The Wisconsin engineer. Volume 16, Number 8 May 1912

Madison, Wisconsin: Wisconsin Engineering Journal Association, [s.d.]

https://digital.library.wisc.edu/1711.dl/7P3DBZ6M5SIJV8I

The Wisconsin Engineer

MAY, 1912

Volume 16 **Number 8**

$1.00 a Year **20c a Copy**

WISCONSIN ENGINEERING JOURNAL ASSOCIATION

Volume 16 **Founded 1896** **Number 8**

The Wisconsin Engineer

$1.00 a Year **20c a Copy**

Entered as second-class matter Sept. 26, 1910, at the postoffice at Madison Wis., under the Act of March 3, 1879.

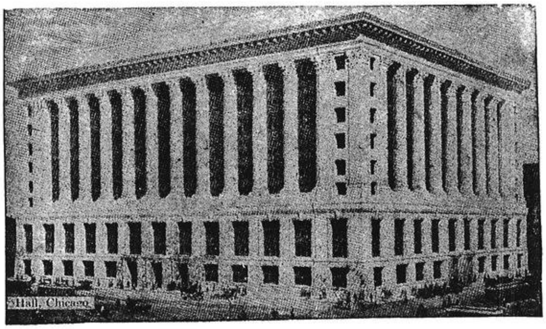
CONTENTS

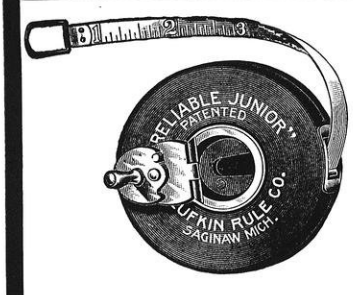
MAY, 1912

Published monthly from October to May, inclusive, by the
WISCONSIN ENGINEERING JOURNAL ASSOCIATION,
Engineering Bldg., Madison, Wis.

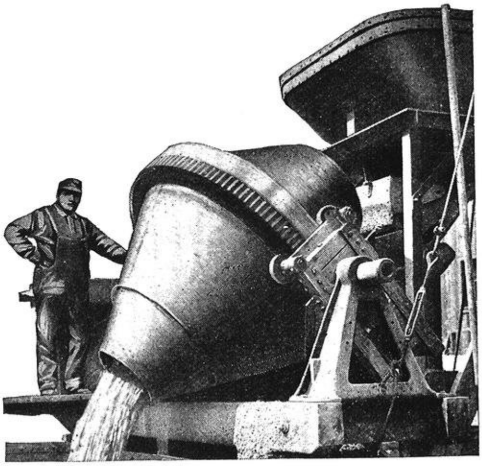
Address all communications to The Wisconsin Engineer.

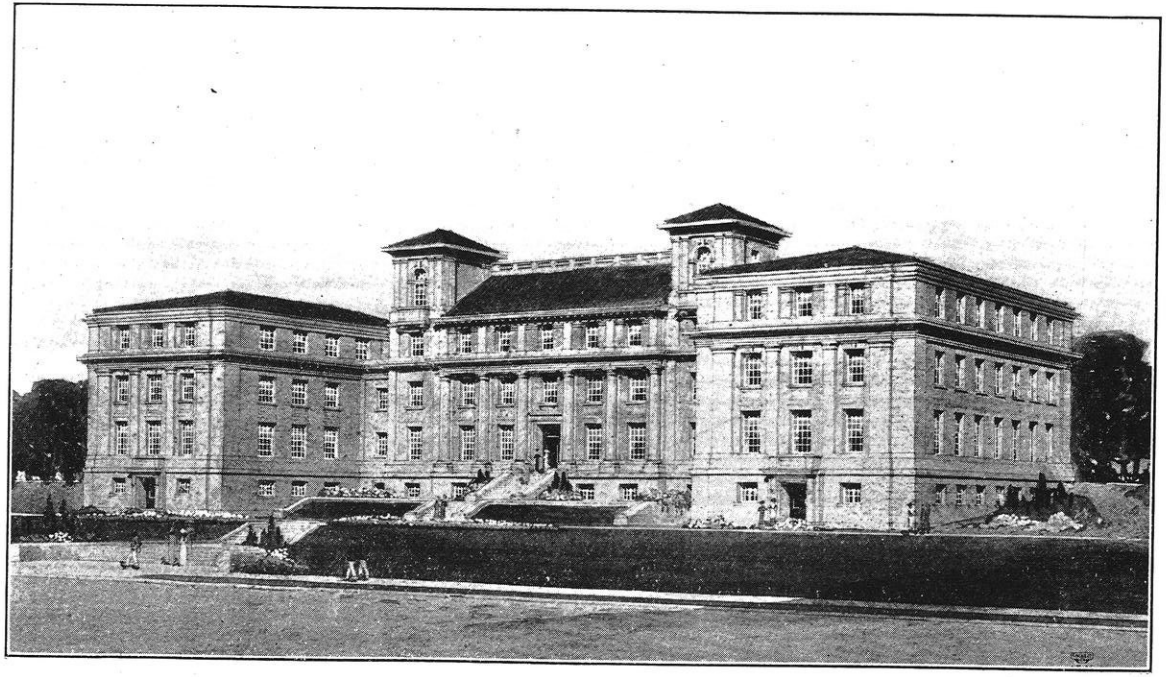
Subscription price $1.00 a year if paid before February 1; $1.25 a year after that date. Canadian subscriptions, $1.25 a year. Foreign subscriptions, $1.50 a year.


Hall, Chicago


"RELIABLE JUNIOR" PATENTED
LUFKIN RULE CO. SAGINAW MICH.


HIGGINS'
AMERICAN
INDIA INK





Home Economics and University Extension Building. (See Page 368.)

The Wisconsin Engineer

VOL. XVI MAY, 1912 NO. 8

MALLEABLE CAST IRON.

JAMES ASTON,
Instructor in Chemical Engineering.

Iron owes much of its supremacy as a metallurgical product to its relatively low cost, due largely to the abundance and richness of its ores, to the low cost of mining, and to the readiness with which these ores are reduced to the metallic state. Aside from this consideration, however, it is undoubtedly true that the great commercial utility of iron is due to the activity with which it alloys with other elements, to its adaptability to various methods of working and to the susceptibility of the alloys to heat influences.

Out of an approximate annual production for the United States of thirty millions tons, of finished iron and steel products the greatest part, say sixty per cent, is formed by rolling or forging. Rolling is particularly suited to the production of large outputs of simple standard shapes, such as rails, structural sections, bars, rods, etc. Many shapes are, however, too intricate to be produced by rolling or forging, and are cast to form by pouring molten metal into a mold formed by a suitable pattern. The foundry industry is an important division of iron and steel metallurgy, producing roughly forty per cent of the iron and steel products. Castings may be of three kinds—cast iron, steel, and malleable cast iron. Each has its particular sphere of usefulness, dependent upon the nature of the service and the fitness of the material for this service, and also upon the cost of the product.

Leaving out of consideration any special alloy additions, commercial iron and steel consists of iron in association with carbon, silicon, sulphur, phosphorus and manganese. The properties of the material are dependent not alone upon the quantities of these elements present, but also upon the manner in which they are associated; an association which is manifested in the structure. Ordinary cast iron is the most impure of the three forms. The general composition is as follows:

Carbon—3½ to 4¼ per cent.
Silicon—1 to 3 per cent.
Sulphur—0.05 to 0.20 per cent.
Phosphorus—0.20 to 1 per cent.
Manganese—0.50 to 1 per cent.

By suitable regulating of chemical composition and rate of cooling, it may range in fracture from gray to white, and in hardness from a material which can be readily machined or filed, to a product which is glass hard. Being a result of simple melting of pig iron and cast scrap, without material chemical conversion, it is of comparatively low cost. Add to this the fact that its high fluidity and "life" enable it to run into thin sections or intricate forms, and we have the principal reasons for its favor. The usual requirement is for a material soft enough to be machined; strength is a secondary consideration. Cast iron has, however, an extreme resistance to compression, and is thus well adapted to machine frames, and the like; if strength in tension or resistance to shock are wanted, they are obtained by massiveness of structure.

Where high strength and ductility are required, the steel casting is most suited. The general chemical composition will be about as follows:

Carbon—0.20 to 0.80 per cent.
Silicon—about 0.20 per cent.
Sulphur—0.02 to 0.08 per cent.
Phosphorus—0.03 to 0.10 per cent.
Manganese—0.50 to 0.75 per cent.

The requisite strength is obtained by suitable chemical control, together with judicious heat treatment. Increase of carbon results in increase of strength at a sacrifice of ductility. The other elements, also, phosphorus in particular, have their influence. Steel castings may be the result of various methods of working; crucible, Bessemer or open hearth, either acid or basic. Because of high cost of raw materials, or the necessity of skillful and costly manipulation in the conversion of the impure iron into the finished steel, the product is necessarily of considerably higher cost than cast iron. Again, its low fluidity and "life," its high temperature, and high shrinkage, are in many cases serious disadvantages. Steel castings, therefore, are generally comparatively bulky in section, and find their greatest application where the added strength is enough to offset the increased cost and other disadvantages.

Malleable cast iron occupies a position between ordinary cast iron and cast steel. It has higher tensile strength than cast iron, but is not so strong as steel. Again, it is fairly ductile and malleable, and may be bent or twisted or hammered to a certain extent without danger of breaking. The great advantage, however, is that it is originally cast of white cast iron, with all of the advantages of fluidity and life to enable it to run into small thin sections and intricate shapes, and low cost of initial production. The ductility and malleability are the result of subsequent treatment.

Although it was predicted that the development in the manufacture of steel castings and the possibility of making small castings of this material, would make serious inroads upon the malleable casting industry, this prediction has been fulfilled only in special cases. The industry has experienced a growth entirely comparable with the other divisions of foundry practice, and today, perhaps a million tons annually represents the output of this country. Malleable castings are largely used in railroad equipment, agricultural implements, pipe fittings, stoves, etc.; in fact, the great outlet is in lines requiring large numbers of pieces of comparatively small size from the same pattern, and where low cost and a fair ductility are factors.

It is not the purpose of this article to go into the details of the manufacture of malleable castings; its object is rather to point out the underlying reasons for the properties which this product possesses; but a few words regarding the process will not be amiss. Those who are interested in the details of practice are referred to the new books of Dr. Moldenke, perhaps the foremost authority in this country.

