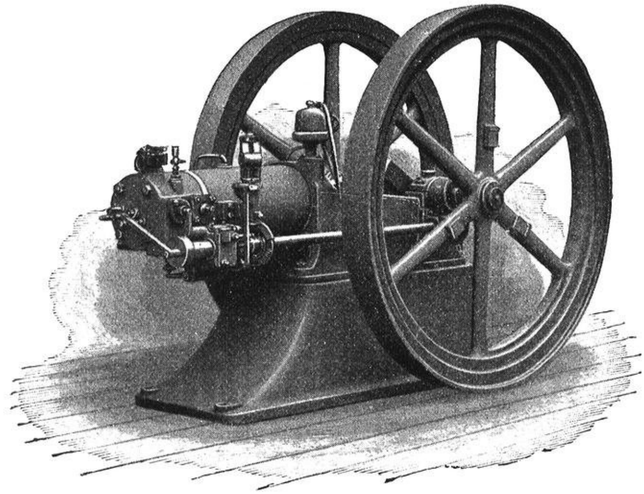
In 1872, Brayton introduced at Philadelphia a motor which promised well. He was the first to employ ordinary heavy oil and kerosene. His engine employed the principle of combustion at constant pressure instead of at constant volume. The charge of gas and air was ignited before its admission into the cylinder, entered in a state of flame, and drove the piston forward without any rise in pressure. A steady combustion was maintained during one-third of the forward stroke, and then expansion took place. The return stroke expelled the products of combustion. A gauze diaphragm prevented the flame from igniting the supplied gas too soon. Two pumps supplied the oil and air at the pressure of explosion. The system of breaking up the petroleum by a blast of air forced into it, rendered possible the use of heavy oil. Brayton was therefore the inventor of the first safe and practical oil engine.

Until 1876, no engine had been constructed which carried out completely the cycle outlined by Beau de Rochas. During this year Otto brought out a motor working according to this cycle and with it obtained results of economy never before realized. The exact reasons for increased economy were not known to the maker of this engine. He attributed the good results to a stratification of the charge.

This engine was single acting. A clearance space equal to about 40 per cent. of the stroke was left in the cylinder into which the piston never entered. The out stroke of the piston sucked in the charge; the return stroke compressed it; ignition took place at the dead point; expansion existed during the entire out stroke; and the next back stroke drove out the exhaust, leaving, of course, the clearance space full at atmospheric pressure. His distributing valve was so arranged that pure air was admitted first, then a weak dilution of gas, and finally pure gas, into which the ignition flame passed. He thought thus to propagate the combustion by degrees and obtain a cushioning from shocks. He supposed that next to the piston existed a charge of the exhaust; then a weak layer of gas and air, and further back in the admission port a rich charge easy to ignite, and attributed his success to this arrangement. His conclusions were faulty, however, as experiments have been instituted which showed no such arrangement. A glass cylinder containing a piston was provided with an admission port at the same point as in the Otto cylinder, and smoke was drawn in during the out stroke of the piston It was found that at the beginning of the stroke the smoke entered in a stream which continued to the piston where it was reflected back and mixed completely with all the contents of the cylinder.

Otto's success was due, however, to the introduction of compression, and, as recommended by Beau de Rochas, carrying out the entire cycle in one cylinder. His success was also no doubt due largely to his good mechanical design and construction.

Few engines more ingeniously constructed than the Otto have yet appeared, and even now, when so many later motors have been brought out, it is still one of the most economical. The German firm had, up to 1892, constructed 35,000 engines, while many other firms in Europe and America have been putting them on the mar-



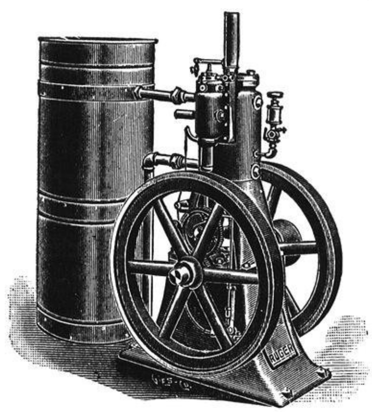
Otto Gasoline Engine.

ket in large numbers. Many changes in detail have been made. Hot tube and electric ignition have been introduced and in most modern engines, including the Otto, makers have discontinued the use of the slide valve, and use in its place lift valves. In general, the proportions of the cylinder have not been changed; the ratio of stroke to diameter being 2 : 1.

It is now generally recognized that the cycle of Beau de Rochas should be carried out to obtain a good engine, but the mechanism which is to do it is a subject for much study. The Otto engine is open to the objection that it gives only one impulse for four strokes of the piston. This causes some irregularity of motion and necessitates a heavy and cumbrous construction. In order to remedy these defects, Clerk brought out in 1880 an engine giving an impulse for every two strokes. Of the four operations of the cycle, Clerk proposed to transfer the first to an auxillary cylinder called the displacer. The gas and air were drawn into the displacer and slightly compressed. The action of the engine was as follows: The charge being compressed in the cylinder and the engine at the dead point, it was fired. Expansion took place during most of the out stroke when the piston uncovered holes in the cylinder through which the products of combustion passed. Soon after the uncovering of these holes, and before the expansion stroke had ended, communication with the displacer was opened and the charge of gas and air, already slightly compressed in the displacer, rushed in and cleaned the remaining burned gases out through the exhaust ports. As soon as the piston returned sufficiently to cover the exhaust holes, compression began and continued during the back stroke, and at the end of this ignition was effected. Of course some mixture of the incoming charge and the burned products took place, and Clerk endeavored to overcome this by the shape of the cylinder. He made the clearance space conical in form and introduced the charge at the small end, hoping to push the contents of the cylinder before the incoming charge without much mixture. Great care was used in determining the volume of the displacer so that as little as possible of the new charge would pass out of the exhaust, and so that the greatest part of the burned gases might pass out. This engine, it is said, worked with some economy, the consumption of gas of a rich quality being a little over 20 cu. ft. per I. H. P. hour in a 12 H. P. engine. It was not, however, a perfect success and its manufacture was discontinued.

Some experimenters thought that the burned gases remaining in the cylinder to be mixed with the new mixture caused a loss of economy, and engines with six strokes in the cycle were built. The best example is the Griffin. Its cycle was, 1st. admission of charge; 2nd. compression; 3rd. explosion and expansion; 4th. expelling the products of combustion; 5th. drawing in air; 6th. expulsion of charge of air. The defects of this cycle are: the want of regularity in the speed, and the loss of power due to the small number of ignitions, there being only one motor stroke in six. This fault was in part overcome in the Griffin by using both sides of the piston. No greater economy was secured by the scavenger charge of air as what was gained by the increased purity of the charge was lost in the increased friction of moving the engine through another revolution per explosion. It was also found that the cooling influence of the piston rod lowered the pressure on that side of the piston by taking away heat.

Another engine which is worthy of note is that of Atkinson. By an ingenious toggle connection between the piston and the crank he succeeded in securing four strokes of the piston to one revolution of the crank, and in varying the length of stroke so as to obtain undoubtedly the most perfect cycle ever invented for a gas engine. The cycle was a short out stroke of the piston, from



A Ruger 5 H. P. Gasoline Engine.

a very small clearance space, which sucked in the charge; then a still shorter back stroke of compression, at the end of which the charge was ignited and expanded through a long out stroke of the piston, securing the full benefit of the expansive force; the return stroke brought the piston back nearly to the head, completely expelling the burned products. This engine on trial gave a small consumption of gas, yet it was not a successful engine as it was large for the power developed. The speed was low as the parts could not be balanced for high speed.

Another engine whose simplicity is noticeable is that invented by Day of England, and which goes by the name of the Sintz type in America. Its cycle of operation is accomplished in the same order as the Clerk, but instead of a displacer cylinder the crank end of the cylinder is surrounded by an air tight case in which the crank revolves. The only valve on the engine is an automatic lift valve operated by the suction of the mixture into the crank case. The operations are performed as follows: The piston being at the top of the stroke with a compressed charge above it, ignition takes place and expansion forces the piston down doing work on the crank and compressing slightly the charge in the crank case. Near the end of the stroke the piston uncovers a port in one side of the cylinder and exhaust takes place. Still nearer the end of the stroke a port in the other side of the cylinder, which leads to the base, is uncovered and the mixture there slightly compressed rushes in, driving before it the exhaust. Soon after the piston returns covering the ports, compressing the charge above it, and sucking in a new charge below, completing the cycle at the dead point.

We now have before us in the preceding pages the most important work which has been done in developing the internal combustion engine. After perusing all the publications on the subject which we could secure, we selected the motors which we have for description because each was the chief representative of its class. The designs which have been gotten out and which have been tried number into the thousands.

(To be continued.)

ELECTRIC MOTORS IN FACTORIES.

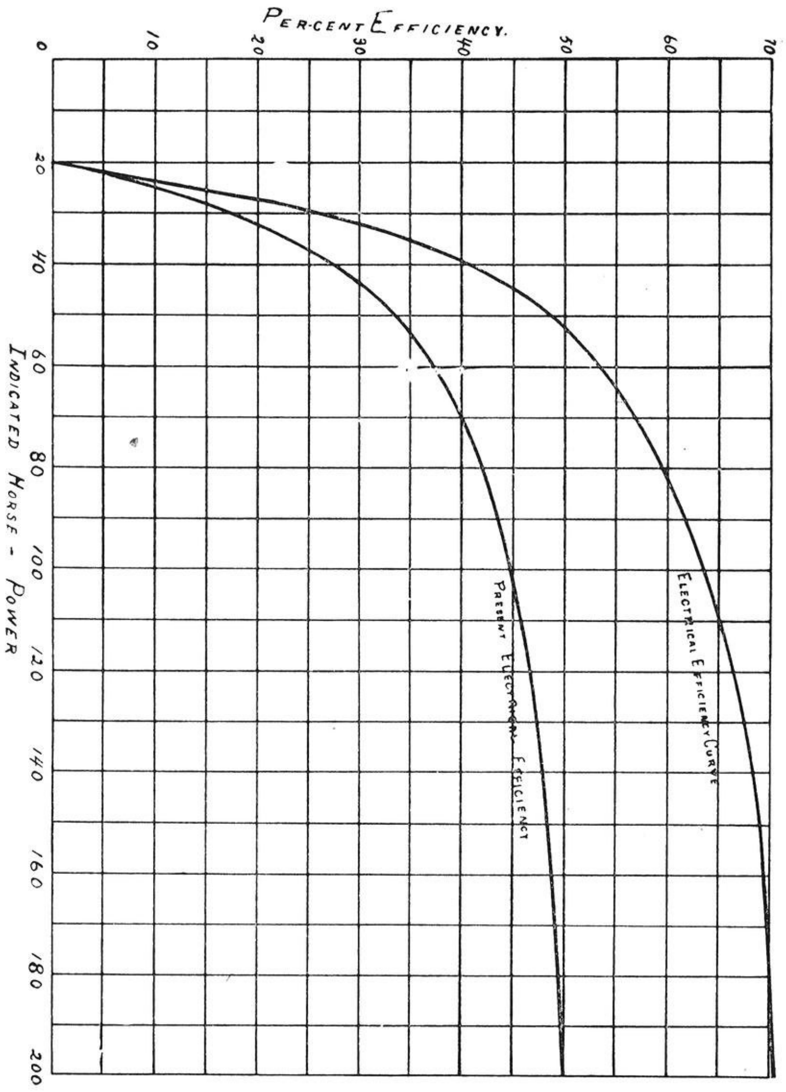
By C. M. CONRADSON, '83; M. E., '85.

In machine shops and factories electric motor driving has in many cases displaced belt and shaft transmissions, sometimes with very favorable results and many times with doubtful economy. In many instances the receipt for making an electrical transmission is as follows: "Leave as much of the line shafting, belting and gearing as possible. Belt a large motor to the line shaft, being careful to set it on the floor where it will be as much in the way as possible. Turn on the current and trust to luck." Contrary to common opinion it is very easy to make an electrical transmission very uneconomical The writer is a believer in direct connected motors wherever possible even on the smallest tools and machines. In existing plants of course it is frequently impossible to direct connect but it should be done in every new plant. Many engineers have other views, however. Quoting from "The Iron Age" of May 28:

First: "When the tool requires only a fraction of a horse power for its operation, it is not the best practice to drive it by means of a motor, the first cost of which would, perhaps, more than counterbalance the benefits arising from its use. To put this more broadly, the tools found in the usual shops, and which vary largely in the power they need, cannot all be driven economically by individual motors, or single units, for each machine."

There may be some truth in the above statement at the present time due to the fact that suitable mechanisms have not yet been developed for connecting the motor to the tool in an economical and efficient manner. This difficulty will rapidly disappear, however, as soon as machine shop proprietors (naturally the most conservative of men) appreciate the enormous advantages to be gained by direct electric driving of each tool, and competent engineers take hold of the problem of designing such connections. There is an enormous amount of new work to be done by machine tool designers, however, before it will be possible to apply motors directly in a thoroughly satisfactory manner.

Many of the combined motors and machine tools that have been brought out so far are very crude. Quoting from a letter received from a distinguished mechanical engineer ("They look as if the designers have just come out of the backwoods and ought to return there.") Some of the most pretentious attempts at combining electric motors and machine tools show the worst engineering. The machine tool to be driven must be harmonized with the driving motor. The method of connection must be simple, effective, durable, efficient and cheap. The requirements of each kind of machine tool must be specially studied and the necessary modifications made both in the machine tool and motor. The arrangement required for an engine lathe will not answer for a planing machine or an automatic screw machine. As soon as it is possible to secure motor driven tools properly designed for the work they have to do there is not the slightest doubt that they will displace shaft and belt driven tools. This is equally true both in the installation of new plants and in adding new tools in an old plant because the motor driven tool can be set anywhere without being forced to fit itself to existing lines of shafting. It is a fact well known to every works manager that it is impossible to arrange belt-driven tools in such a manner as to cover a given floor space to the best advantage. Frequently a line shaft becomes so filled up with pulleys that it is impossible to find room for the necessary driving pulleys for the new machine, while at the same time there may be ample vacant floor space. It then becomes necessary to put up another short line shaft or else locate the machine in some other (perhaps much less desirable) point where it is possible to belt to countershaft. It is generally forgotten in comparing belt driving with motor driving that the machine tool must be charged with its share of the cost of the building in which it is located, as well as its share of the cost of the entire transmission plant. In the first case the total amount of space utilized for machine tools must be charged pro rata to the various tools, including all waste space; as for instance that directly under the line shaft, which is generally unavailable. The cost of the transmission plant should be pro rated proportionally among the various tools according to the amount of power required by each. To obtain the running expense, interest, and all expense for the power plant, depreciation, taxes, insurance, repairs, etc., must be charged proportionally to each tool. When the total first cost of installing a tool is figured out on this basis it will be seen that the first cost of the tool itself is not the only item to consider in installing the tool. There may be considerable space wasted directly due to the fact that the tool is belt driven and that its location is therefore fixed by other considerations than those of economy of manufacture. It is safe to say that motor driven tools will not occupy more than sixty per cent. of the floor space of corresponding belt driven tools; hence a large saving in the cost of the shop chargeable directly to the tool. This percentage will vary with different shops, but the above figure has been obtained by actually comparing an existing modern shop with a proposed plant of the same tools motor driven and arranged in better shape for economical work. In the motor and line shaft driven shop there is no advantage obtained over the ordinary belt and line-shafting transmission. In the motor driven shop there



FIG, I.

will be no main belting, jack shaft, main and secondary line shafts, pulleys, hangers, etc., the net cost of which will be saved and which can be applied for the purchase of motors and the necessary electrical equipment. Furthermore in a new plant a large saving can be made in the cost of the shop itself due to the fact that the framing can be made much lighter, as there are no line shafts or countershafts to support and the sole function of the framing will be to support the roof. In a line shaft driven shop the friction load in the shaft transmission is practically constant and it is not diminished materially even if all of the tools are stopped. In the motor driven shop under like conditions there is no power being used chargeable to the transmission excepting enough to overcome the friction in the generator. In an all electric transmission the efficiency from the engine shaft to the machine tool will not be less than seventy per cent. (at fair loads with scarcely any loss when the driven machinery is shut down.) The best that can be done with line shafts driven by electric motors gives an efficiency of from 20 per cent. to 30 per cent. less, depending upon the condition of the shafting and amount of load.

The writer has just completed a power test of about two hundred machines in a large factory to determine if electrical motor driving can be profitably substituted for the present belt, shafting and gearing transmission. A test of a new electrical transmission recently installed in another factory owned by the same firm has also been made to determine the efficiency actually obtained and to secure such further data as might be available in making the new installation. The curves shown on Fig. I. represents the actual electrical efficiency of the present plant and the expected electrical efficiency of the best possible plant that can be installed to do the work.

Fig II. shows the efficiency of the belt transmission of the old plant and also shows the electrical efficiency expected from an electrical transmission where as many as possible of the motors are direct connected. In this case the old engines will be retained, which reduces the efficiency somewhat. To operate the 249 machines a total of 124 motors is recommended. About 80 of the machines will be direct connected. It will be readily seen that the electrical transmission as at present running does not show any economy over belt transmission. It is about 17 per cent. less than would be obtained by a rope transmission accomplishing the same purpose, i. e., driving a line shaft 150 feet long at a distance from the engine room. The specific reasons for the poor economy shown by the electrical transmission are as follows:

1st. The generator is driven by a countershaft belted to the engine by a nearly vertical belt.