The pig iron used as a raw material is usually classed as malleable Bessemer; that is, it conforms to the usual requirements of a Bessemer pig, except that the phosphorus exceeds the steel making limit of 0.10 per cent. Ordinarily it is the product of a coke blast furnace, but for the highest grades of product, charcoal pig iron is used. The general analysis will be as follows:

Carbon—about 4 per cent.
Silicon—0.75 to 2.0 per cent.
Sulphur—about 0.05 per cent.
Phosphorus—not over 0.225 per cent.
Manganese—0.50 to 0.75 per cent.

With this is mixed the proper amount of steel or malleable scrap to bring the castings of an appropriate analysis of

Carbon—about 3 per cent.
Silicon—0.50 to 1.0 per cent.
Sulphur—below 0.08 per cent.
Phosphorus—below 0.225 per cent.
Manganese—0.25 to 0.50 per cent.

The amount of silicon allowable will depend upon the size of the casting, and to a certain extent upon the amounts of sulphur and manganese present; these last named elements are, however, preferably kept to a minimum. Phosphorus is held to as low an amount as possible (because of its tendency to promote brittleness), and yet have sufficient fluidity in the molten metal.

In this country the melting is usually done in a cupola furnace for the lower grades of work, or in an air furnace (reverberatory) for the greater part of the output. Recently, the open hearth furnace, similar to that used in steel making, has come into a little favor. The air furnace owes its advantages to the isolation of the solid fuel from the charge, the possibility of regulation of the chemical action of the flame, and to a consequent better control and higher quality of material produced. The furnace action should ideally be one of melting only; actually there is some chemical change, principally in an oxidation of silicon and manganese, and a slight gain in sulphur.

The castings as taken from the sand are hard, white and brittle, and entirely unsuited for their intended service. They are inspected and cleaned of all adhering sand, mainly by means of a tumbling barrel; then trimmed of sprues by chipping, and sorted, after which they are ready for annealing, the distinguishing feature in the malleable casting process. For this operation the castings are packed in annealing boxes, or pots, which are open frames, usually rectangular in shape, and of somewhat varying sizes in different plants. An average size is 30 inches by 16 inches and about 16 inches deep with an initial thickness of three-fourths to one inch. They are usually cast largely of malleable scrap. The pots are stacked three or four high on a bottom plate or stool.

Into these boxes, the castings are carefully packed in mill scale, iron ore, sand or a mixture of these substances. The two first named are oxidizing agents for the carbon, while sand, or the like, is inert. The object is usually to get an oxidizing medium not too active; a refreshing of the spent or used packing with new scale usually suffices. The essential principle in the packing is to see that all castings are well surrounded with packing material in order to prevent passage of air and have uniform action, and also to prevent settling and consequent warping of the castings when heated. The stack of pots is finally covered and luted with clay and makes, therefore, a fairly airtight container for the castings.

A number of these stacks of pots (20 to 40) are run into a large brick annealing oven, and the brick doors of the oven are closed. The ovens may be gas, oil or coal fired; usually the first or last named, since the oil flame is too localized in its action, and results in uneven heating throughout the oven. The annealing operation requires about one to two days to bring the temperature up to that required, two to three days at this temperature and a day or two for cooling down, making a total of five to six days for the complete cycle. The temperature varies somewhat with the character of the castings and the melting stock used, as well as with the kind of melting furnace, but is generally between 1300 and 1650° F. (700 to 900° C.). The pots are withdrawn from the oven and the castings are dumped after having cooled sufficiently. After a final cleaning, grinding, and sorting, the product is ready for shipment as the finished malleable casting.

The result of the annealing operation is to convert the hard, brittle casting with white fracture, to one soft, relatively ductile and malleable, and having a black fracture (black heart) except for a steely shell (case) of varying thickness, usually 1/32 to 1/16 inch. The tensile strength according to the standard specifications of the American Society for Testing Materials must be not less than 40,000 pounds per square inch, with an elongation of not less than 2½ per cent in 2 inches. The great advantage, however, is a product resilient enough to withstand the shocks and repeated stresses of severe service.

The popular idea among the uninformed is that the packing of the castings in an oxidizing substance has resulted in an abstraction of carbon from the body of the casting, producing a material which is a mean between ordinary steel and the original white cast iron, depending upon the activity of the oxidizing substance. It must be said, however, that a product essentially the same as the every day malleable would result, even though the packing material were inert or nonoxidizing in character. A thorough understanding of the mechanism of the annealing operation has come only with a knowledge of the influence of the several elements present. Chemical analysis has been a big stepping stone; the miscroscope, also, while not as yet having much application in the industry, has been of invaluable assistance.

Cast iron, as pointed out previously, is a complex alloy of iron and several other elements. Carbon is of primary importance, and the material owes its properties mainly to the state of the carbon. The other elements are largely secondary, having their effect on the properties mainly by influencing the state of the carbon. All cast iron may be considered as an alloy of iron with approximately four per cent of carbon. The white castings forming the initial stage of the malleable casting may be considered in this class, although there is usually a lower amount of carbon present, due to additions of steel or malleable scrap; this fact, however, is not material to the discussion of the mechanism of the annealing process.

Carbon is associated with iron in three different states; in the free or elemental state, as graphite; as a definite carbide, combined carbon or cementite, with a formula Fe_3C; and as a solid solution of carbon or combined carbon in iron. The last named is of particular importance in the consideration of the hardening and tempering of steels, and need not be considered in connection with the problem under discussion. During the solidification and cooling to normal temperatures of a molten bath of cast iron, the carbon may finally exist entirely combined with the iron as Fe_3C, in which case the product is known as white cast iron, and is hard, brittle, and of silvery fracture because of the influence of the properties of this iron carbide; or the carbon may bcome separated in the free or elemental state as graphite, forming gray cast iron, with gray fracture and soft, due to the influence of the free carbon; or there may be any degree of mixture of the combined carbon and free graphite, resulting in the commercial mottled irons. Should all of the carbon exist in the combined state, as Fe_3C, carrying 6.67 per cent carbon, an ordinary iron with three and one-half per cent of carbon would consist roughly of one-half cementite and one-half free iron. On the other hand, if all of the carbon exists as free graphite, the material structurally, on the basis of specific gravities of 3 to 1 for iron and carbon, will be made up of iron plus ten per cent by volume of free graphite.

The fundamental influences affecting the state of the carbon are the rate of cooling and the effect of the secondary elements, especially silicon, and to a lesser degree sulphur and manganese. Silicon promotes the formation of graphitic carbon; sulphur and manganese tend to form combined carbon. For simplicity, we may consider the function of silicon as first, to counteract the adverse chemical influence of the sulphur and manganese, and second, to overcome any effects of cooling, and throw out carbon in the free state. As for the influence of cooling, a slow rate promotes the separation of free graphite, while rapid cooling tends to form combined carbon. Manifestly by judicious control of chemical composition and rate of cooling, it is possible to vary the character of cast iron within wide limits.

Ordinarily, in gray iron castings, softness is the desired feature. This means much free graphite in the product, and little combined carbon; or a moderate silicon contents of 1.5 to

2.0 per cent with low sulphur for bulky castings which cool slowly, and 2 to 3 per cent in lighter and thinner products which necessarily cool more quickly. In this kind of castings the graphite separates out during normal solidification, and in a still molten matrix of iron; obviously conditions are entirely favorable to crystallization of the carbon, and we find it existing in the well known form of flake graphite. Figures 1 and 2 are typical of this distribution, at a magnification of 70 diameters. In Fig. 1 the graphite is very coarse in texture, due to the slow cooling of a piece of pig iron; while Fig. 2 illustrates the finer texture in a casting of average section. With such distribution of the carbon, we can expect nothing else than a weakness in tension, and an entire absence of ductility; on the other hand, because of the very thinness of the graphite flakes, there is little weakening of the material under compressive stress.

The malleable casting is initially made of white cast iron. The silicon content is so controlled that under the existing rate of cooling, its influence is not sufficient to throw out the graphite in the free form, and it is therefore all combined as Fe_3C in the castings. These are hard, brittle, and practically worthless for service. Typical micro-sections of white cast iron are shown in Figures 3 and 4, both at a magnification of 70 diameters. The former is of white pig iron, and is coarser in its crystallization than the latter, a section of a thin casting. To the uninitiated it may be well to mention that the black areas in these photographs should not be compared with the graphite of the previous figures. These black areas show the distribution of the iron bearing constituent, which is differentiated by acid corrosion; the white areas, in contrast, show the free combined carbon. The brittleness and whiteness of fracture are due to a cleavage through these areas of combined carbon.

Although the silicon content is not sufficient to cause a separation of free carbon during the normal cooling of the casting, the combination of this silicon content, with the proper application of temperature effect and time of reheating, will effect the change, according to the reaction:

$$Fe_3C + \text{heat} = 3\ Fe + C$$

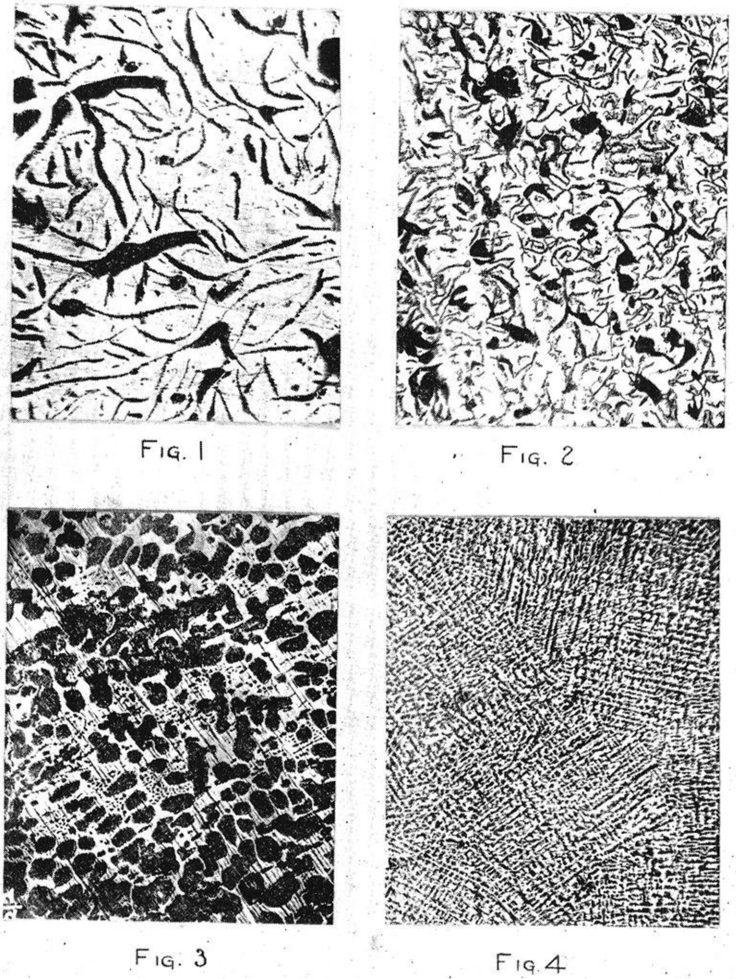


FIG. 1 FIG. 2

FIG. 3 FIG. 4

PLATE 1.—*Showing Micro-sections of Various Grades of Cast Iron.*

This is the essential feature of the annealing operation, and it is obvious that, with chemical composition, temperature, and time correctly regulated, the nature of the packing material is of little importance. The vital feature of the malleable casting process lies in the use of annealing temperatures of 1300° to 1650° F. (700 to 900° C), or well below the point of fusion of the metal. Consequently, while the combined carbon is decomposed and the carbon precipitated, the latter is not free to assume its normal crystal form as thin flakes, but must collect in the most compact state, and is thus found in the form of globules in the amorphous condition, the so called "temper" carbon Such a distribution, as will be noted in Figures 5 and 6, is without the disastrous effect on the tensile strength and ductility characteristic of the flake distribution in gray cast iron; and the resultant product is one of fair strength and ductility.

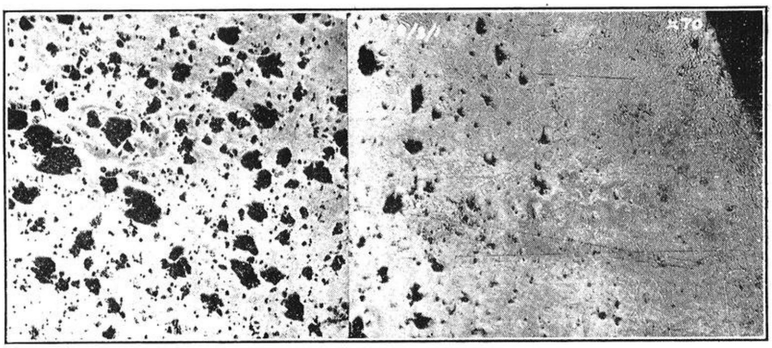


FIG. 5.—*Micro-section Showing Effect of Oxidizing Packing.*

Figures 5 and 6 show the effect of the oxidizing packing. In Fig. 5, of a section not etched with acid, it will be noted that adjoining the edge of the annealed casting there is a zone free from graphite areas. This is the result of the decarbonization of the surface layer by the iron oxide, according to the reaction

$$Fe_3 C + FeO = 3 Fe + Co + Fe$$

After etching, as shown in Fig. 6, this surafce zone is seen to be a shell of steel which may be of mild, medium, or high carbon, and of a depth depending upon the time and temperature of heating and the avidity of the decarbonization. This surface decarbonization, together with the use of steel or malleable scrap to lower the total carbon in the castings, are details of practice making for greater success of the process, but are not the fundamental principles involved. The entire process is built upon the ability to control the state of the carbon by proper regulation of three factors: chemical composition, temperature and time.

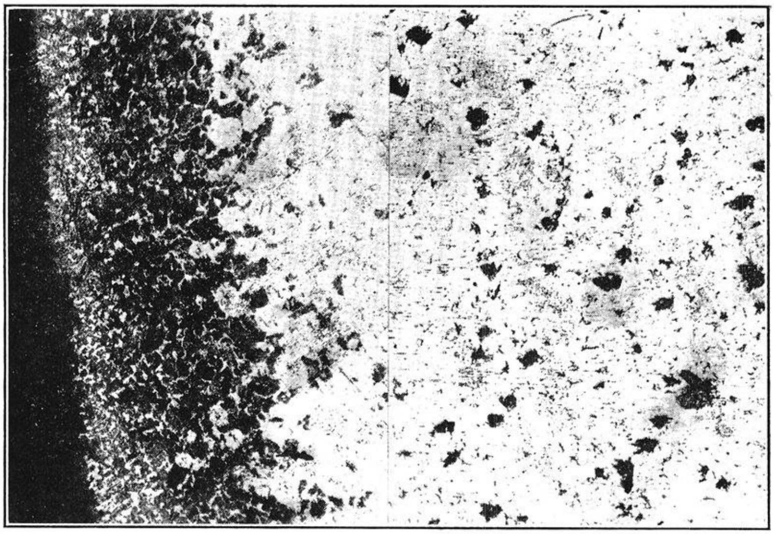


FIG. 6.—*Micro-section Showing Effect of Oxidizing Packing. Section Etched with Acid.*

INCANDESCENT ELECTRIC LAMPS.

METHODS OF MANUFACTURE AND OPERATING CHARACTERISTICS.

Glen P. Cowan, '11.

An electric incandescent lamp, by definition, is a lamp in which light is emitted by a body that has been brought to incandescence by means of an electric current. Ordinarily, however, this term is used to denote only that type of lamp in which a filament is made to glow by heating it electrically in a vacuum. The name will be used in the latter sense in this article.

Incandescent lamps are classified according to the filament material used in them. The four main classes of incandescent lamps are the carbon, Gem, tantalum and tungsten classes, in which the filament materials are respectively, carbon, graphitized carbon, metallic tantalum and metallic tungsten. The carbon and Gem lamps are often referred to as carbon-filament or low-efficiency lamps, while the tantalum or tungsten lamps are called metallic-filament or high-efficiency lamps. A consideration of the requirements of a lamp filament soon reveals the reason for the adoption of these filament materials. From the physics of the production of light it is known that the higher the temperature of operation of the filament and the higher the selectivity of radiation (up to certain unattainable limits), the higher the luminous efficiency. Consequently, to be a good filament material, an element must have a high melting point and a high selectivity of energy radiation. In combination with a high melting point the filament must have a low vapor tension at temperatures below the melting point, for the rate of vaporization and deposition on the bulb of the filament affects the life of the lamp and determines the working temperature. It is for this reason that the carbon lamp can not be operated at a higher temperature. While carbon has the highest melting point of any known substance, its vapor tension is so high that it can not be operated at temperatures as high as can other materials with much lower melting points. The results of the vaporization of the filament are the black deposit on the bulb, which materially decreases the percentage of light transmitted through the bulb, and the disintegration of the filament, which increases the resistance and decreases the total amount of light produced.

The other requisite, a high selectivity of radiation of energy, means a comparatively high percentage of energy radiation within the visible spectrum. Only the energy radiated within certain limits of wave lengths is useful in producing light, and a body is said to possess luminous selectivity if it radiates relatively more energy within these limits (the limits of the visible spectrum) than does a black body at the same temperature. It should be added that the location of the radiation within the visible spectrum also affects the degree of selectivity—0.545μ is the wave length at which the eye has its maximum sensibility. In addition to these physical properties that are required of a filament material, there are, of course, the commercial considerations of adequacy of supply and facility of working.

The melting points of the more common filament materials are carbon 3600° C., tungsten 2950° to 3050° C., tantalum 2800° to 2900° C. and osmium 2700° C. Because of its low vapor tension and high degree of selectivity, osmium is a very desirable material, but it is extremely scarce and is not used extensively for that reason. Tungsten is probably just as good as osmium; its selectivity is not so high, but its melting point is higher. It is found in considerable quantities in several countries. Tantalum possesses less selectivity than either osmium or tungsten and can not be operated at as high a temperature. Carbon possesses practically no selectivity; graphitizing it, however, lowers the vapor tension and permits a higher working temperature. It is a question as to whether the higher operating efficiencies of the metallic-filament lamps, as compared with the carbon lamps, are attributable to higher temperatures or not, although it is commonly believed that the higher luminous efficiency is a result of both higher selectivity and higher temperature.

The history of the development of the manufacturing processes for making these different classes of filaments is an interesting story, but necessarily a very long one. No attempt will be made to touch on this phase of the question, but the present processes will be outlined. All the so-called carbon filaments, the untreated carbon, the treated carbon and the graphitized carbon (Gem) filaments, are made of pure cotton, and up to certain steps in the processes are the same. The cotton, which has been purified by special treatment, is dissolved in a solution of zinc chloride, forming a thick heavy dark-brown syrup called the ''cellulose mass.'' This syrup is strained and later boiled in partially evacuated bottles in order to set free all occluded gases. The bottles containing the mass, or syrup, are put on the squirting racks, and by means of compressed air the syrup is forced out of the bottle through a platinum die. The die exudes the fine thread of the mass into a slowly revolving jar of wood alcohol. The instant the syrup comes in contact with the alcohol, it coagulates forming an elastic translucent thread. The jar is revolved slowly so that the filament will lay itself down in coils, and will not tangle when reeled off.

After the bottle has been emptied, the thread is taken from the alcohol jar and washed thoroughly, first in dilute acid, and then in distilled water. It is essential that all the foreign material be washed out of the thread at this stage, since the presence of such material tends to make the filaments brittle when carbonized. The washed thread is wound out on large wooden drums, on which it is allowed to dry. Why dry, it is taken from the drums, inspected, and sent on to the forming room: at this stage the fiber resembles cat gut. In the forming room the fiber is wound on brass forms and baked for a short time at a moderate temperature. This gives the fiber a permanent set, and it retains the shape of the form, which is that of the desired filament. After the filaments are cut off the forms, they are packed in powdered peat in small cast iron boxes, ready for carbonizing. The carbonizing process consists of a preliminary baking in a gas furnace, after which the contents of the iron boxes are transferred to a graphite crucible, and a final baking in a high-temperature oil furnace. The rate of raising the temperature and the rate of cooling affects the structure of the carbon very materially, and these operations are necessarily watched very carefully.