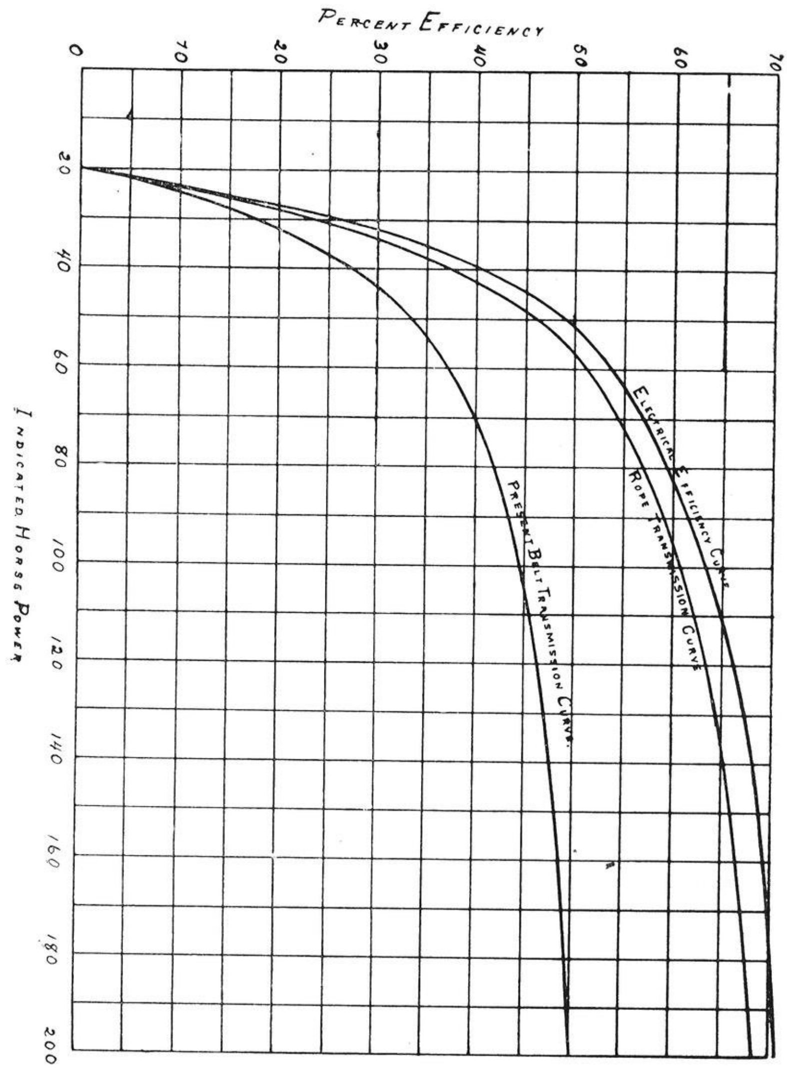


FIG. II.

2nd. The belt from the countershaft of the generator is also nearly vertical.

3rd. The motor installed for driving the line shaft is so large that it is only loaded from 30 to 35 per cent. of its rated capacity.

4th. The motor is belted to a line shaft, causing considerable friction.

5th. The line shaft is out of alignment.

6th. The belt transmissions from the line shaft and countershaft to driven machines causes further unnecessary loss.

Leaving efficiency out of consideration, motors should be direct connected because it was shown in the test referred to above that on the average but 55 per cent. of the machinery was in operation at one time and this at a time when every foreman was specially instructed to put on as much load as possible. There is every reason to believe that under average running but 30 to 40 per cent. of the machinery will be in operation at any one time.

In the factory operated by line shafts and large motors the motors will necessarily be running all the time unless the entire department is shut down, consequently large losses will result if there is a breakdown in the motor. In a factory of the kind tested operated by direct driven machinery the motors will last much longer as they will be in actual operation but one third to one half of the time. A breakdown in a single motor will cause no more delay than is caused by the failure of a belt lacing.

Quoting further from the Iron Age: "Grouping these tools and operating them from a short length of counter shafting, possesses decided advantages. In this method the aggregate power required is less than would be the case of individual motors and the first cost of the plant is greatly reduced." All other conditions being equal there is but one reason for greater aggregate power being required in the case of individually driven tools than in the case of shaft driven tools, and that reason arises from the fact that very small motors cannot be made so efficient as the larger sizes. As a matter of fact, however, the loss from this source will be comparatively slight, especially when the large net saving of power that arises from individually driven tools is taken into account. From the very fact that it rarely happens that the power required is the sum total of the maximum required for each tool, arises the chief economical advantage of the individually driven tool as compared with the shaft driven tool with the direct electric motor drive. Absolutely no power is being used except when the tool is doing useful work. It seems that this writer has confused the maximum power required by an individual tool with the total aggregate power required to drive a complete plant. It is true the cost of the electric motors for an individually driven plant will be much more

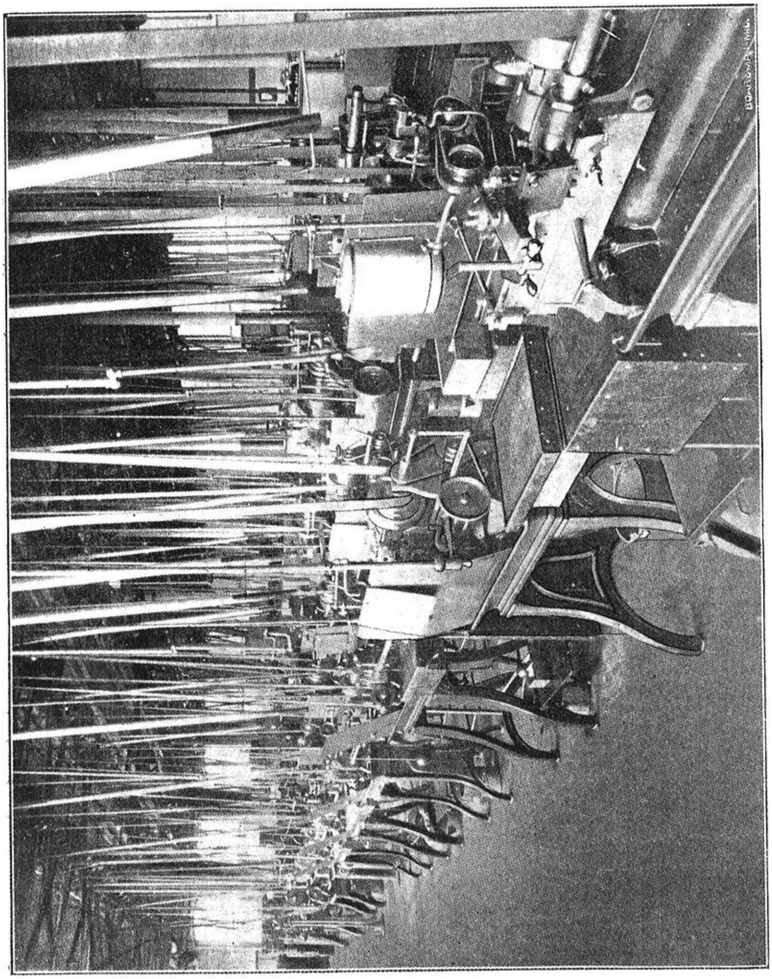


Fig. III.

than the cost of motors for driving by short lengths of shafting. It is not true that the aggregate power required to drive a whole plant will be greater. On the contrary, there is every reason to suppose that it will be much less. It is almost impossible to give accurate figures in this branch of engineering, as very few reliable tests have been made of the power required for operating tools. Some of the tests that are on record are peculiarly amusing. An electrical engineer of high standing naively states that a "small lathe operating on a light cut," requires at 110 volts, 1.14 amperes, equivalent to 1.68 HP. The volts, amperes and HP. required are accurate to the second decimal place. Such comparatively unimportant details as the size of the lathe, the diameter of the work being operated on, the kind of metal, cutting speed, rate of feed, kind of cutting tool, etc., are passed by. The reason why motors are being put in to operate short lengths of shafting at the present time is because the manufacturers of machine tools and electrical motors are in this particular very much behind the times. The writer does not pretend to have any prophetic instinct but will venture the assertion that all ordinary machine shop tools will be electrically driven in less than five years. There are other considerations besides economy of operation, which will be apparent from an inspection of the machine shop interior shown. This photograph is from probably the best arranged manufacturing plant in the world and certainly shows some of the disadvantages of belt driven machines without much argument.

The following conclusions seem to be true:

1st. The most efficient means of transmitting power to machine tools is by means of electric motors directly connected to each tool.

2d. The cost of the necessary electric motors for such a transmission is considerably more than if the line shaft method is used but the total cost of plant need not and probably will not be as large.

3d. The efficiency of the direct connected plant will be at least 10 per cent. higher than of the line shaft driven plant.

4th. The cost of maintenance of the transmission plant as a whole will be about the same in each case.

5th. Motor driven machine tools can be arranged in any way desired and frequently with considerable economy in floor space over belt driven tools.

6th. There is no loss of power and no wear and tear of loose pulleys and shafting when the machinery is not employed.

7th. A motor driven shop would be much cleaner, as there would be no overhead countershafts and belts to throw oil.

8th. The light in the motor driven shop will not be obstructed by vertical belts.

9th. The cost of a machine shop building for motor driven tools will be materially less than necessary for the line shaft driven shop.

10th. There is nothing to obstruct the free movement of either jib or traveling cranes in the motor driven shop.

11th. Properly designed motor driven tools will be much more efficient than ordinary belt driven tools.

12th. The direct motor driven plant will be more durable; break-downs will not be so likely to occur and will cause less loss when they do occur; furthermore repairs can be easily effected without shutting down.

A COMPARATIVE TEST OF STEAM INJECTORS.*

By G. H. TRAUTMANN, B. S., '96.

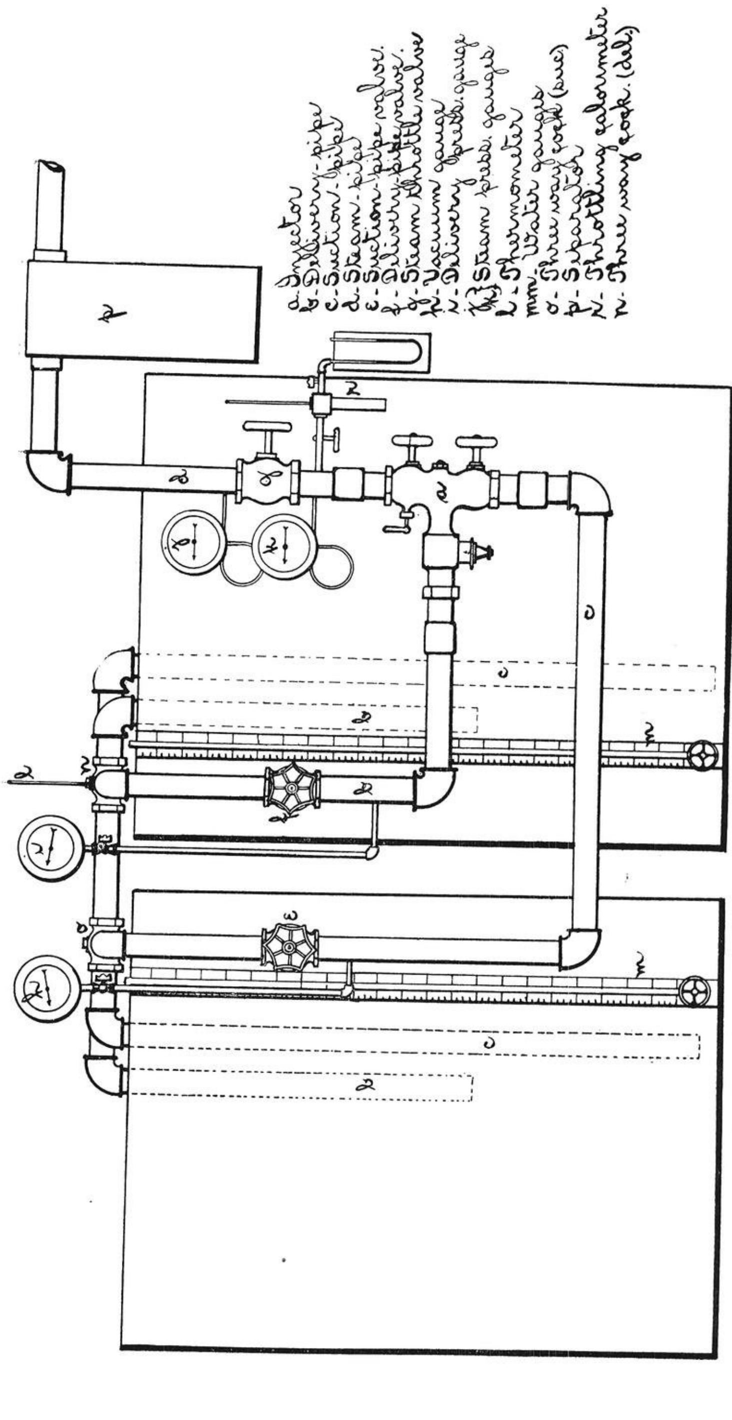
This test was made in the Engineering Laboratory of the University of Wisconsin and extended over a period of several months. The object of the work was to test each of the eight injectors according to a definite system so that they could be compared exactly in every detail carried out. The plan of the apparatus used explains itself. (See page 52.)

The steam is supplied from the boiler-house, passes through a separator before entering the injector and is regulated by means of a throttle-valve (g). The feed water is drawn from one of the tanks and is conveyed to the injector by means of the suction pipe (c) into which is placed a valve (e) which regulates the lift. The suction is measured by the vacuum gauge (h). The water, after passing through the injector is conveyed to the other tank by means of the delivery pipe (b) into which is placed a valve (f) for regulating the delivery pressure. This pressure is registered by the pressure gauge (i). The steam gauges (j) and (k) register the pressures at injector. Temperatures of water, steam, and the room are taken by means of accurate thermometers, and the weight of water is measured by means of water gauges (m) attached to the tanks.

In making out the log of the injector test the following readings were observed:

Duration of run; pressure at injector; delivery pressure; suc-

* Abstract of a thesis for the degree of B. S., in mechanical engineering. Received special honors.



Apparatus for testing injectors.

tion in inches of Hg. from which is obtained the lift in feet; delivery in feet, calculated from the delivery pressure and lift; temperatures of supply and delivery water; barometer; quality of steam, calculated from the throttling calorimeter readings; pounds of water supplied and delivered; pounds of steam used, obtained by subtracting the number of pounds of water supplied from the number of pounds of water delivered; water per pound of steam by experiment; and the same by calculation.

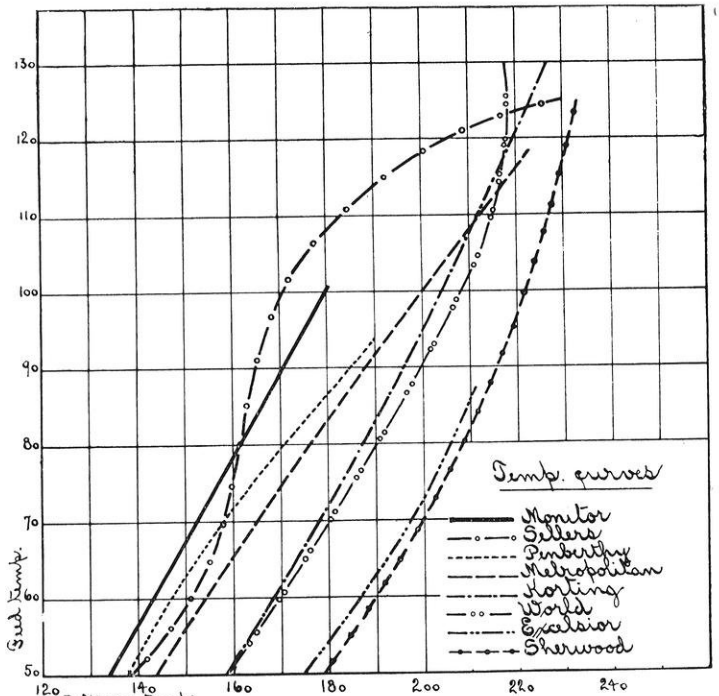


PLATE I

The formula for this last value was the following:

$$y = \frac{x_1 r_1 + q_1 - q_4}{q_4 - q_3} \text{ in which}$$

y = the number of pounds of water per pound steam;
x_1 = quality of steam as found;
r_1 = heat of vaporization corresponding to the steam pressure at injector;
q_1 = heat of the liquid corresponding to the steam pressure at injector;
q_4 = heat of the liquid corresponding to the temperature of water delivered
q_3 = heat of the liquid corresponding to temperature of feed water.

The efficiencies of each test were worked out according to the formula—

$$\text{Efficiency} = \frac{\frac{W}{w}(q_2 - q_1) + q_2 + \frac{(W + w)\,h}{w\,772}}{q + rx} \text{ in which}$$

W = weight of water supplied;
w = weight of steam used.
q_2 = the heat of liquid corresponding to delivery temperature;
q_1 = the heat of liquid corresponding to the feed water temperature;
q = the heat of liquid corresponding to pressure at injector;
h = lift in feet;
(r) and (x) the same as in preceding formula;
$\frac{1}{772}$ = number of foot-pounds in one heat unit.

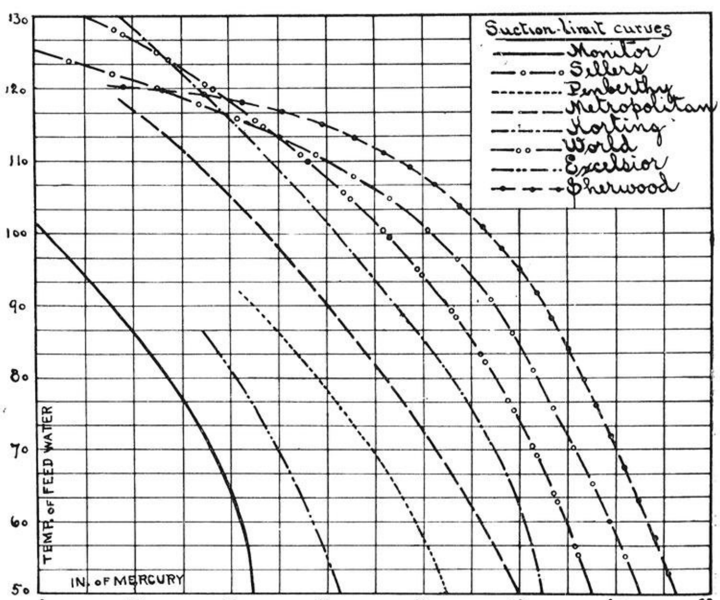


PLATE II.

The results given by this formula are all very nearly equal. With hardly a single exception the first three figures in the expression for efficiency are 9's, thus showing that the efficiency of the injectors is nearly 100 per cent.

The following injectors were tested:

Penberthy—Scott Valve Co., Chicago, Ill.

Korting—Made at Hanover, Germany.

Sellers—Wm. Sellers Co., Philadelphia.

World—American Injector Co., Detroit, Mich.

Sherwood—Sherwood Injector Co., Buffalo, N. Y.

Monitor—Nathan M'f'g Co., N. Y. City, 92--94 Liberty St.

Excelsior—N. A. Watson, Erie, Pa.

Metropolitan—The Hayden & Derby M'f'g Co., N. Y. City, 111 Liberty St.

All injectors in this test were lifting injectors. The Korting, World, Metropolitan, and Sherwood are double tube, and the Sellers, Monitor, Penberthy and Excelsior are single tube injectors.

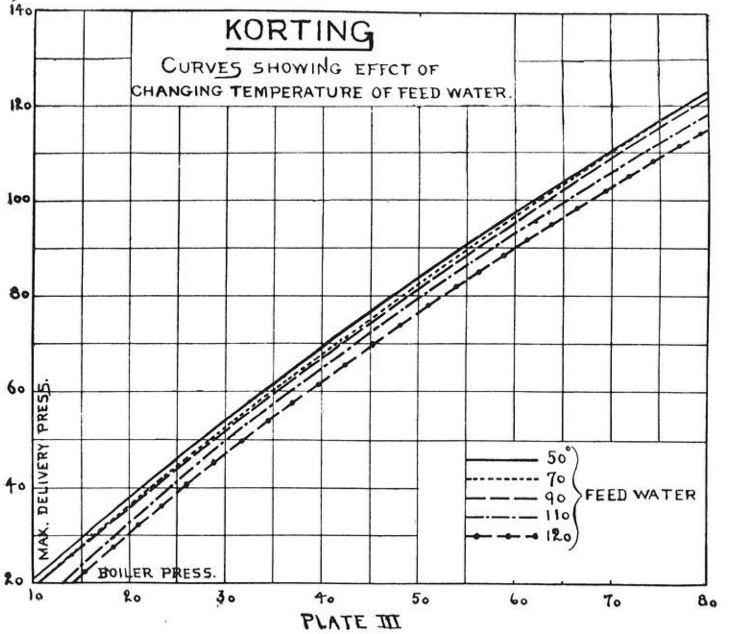


PLATE III

The system used to compare the injectors was as follows:

The pressure at injector was always kept at 80 pounds. The lift was always kept constant at 8″ of Hg. The discharge pressures were taken at 20, 40, 60, 80, 100, 120, etc., to the limit. For each one of these pressures a run of a certain number of minutes was made keeping all values constant during the run. Temperatures of feed water were 50°, 70°, 90°, 110°, 120° F., etc., to the limit. For each change of feed water temperature a complete series of tests was made using the discharge pressures as given above. The limits were also determinted after each series of tests. In order to determine the limit of delivery, the pressure at injector being kept constant at 80 pounds and the vacuum gauge at 8″, the discharge pressure was carefully increased until the injector would stop working. This highest pressure being the limit of discharge for 80 pounds boiler pressure and a lift of 8″ of Hg. for each certain temperature of feed-water used. This series of discharge-limit tests was carried out for boiler pressures at 80, 60, 40, 20, etc., to the lowest limit at which the injector would work.

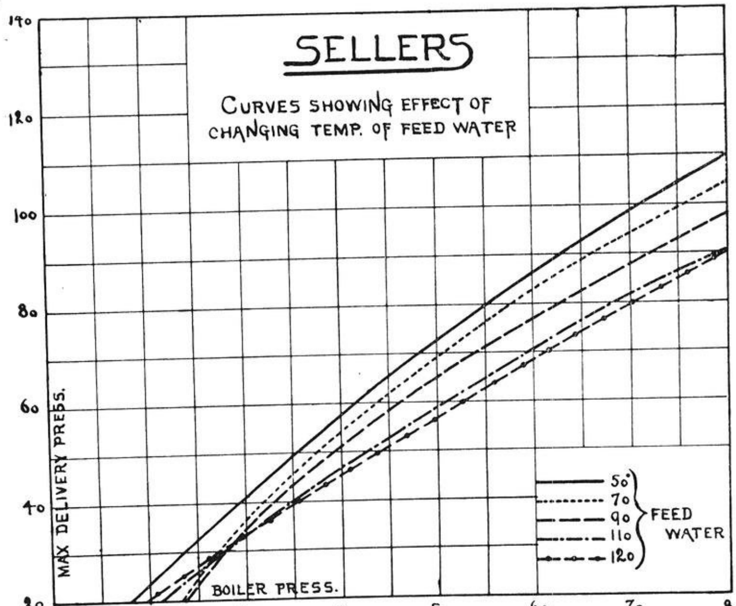


PLATE IV.

Suction limit tests were also made for each change of feed-water temperature. This was done by keeping the boiler-pressure constant always at 80 pounds, and finding the limit of suction for varying pressures of discharge, i e., at 20, 40, 60, 80, 100, etc.

Several curves were drawn in order to compare the workings of the injectors more easily. The curves on Plate I. are temperature curves. The feed-water temperatures are taken as ordinates and the delivery temperatures as abscissas. The different injectors are shown by lines drawn according to the key at the bottom of the plate. This plate shows that the Sherwood heats the water to a higher temperature than any other but the following table shows that the number of pounds of water per pound of steam (7.83) is much less than the others. This is a natural consequence as a smaller amount of water would be heated to a higher temperature:

No.	Name.	Gall'ns per hour.	Temperature of feed water.	Size of steam pipe.	Average water per lb. of steam.	Temp. of delivery.	Suction limit.	Limit of feed Temp.
1	Sellers..............	615	50	1¼ in.	12.17	137	20.5 in.	125
2	Sherwood..........	579	50	1 in.	7.83	179	21.25 in.	122
3	Metropolitan.......	645	50	1 in.	11.07	144	17.75 in.	118
4	Monitor............	511	50	1 in.	12.37	175	12.5 in.	102
5	Penberthy..........	478	50	¾ in.	12.03	137	16.5 in.	94
6	Korting............	508	50	1¼ in.	9.47	159	18.5 in.	130
7	World..............	370	50	¾ in.	9.22	160	19.5 in.	130
8	Excelsior	286	50	¾ in.	7.95	175	14 25 in.	87

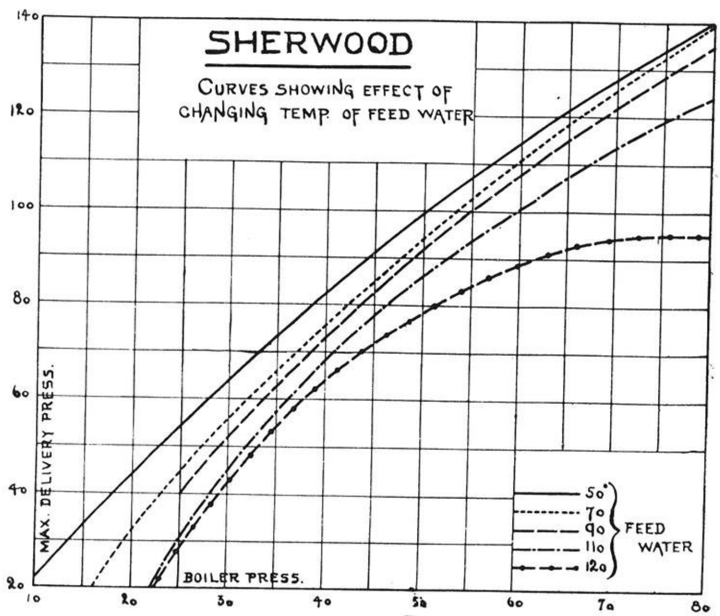


PLATE V.

This same table shows that the Monitor delivers the greatest number of pounds of water per pound of steam (12.37), but in plate I. it ranks last in heating capacity. The World and Korting are nearly the same in plate I. They are a little above the average in heating capacity and are nearly up to the average in the table for the number of pounds of water per pound steam, the World being (9.22) and the Korting (9.47). The table as well as plate I. shows that they are higher than all the others in the range of feed-water temperature, being equal at the limit (130°). The Sellers averages up well, the limit of feed-water temperature being 125°, the number of pounds water per pound of steam, 12.17 (ranking second) but the heating capacity is quite low, ranking about sixth in plate I.

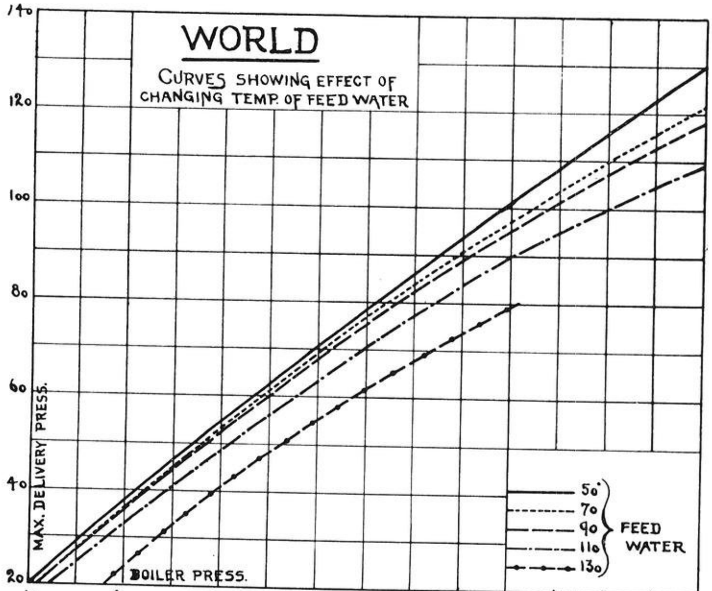


PLATE VI

The Metropolitan is fifth in rank on plate I., being the lowest of the double-tube injectors for the limit of feed-water temperature (118°), and next to the lowest in heating capacity. It ranks fourth in the above table, the number of pounds water per pound steam being (11.07). Plate I. shows clearly that the double-tube injectors are best suited for hot water. The heating capacity of the single-tube injectors are all much lower than the double.

Plate II. shows that the order of highest suction limit is as follows:

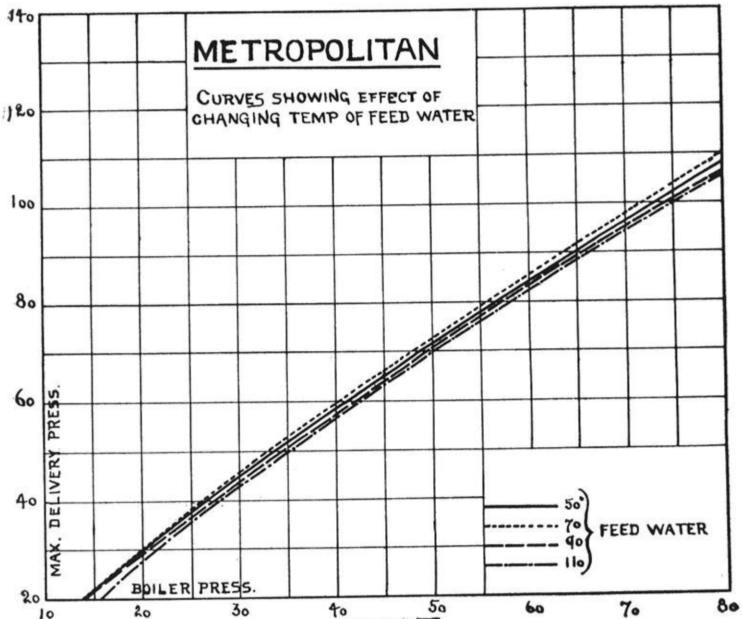


PLATE VII.

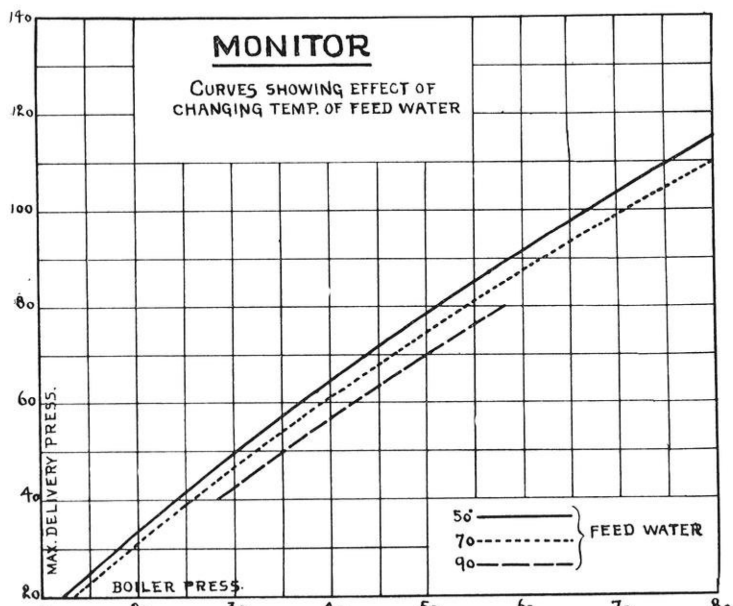


PLATE VIII.

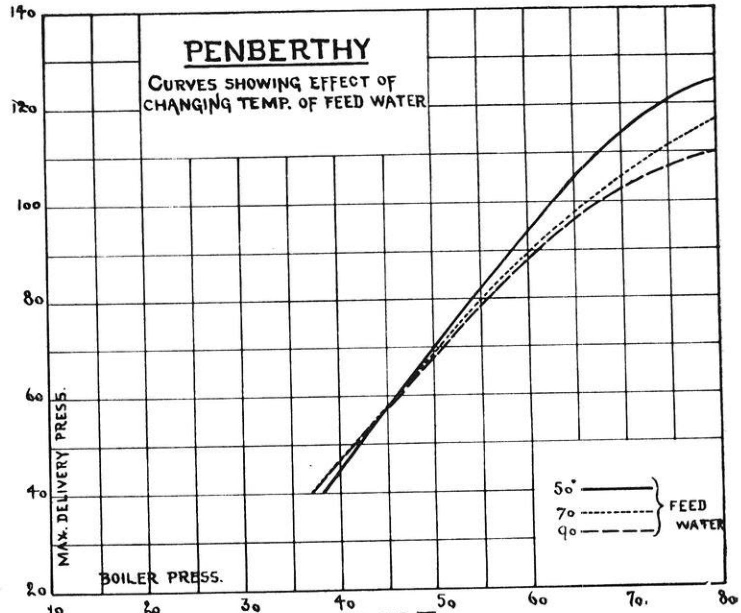


PLATE IX.

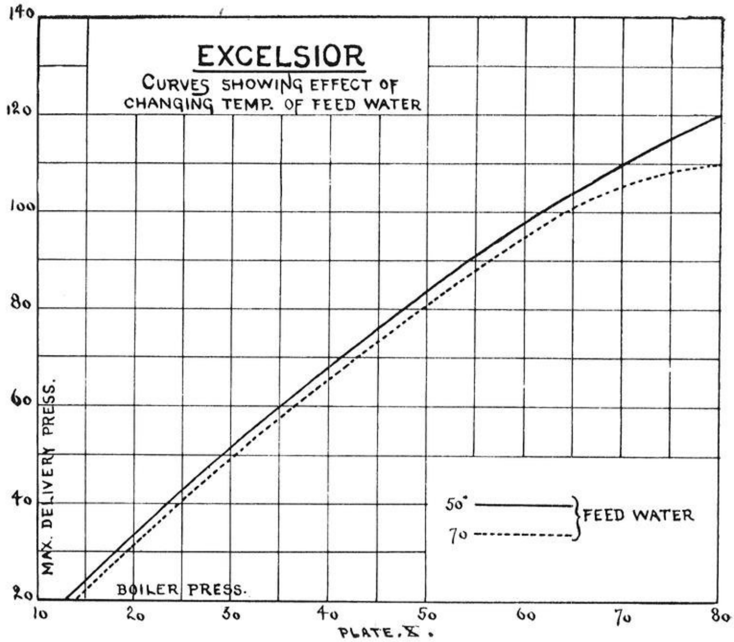


PLATE X.

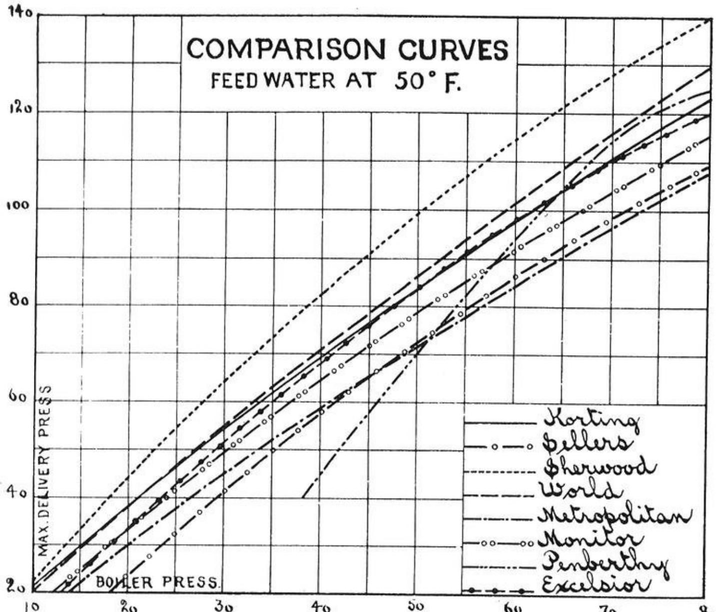


PLATE XI.

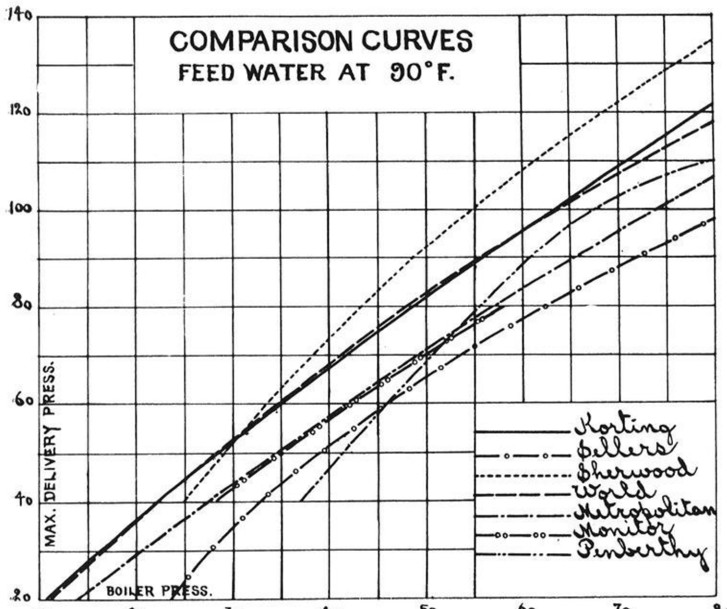


PLATE XIII.

1.	Sherwood..............double.	5.	Metropolitan...........double.
2.	Sellers..................single.	6.	Penberthy..............single.
3.	World..................double.	7.	Excelsior...............single.
4.	Korting................double.	8.	Monitor.................single.