The filament, as taken from the oil furnaces, is the untreated carbon filament. Before it is mounted in a lamp, however, it is tested for spots, measured for resistance, and sorted. The spot testing merely consists of heating the filament to a dull red heat in an evacuated bottle, and inspecting it for bright or dull places. Any such bright or dull spots indicate a variation in cross-section, and filaments showing these spots are thrown out.

The treated-carbon filament is simply an untreated carbon that has been flashed in hydrocarbon vapors. In the flashing process the filament is placed in a jar and, after the air has been withdrawn, gasoline or similar vapors are allowed to flow in. Then the switch is closed, and as the filament heats up carbon is deposited on it; more carbon will be deposited where the filament is small because this part of the filament becomes hottest. Hence, the deposit evens out the filament and, in addition, leaves a layer of low-resistance carbon on the high-resistance core. As the carbon is deposited on the filament, the cross-section is enlarged and the current increases; this action continues until the current reaches a certain predetermined value when a series relay opens the circuit. Filaments of any desired resistance can be made in this way by setting the trip on the series relay so that it will open when a certain value of current is reached with a given voltage applied.

In making the Gem, or graphitized carbon, filament the carbons are taken from the oil furnace to the electric-tube furnace, where they are packed in graphite and raised to an extremely high temperature. The heat at this high temperature shrinks the carbon and lowers its resistance. Then the filament is treated in the flashing room and reheated in the electric furnace. At this point the big change takes place. The high resistance core is unchanged by this second heating, but the deposited carbon is softened, its temperature coefficient is changed, and the resistance is reduced to about one-fourth its original value. The real gain is in the lowering of the vapor tension, which permits higher operating temperatures and consequently higher efficiency of light production.

Experiments are being carried on with a new Gem lamp in which the filament is made by forcing a graphite paste through a die and baking it subsequently in the electric furnace. The lamp is in the developmental stage yet, however, and, while some preliminary tests show it up well, no predictions can be made as to its possibilities.

Of the three carbon filaments, the untreated carbon is least satisfactory. It has a relatively high resistance, however, and is used for that reason in high-voltage lamps. The treated carbon gives more uniform performance than the untreated and about twenty per cent higher efficiency. Because of its low resistance, it is not used in the 220-volt lamps. The Gem operates at an efficiency from fifteen to twenty per cent higher than the treated carbon filaments, and gives practically the same performance.

The only two metallic filaments of any commercial importance are the tungsten and the tantalum, and the tantalum is being rapidly displaced by the drawn-wire tungsten. It still has a strong hold in Germany where it was perfected. The investigators experienced considerable difficulty in producing the brittle metal tantalum in a state so that it could be drawn, but they finally perfected a process. The exact method of working the metal and drawing it is not generally known, but it is probably quite similar to that used in making tungsten wire because of the similarity of the two metals.

Two types of tungsten filaments are used, namely, the pressed filament and the drawn-wire filament. The pressed-filament lamps were made before a method of drawing tungsten had been perfected, and they are still made by several manufacturers. There are several different processes of making pressed tungsten filaments, but in general the scheme is to mix finely powdered metallic tungsten with a binder of some sort, to force this plastic mass through a die forming it into filaments, and to burn out the binder and sinter the particles together by passing a current through the filaments in a reducing gas.

In making the drawn-wire filaments, the tungsten is received at the lamp factory as the yellow oxide, WO_3. This oxide is reduced and purified, and finely divided metallic tungsten is obtained. The metallic powder is pressed into small ingots, and the particles are sintered or welded together by an electric current. These ingots are worked until the metal changes from a crystalline to a fibrous structure, and they are then drawn down through diamond dies to the standard sizes of wire. Wire less than 0.001 of an inch in diameter can be drawn successfully. The wire is rated according to its normal amperage, and wound on to spools on which are marked the current rating and number of feet of wire.

Before burning, tungsten wire is stronger than steel wire of the same size; the tensile strength is over 400,000 pounds per square inch in the small sizes of wire. On burning, however, it loses considerable of this strength on account of the crystallization of the metal, but at any stage of its life it is stronger than the pressed filament. The tantalum filament is stronger than either the drawn-wire or pressed tungsten filament, but it lacks much in efficiency. As an average, the efficiency of the two types of tungsten lamps is considered 1.25 w. p. c. and that of the tantalum 2.0 w. p. c. (the unit w. p. c. is watts per mean horizontal candle-power).

So far only the filaments and their manufacture have been dealt with. While perhaps the filament is the most important part of a lamp, the mechanical make up is also important, and the operations of mounting, sealing in, exhausting, and finishing are very interesting. In order to give an idea of how a lamp is made, a drawn-wire tungsten lamp will be traced through the factory. Only one class of lamp will be taken up, for the mechanical make-up, with the exception of the mount, is very similar in all classes of lamps. The low specific resistance of the metallic-filament materials necessitates a long thin filament, which in turn requires a mount that will support the great length of wire and keep the strands apart. In the case of the carbon lamp, no central support with radial arms is needed, for the filament is comparatively short and rigid; a stiff wire anchor securing each loop in the filament to the stem is usually used, however.

The lamp factory beyond the filament or wire-drawing department may be divided up into five rooms or departments; they are in their order, the glass room, winding room, exhausting room, photometer room, and finishing room. Since the lamp starts in the glass room, the description of the manufacturing process will begin there. Glass tubing, ranging from 3/8 to 3/4 of an inch in diameter, is cut up into the proper lengths on a carborundum wheel, and fed into an automatic flanging machine. In this machine these short pieces of tubing are automatically fed into a revolving chuck, where they are heated on one end, flared out, and dropped into a receiving pan. The stem of the lamp, that is, the part through which the lead-in wires are sealed, is made of this tubing, and one end of the tube is flared out for sealing into the bulb. The supporting rod which is welded on to the stem is made by an automatic machine, called the button machine. Long pieces of glass rodding are fed into this machine four at a time. As the head revolves, concentrated gas flames heat the rodding to a red heat at the places the buttons are desired, and during the last quarter revolution a compression is applied to that portion of the rod between the clamps, which causes the rod to flatten out where it has been heated and forms the buttons. The rod is then nicked above the top button and broken off automatically. At the beginning of the second revolution the clamps release and allow the rodding to feed in for the next rod.

On the stem-making machine the leading-in wires are inserted through the flanged tube, then the end of the buttoned rod and the unflanged end of the tube are heated and welded together. A clamp actuated by a foot-pedal pinches the molten glass around the leading-in wires. A section of the leading-in wire that is sealed in the glass is made of platinum. Platinum is used because it expands and contracts with the glass, and thus keeps an airtight joint at all temperatures. Another reason for its use is the fact that it is the only metal that will not oxidize in the flames while on the stem-making machine. The copper hooks are next inserted into the beads or buttons on the glass rod; this operation, which is performed by hand, consists merely of heating the rod and hooks in a Bunsen flame, and inserting the hooks at the proper spacings while the glass is soft.

The mount is next taken to the winding room, where the proper length of tungsten wire is measured off the spool and wound over the supporting hooks. The joint between the filament and the leading-in wires is made by pinching the filament ends in the hollow ends of the leading-in wires. From here the wound mount is returned to the glass room where it is sealed into the glass bulb. Before the bulb is ready for this operation, it has been washed, tubulated, and necked down. The tubulating consists of blowing a small hole in the bottom of the bulb and sealing a small piece of glass tubing over the hole. This piece of tubing is used to connect the lamp to the pumps in the exhaust room. The small hole is made by training a pointed flame on the bulb at the point the hole is desired, and applying air pressure inside the bulb, which blows out the glass as soon as it becomes soft. The necking down consists of cutting off with a flame the superfluous length of neck on the bulb.

The prepared bulb and wound mount are taken to the sealing-in machine, where the bulb is placed over the mount and the two gradually heated up and sealed together. As the glass cools off, the operator trues up the mount in the bulb. Special suction holders are provided to insure an even cooling of the seal and prevent the setting up of internal stresses in the glass. After the seal has been tested for leakage by a mercury U-tube, the lamp is ready to be exhausted.

In the exhaust room, the inside of the exhaust tube on the lamp is painted with a solution of red phosphorus, and the lamps are placed on the exhaust racks, six lamps to a pump. There are three stages in the mechanical exhausting of a lamp of about five minutes' duration each. In all the stages the pumps are working on the lamps. In the first stage no current is flowing in the filaments, but the lamps are heated externally in a gas oven; in the second stage about fifty per cent normal voltage is applied with the oven still going; in the third stage the oven is lifted and 110 per cent voltage is applied. The lamps are pumped hot so as to drive off the thin film of air and the occluded gases which tend to cling to the lamp surfaces. At the end of the third stage the lamp is ready for the chemical exhausting and sealing off. The operator turns the sealing off torch on the red phosphorus in the tube, and volatilizes it. Upon the application of a sudden high voltage, the phosphorus is ignited and combined with the remaining traces of air to form a solid precipitate. The exhaust tube is then melted off close to the bulb, thus sealing the bulb and forming the tip. The so-called tipless lamps are not tipless, but the exhaust tube has been welded on to the bulb near the seal, so that when the brass base is put on the lamp, the tip is concealed.

The lamps are aged approximately the equivalent of ten hours by burning them at 118 per cent voltage for fifteen minutes. This preliminary burning is given to cull out any defective lamps and to bring the lamps to their steady burning conditions before photometering them. After being aged, the lamps are tested for vacuum by applying a high-tension, high-frequency current. The presence of any air or gas, between certain limits of pressure, will be evidenced by a glow in the bulb caused by the conduction of the electricity by the rarified gas. The color of the glow indicates the composition of the gas present.

In the photometer room each lamp is measured to determine at what voltage it should be burned in order to give the rated candle-power, and the current is read at this voltage to see whether the lamp comes within the specified wattage and efficiency limits. Of a lot of lamps intended to burn at some given voltage a large percentage will come out right, but, due to variations in the materials and processes, there is always a small percentage that fall a few volts low or high. For this reason the manufacturers rate every lamp. After being rated the lamps are sorted and put in stock unbased and unfinished.