Plates III. to X. show the effects of changing the feed-water temperature. Each is for a separate injector. In these curves the maximum delivery pressures are taken as ordinates and the boiler pressures as abscissas. In these curves it is shown that the Korting and Metropolitan are the least affected by change of feed-water temperature, the curves for different temperatures being nearly identical. The Sellers and World vary quite a little, while the Sherwood changes considerably. On plates XI. and XIII. will be found comparison curves for feed-water at 50° and 90° F. Plate XI. is made up by transferring the 50° curve for each injector to the same plate, the object being to make a plate of curves where the injectors could be directly compared. Plate XIII. is made up in the same manner with 90° curves.

It is difficult to draw definite conclusions from these tests since injectors may be used under so many different conditions. Probably the most important property of an injector is its ability to use hot feed-water, and next its lifting power. The other properties do not figure so much since the efficiencies are all nearly 100 per cent.

NEW U. W. PUBLICATIONS.

The two following publications have recently appeared. Their origin is distinctly U. W. and Wisconsin may well feel proud of the authors. Mr. Ford took his second degree last June. He is a very young man and we hope he will live to realize the bright future his past work has indicated. Professor D. C. Jackson is also a young man, when his reputation is considered, and it will be a long time before his sun shall have risen to its zenith.

BULLETIN OF THE UNIVERSITY OF WISCONSIN.

ENGINEERING SERIES, VOL. 2, NO. 1.

A COMPLETE TEST OF MODERN AMERICAN TRANSFORMERS OF MODERATE CAPACITIES.

ARTHUR HILLYER FORD, Fellow in Electrical Engineering.

The publication begins with an introductory note by Prof. D. C. Jackson, addressed particularly to central station managers, containing in condensed form a method for making tests and some guarantees which should be required for transformers.

These guarantees are as follows: Iron loss from 30 watts to 150 watts, and exciting current from .055 amperes to .2 amperes for sizes from 1,000 watts to 10,000 watts output, with primary pressure 1,000 volts and at a frequency of 100 cycles per second. Pressure drop in secondary 3 per cent. between no load and full load. Maximum rise in temperature 70° F. Disruptive strength of insulation between primary coil and core to be 10 times the primary pressure. Testing all transformers on the line at least once a year is also advised.

The body of the publication is taken up with the results of the tests on 21 different transformers, ranging in size from 1,000 watts to 10,000 watts capacity, representing all the American makers except two. Most of the tests were made during the year 1895, but others have since been made on new types of transformers so that the tests show the practice up to July, 1896.

The points tested are copper loss, core loss, exciting current, regulation and heating. The methods used in the tests are then given, after which follow the results of the tests in the form of tables and curves, showing losses and efficiencies. Following this is the discussion of results. *Instruments*—Even the best instruments for the measurement of alternating currents are unreliable. *Methods*—The method devised by Dr. Sumpner for determining the losses was found to be the best. The iron losses are measured with a wattmeter by connecting the low pressure coil of the transformer to a source of alternating current, having the pressure at which the coil is designed to work, through the wattmeter, the primary being open. The copper loss is measured by short circuiting the secondary through an amperemeter and supplying an alternating current to the primary through a wattmeter; the pressure being just sufficient to force the desired current through the secondary. The wattmeter gives the copper loss in the transformer plus that in the ammeter, which can be easily calculated. *Losses and efficiencies*—The iron losses are all reduced to the loss per cubic centimeter and the hysteresis factor is calculated so that the quality of the iron used in the different transformers can be compared. Measurements of the foucault current losses are attempted but were not satisfactory. *Exciting current*—The presence of butt joints increases the exciting current. *Regulation*—Transformers with coils having the greater dimension of their cross section parallel to the axis have better regulation than those with square cross section. Transformers for giving constant current with primaries at constant pressure which depend on the magnetic leakage, for their regulation will work at only one frequency. *Conclusions*—It pays to make a careful selection of transformers and even to throw away those on the line which do not come up to the standard. Transformers which are permanently connected to the line and which have the load on for only a small portion of the time should be built with the maximum efficiency at about quarter load even at the expense of regulation, instead of at or above full load, as is now done in most cases.

ALTERNATING CURRENTS AND ALTERNATING CURRENT MACHINERY.

BEING VOLUME II OF THE TEXT-BOOK ON ELECTRO-MAGNETISM AND THE CONSTRUCTION OF DYNAMOS.

By DUGALD C. JACKSON, C. E., and JOHN PRICE JACKSON, M. E.

The Macmillan Company, New York.

This book is based mainly on the lectures of Professor D. C. Jackson to seniors and graduate students in the University of Wisconsin, but the manuscript was carefully revised and extended by Professor J. P. Jackson of Pennsylvania State College. The book contains over seven hundred pages and deals with the subject in a very thorough manner. There are a number of original demonstrations which help to clear up the somewhat difficult problems in alternating currents. A great many words are saved by the free use of diagrams and all the illustrations have been selected for their clearness. An important change in nomenclature has been introduced: the term *active* to represent the component of electromotive force in phase with current, and to represent the working component of current. This removes the inconvenience caused by the use of the term *effective* as formally adopted to mean $\sqrt{\text{mean.}^2}$ A number of the laboratory tests referred to were worked out by students at U. W. In most cases foot-notes acknowledge the authors' indebtedness.

Following is a review of the contents:

As the essence of the book is taken from lectures to college classes, its chief function will be that of a text-book, and for this reason it is so designed that it may be used for either a long or a short course. In the latter case, chapters IV., X., XI., XII., XIII., XIV., XV., and the appendices may be omitted. An abbreviated course is not, however, advised by the authors, for students in Electrical Engineering.

Descriptions of commercial machinery are avoided as the student is expected to get his working knowledge from the laboratories and by reading the numerous references.

The practical engineer will find in this volume an excellent reference book. There is no padding, the tables are modern, theory is simple and the mathematics are not such as would stagger a person. These good points, however, would be of little avail to the busy engineer, were it not for the index which was compiled for *use*.

COLLEGE TECHNICAL JOURNALS.

The Technograph for 1896, published annually by the Association of Engineering Societies of the University of Illinois issued in May, contains several interesting articles on technica subjects. It also contains a descriptive index of central stations giving a brief description of situation and equipment of the principal central stations in the United States, as described in the leading technical journals.

The Minnesota Year Book, issued annually by the technical students of the University of Minnesota, contains several valuable articles of interest to scientific men and engineers. The articles are contributed by professors and students and many of them are the resuit of extensive research in their respective lines.

EDITORIAL.

The marked success which attended the first appearance of the ENGINEER was gratifying not alone to the editors, but to all the professors, students and alumni of the University. This success was due in no small part to the active interest taken by all in the new magazine. The immense amount of work required in its edition was gladly given by those who were able to assist.

Naturally it is to be expected that many things in the new magazine can be bettered. But time and experience will soon show what is best. Beginning with this number, the ENGINEER appears in a permanent cover. This, we think, will greatly improve its external appearance. Some changes have been made in the magazine itself. Smaller type has been used in the index, making it much more compact, and it has been improved by the addition of index letters, making it more convenient for use.

The senior engineers and several of the engineering faculty are indebted to the Western Society of Engineers for a very pleasant and instructive trip to Louisville. The party, consisting of members of The Western Society with their wives and friends, left Chicago Thursday evening, October 15th, on a special train consisting of five Pullman sleepers on the Monon route. Thursday morning the party found themselves at Bloomington, Indiana, where, after partaking of breakfast as guests of the Stone Quarry companies, they proceeded to inspect the quarries at Bloomington and Bedford. In the afternoon the train proceeded to Louisville, arriving in time for supper. On Saturday morning the party became the guests of the Louisville Cement company and were taken from the depot to the Louisville Hotel in a special train of five electric cars. From there the party took a train on the Panhandle road to the quarries of the Louisville Cement company, where the complete process of the manufacture of cement was seen. The works of the Black Diamond company were also visited. Here a large blast was exploded for the benefit of the party. After dinner a steamer was boarded and a trip was taken up the Ohio river to the Louisville waterworks, where the large pumping engine and the filters for purifying the river water were inspected.

It was expected that the party could go on to the Mammoth

Wisconsin Engineer Index

To Current Engineering Periodicals.

Explanation:—W, words. M. Jan., W. Jan. 4, or P. Jan. 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 Electrtc Power digest for January.

List of periodicals from which articles are indexed:

American Architect, The. *w.* $6. Boston.
Am. Engineer and Railroad Jour. *m.* $2. New York.
Am. Chemical Journal. *b-m.* $4. Baltimore.
Am. Gas Light Journal. *m.* $3. New York.
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.
Architectural Record. *qr.* $1. New York.
Architect, The. *w.* 26s. London.
Architecture and Building. *w.* $6. New York.
Architectural Review. *qr.* $5. Boston.
Australian Mining Standard. *w.* 30s. Sidney.
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 Engineer. *m.* $1. Montreal.
Canadian Mining Review. *m.* $1.50. Ottawa.
Cassier's Magazine. *m.* $3. New York.
Clay Records. *m.* $1. Chicago.
Colliery Engineer. *m.* $2. Scranton.
Colliery Guardian. *w.* 27s. 6d. London.
Domestic Engineering. *m.* $2. Chicago.
Electric Power. *m.* $2. New York.
Electric Railway Gazette. *w.* $3. New York.
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. *m.* 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.
Electrochemische Zeitschrift. *m.* Ger.
Electrotechnische Zeitschrift. *w.* Ger.
Engineer, The (Eng.) *s-m.* $2.50. 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.
Foundry, The. *m.* $1. Detroit.
Gas Engineers' Magazine. *m.* 6s. 6d. Birmingham.
Heating and Ventilation. *m.* $1. New York.
Ill. Carpenter and Builder. *w.* 8s. 8d. London.
India Rubber World. *m.* $3. New York.
Gas World, The. *w.* 13s. London.
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.* 30s. 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.
L'Eclairage Electrique. *w.* France.
L'Electricien. *w.* France.
L'Energie Electrique. France.
L'Industrie Electrique. *b-m.*
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.
National Builder. *m.* $3. Chicago.
Nature. *w.* $7. London.
New Science Review, The. *qr.* $2. New York.
Paving and Municipal Engng. *m.* $2. Indianapolis.
Physical Review. *b-m.*
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.

cave, but owing to the short notice plans could not be perfected; so Saturday evening the party left Louisville, arriving in Chicago Sunday morning. After returning to Chicago the seniors divided into their respective courses and made their regular inspection trips among the various works of interest in the city. As guests of the Western Society and the Cement and Stone companies, the seniors speak most highly of their entertainment and are exceedingly grateful for the opportunity from which they were able to derive so much pleasure and benefit.

A word about our index may not be amiss. It has received many compliments and has also been severely criticised by some whom we believe do not understand our intentions. The primary object in view on starting the index was to continue the work of the Associated Societies which had been discontinued on account of the heavy expenses involved. It was decided that to start an index with a digest of each article would be impracticable on account of the immense amount of work required and also the space needed would make it prohibitive. It was then decided to publish an index that would give the name and length of every article, the periodical in which it might be found and, if reviewed in one of the large magazines, the fact was to be mentioned. In this the index becomes similar to Poole's Index. All American Technical Journals and the principal foreign journals are indexed. Thus if any one wishes to find what current literature there may be on any technical subject it is only necessary that he should look under its principal alphabetical heading and there will be found all that has been published in the last three months. To find a year's writings it is necessary to refer to but four numbers. In order to do this with the others it would require the examining of twelve different numbers and as many different headings. Another desirable feature is the printing of the index on one side of the paper only. This makes it convenient for clipping where engineers desire to clip titles to insert in their scrap books for future reference.

It is our desire to make the index as complete and convenient as possible, and any suggestions for its betterment will be gladly received.

A new scientific organization to be known as The Science Club of the University of Wisconsin, has recently been formed. Its existence is due to the energy of Professor George C. Comstock. In the past there have been a number of minor clubs devoted to special branches of science; but the experience has been that the interest taken in them, while very great at their inception, gradually dies out, leaving the major part of the work in the hands of a few over-taxed specialists. This is due to the decidedly technical character of the programs and for this reason a larger body of a less technical nature is desired. Such an organization will not encroach upon the ground of the smaller clubs devoted to special branches of science, but these will not be expected to have so large a membership.

The object of the organization is expressed in the preamble: "For the promotion, within the University of Wisconsin, of an interest in and knowledge of the physical and natural sciences and their useful application." * * * One of the by-laws reads: "The programme and discussion at regular meetings of the association shall be, so far as possible, of an untechnical character." Meetings will be held once a month.

The advantages of the club may be enumerated as follows:

1. The untechnical character of the program enables men of science to become acquainted in a general way with the branches of science in which they themselves have not specialized and to an extent which would otherwise require the expenditure of more time and study than the returns would warrant.

2. The research work in the University can be presented by the investigators, which is a great advantage.

3. The members become well acquainted with one another socially.

The present officers of the club are: President, Professor George C. Comstock; Vice President, Professor D. C. Jackson; Secretary and Treasurer, Dr. William S. Marshall. These three men constitute the executive committee.

The program committee consists of Professor Comstock, ex-officio chairman, Dr. Edward Kremers and Dr. Joseph Jastrow. There are about fifty charter members, consisting of members of the faculty and graduate students.

The Wisconsin Engineer wishes the club success and will publish a resumé of their proceedings in its future numbers.

Messrs. Williams and Perkins in their article of this number, have used the terms static torque and starting torque in connection with their tests on alternating current motors. The static torque was found by clamping the band of their brake tightly and balancing the pull of the rotor*; the starting torque by loading the brake to the maximum value at which the machine would start, and come up to speed. This distinction is a good one. Some manufacturers have been calling static torque the starting torque, and this is misleading. Static torque is of no use whatever except to show what limit the starting torque can be made to approach by the use of finely divided resistances in the armature† circuit, as pointed out by the writers.

Messrs. Williams and Perkins found loads between the starting torque and the static torque under which the rotor would revolve but would not come up to speed. This seems to indicate that the starting torque is a variable quantity, depending on the kind of load to which the motor is subjected; i. e., a line of heavy shafting with a large static resistance to turning and a small running friction, could be brought up to speed by a certain motor, and perhaps this same machine would fail on a piece of machinery intended to be driven at the same speed and having the same static resisting moment, but a larger running friction than the shafting. The starting torque of Williams and Perkins' tests holds for light machinery with small moment of inertia. It would be interesting to know just how much this quantity can vary with different classes of loads.

One of the special advantages which the students in engineering at the University of Wisconsin enjoy is the Special Lecture System. Successful men in practical life are invited to talk to the different departments of the University and the engineering lectures are quite frequent. These lectures are given on Friday afternoons, the work in the class rooms and laboratories being suspended that all may take advantage of the treat. It is a good thing for young engineers to listen to older men of experience in the profession, for their talks are always profitable and of a practical nature. The observing student not only gets in-

* Part which revolves.

† Part in which current is induced.

Arc Lamp, Pilsen (Ill)—L'Elec June 6. W June 27.
Arc Lamp, The Evolution of the—L. H. Rogers, Elec Rev, May 20. 5500 w. M July.
Arc Lamp with Inclined Carbons—Zeit f Beleucht, May 10. W June 6.
Arc Lamps, A New Method of Studying the Light of Alternating—W. L. Puffer, Abs Paper A I E E, Elec Apr 1. Elec Eng, April 1. Elec Rev, Apr 15. 600 w. M May.
Arc Lighting from Alternating Current Stations—F. Lewis, Elec Rev, Lond, July 3. 1100 w.
Arc Lighting from Railway Circuits—L'Ind Elec, Apr 10. W May 9.
Arc Lighting on Motor-Generator and Converter Systems, Public—Elec Rev, Lond, June 19.
Arc Lighting on Motor-Generator and Converter Systems, Public—Elec Eng, July 15.
Arc Lighting Practice—Alex Dow, Elec Engng, Apr. 3400 w. M June.
Arc, Mercury—Electn, June 12. W July 12.
Arc, On the Alternate Current—Elec Rev, Lond, May 1. 1300 w. M July.
Arc Spectra, Photographic, Study of the—Baldwin, Phys Rev, May, June. W May 30.
Arc, The True Resistance of the—Frith and Rogers, Electn, May 15. W June 6.
Arc—See Thermo Electric.
ARCHES, The Austrian Tests of (Ill)—Eng News, April 9. 2200 w. M June.
ARCHINGS, Brick—Br Build, Mch. 1000 w. M May.
ARCHITECT and Contractor, The—Thomas A. Fox, Serial Part 1. Br Builder, Mch. 800 w. M May.
Architect's Use of Color, The—H. R. Ricardo and Christopher Whall, Paper R I of B A. Jour of Roy Inst of Brit Archs, Apr 23. 14000 w. M July.
Architecture and Decorative Art Institute at Chicago—P. B. Wright, Arch, July. 2000 w.
Architecture and Engineering—A. D. Hamlin, Eng Rec, Mch 21. Serial aPrt 1. 3000 w. M May.
Architecture at the Royal Academy, the Present Position of—F. Masey, Arch, Lond, May 1. 3500 w. M July.
Architecture, Domestic—Grant Helliwell, Can Arch, Mch. 3000 w. M May.
Architecture in Australia—Arch, Lond, April 17. 2200 w. M June.
Architecture in Scotland During the Past Century, Church—John Honeyman, Brit Arch, Mch 20. 1100 w. M May.
Architecture in India—Nanaje Narayan Waslekar, So Arch, May. 2000 w. M July.
Architecture in Washington City, Domestic (Ill)—Glenn Brown, Eng Mag, June. 3600 w. M. July.
Architecture, Japanese (Ill)—C. T. Mathews, Arch Rec, Apr. 5000 w. M June.
Architecture of China, Notes upon the—F. M. Gratton, Arch & Build, May 9. Serial Part 1. 3800 w. M June.
Architecture of Holland, The Brick (Ill)—R. C. Sturgis, Br Build, Mch. 1200 w. M May.
Architecture of the Teutonic Order, The—C. Fitz Roy Doll, Builder, Mch 28. 8000 w. M May.
Architecture, Restraints upon the Practice of—J. B. Robinson, Eng Mag, May. 2100 w. M. June.
Architecture, Romanesque—Prof. Aitchison, Builder, Mch 7. 5000 w. M May. Builder, Mch 14. 4000 w. M May.
Architecture, Truth in—W. E. Doran, Can Arch, May. Serial Part 1. 2000 w. M July.
Architecture—See Graeco-Phoenician.
Architectural Aberrations—Arch Rec, July—Sept. 1200 w.
Architectural Club, Ninth Annual Exhibition of the Chicago—Peter B. Wight, In Arch, Apr. 2000 w. M July.
Architectural Competitions—John A. Fox, Am Arch, June 20. 8500 w. M Aug.
Architectural Drawing at Columbia College, The Instruction in (Ill)—William R. Ware, Sch of Mines Quar, Apr. Serial Part 1. 4500 w. M July.
Architectural Design, Authority in—J. B. Robinson, Arch Rec, July—Sept. 3500 w.
Architectural Rendering in Pen and Ink (Ill)—D. A. Gregg, Brickbuilder, April. 1600 w. M June.
Architectural Tour in England and France, Notes on—W. A. Langton, Can Arch, April. 2100 w. M June.
ARGON and Helium When Submitted to the Electric Discharge, Behavior of—Collie and Ramsey, Elec, Apr 24. W May 16.
ARID Belt, Our Sub-—E. V. Smalley, Forum, June. 3800 w. M. July.
ARMATURE Currents in Electrical Machines—O. T. Blathy, Electn, July 17.
Armature—See Motor, Telegraph, Coils.
Armatures, How to Insulate Grooved—Wm Baxter, Jr., Am Mach, June 11. 1700 w. M Aug.
Armatures, Self Induction in Alternating—Breslauer, Electrotechn Zeit, July 16. W Aug 8.
Armatures, The Advantages of Grooved—Wm. Baxter, Jr., Am Mach, Apr 16. 2300 w. M June.
ARMOR, Formulae of Calculating the Perforation of—Capt. Tressider, Eng, Lond, Apr 24. 1800 w. M June.
ARRESTER, Automatic Potential—Johnson & Steel System, Elec Rev, July 29.
ARTESIAN Well, A Novel Test on the Flow of an—W. Pence, Ill Soc of Engs & Surv, 11 An Rept. 2200 w.
ASBESTOS—G. Heil, Arch & Bld, July 11. 1800 w.
Asbestos—G. H. Guy, Elec Eng, June 10. 3400 w. M Aug.
ASPHALT and Brick, From Cobblestones to—N. P. Lewis, Pav & Mun Engng, Apr. 2800 w. M May.
Asphalt—See "Reservoir Linings."
Asphaltum, The Chemical Relations of—S. F. Peckham, Pav & Mun Engng, May. 1500 w. M June.
ASTRONOMICAL Telescope in Fifty Years, The Development of the—Sci Am, July 25. 240 w.
ASTURIAS Spain, Mining in—Min Jour, July 18. 1100 w.
ATMOSPHERIC Electricity—Chree, Electn, July 24. W Aug 15.
Atmospheric Temperature and Humidity on Melting Iron in a Cupola, The Effect of—A. Sorge, Jr., Foundry, April. 600 w. M June.
AURIFEROUS Beach Sands on the North Coast, The—J. E. Crane, Aust Min Stand, Mar 12. Serial Part 1. 5200 w. M June.
AURIFEROUS Ores and Gravels by Means of Amalgamation and Blowpipe, The Assay by Prospectors of—W. H. Merritt, Tr Am Inst Min Eng, Apr. 1500 w. W June.
AUSTIN Friars and Its Cloister—A. S. Walker, Builder, Apr 4. 2800 w. M June.
AUSTRALIA as a Field for Electric Supply—Dawson, Electn, June 12. Elec Eng, July 8.
Australia, The Scientific Exploration of Central—W. A. Horn, Aust Min Stand, Mar 26. 3600 w. M June.
Austrian Electric Railway Statistics—Elektrotechn Zeit, June 15.
AUTOCARS, Electrical—Elec Rev, Lond, July 24. W Aug 15.
AZIMUTH, Longitude and Time, Approximate Methods for Rapid Determination of—Geo. C. Comstock, Wis Eng, June. 1500 w.