When an order comes in for a certain number of certain voltage and wattage lamps, these lamps are selected from stock, sent through the finishing room and shipped out. The first operation in the finishing room is the basing of the lamps. The brass base or shell is partly filled with cement and put on the lamp with one lead-in wire projecting out through a hole in the bottom of the shell, and the other turned back along the side of the bulb. The lamp is put on the slowly revolving basing reel, which carries it through a gas oven. A spring holder on the reel holds the base in place, and the heat in the oven drives out the alcohol and sets the cement by the time the lamp has emerged from the other side of the oven. Before the base is put on, a piece of felt is inserted in the stem, the purpose of which is to keep the leading-in wires apart and prevent a short circuit. The lamp passes on to the solderers next, who solder the leading-in wires to the cap and shell of the base and cut off the loose ends. The lamp is then cleaned, labelled, thoroughly inspected and sent to the shipping room where it is packed and shipped out.

In telling of the manufacture of this lamp almost no mention has been made of the numerous rigid inspections that are made during the progress of the lamp through the factory, yet these inspections play an important part in the present day lamp manufacture. Today the first aim of the lamp manufacturer is quality, and it is only by these rigid inspections that the highest quality can be maintained. In all there are thirty-five operations and twelve inspections in the making of a drawn-wire tungsten lamp, aside, of course, from the operations and inspections in the wire-drawing department where the wire is prepared.

Practically everyone, who has had anything whatsoever to do with incandescent lamps, knows that the candle-power of a lamp is increased if the applied voltage is raised, but not everyone is familiar with the attending results and the importance of burning a lamp at the proper voltage. The five factors, voltage, candle-power, current, efficiency and life, are all interdependent, and with a given lamp any change in one of the factors affects all the others. For instance, an increase in applied voltage increases the current, candle-power, and efficiency, but decreases the life of the lamp.

Exponential equations have been worked out which express the relations between these different factors, and the exponents have been evaluated for all the different classes of lamps. The equations showing the voltage-candlepower and voltage-life relations for the Mazda drawn-wire tungsten lamps are, respectively,

$$\frac{c}{C} = \frac{(v)}{(V)}^{3.66} \text{ and } \frac{1}{L} = \frac{(v)}{(V)}^{14-}$$

A glance at the voltage-life equation shows that a very slight change in operating voltage affects very materially the life of the lamp, hence, the necessity of burning a lamp at its rated voltage. The accompanying table giving the rating of a regular 60-watt Mazda tungsten lamp shows how some of the quantities vary with the applied voltage.

Sixty-watt Mazda drawn-wire Tungsten Lamp.

Voltage	EFFICIENCY	CANDLE-POWER		
	Watts per Mean Hor. c-p	Watts	Mean Horiz.	Rated Life Hours
112	High efficiency—1.16 w. p. c...	60.0	51.7	1,000
110	Medium efficiency—1.21 w. p. c.	58.3	48.4	1,300
108	Low efficiency—1.26 w. p. c....	56.6	45.1	1,700

Of the four classes of lamps the variation of life with voltage is least with the tungsten-filament lamp and greatest with the carbon. The order from least to greatest variation in life with a given change in voltage is tungsten, tantalum, Gem and carbon.

At first thought it might seem from the above table that it would be cheaper to burn a lamp at a low efficiency (high watts-per-candle) and thereby make it last longer. This is not the case, however, for the added energy costs for the same amount of light is much greater than the saving in renewal costs, with the average rates of energy. Take for an example the 60-watt lamp listed above. If this lamp were to be burned at rated low-efficiency, 1.26 w. p. c., it would last 700 hours longer than when burned at high efficiency, 1.16 w. p. c., but the rate of energy consumption would be 0.1 w. p. c. higher, or since the lamp gives 50 c-p., 5 watts per lamp higher to give the same amount of light. In 1,700 hours this would amount to 8½ kw-hrs., which figured at 10 cents per kw-hr. would represent a difference in power bills of 85 cents for the same amount of light. The difference in lamp renewal costs is only 53 cents (figuring the lamp at list price, 75 cents), for the lamp was made to last 700 hours longer by burning it at low-efficiency. In this particular case, then, a saving of 32 cents is effected on each lamp every 1,700 hours by burning the lamps at the manufacturer's high-efficiency rating (as compared with the low-efficiency rating) and renewing the lamps oftener.

All classes of lamps are rated at three voltages, but most of them are ordered to be burned at high efficiency, that is, top voltage, for with the average rates of power or even rates below the average, this is the most economical operation.

So far not much has been said of the comparative economy of the different classes of lamps. The approximate operating efficiencies of the four classes are:

Tungsten	1.25 w. p. c.
Tantalum	2.0 w. p. c.
Gem	2.5 w. p. c.
Treated Carbon	3.1 w. p. c.

Untreated carbon operates at about 3.75 w. p. c. The high efficiency is the one great advantage of the metallic-filament lamp, as compared with the carbon lamp, although it possesses several other advantages. The following table shows the saving of the tungsten lamp over the carbon. The comparison is made on the basis of the same amount of light. The initial candle-power of the two lamps is the same, but over a period of time the tungsten lamp will give more light on account of its superior candle-power maintenance throughout life.

Cost of Light = Energy Costs + Lamp Costs.

Lamp	Initial C-P.	Energy Cost per 1,000 hrs. at 10 cents per kw-hr.	Lamp Costs (Assume free Carbon lamps)	Total Cost of Light for 1,000 hours
24-watt Mazda	20	$2.50	$.50	$3.00
60-watt Carbon	20	6.00	....	6.00

Saving effected by Mazda Lamp — $3.00

The table shows clearly that one is losing money if he uses carbon lamps that are given to him. Even if the tungsten lamp were extremely fragile, it would probably be cheaper to use it in the long run, for one could afford to break a half a dozen every 1,000 hours and still come out ahead.

The Gem lamp has a certain field; because of its ruggedness it can be used in some places where a metallic filament lamp cannot be employed, and its low first cost makes it desirable for certain types of installations. Where a cheap rugged lamp is required, or desired, a considerable saving is effected by using the Gem lamp as compared with the carbon. Calculations made on the same basis as those in the Cost of Light table show that for an energy rate of three cents or more per kilo-watt hour, it is more economical for the consumer to use Gem lamps, even if the carbon lamps are supplied free of charge. Very often the Gem lamp serves as a stepping stone from the carbon to the tungsten-filament lamp.

Cost of Light = Energy Cost + Lamp Cost.

Lamp	C - P.	Energy Cost for 700 hours at 10 cents per kw - hr.	Lamp cost for 700 hours	Total Cost of Light for 700 hours
60 - watt Carbon....	20	$4.20	.16	$4.36
50 - watt Gem.......	20	3.50	.20	3.70

Same amount of light — net saving per lamp 66 cents.

The tantalum lamp is steadily dropping out of the race. Its invention marked great progress in lamp manufacture, for it is a vast improvement over the carbon lamp, and it would undoubtedly have been a great lamp had it not been so nearly co-eval with the more highly efficient tungsten lamp. The tantalum is more efficient than the Gem, but if a metal-filament lamp can be used, the tungsten lamp has much more to offer.

The fragility of the tungsten-filament lamp, as first made, did much to hold it back, but, with the perfection of the wire-drawing process and other improvements in the manufacture, this objection has been overcome. While the drawn-wire lamp cannot be compared with the carbon on this score, it is rugged enough to withstand the ordinary shocks encountered in shipping and in use. Shock tests have shown it to be stronger than the pressed-filament lamp at any stage of its life. The satisfactory service of the tungsten-filament lamp in street cars, railway trains, automobiles, and the like, is an evidence of its ruggedness. The four classes of lamps in the order of their mechanical strength are carbon, Gem, tantalum and tungsten.

The candle-power maintenance of the tungsten lamp is much better than that of the other classes of lamps. In this respect tantalum is next, then Gem, and carbon. The tungsten lamp gives a longer life also at the rated voltages. All the lamps operate satisfactorily on either alternating or direct current with the exception of the tantalum. When burned on alternating current, the tantalum filament seems to offset and its life is very unsatisfactory. The operation of the tungsten-filament lamp on fluctuating voltages is more satisfactory than that of the other lamps, for it has a higher temperature-resistance coefficient and a given change in voltage does not produce as large a variation in candle-power. The carbon lamp with a negative temperature-resistance coefficient is affected most by a given change in voltage.

The quality of light emitted from a tungsten-filament lamp surpasses that from any of the other classes of lamps. All incandescent lamps give off relatively too much red light, that is, they are deficient in the blue and green end of the spectrum, and objects viewed in their light do not show their true color values. It is for this reason that dark blue cloth appears black in the light of a carbon lamp. In the tungsten lamp, however, the percentage of blue and green light is considerably higher and the resultant light approaches daylight more nearly. Next to tungsten in this respect comes tantalum, and then the Gem and the carbon.

As compared with other types of illuminants, the incandescent lamp, particularly the more efficient ones, possess many advantages. Among them are low first cost, low maintenance costs, adaptability to different types of reflectors, large range of sizes, range of voltages, reliability, convenience, safety and good quality of light. The tungsten-filament incandescent lamp, then, with its high efficiency and increased strength, bids fair not only to displace other classes of incandescent lamps, put to push into the fields of other types of illuminants.

BUILDING CONSTRUCTION AT THE UNIVERSITY.

W. P. Blocher, '14.

While innumerable statistical statements have been published to show the growth of our University, its present rate of expansion can be most popularly illustrated by a review of the building construction now under way or about to start. When we consider that aside from the several buildings recently completed and now occupied, there are in the process of construction no lss than six separate buildings, totaling in cast to seven hundred thousand dollars, the most avowed pessimist cannot but admit that Wisconsin is maintaining a most favorable position in the growth of American Universities.

In the April, 1909, issue of the Wisconsin Engineer, there appeared an article written by Supervising Architect Peabody on the general design of the University grounds and buildings, in which a general plan for futuer expansion was described. The construction now under way, while not entirely in accord with the general design mentioned, presents no radical departure.

BIOLOGY BUILDING.

Of the present construction, the Biology Building is the largest single piece of work. It consists of a four story building of yellow sandstone, 240 ft. x 44 ft. in main plan with a 50 ft. auditorium extension on one side, and appendages such as greenhouses and aquarium on the south side. It is situated on the southerly slope of the hill below Main and South Halls. Work has been in progress for about eighteen months, and the completion of the building is assured by August. Including the large amount of diverse equipment that it will contain, the building represents an investment of over two hundred thousand dollars. It is most modern in every detail, and will fill a long-felt want in providing up-to-date facilities for thorough scientific study.

The apparently peculiar location and shape of the building is accounted for by the unusual requirements that had to be met.

As the question was explained, these requirements (such as a long south facade for plants, and a long north facade for microscopic work) made it imperative that the building be long and narrow in plan, with its major axis running east and west, and that it be located on high, unobstructed ground, exactly as now built. When further consideration was given to accessibility, the available locations were narrowed down, leaving after all objections had been overcome its present location as the only feasible one that would fit the general plan for expansion.

It might be mentioned that with the proposed enlargement of University Hall dome, and the contemplated building on the north slope corresponding, the Acropolis effect, as sought in the general design, will overcome many of the popular criticisms that have been raised, such as the present disturbed appearance of the hill from a distance.

ADDITION TO CHEMISTRY BUILDING.

The demand for more room due to the growth of the Chemistry Department is being met by the construction of a four-story and basement wing, 140 feet long and 50 feet wide. The addition is to be of buff-colored pressed brick with stone trimmings, harmonizing with the present building. The construction is designed to be entirely fireproof, necessitating concrete floors, and will entail a cost of $85,000. The first floor is designed for laboratories in general chemistry; the basement will be used for physical and electro-chemistry, while the remaining space is yet unassigned.

The basement excavation and concrete foundation walls were completed last fall, and the entire wing will be finished by September.

HOME ECONOMICS AND UNIVERSITY EXTENSION BUILDING.

Only a few years ago, in preparing the general design of the University, it was not felt necessary to provide separate facilities for the department of Home Economics; yet so great has been its growth that a permanent four-story and basement home is now being build at a total cost of $105,000. The plans provide for ultimately a main building and two wings, although one wing is being left for future construction. The building will be faced with light-colored brick, similar to that of the Central Heating Station, and will have Bedford stone trimmings. It is located along Linden Drive, just east of Agricultural Hall, facing the south, occupying the location originally intended for the Scientific Library.

AGRICULTURAL CHEMISTRY BUILDING.

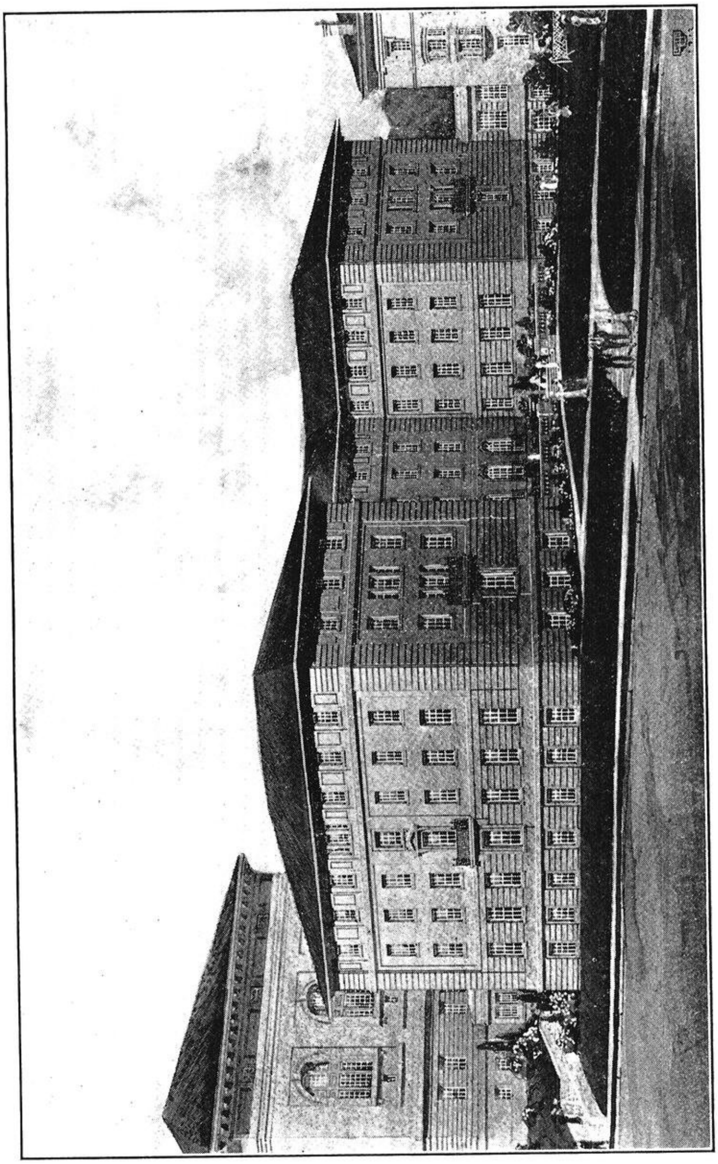
That the valuable work of the College of Agriculture is well recognized is evident from the liberal policy which the state is pursuing in providing facilities for this work. Hardly have the Agronomy, Agricultural Engineering and Horticulture Buildings been completed when we find provision made for a building for the Department of Agricultural Chemistry. It is located south of Agricultural Hall, in the same group with the above-mentioned buildings. It is to be a two-story and basement structure, of dark colored brick with stone trimmings and tile roof, harmonizing in architectural effect with the other buildings in the group. The appropriation to cover the cost of its construction amounts to $90,000, of which $2,200 has been spent for the foundation work. The contract for the building proper has not yet been let, but is now under consideration.

The building will be occupied exclusively by laboratories for agricultural chemical work and for the work of the experiment station.

ADDITION TO HISTORICAL LIBRARY.

The State Historical Library is to be enlarged by the construction of the previously planned northwest wing. This is to be a four-story and basement addition, 50 ft. x 60 ft. in ground plan. The construction will be of steel framework with cut stone facing, as the present part. While the architectural treatment will be identical with that of the southwest wing, the interior will be greatly improved, and the space for books largely augmented.

The entire wing, exclusive of furnishings, is estimated to cost $56,000, the contract for which has recently been let to the In-



Girls' Dormitory.

terstate Construction Company of Saginaw, Mich. The foundation excavation and concrete foundation walls were completed last fall under a separate contract at a cost of approximately $2,500.

DORMITORY FOR GIRLS.

The Girls' Dormitory which is being erected on University Avenue between Chadbourne and Lathrop Halls will be the first of the dormitory system. The building will be four stories high, with basement, 140 ft. x 50 ft. in plan, with two 50 ft. x 50 ft. wings, and will cost about $150.000. It will be built of yellow sandstone, of the variety used on University Hall, and will have a tile roof similar to one on Lathrop Hall. Connection will be provided to Lathrop and Chadbourne Halls by closed passage ways.

It is intended to provide kitchen facilities on the west side sufficiently extensive to take care of the necessities of Chadbourne and Lathrop Halls as well, thus making available additional room in these buildings.

All the above-mentioned buildings and additions will be connected to the University heating system. The installations present no unusual features, all the heating outfits being of the university standard type, with automatic valves designed to maintain a temperature of 70 degrees Fahrenheit, except in the Girls' Dormitory, where the ordinary throttle valve will be provided.

GLIMPSES OF THE PANAMA CANAL.

E. D. GILMAN, '13.

The Canal Zone is a strip of land about ten miles wide with the canal as a center line, which crosses the Republic of Panama at its narrowest point. The distance from sea to sea is 47 miles. The Zone includes an area of about 448 square miles. This land was formally acquired by the United States from the French Canal Company on May 4, 1904. By a treaty with the Republic of Panama the United States paid to the Republic $10,000,000, and agreed to pay thm $250,000 annually, beginning nine years after the signing of the treaty. Under this treaty the United States secured absolute control of the Canal Zone, with jurisdiction over the adjacent water for three miles from shore. The cities of Panama and Colon with their water fronts, though within the five-mile limit of the center line of the canal, are excluded from the Canal Zone, and are under Panama government. The United States, however, retains the right to regulate their sanitary conditions.

The success of the Americans can largely be attributed to the thoroughness with which the preliminary plans were worked out. The first two and one-half years were largely devoted to work of preparation; building up a suitable organization; procuring plant and equipment; combating unsanitary conditions; improving terminal facilities; making provision for adequate transportaton to the Isthmus from the United States; building quarters for the army of workers who were to follow; and establishing a stable form of government, including courts, schools, police and fire departments. In a little over two years the jungle infested with mosquitoes and various low forms of animal and vegetable life injurious to health, was transformed into a comparatively healthful country, with advantages of comfort, food, and quarters quite comparable to those enjoyed by the average citizen in the United States.

The Atlantic entrance to the canal lies west of the Pacific entrance. Ships passing from the Atlantic Ocean to the Pacific

Ocean will move eastward. The neck of land between North and South America makes a large bend, and at that point through which the canal is being dug, runs nearly northeast and southwest. It is a strange fact that riding in the late afternoon on the Panama Railroad toward Colon, the Atlantic port, the train moves toward the setting sun. It is possible to see the sun set in the Atlantic Ocean and rise in the Pacific Ocean from the Canal Zone.

The lock canal which is being built consists of a sea-level entrance channel, seven miles long, and 500 feet wide on the Atlantic side to the foot of the Gatun locks. On the Pacific side there is a corresponding sea-level channel nearly eight miles long to Miraflores. At Gatun ships will pass from sea-level to the 87 foot lake level and vice versa, by a series of three adjoining locks in duplicate. They will cross the Isthmus 87 feet above the sea as far as Pedro Miguel, 32 miles from Gatun, where by one lift, with duplicate locks, they will be lowered to Miraflores Lake, 54⅔ feet above sea-level. One mile from Pedro Miguel, at Miraflores, vessels will be lowered by two locks in duplicate to the sea-level on the Pacific side, and proceed down the eight-mile channel to the ocean. The 87-foot level of the canal and Gatun Lake is mantained by a great dam at Gatun and by a smaller one at Pedro Miguel. All land between these points which is lower than this elevation will be flooded. It has been necessary to abandon whole villages on this account. The tide on the Atlantic coast has a variation of less than two feet. On the Pacific coast the variation is more than twenty feet. The great difference in the tides at the ends of the canal would have been a serious problem in the construction of a sea-level canal.

Huge breakwaters extending several miles into the ocean are being built to transform Colon Bay from a dangerous to a safe harbor. These breakwaters are being constructed with large rock from Porto Bello, and with spoil from the Canal Prism. It is here that the work of the Isthmian Canal Commission and of the Atlantic Division starts. Excavation of a 500-foot channel is being carried on within the breakwater, by a sea going suction dredge, dipper dredges, and old French ladder dredges.