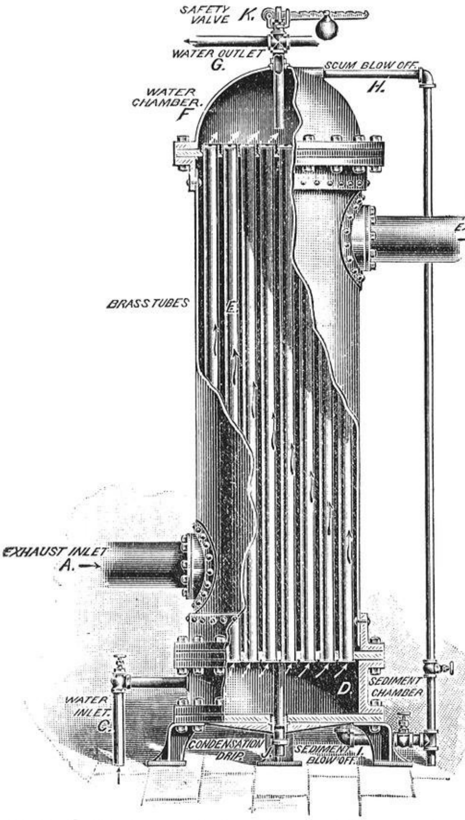
BACTERIA in Milk—H. W. Coon, Sci Am, May 2. 1800 w. M June.
Bacteria, Influence of Induced Currents on—Lortet, L'Ind Elec, May 10. W June 6.
BACTERIOLOGICAL Researches, The Practical Results of—George M. Sternberg, Pop Sci M, Apr. 6500 w. M May.
BAKER and Its Oil Industry—W. Hume, Nature, July 9. 2400 w. M Sept.
BALATA and the Supply, The Demand for—Ind Rub Wld, July 10. 900 w.
BAND Saw, The Making of a (Ill)—Ir Age, July 30. 2000 w.
BANK Building, The Heating and Ventilating of a (Ill.)—Eng Rec, July 11. 1100 w.

formation from the substance of such a lecture but learns something of the successful man's method of thinking. This is well shown when the lecturer recites some of his experiences with difficulties and his methods of overcoming them. Many of our lecturers are men of national reputation and their talks are often published as University bulletins. Following are names of some of the lecturers and their subjects:

1894-95.— Bell, Alexander Graham — Radiophony. Gray, Elisha — Early Reminiscences. Abbott, Arthur V., C. E., Chief Engineer—Electric Transmission of Power. Baker, W. E., C. E. Chief Engineer — Electric Equipment of Elevated Railroads Benzenberg, George H., C. E., City Engineer — Water Supply Tunnel. Brownell, H. G., B. S., Designer — The Operation of Galvanoplasty. Cooley, L. E., C. E., Trustee — Deep Waterway from the Great Lakes to the Atlantic. Ferguson, Louis A., B. S. Electrical Engineer — Modern Electric Power Stations. Grafton, W. McC., Signal Engineer — Interlocking Signal System. Johnson, J. B , C. E., Professor Civil Engineering — The United States Timber Tests. Lewis, F. H., C. E., Consulting Engineer — Specifications and Tests for Structural Steel ; Specifications and Tests for Cements. Lindemann, August, M. E , Superintendent — Presses and the Die and Tool Work connected therewith. Loree, L. F., M. Am. Soc. C. E., Superintendent — Emergencies Arising in the Operation of Railroads. Mead, Daniel W., B.C.E., Consulting Engineer—Water Supply Engineering. Peck, S. B., M. E., Consulting Engineer—Conveying Machinery. Sweet, John E., M. E.—The Modern Steam Engine.

1895-96.—Baker, W. E , C. E.— Electric Equipment of Elevated Railroads. Brown, Charles C., C. E., Consulting Engineer — Sanitary Engineering. Gannett, Henry, Chief Topographer U. S. Geological Survey — Topographical Methods of the Geological Survey. Gregg, J. H.— The Prevention of Scale in Steam Boilers. Johnston, Thomas T., C. E., Assistant Chief Engineer—Construction of the Canal. Lundie, John, C. E.— Motocycle Tests. Pierce, R. H.— Electrical Storage Batteries. Summers, E. E.— Motocycle Tests. Swenson, Magnus, M. E.— Economical Evaporating Machinery. Van Ornum, John L., C. E.— Topography.

BUNDY FEED WATER HEATER.



A New Feed Water Heater has been brought out called the BUNDY, a rather peculiar name, altough quite well known on account of the radiator made bearing the same name.

The Bundy Feed Water Heater is of the cylindrical tubular type having an outer shell of wrought iron, containing a series of 2 inch brass tubing. The exhaust enters the wrought iron shell at A and passes out at B, heating in transit the water that enters at C, passes through the pipe E and out at G. D is a sediment chamber and F a water chamber, each supplied with blow off connections, I for sediment discharge and H for scum blow off. K is a safety valve and J the condensation drip.

The exhaust steam inlet and outlet may be changed to different parts of the cylinder or be reversed, the steam entering at B and leaving at A, or both may be on the same side.

It will be observed that the exhaust steam acts on the exterior of the brass pipes and this the manufacturers claim heats the water to a higher temperature than it is possible to secure with a heater in which the exhaust steam passes through the pipe having the water on the outside. Then again the friction in passing the exhaust through the pipes is liable to induce a back pressure on the engine which the makers of the Bundy guarantee cannot occur with this heater.

It will also be observed that the water outlet pipe G enters the water chamber several inches drawing the water that is pure while the scum rises to the top and is removed by occasionally opening the valve in the water blow off.

The water outlet pipe G may be connected to a return trap setting on the boiler three feet above the water line of the boiler and so the water be put into the boiler without cost for running a pump.

The Bundy is the product of the A. A. Griffin Iron Co., 66–68 Center St., N. Y. City, with offices at 177–179 Fort Hill Square, Boston, and 702 Arch St., Philadelphia, and works at Jersey City, N. J. Printed matter may be had of them for the asking, giving further particulars and prices.

SIX MONTHS OF ELECTRICAL JOURNALISM.

The ELECTRICAL REVIEW has just completed its twenty-eighth volume, which contains some of the best newspaper work ever done by a techincal journal. In addition to giving thoroughly reliable news of the progress of electrical work in all its branches, the ELECTRICAL REVIEW has secured in the past six months a large number of unusually valuable and exclusive articles on important subjects. It printed the first official interview with Professor Roentgen and the only interview with Professor Salvioni, of the University of Perugia, Italy, who made some very interesting and remarkable discoveries on the Roentgen ray.

The REVIEW was also the first to give an illustrated description of the new Westinghouse-Baldwin electric locomotive, and obtained the first official interview with Thomas A. Edison on his new fluorescent lamp. This interview was illustrated with a sketch of the lamp made by Mr. Edison for the REVIEW. The greatest honor that this journal has attained is that it was selected exclusively by Nikola Tesla for giving to the world the remarkable series of articles written by him, describing his wonderful progress in X-ray photography and in vacuum-tube lighting.

The electrical field is rapidly broadening and the class of people interested in its progress is as rapidly widening; the progress made from week to week is faithfully delineated for their benefit in the ELECTRICAL REVIEW, of New York City.

THE STREET RAILWAY REVIEW, commencing with January, 1897, will begin the publication of a foreign edition of their magazine.

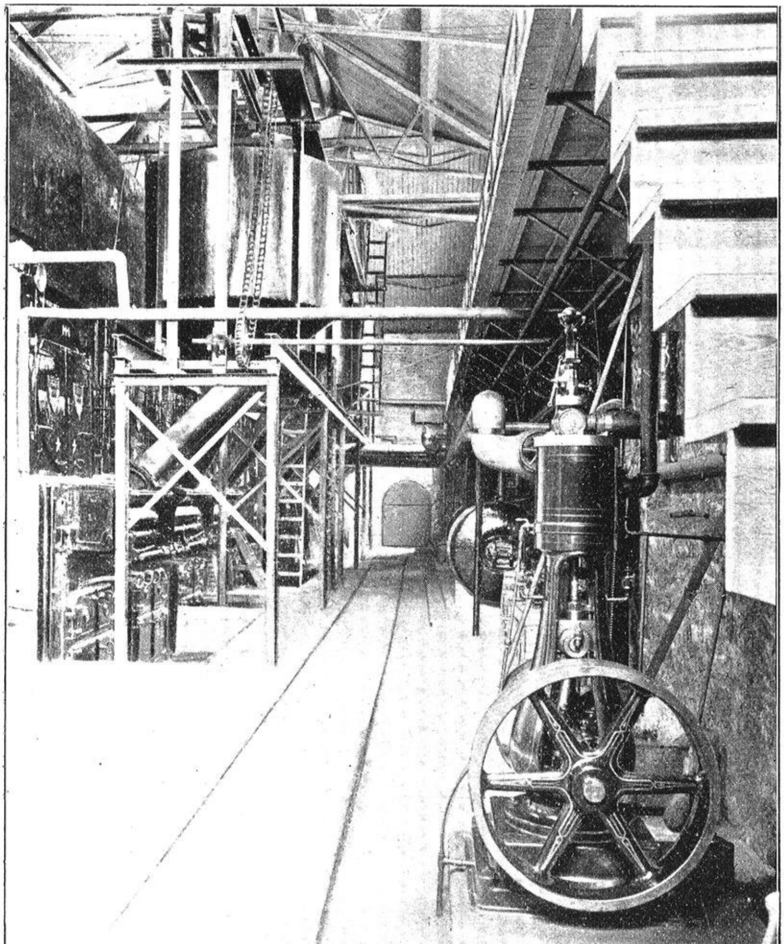
The new publication will be similar in appearance to the home edition, which will continue as a quarterly. It will contain descriptions of the principal street railway plants outside of the United States, and also a resumé of the best and latest appliances and ideas which have been brought out in this country.

As this new edition can not help but boom American interests, we all unite in the hope that it will be a success.

University Views.

PHYSICAL LECTURE ROOM.

The Physical Lecture Room contains seats for 200. Its equipment is the most modern. The lights are connected with a stage dimmer by the use of which they can be regulated to any desired degree of illumination. By means of curtains controlled by a hydraulic device the room can be darkened on turning a valve. There are two stereopticons, the screens for which can be raised or lowered at pleasure. The lecturer's table is fitted with a small Pelton-wheel for operating light machinery. There are numerous other conveniences, all of which help to make this an ideal lecture room.



BOILER HOUSE.

The Boiler House of the University is situated back of Science Hall and is the best equipped boiler plant in the state. There are at present six tubular, two Heine boilers, a Root and a Standard boiler, but two more will be added, making the plant 1500 horse power. The new boilers are to provide for the heating of the new Library and also the old Library and Ladies' Hall are to be neated from the plant. When this is done all of the University buildings with the exception of those of the College of Agriculture and the Washburn Observatory will be heated from this plant. At one end of the Boiler house is the coal pit, having a capacity of 1,000 tons. The boilers are stoaked by the Roney stoaker. The steam is conducted to the various buildings through pipes carried in underground tunnels. The water from the condensed steam is returned direct but the high pressure feed water is passed through the fuel economizer.

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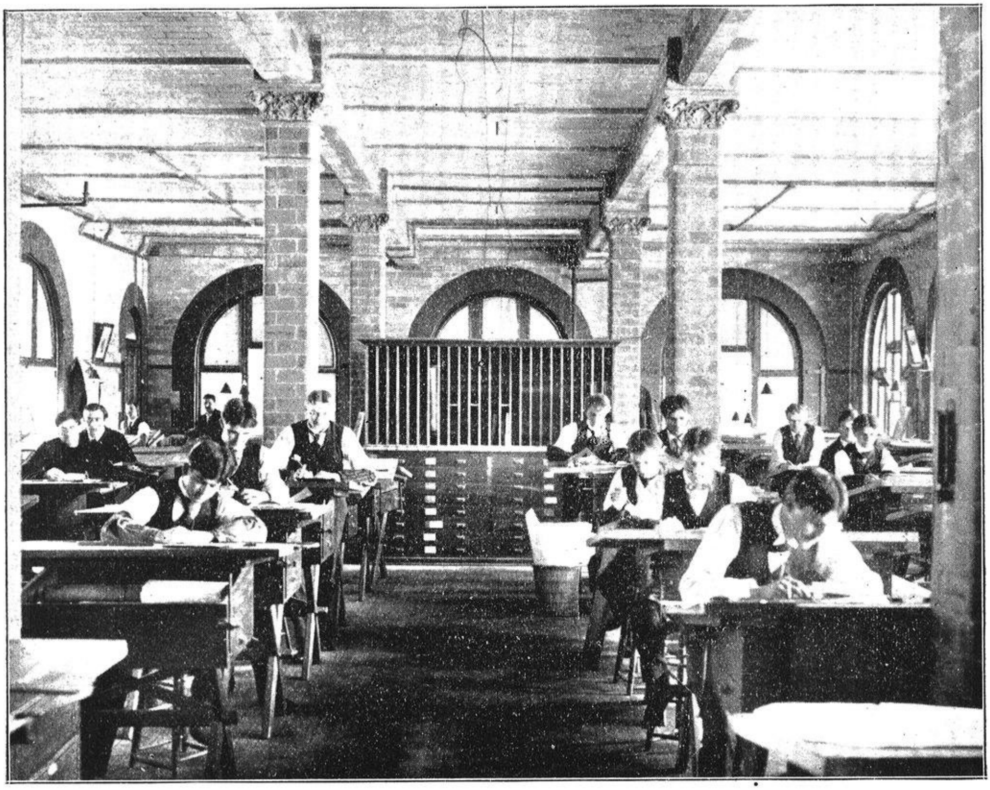
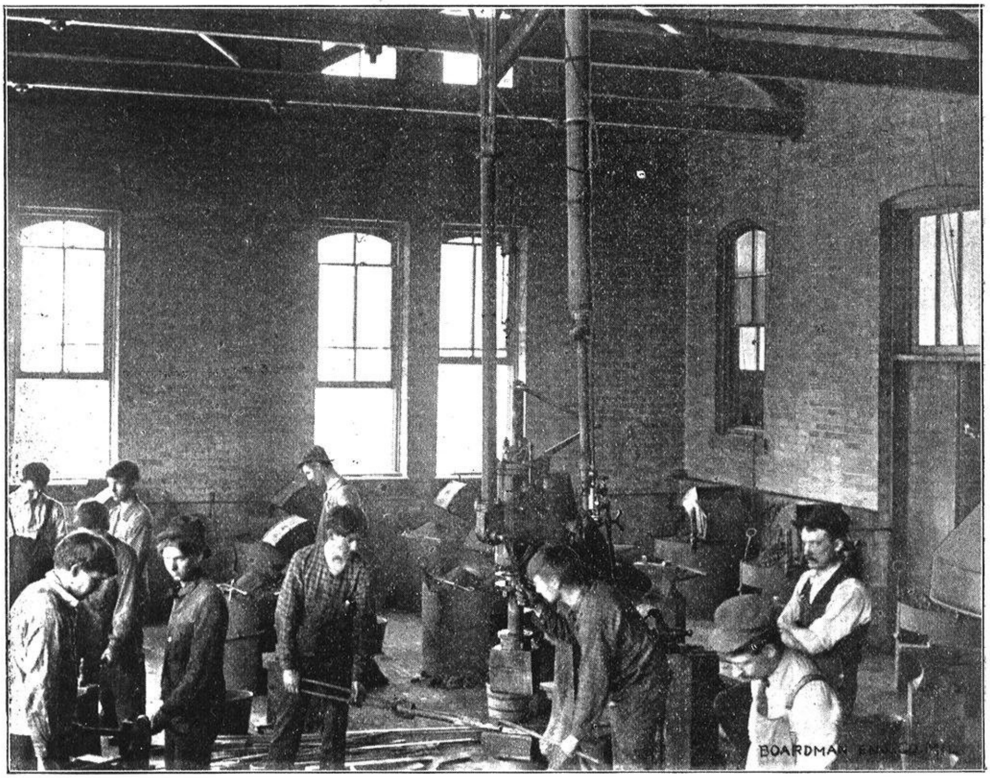