At the left of the channel, three miles from its beginning, lies Cristobal, the American port of the Canal Zone. A mile farther the back of the bay is reached and here commences the dry excavation through the Mindi Hills. Beyond this low range of hills is a swampy tract of land through which the channel is excavated by dredges. At Gatun, seven miles from the entrance, the sea-level channel ceases and ships will be raised to the higher level by means of the locks.

The Gatun Lake, above the Gatun Dam, does not exist at present, but will undoubtedly be allowed to fill during the coming year. It will be a body of fresh water with an area of 164 square miles, fed by the Chagres River with a drainage area of 1,320 square miles. The water will be utilized for passing ships through the locks, and for generating electric current for lighting and power; and much, too, will be lost by evaporation and seepage. A careful study of data and records has eliminated all fear of a scarcity of water supply.

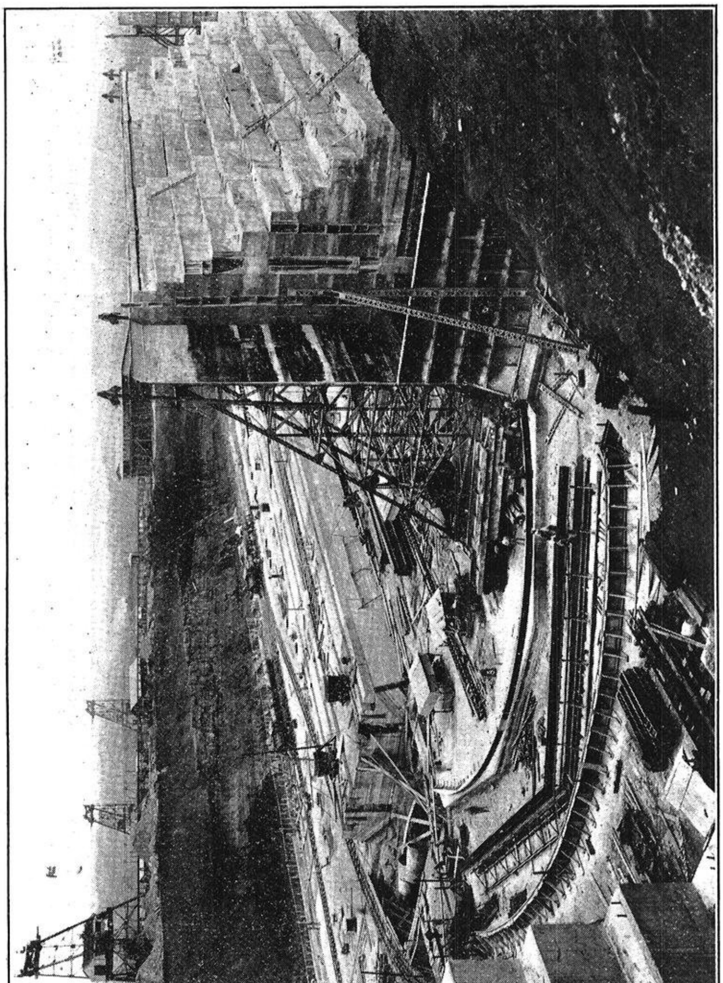
The water in the lake is backed up by the great Gatun Dam. This is about 9,000 feet long measured along its crest, including the spillway and locks. The thickness of the dam at its base will be fully 2,000 feet; at the water surface 400 feet; and at the top, 30 feet above the water level, 100 feet. The construction of the dam is being carried out by building two walls of rock, composed of spoil from the canal and lock excavation, about 1,200 feet apart. Impervious material is pumped between these two retaining ledges by pipe line dredges. Outside of the toes of the dam waste piles will slope gradually and extend as far as available material will carry them.

The spillway is a concrete lined channel cut through a hill of rock along the line of the dam near its center. It is provided with gates so designed as to allow the lake level to be regulated.

The locks are near the eastern end of the dam. The lift to the lake level is accomplished by three locks in series, the average raise being about 29 feet. The locks are all in duplicate, making a total of six which are being built at Gatun, and twelve along the whole canal.

The locks are of such a size as to accommodate a boat with 110-foot beam and 1,000 feet long. The *Olympic*, one of the largest boats afloat, has a 92-foot beam and is 882 feet long. Each lock is a chamber with concrete sides and bottom. Across the bottom at regular intervals extend rows of holes, through which the water is admitted or withdrawn, and the level regulated by the operation of valves in the side and middle walls, which permit water to flow into and out of the locks by gravity.

A principle of design has been that at all times there shall be not less than two barriers separating a high level from a low level of water. To carry this out, there are two gates at the upper end and two gates at the lower end of each lock. These double gates will be operated simultaneously. The 92 gate leaves required weigh 58,000 tons, and the contract for them was let for about $5,600,000, one of the largest single contracts ever let. A chain stretched across the lock one hundred feet in front of each gate passes over friction drums within the walls, which are so designed that as the chain pays out the friction increases, and will stop a ship of 10,000 tons moving five miles per hour before it can reach the gates. The engineers have not "sat up nights to devise a method whereby the largest boats will have no momentum," as stated in a recent *Outlook*, but have left nature as it is, and have simply devised a method to control it. In case of mishap to the gates, damage to the locks is guarded against by emergency dams above the upper gates. These are essentially a swing drawbridge which can be thrown across the locks. The flow of water can be stopped by means of wicket girders lowered into a groove in the bottom of the lock. All vessels will be towed through the locks by electric "mules" running upon rack tracks on top of the walls, and no vessel will be allowed to move its propeller while within the locks. This obviates the danger of mistaken signals between the pilot house and engine room. Both of the side walls and the middle wall are traversed the entire length by an operating tunnel. The walls are honeycombed by machinery chambers in which are placed the motors and machines for operating the gates, Stoney gate and cylindrical valves, fender chains, float wells, etc. As a boat passes through the locks in the near future those on deck will see nothing but the smooth outline of the concrete walls and the tracks upon them. They will not realize the depth of



Gatun Upper Locks, Showing Side Walls and Sills of Intermediate Gate.

water under them or the great height of the walls. They will not see or realize the enormous amount of work in the design and lay-out and the construction of the various machinery chambers. It is too bad that there is not some transparent material which could be substituted for concrete so that the intricate character of the operation could be noted in the passage.

The operation of all the movable parts of the locks, with the exception of the "mules," is to be controlled from a single central station upon the middle wall. Everything is operated by electricity and is so interlocked that it is mechanically impossible to operate any machinery in a wrong sequence or at the wrong time. The personal element of danger is reduced to a minimum.

Electric energy is at present being used in the construction of the locks, to operate the entire concrete handling system, cableways, etc. The power during construction is obtained from steam turbines, fed from boilers using oil as fuel. Eventually this plant is to be abandoned and the power for operation will be generated by water turbines from the head created by Gatun Lake. This power plant is to be situated just below the spillway. The man in charge of the design and layout of power both for present construction and for future operation, and of the design of the operating machines for the various parts of the locks, both electrical and mechanical, is a graduate of the University of Wisconsin—Mr. Edward Schildhauer, '97, E. E. '11. For several years he has been ably assisted by Mr. W. R. McCann, ex-'11, Assistant Engineer.

The middle wall of the lower and of the upper locks extends for 1,200 feet beyond the lower and upper gates as an approach wall. The magnitude of the construction may be partly realized from the fact that the distance from the lower end of the upper approach wall of the Gatun locks is something over one and one-quarter miles.

About 2,000,000 yards of concrete are to be placed in the Gatun locks. The total amount of concrete used in the entire construction, including the other locks and the spillway, will be over 5,000,000 cubic yards. Broken stone for the Atlantic Division is brought from a quarry and crushing plant at Porto

Bello, 17 miles east of Cristobal. For the Pacific Division the stone is quarried at Ancon Hill. Sand is brought from Nombre de Dios, several miles beyond Porto Bello, for the Atlantic Division, and from Chamé on the Pacific coast for the Pacific Division. Nearly 5,000,000 barrels of cement will be shipped from the United States to Panama.

The channel, for the first fifteen miles through Gatun Lake, will be 1,000 feet wide and 75 feet deep. For the first eight miles the natural elevation of the ground is such that no excavation has been necessary. At Tabernilla, eight miles from Gatun, the first difficult excavation was encountered, and the channel narrows to 700 feet. Twelve miles farther at Bas Obispo it narrows to 500 feet and turns abruptly southeast and enters the nine mile cut, known as "Culebra Cut," through the Cordilleras, the continental divide.

Culebra Cut starts at Bas Obispo and ends at Pedro Miguel. The minimum bottom width is 300 feet, and depth 45 feet. At Gold Hill across the cut from Culebra is the deepest excavation. From the top of this cut to the water level will be nearly 300 feet, and the decks of boats passing through will be below the level of the surrounding country.

The various operations in excavation are—drilling, blasting, loading, transporting, and dumping. A battery of from 4 to 12 drills proceeds each shovel, and by the drilling and blasting the ground is loosened ahead of the shovel. Over 1,000,000 pounds of dynamite per month are being used. Power to run the drills is furnished by one of the largest compressed air plants and supply mains in the world. A 10-inch main runs the entire length of the cut, and is supplied by three plants having a capacity of over 30,000 cubic feet per minute at 100 pounds pressure.

The smaller steam shovels used in excavating weigh 70 tons and have 2½-yard dippers. The larger shovels weigh 95 tons and have 5-yard dippers. The greatest problem of excavation has been to keep the shovels supplied with cars so that they can work continuously. The record for one shovel for one month has been as high as 58,000 cubic yards, and for one day of eight hours 3,900 cubic yards, which is equivalent to the work of 600 men. All repair work upon the shovels is done at night, and each shovel is supplied with coal and oil by night gangs, so that the entire day is available for actual work.

The material excavated is loaded into long flat cars and carried to the dumps. The cars are unloaded by a five-ton steel plow operated by a "Lidgerwood" unloader receiving steam from the locomotive. The whole train of eighteen cars can be unloaded in five minutes. There are also steel cars in use. The smaller ones are dumped by hand and the larger ones by compressed air.

The total excavation to be made in Culebra Cut is about 100,000,000 cubic yards, including 5,000,000 estimated for slides. At present, about 84 per cent of excavation in this cut has been completed. In the total length of the canal there have been 163,000,000 cubic yards excavated to date; there remain 32,700,000 to be excavated. Thirty million cubic yards of the French excavation is available for the present canal, making the total amount of earth removed in the construction of the canal about 225,000,000 cubic yards.