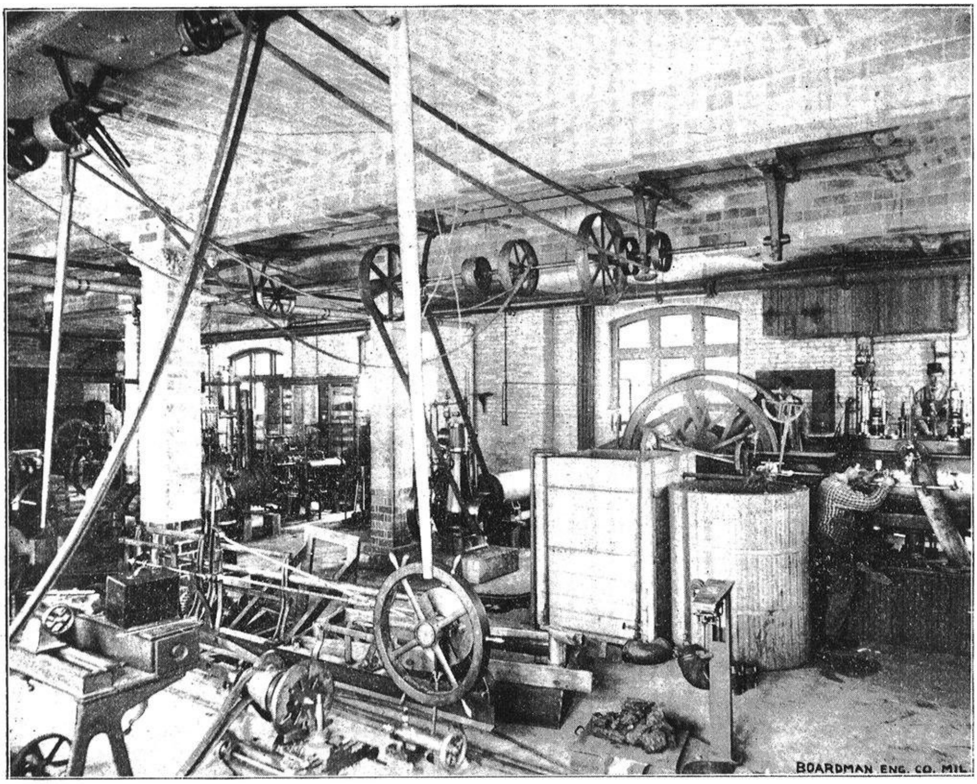
DRAUGHTING ROOM.

The above engraving shows the interior of the largest of our three draughting rooms. It is used by the senior, junior and sophomore mechanical and electrical engineers. The room is well lighted, having windows on three sides. The photograph dces not do justice to the size of this room as there are 150 individual desks besides cases for filing drawings, instrument cases and cases for models and specimens.



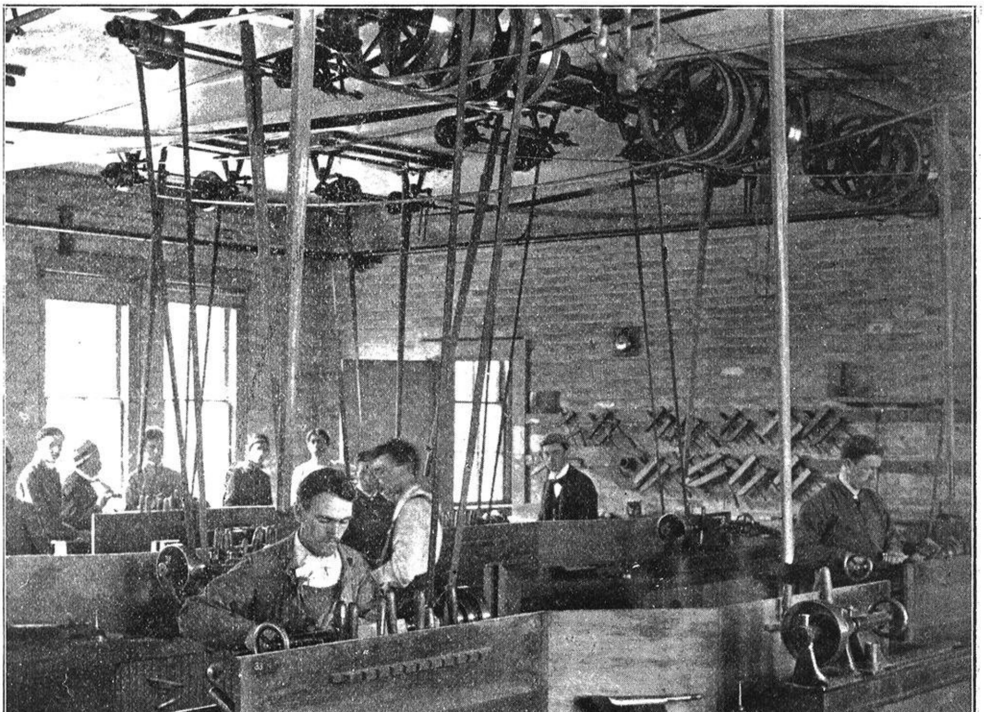
BLACKSMITH SHOP.

The Blacksmith-shop is located in the northeast wing of the machine shops. It contains forges and anvils for 50 students. The system was installed by the Buffalo Forge Co. All of the pipes (both suction and blast) are underground and the forges are provided with the anti-clinker, dumping tuyeres. The large cooling tank is also underground. The steam-hammer which plainly shows in the cut was designed and built by the students in mechanical engineering. It is used in the heavier forgings and it makes possible the working of "scrap" into bars. The work consists of exercises in bending, upsetting, welding, etc., also forging and tempering such tools as chisels, punches and lathe tools. As in the other parts of the shop the exercises must be made according to the drawings on blue-print cards.



STEAM ENGINEERING LABORATORY.

The Steam Engineering Laboratory is located in the basement of Science Hall. It contains a hot-air engine, a gas engine and several steam engines of various types. The most important of these is a fifty horse-power, compound, experimental engine, so arranged that either cylinder can be supplied with live steam and run as a simple engine. The condenser and pumps can be disconnected so that the engine may be run as a non-condensing one. Both cylinders and receiver are provided with steam-jackets which may be used at will. By means of a Proell governor the revolutions can be varied from 50 to 125. The cylinders each have four poppet valves, and the cut-off, controlled by the governor, may vary from zero to nine-tenths of the stroke. A Root boiler placed in the boiler house, furnishes the steam for this engine. The laboratory is supplied with friction brakes, dynamometers, and means for testing steam, vacuum, and other gauges; there are also the necessary tanks, weighing apparatus, pyrometers, calorimeters, indicators, counters, etc., for making complete engine and boiler tests. An engine of the type used in creameries has been placed in the laboratory by the Dairy department to enable the dairy students to become familiar with the type of engine they are apt to meet with in practice.



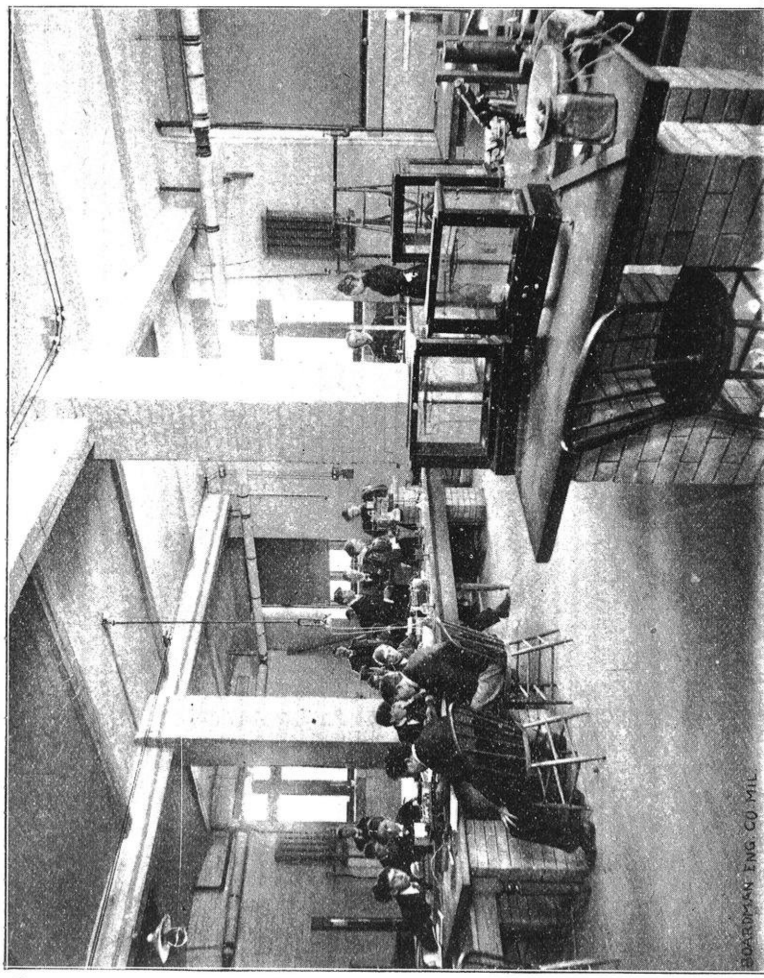
WOOD SHOP.

The Wood Shop is in the second story of the Machine Shop. There are thirty-two lathes all of which were built at the University. There are also the same number of benches so that sixty-four students may work at one time. The freshmen begin their shop practice here, the work being elementary, consisting of carpenter work, turning and later some pattern work. Each is required to use his own patterns for the exercises in moulding. Blue prints of all the exercises are furnished and the students are required to follow the drawings.

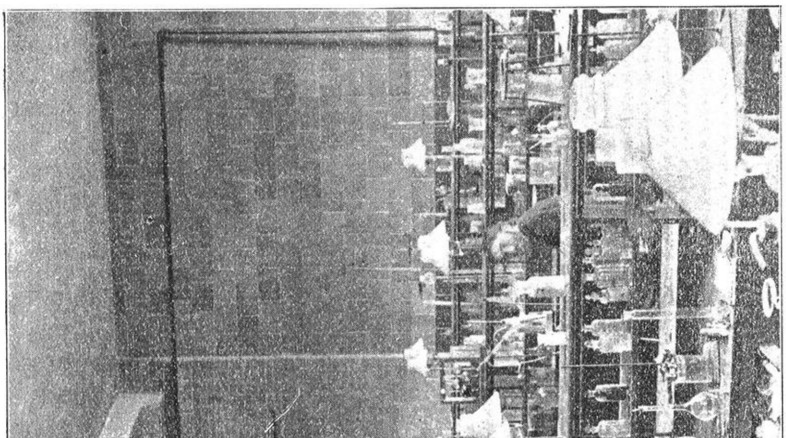
LIBRARY OF WASHBURN OBSERVATORY.

The Woodman Astronomical Library, established in connection with Washburn Observatory, and supported from the income of a fund given by the late Cyrus Woodman, Esq., possesses a large and valuable collection of works upon astronomy and kindred subjects.

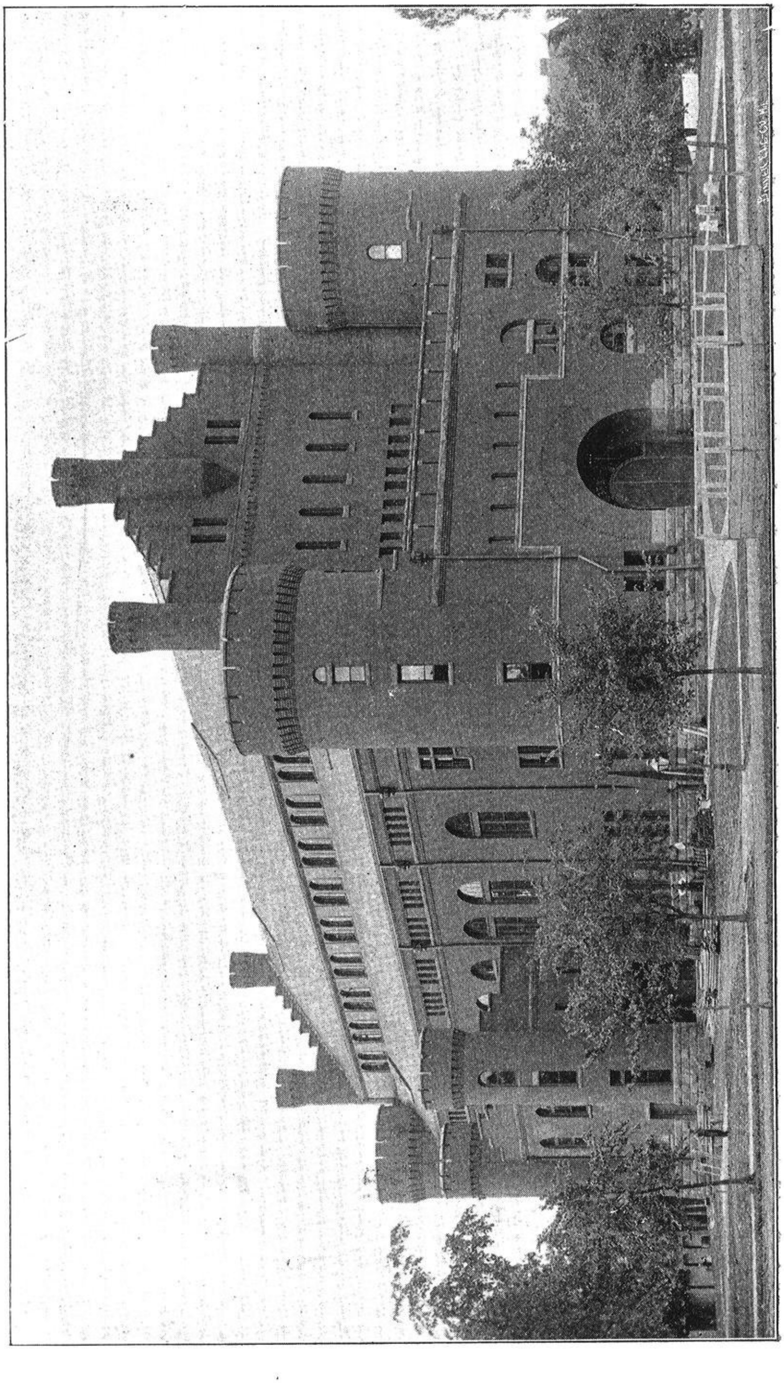
By provision of law the results of important investigations conducted at the Observatory, are published by the State, and under this provision nine volumes, representing the more important work done here, have been issued.

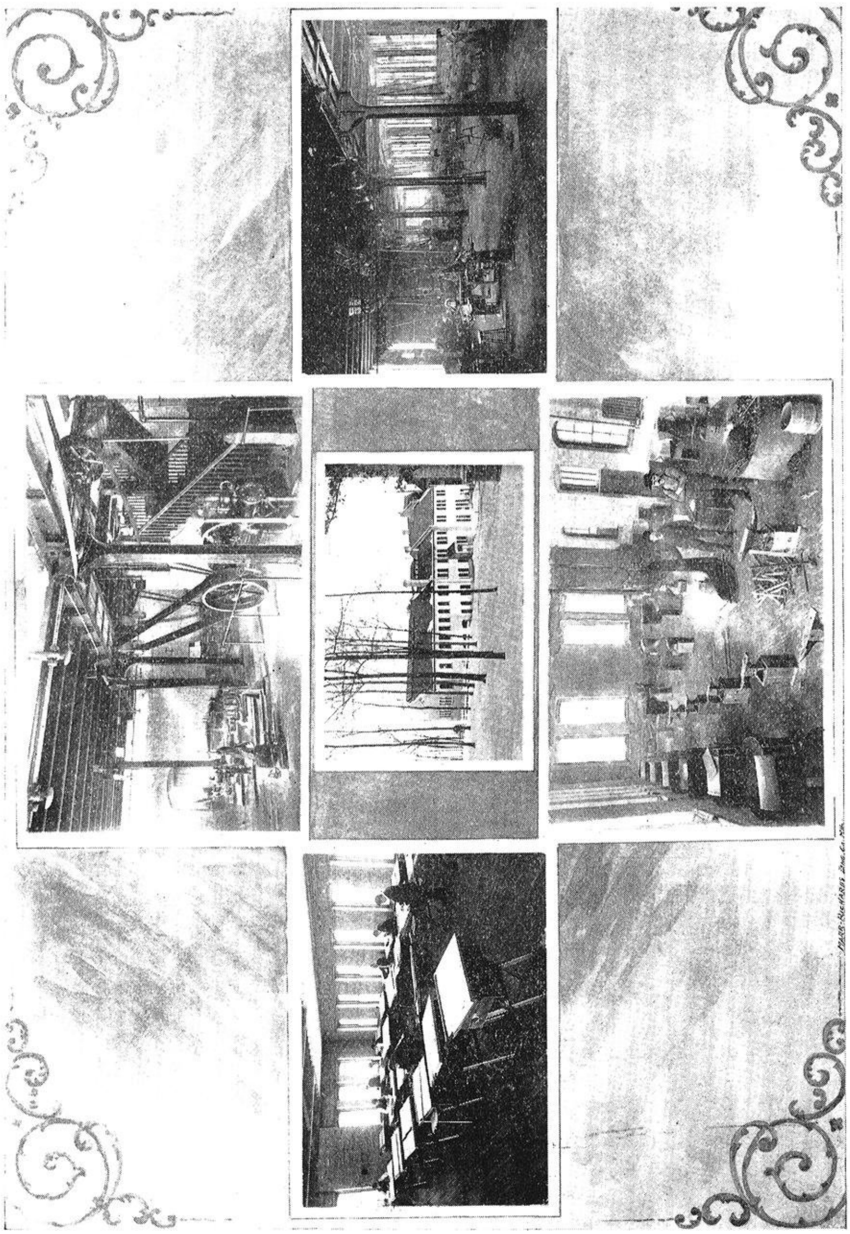


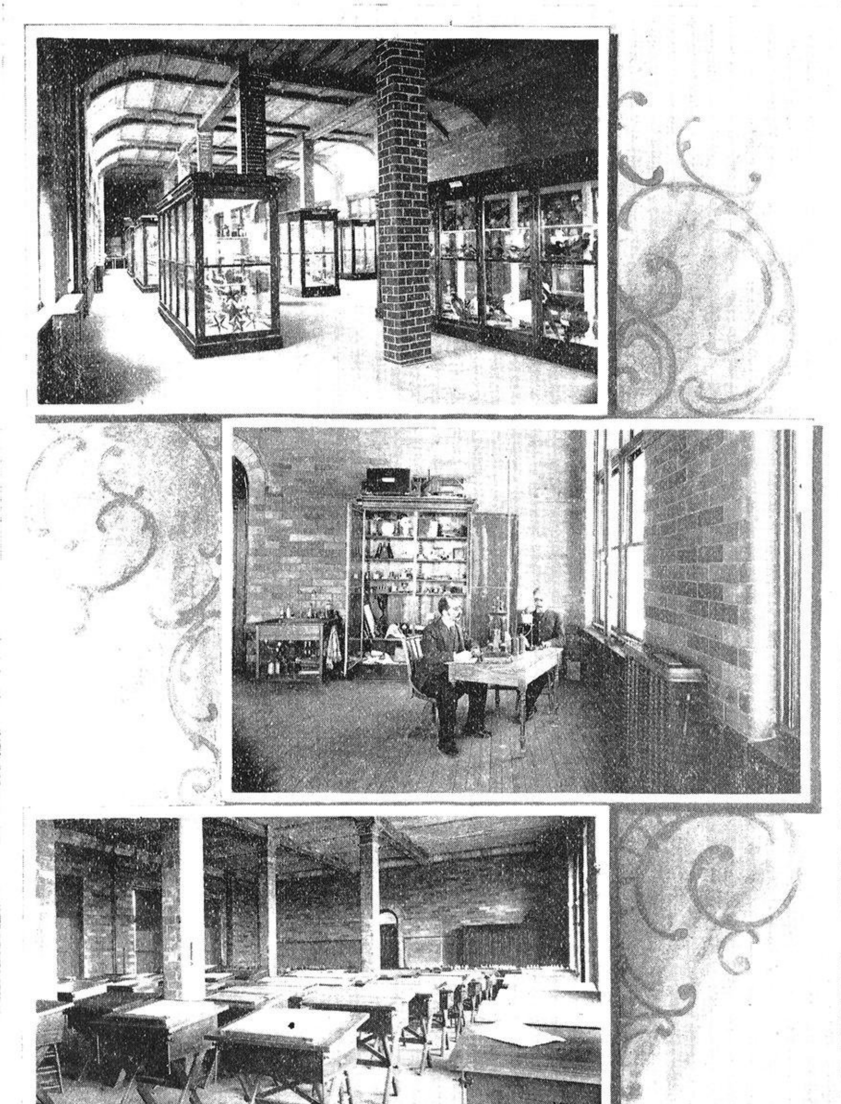
PHYSICAL LABORATORY.

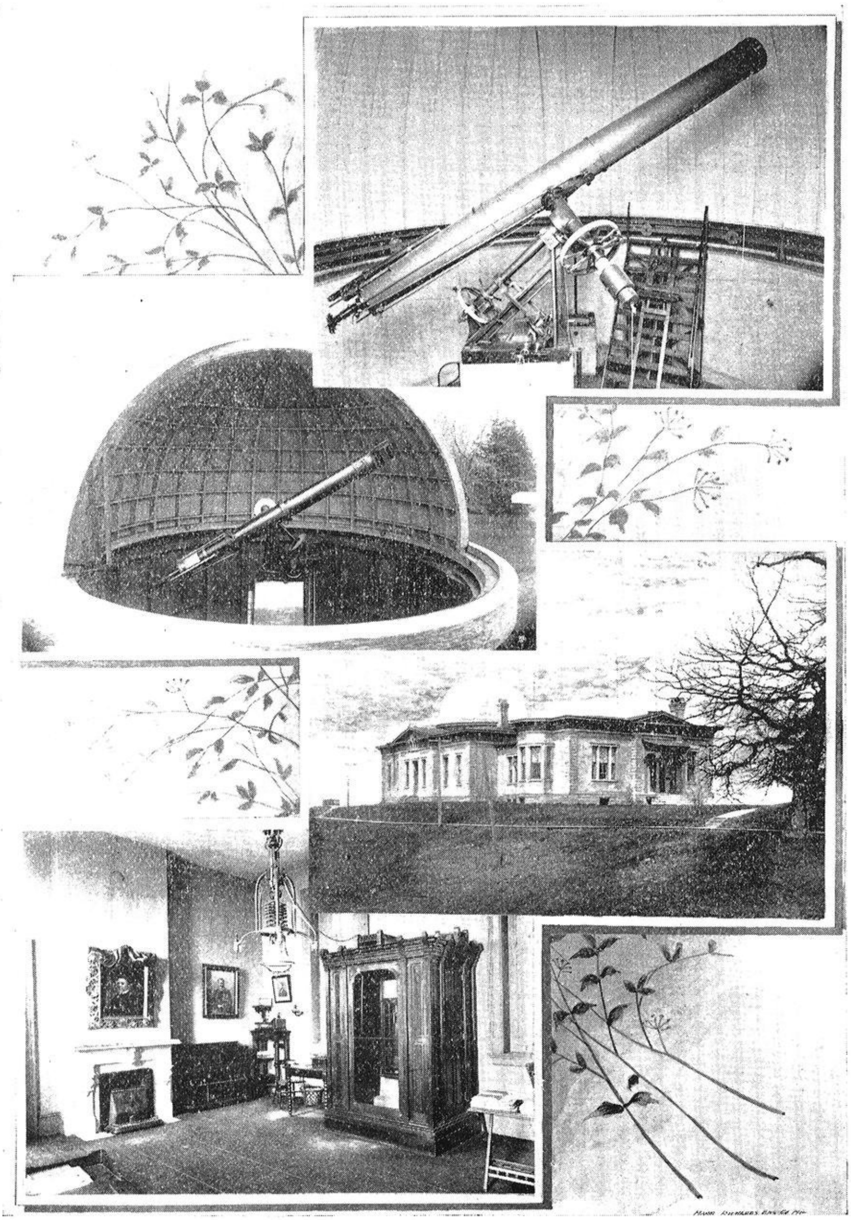


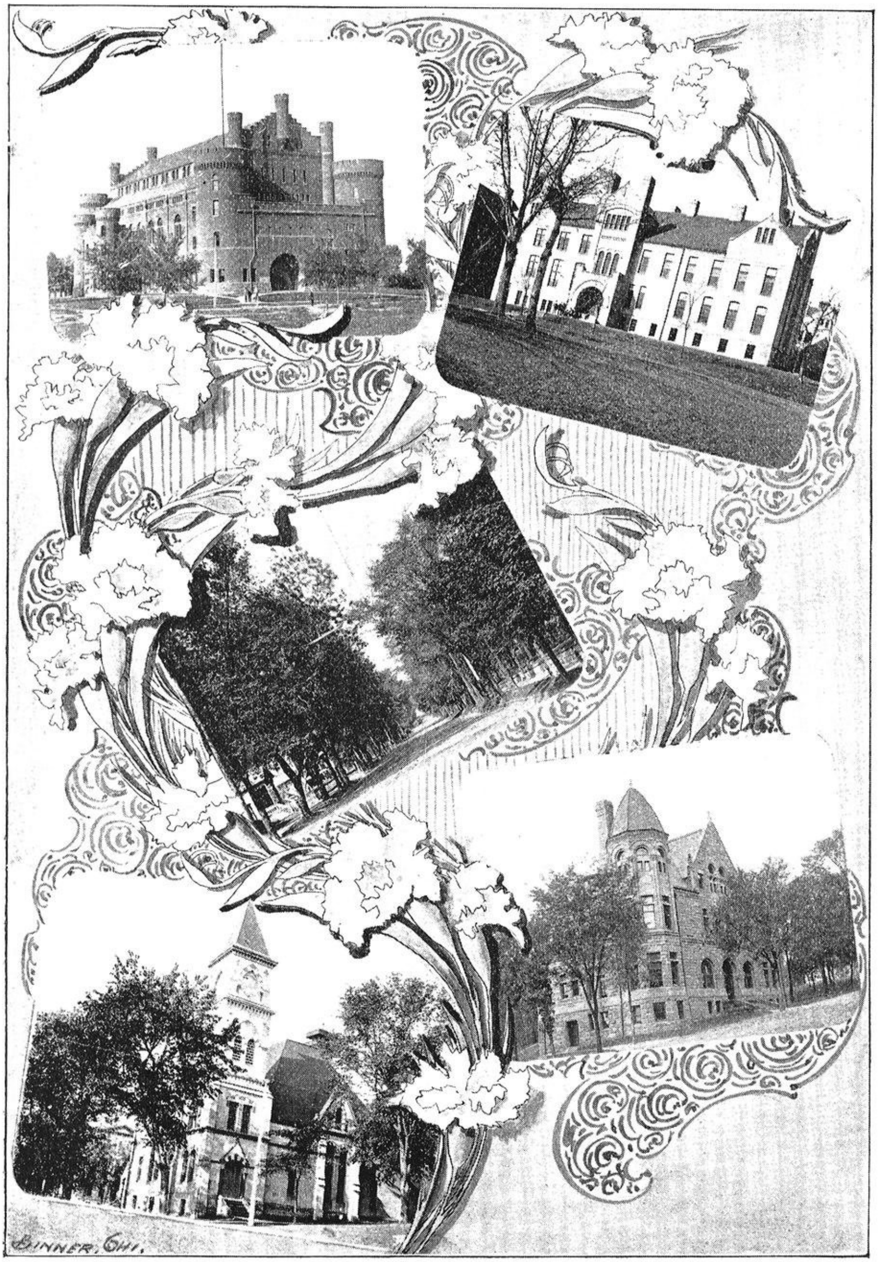
CHEMICAL LABORATORY.







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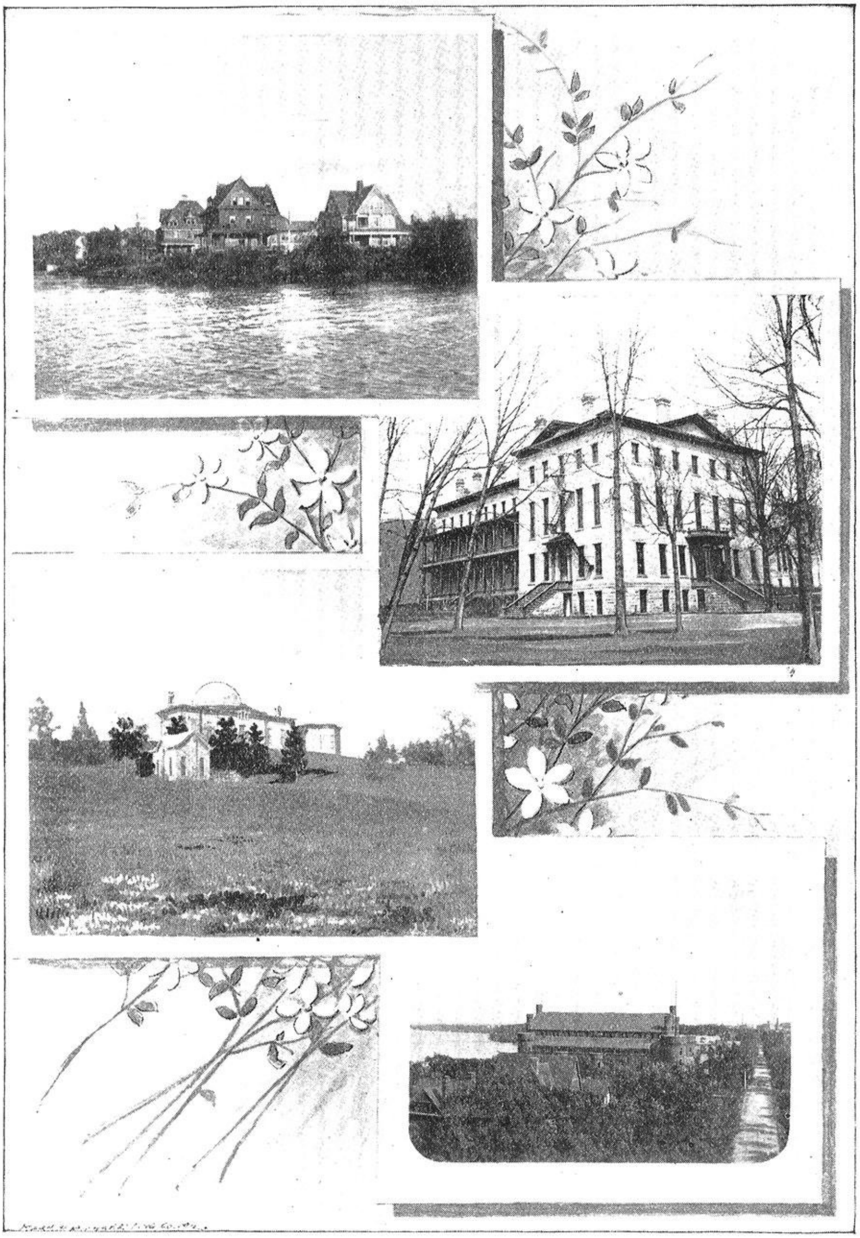

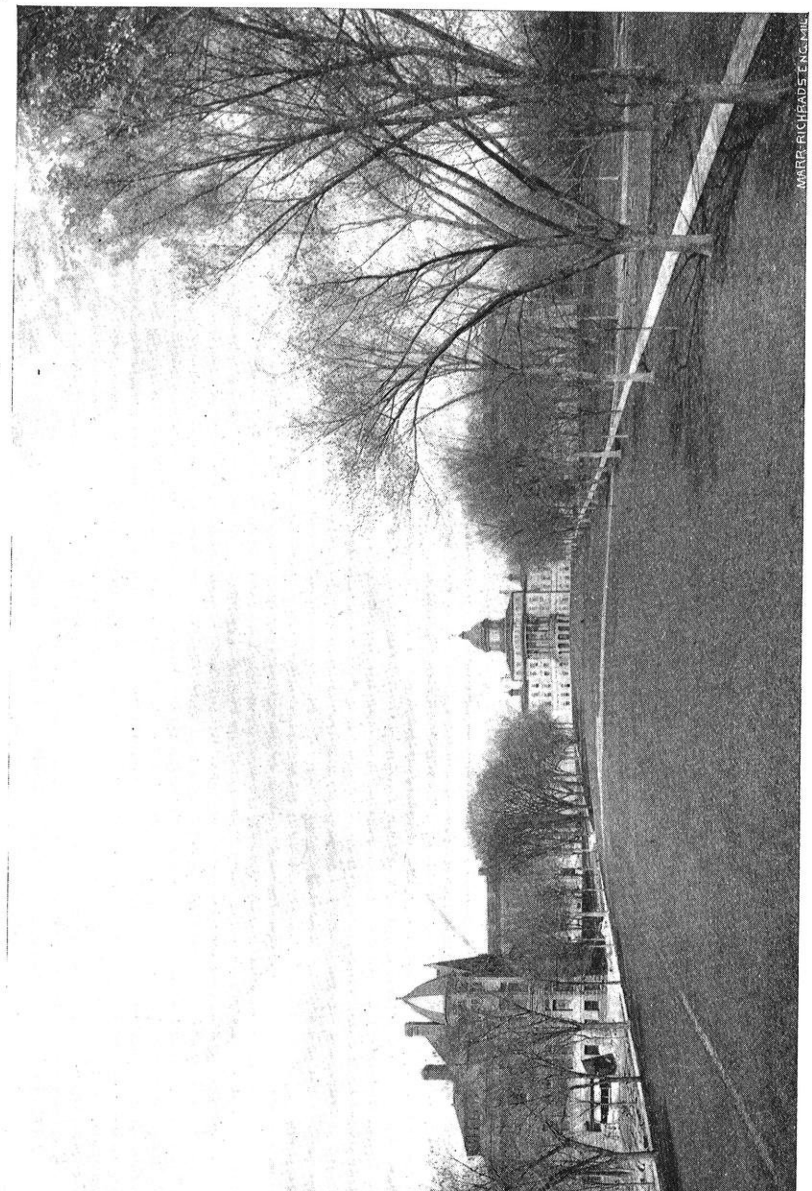
MARR-RICHARDS ENG. MIL.

KOLIN Mine, A Florida—Clay Rec, Mch 28. 1800 w. M May.

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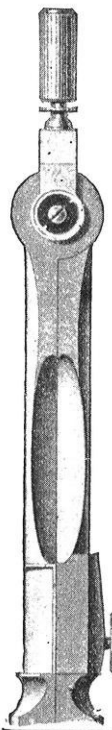
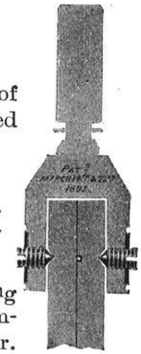




PIECE WORK SYSTEM, The—Ry Mas Mech, Apr. 600 w. M May.

PIER and Pavillion, Clacton-on-Sea (---)—Engng, Mch 20. 2000 w. M May.

PILES, New Method for Determining the Supporting Power of Piles—Franz Kreuter, Ry Rev, May 9. 1000 w. M July.

PINE, Mechanical and Physical Properties of Southern—U. S. Dept Agri, Cir 12. 5800 w. M June.

Pine, Notes on Overloaded White—Ry Rev, Mch 28. 500 w. M May.

PIPE Laying, Costs of—Eng Rec, April 11. 900 w. M June.

PIPES, Areas and Discharging Powers of—J. L. Bixby, Jr., Met Work, Apr 18. 700 w. M June.

Pipes from 28 to 42 Inches in Diameter, Flow of Water in Wrought and Cast-Iron—Isaac W. Smith, Am Soc of Civ Engs, May. 4600 w. M July.

Piping, Fittings and Joints for High Pressure (Ill)—John Platt, Eng News, Mch 19. 1100 w. M May.

PISTON Rings, Snap—F. Halsey, Am Mach, July 30. 1200 w.

Piston Rods, Some Interesting—H. K. Landis, Ir Age, June 11. 1000 w. M Aug.

PLACER Machine, A Dry (Ill)—Min & Sci Pr, Mch 14. 400 w. M May.

PLANER, A Stone (Ill)—Am Mach, Apr 2. 1000 w. M May.

PLANING, Peculiar (Ill)—John Randol, Am Mach, June 25. 1400 w. M Aug.

PLANT, A Cotton Mill Electrical Transmission (Ill)—A. F. McKissick, Elec Wld, Mch 14. 1300 w. M May.

Plant, An Interesting (Ill)—S. D. Benoliel, Elec Pow, Mch. 3000 w. P May. M May.

Plant at Scranton—Elec Ry Gaz, Apr 10.

Plant at the New York Custom House, Electric Lighting and Power (Ill)—Elec Wld, July 18. 1500 w.

Plant, Bergen County (Ill)—Elec Eng, June 3.

PLANTS, Combined Light and Power (Ill)—Engng, July 10. Serial Part 1. 1700 w.

Plants, Combined Lighting and Traction—J. Hésketh & J. H. Rider, Elec Rev, July 29. 2000 w.

Plant, Private (Ill)—Elec Eng, July 15.

Plant, Rome (Ill)—Engng, Lond, July 24. W Aug 22.

Plant, Rules and Regulations in Japan—Engng, Lond, July 31.

PLATFORMS, Advantage of Station, Loc Engng, May. 450 w.

Platform for Railway Work, Traveling—Elec Eng, Lond, July 3.

PLOW, Electric—West Elec, July 4.

PLUMBING Details in Three Large Apartment Buildings (Ill)—Dom Engng, May. 2800 w. M July.

Plumbing in a New England Residence (Ill)—Eng Rec, June 27. 1200 w.

Plumbing in Hotel Jefferson (Ill)—Eng Rec, July 25. Serial Part 1. 1600 w.

Plumbing in the American Surety Building (Ill)—Eng Rec, Mch 14. Serial Part 1. 1400 w. M May.

Plumbing in the Metropolis of the Mississippi, Early—T. D. Turner, Dom Engng, May. 1800 w. M July.

Plumbing, Kitchen (Ill)—Dom Engng, Mch. 500 w. M May.

Plumbing, Samples of Work (Ill)—Dom Eng. June. 350 w. M Aug.

Plumbing System, A Stand-Pipe (Ill)—Eng Rec, June 13. 900 w. M Aug.

Plumbing, The "Sancet" Commission on—Arch, Lond, July 10. 2500 w.

PLUMB Our Houses, How to—H. C. Patterson, Dom Engng, Apr. 2200 w. M June.

PNEUMATIC Appliances, Some Convenient (Ill)—Ry Rev, May 2. 800 w.

Pneumatic Gun, The Dudley Power—Sci Am, April 25. 1400 w. M June.

Pneumatic Power in Workshops—F. Barnett, Can Eng, July. 6000 w. M Sept.

Pneumatic Process, William Kelly's Own Account of His Invention of the—Bul of the Am Ir & St Assn, June 1. 1500 w.

POLARITY Tester—Keim, Amer Elec, July. W. Aug 8.

POLARIZATION and Resistance of Galvanic Cells—Streintz, Electrotechn Zeit, June 25.

Polarization of Thin Metallic Membranes—Luggin, Proc Lond Phys Soc, June.

Polarization Phenomena in Electrostatic Fields—Lombardi, Elektrotechn Zeit, July 30. W Aug 22.

Polarization, Rotary Magnetic—Cotton, L'Eclair Elec, July 25.

Polarization—Streinitz, Electn, May 1. W May 23.

POLE DECISION, An Important—St Ry Rev, July 15. 900 w.

POLYPHASE Circuits, Measuring Power in—Guilbert, L'Eclair Elec, Aug 1.

Polyphase Currents, Notes on—Gerard and Hanrard, Jour Inst Elec Eng, July. L'Eclair Elec, May 2.

Polphase Mountain Railway up the Gornergrat at Zermatt—Electn, June 5. W June 27.

Polyphase System of Ferraris and Arno—L'Eclair Elec, June 13.

POOLING of Freight Equipment—R. Cavanaugh, Ry Age, July 31. 1900 w.

PORCELAIN: How Beleek Ware is Made—Clay Rec, May 14. 1000 w.

Porcelain Works at Meissen, The (Ill)—Sci Am Sup, Apr 4. 2200 w. M May.

PORTSMOUTH, The New Docks at—Trans, June 19. 4200 w. M Aug.

POTASSIUM, Platino-Cyanide—Sci Am, May 23. W May 30.

POTENTIAL and Dielectric Constants, Measuring—Lombardi, Electn, June 26.

Potential Arrester, Automatic (Ill)—Elec Eng, Lond, July 10. Elec Rev, Lond, July 10. W Aug 1.

Potential Differences, Measurement of Very High—Abraham and Lemoine, Jour Inst Elec Eng, May. W June 13.

PO, The Embankments of the River—Frank D. Adams, Science, May 22. 1500 w.

POWDER, High Explosives and Smokeless—Hudson Maxim, Jour Soc of Arts, May 8. 5700 w.

POTENTIOMETER (Ill)—Kollert, Elektrotechn Zeit, Apr 16.

Potentiometer—Fisher, Electn, May 1. W May 23.

Potentiometer, The Crompton—Fischer, Electn, June 26. W July 18.

POWER at Rheinfelden, Transmission of—Rathenau, Elec Eng, Lond, July 17.

Power by Wire Rope, The Transmission of—Wm. Hewitt, Eng News, May 7. 1200 w. M June.

Power Development, Future of—Strong, West Elec, Sept 12.

Power Factor, Practical Significance of the—Elec Rev, Lond, July 3.

Power House, Economical Equipment Operating of—H. S. Newton, Lords Mag, April. 1800 w. M June.

Power House, Foundations for a—George J. Loy, Eng's Yr Book, Univ of Minn. 1000 w. M July.

Power House Performance—St Ry Rev, Apr 15. 800 w. M June.

Power in Brick Yard and Foundry, Electric (Ill)—F. M. Tait, Elec Eng, Apr 22. 800 w. P June. M June.

Power in Central Stations, The Economical Generation of—C. J. Field, Sib Jour of Engng, May. 2700 w. W June 27. M July.

Power in Factories, Transmission of—J. J. Flather, W Elec, Apr 18. 1300 w. M June.

Power in New England, Water—James Francis, Eng Rec, May 16. 2200 w. M July.

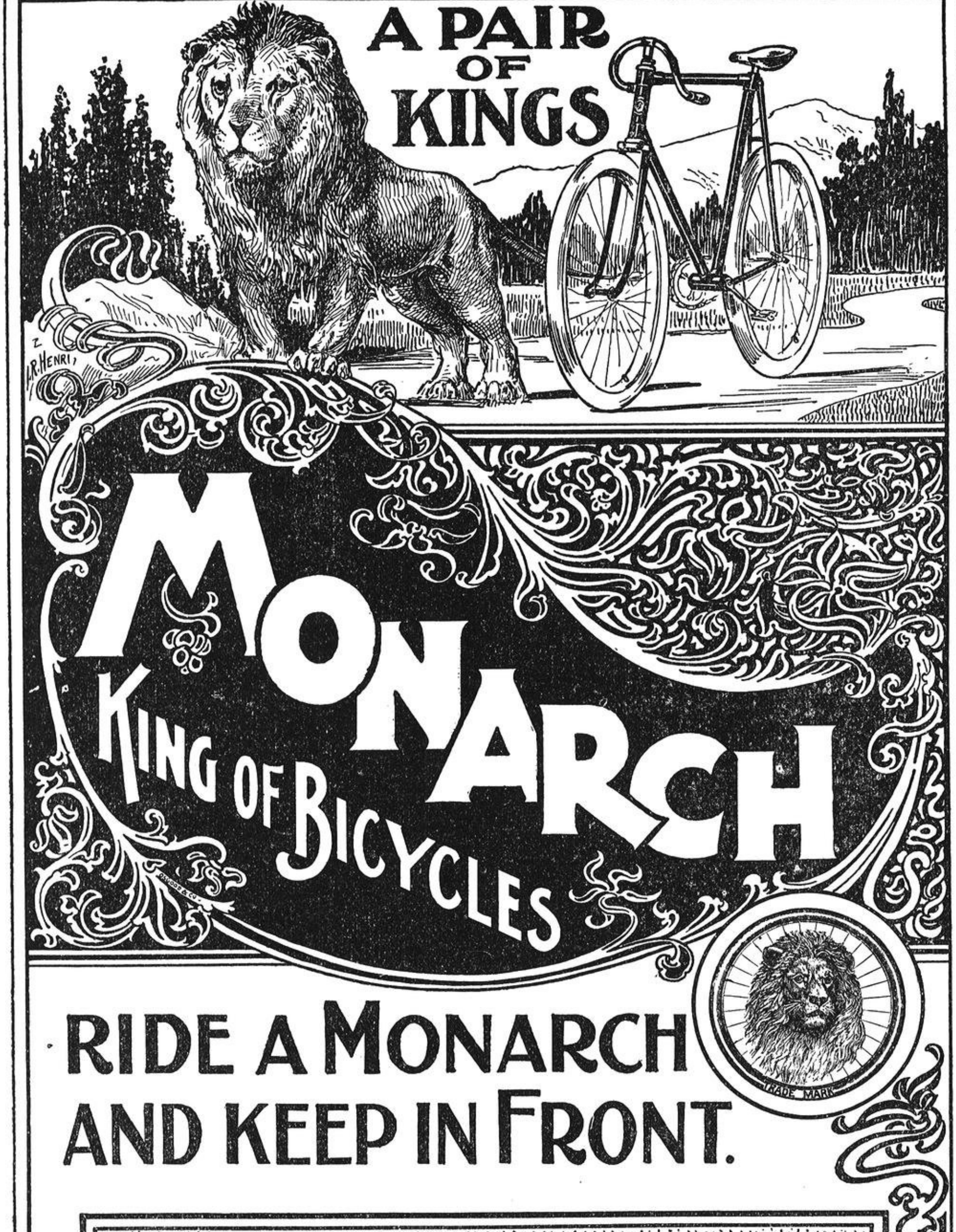
Power of the Future, The—T. Frood, Can Eng, July. 1500 w. M Sept.

Power Plant, An Interesting—Eng Rec, July 4. 800 w. M Aug.

Power Plant at La Goule (Ill)—Brunswick, L'Elec, Apr 11.

Power Plant at North Tonawanda, Test of—Sib Jour, May.

Power Plant at Pelzer, S. C., The (Ill)—Eng Rec, May 2. 2200 w. M June.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SEWER INTERSECTION at Baltimore, Md. (Ill)—C. P. Kahler, Eng News, April 9. 350 w. M June.
Sewers, Maintenance of a Separate System of —T. H. Jones, Eng News, April 23. 900 w. M June.
Sewer Pipe in Macon, Ga., Alignment of Tile (Ill)—Eng Rec, Mch 14. 300 w. M May.
Sewer Tunnel, The Providence—Eng Rec, July 25. 600 w.
SEWING Machine, The (Ill)—Sci Am, July 25. 3000 w. M Sept.
SHADOWGRAPHS, Lightning—Knudson, Elec, Apr 22. W May 2.
SHADOW Pictures by Arc Light Rays—W. W. Kerr, Elec Eng, Mch 25. 700 w. P May. M May.
SHAFT at Sea, Repairing a Broken Thrust—Steamship, Mch. 1200 w. M May.
Shaft at the Colliery of the West Bohemian Company Near Pilsen, Sinking a New—K. Anton Weithofer, Col Guard, May 1. 2200 w.
Shaft Sinking, The Gobert Freezing Process of—A. Gobert, Col Guard, June 12. 2500 w. M Aug.
SHAFTS by Poetsch's Process at Ounaing Near Valenciennes, France, Notes on Sinking Two—H. F. Olds, Min Jour, May 9. 1000 w. M July.
Shafts, Honigman's Method of Boring Mine—W. Schulz, Col Guard, May 1. 2000 w. M July.
SHEAVE-Wheel with Wrought Iron Arm (Ill) —W. H. Osborne, Ir Tr Rev, Mch 19. 700 w. M May.
SHIPBUILDING, American (Ill)—Sci Am, July 25. 200 w.
Shipbuilding, British and Foreign—Mach, Lond, July 15. 1300 w.
Shipbuiding in Germany—C. F. Laeisz, Paper Inst Nav Arch. Eng, Lond, June 12. 2100 w. M Aug.
SHIPPING and Transit Needs of New York—Arch & Build, June 6. 1100 w. M July.
Shipping Competition, Foreign—Engng, July 3. 2000 w. M Sept.
Shipping Facilities, A Revolution in—A. Phenis, Mfrs' Rec, July 17. 5500 w. M Sept.
SHIP Protection by Discrimination—Sea, Apr 16. 1600 w. M June.
SHIPYARD, A Great Lake (Ill)—Sea, May 14. 900 w. M July.
SHIPS—See Geometry.
SHOP Kinks at Valley Falls, O. H. R.—Loc Engng, May. 900 w.
Shop Management, Points on—B. F. Fells, Ir Tr Rev, July 30. 1100 w.
Shop Notes Atchison, Topeka & Santa Fe Ry., Topeka, Kan.—Ry Rev, April 18. 2800 w. M June.
SHOPS of the Pennsylvania Railroad, The Altoona—Am Eng & R R Jour, June. Serial Part 1. 5800 w. M July.
Shops, Philadelphia and Reading—Loc Engng, Apr. 2800 w. M May.
SHOVEL, Railroad Steam—H. E. Riggs, Eng News—July 23. 800 w.
Shovel Work, A Record of Steam—Eng News, July 23. 800 w.
SHUNT, Universal (Ill)—Elec Rev, Lond, Apr 10.
SIBERIAN Railway—Ind & East Eng, June 20. 1700 w.
S[illegible]LING, Block—Tr Assn Civ Engs Cornell Univ, June. 1400 w. M Aug.
Signaling, Mechanical Fog—Eng, Lond, July 10. 1600 w.
Signaling, Railway Block—J. Pigg, Elec Eng, Lond, July 3. Serial Part 1. 1700 w.
SIGNALS and Care of Interlocking Apparatus, Distant—Charles Hausel, Ry Rev, Mch 21. 1500 w. M May.
Signals and Permissive Blocking, Three-Position—R R Gaz, April 17. 400 w. M June.
Signals Between Stations and Trains in Motion, Agabey's System—Ind Engng, May 9. 900 w. M Aug.
Signals, Rules for Operation and Maintenance of Interlocking—Eng News, Apr 2. 2400 w. M May.
Signals, Colors for Night—Eng News, Mch 12. 1800 w. M May.
Signals, Color for Night—R R Gaz, Apr 3. 2400 w. M May.
Signal Department Standards (Ill)—Ry Rev, May 2. 1400 w.
Signals, Electric Controller for Grade Crossing Alarm (Ill)—Eng News, May 21. 500 w.
Signals on Electric Railways—St Ry Jour, May. 2400 w.
Signals on the Boston & Albany, Automatic —G. Blodgett, R R Gaz, July 24. 2000 w.
Signals, Uniformity in Senaphore—Ry Rev, April 11. 400 w. M June.
Signal Standards on the Pennsylvania Lines West of Pittsburg (Ill)—R R Gaz, Mch 27 1600 w. M May.
SILK Covered Wire Testing (Ill)—Elec Rev, Lond, July 31. W Aug 22.
Silk Fabric Made by Insect Larvae (Ill)—W. G. Johnson, Am Miller, Apr. 1600 w. M May.
SILVER in Chloridizing—Roasting, The Volatilization of—L. D. Godshall, Eng & Min Jour, May 16. M July.
Silver Mines in Australia, The Broken Hill—Eng & Min Jour, July 11. 2000 w.
Silver, Separating Lead from—Tomasi, L'Ind Elec, July 20. W Aug 8.
Silver—See Lixiviation.
SISAL Industry in the Bahamas, The—D. Morris, Jour of Soc of Arts, Mch 20. 10000 w. M May.
SKY Scrapers of Rome, The—Rololfo Lanciani, N Am Rev, June. 3800 w. M July.
Sky Scrapers, The Construction of—C. T. Purdy, Tr Assn Civ Engs of Cornell Univ, June. 6400 w. M Aug.
SLATE in Great Britain, American—Stone, April. 1300 w. M June.
SLIDE RULE, The Use of the—F. A. Halsey, Am Mach, May 28. Serial Part 1. 1800 w.
SLEEPERS, The Use of Iron and Steel for Railway—Ir & Coal Tr Rev, Apr 10. 1800 w. M June.
SMELTING in California, Matte—H. Lang, Eng & Min Jour, July 25. Serial Part 1. 3000 w.
Smelting, Matte—W. L. Austin, Min & Sci Pr, Mch 28. 3000 w. M May.
SMELTERS, Flux for the (Ill)—Aust Min Stand, March 5. 800 w. M June.
SMOKE Prevention from a Mechanical Standpoint—C. Benjamin, Safety V, July. 1500 w. M Sept.
Smoke Prevention—See Combustion.
SOLIDS and Vapors—Wilder D. Bancroft, Phys Rev, May–June. 6000 w. M July.
SOUTH Rocky River Bridge, The (Ill)—Eng Rec, June 13. 1500 w. M Aug.
SPANISH Brick and Tile Work (Ill)—C. H. Blackall, Br Bu[illegible]er, June. Serial Part 1. 2500 w. M Aug.
SPARK, Globular—J Inst Elec Eng, June. W July 25.
SPARKING Distance and Ultra-Violet Light—Swyngedauw, L'Eclair Elec, May 23.
Sparking of Closed Coil Direct-Current Armatures—George T. Hanchett, Elec Ry Gaz, Mch 28. 2300 w. M May.
SPECIFICATIONS, Concerning—R R Gaz, May 1. 1600 w.
SPECTRA of the Bunsen Burner and Exhausted Bulbs, The—W. H. Birchmore, Elec Eng, Mch 25. 2300 w. M May.
Spectra in Exhausted Tubes, On the Cause of Continuous—Elec Eng, July 8. 2700 w. W July 18. M Aug.
SPECTRO PHOTOMETER, How to Make and Use a Simple (Ill)—W. H. Birchmore, Pro Age, May 1. W May 22. 1100 w. M June.
SPEED of Electrical Machinery—Wm. Baxter, Jr., Elec Wld, June 20. 1900 w. M Aug.
Speed, The Problem of—M. J. N. Normand, Eng, Lond, May 22. 2000 w. M July.
SPRINGS, Coiled—E. T. Adams, Am Mach, May 21. 1300 w. M July.
Springs, Intermittent—Walter C. Garretson, Sci Am Sup, Apr 11. 1200 w. M May.


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