At Pedro Miguel a ship is to be lowered by one flight to the level of Miraflores Lake, and a mile farther at Miraflores by two locks to the ocean level. The bottom lock at Miraflores is provided with a tidal gate, and excavation is such that the locks can be operated at any stage of the tide. From Miraflores to the ocean is a channel eight miles long with a minimum width of 500 feet. A channel 500 feet wide and four miles long is being dredged into the ocean. The Pacific entrance is well protected by many islands and a breakwater is scarcely necessary for protection from storms. Heavy currents exist along the coast, however, due to the great tide, and Naos Island, four miles from shore, is being connected with the mainland by a dike built of spoil from the cut. This is to prevent the large quantities of silt which the current carries from settling into the canal channel.

The number of men employed upon the Isthmus has been steadily decreasing in the last few years. There are at present about 26,000 laborers and 4,500 white men, a total of about 30,500. The department of construction and engineering employs 24,700 men. The white men are mostly Americans. Their work is the control and direction of the various places of the different departments. Among them, and especially among the engineering forces, are to be found many college men. The laborers are mostly negroes from Barbados and Jamaica. Spanish contract laborers of which there were a great number a few years ago are leaving the Isthmus. The negroes are a peculiar class of ignorant and superstitious people. They are very proud of the fact that they are "objects" of the king of England.

The engineering department consists of four main divisions, the office of the Chief Engineer and the three divisions before referred to. The office of the Chief Engineer consists of two divisons, the department of design and the department of statistics, records and meteorology. The department of design under the Assistant Chief Engineer consists of five departments under civilian designing engineers. The Electrical and Mechanical Engineer (Mr. Schildhauer) has charge of the design of all motive power and machinery connected with the construction and the operation of the locks. Other designing engineers are in charge of masonry design, spillway design, emergency dam design, and the design of the lock gates. The plans for the spillways were completed nearly a year ago and the office force disbanded. Mr. Schildhauer's department of machine design consists of the force in the office at Culebra, the inspection force in the United States, and the erection force upon the work.

The conditions surrounding a life among this organized activity cannot be clearly understood by reading accounts of it. One must live in it to really appreciate what it means. Most often is it asked whether it is hot down there. It is not excessively hot, the temperature seldom going above 90 degrees, but the heat is rather oppressive as the humidity is nearly 80. The atmosphere is so damp that clothing, shoes, books, and especially any leather goods become covered with a nasty green mold if left unbrushed for even two days. Most people dress in white crash or khaki, which can be sent to the laundry and thoroughly washed and ironed. Quarters are furnished to the employees free of charge. The houses present the same appearance from the outside, enclosd in black screening from the ground to the roof. The screening used is copper, as it has been found that iron deteriorates too rapidly to be of any use. The roofs are peaked, built of galvanized iron. The most common type of quarters for the bachelors is an eight room house, four on each floor. The rooms accommodate two men each, and are furnished with two iron beds, two dressers, chairs and a table. The employees have to provide their own bedding. A large eight foot veranda extends around the entire building on both floors, outside of which is the screening. The windows do not have glass, but are protected by green wooden blinds. Each floor is provided with a shower bath, and each house with a "dry room" heated by an electric stove, in which clothes, books, etc., can be kept free from mold. A negro janitor cares for the house, makes the beds and cleans the rooms. For a small tip each month he keeps shoes shined, cares for laundry, and performs other personal services. The quarters of the married people are of a different type. The size of a man's house and the kind and number of pieces of furniture with which he is supplied depends upon his salary. In consequence the quartermaster has hard work to keep out of hot water, for if one man's wife calls upon a neighbor whose husband is getting the same salary, and counts one more or a better grade of chair than she has, there is trouble. This system also furnishes ample opportunity for the spreading of village news. As soon as a man gets a raise his wife hurries to the quartermaster and receives another chair or table, and displays it in a conspicuous place. By the kind of chair or type of furniture those versed in the mystery of the quartermaster's equipment can tell the amount of raise which a neighbor got.

Unmarried people in Culebra board at the I. C. C. (Isthmian Canal Commission) Hotel. Meals cost thirty cents each, and in general are good. The food is much the same as is served in hotels in the states, though most of it has been canned, and the meat has been in cold storage. Tropical fruits and vegetables, such as yams, alligator pears and mangoes, are served to a great extent. The hotels are neat and clean. A partition divides the room into two parts: in one a man eats with his coat on and is served from a table with a linen cloth and given a linen napkin; in the other he leaves his coat off and eats from tables covered with oil-cloth, and uses a paper napkin. This arrangement is to accommodate the men from the office as well as the men from the cut, many of whom prefer to eat before cleaning up. The food on both sides is the same.

The center of the social life upon the Isthmus may be said to be the I. C. C. Clubhouses. They are under the efficient management of the Y. M. C. A., but are everywhere known and regarded as the "clubhouse." There are seven of these buildings upon the Zone, each under the managment of a secretary and assistants. The buildings are large and attractive. Within are found bowling alleys, billiard and pool rooms, chess and checker rooms, refreshment counters, barber shops, and reading rooms. The reading rooms are provided with most of the magazines published in the United States, and with newspapers from the larger cities. On the second floor are large gymnasiums. The several clubhouses have their basket-ball, bowling, indoor baseball, and track and field teams, and a tournament of some sort is at nearly all times taking the interest of the members. Discussion clubs are held weekly, and classes in Spanish and other subjects are held regularly. The Y. M. C. A. also provides many entertainments, having their glee club concerts, smokers, minstrel shows, amateur theatrical societies, and choral societies. In addition to this local entertainment, speakers and concert companies are brought down from the states.

The many departments in the complete organization of the Isthmian Canal Commission under Colonel Goethals are as varied as the many occupations in any representative city. The civil administration and law, the disbursing, accounting, sanitary, quartermasters, subsistence and the departments of the engineering staff, furnish men in all the professions and work found in city life in the United States. These are all organized to the highest point of efficiency with one head. The result furnishes an example of what efficient administration may accomplish, providing, of course, that such a man can be found to place at the head as is at the head of the Isthmian Canal Commission. It is team work with a wonderful captain, and each man sacrificing individuality for the sake of the team, that is to make the Americans successful in this great undertaking.

TESTS ON REINFORCED COLUMNS.

The results of an extensive series of tests of the strength and elastic properties of concrete columns reinforced with spirals and longitudinal rods, conducted by Prof. M. O. Withey, assistant professor of mechanics in the university laboratory for testing materials, are contained in Bulletin 466, University of Wisconsin, Engineering Series, Vol. 7, No. 1, just issued. The tests were made from a rather comprehensive point of view, no less than seven elements being thoroughly investigated; to do this, sixty-six columns of commercial size were tested. The findings, which in most cases are noteworthy, briefly comprise the following:

1. With respect to varying the richness of the mixture, the fact was developed that rich mixtures are more economical than lean ones, provided materials can be obtained at average prices. It was found that more economical mixtures are produced when the proportion of cement to aggregate, by weight, lies between 0.2 and 0.7.

2. With reference to the effect of varying the percentage of spiral reinforcement, the tests showed that although the yield point is practically independent of the spiral reinforcement, the ultimate strength and toughness are directly affected by it; one per cent. of closely-spaced spiral of high carbon steel was shown to be sufficient for lateral reinforcement.

3. As to varying the percentage of longitudinal reinforcement, it developed that the addition of longitudinal steel can be made to considerably increase the yield point, ultimate strength and stiffness. As, however, cement is ordinarily a more economical reinforcement than steel, it does not seem advantageous to use in combination with a rich concrete, more than two or three per cent. of longitudinal steel.

4. In regard to the effect of repeated or time loadings, no definite conclusion was reached, although the results plainly indicate that there is practically no increase in set or deforma-

tion after a few repetitions of loads equal to 40 to 50 per cent. of the yield point.

5. With respect to columns eccentrically loaded, the close agreement between the values derived from the tests and the theoretical values shows that common formula

$$S = \frac{P}{A} = \frac{Mc}{I}$$

for short homogenous columns eccentrically loaded, is applicable to reinforced concrete columns.

6. As to the effect of differences in end conditions, that is, the bearing surfaces, the tests disclose that the strength of a column will be about as great when resting on a footing as when bedded on a metal plate, provided the base is properly reinforced.

7. With reference to the relative value of plain and deformed bars for longitudinal reinforcement, the results with the use of corrugated bars of high carbon steel were so uniform and the strengths so high that this type deserves much consideration. The use of deformed bars of high elastic limit was shown to be more economical, with certain ratios of unit prices, than plain round bars of mild steel.

The bulletin contains a very complete bibliography of published matter on the subject of testing reinforced concrete columns.

The Wisconsin Engineer.

EDITORIAL.

To the Class of 1912:

We offer our congratulations. You have made somewhat of preparation for your professional career. It is probable that your professional knowledge at this time is not a large part of what it will be at length, but it is none the less valuable, both intrinsically and as an earnest desire of the wider learning of riper years. We hope and believe that opportunity will be yours; opportunity which you will be the better able to seize upon, because you are well prepared; opportunity which will bring to you this world's rewards and a consciousness of work well done. In the busy world of commerce you will find other opportunities, less selfish in their nature, and in their presence you will not forget the watchword of our University, "Service."

As you go out from among us you are to find life very full of interest and achievement, but we ask that you do not let these new interests supplant the old. Keep in touch with your college. The contact will be mutually beneficial. Keep posted as to what is being done in your college, and let us know what you are doing. We offer as a convenient medium THE WISCONSIN ENGINEER.

* * *

At stated periods it is customary to make inventory. We believe that as a class is graduated from a professional school there exists an unusual opportunity for the individuals of this class to take stock. It will be well to see what you have of equipment, and what more should be provided. You entered a professional school presumably to fit yourself for the practice of your profession. By this action you seem to have differentiated in your mind between the high grade engineer and the high grade mechanic. Have you in your equipment that which will if properly augmented and utilized enable you to realize your ambition of professional success? To attempt to add to the many definitions of Engineering is futile; yet we must consider at least some of its phases if we wish to consider fitness for its successful practice.

Engineering is both an art and a science; it is a profession of action as compared with other professions which are chiefly conservative; it is a profession dealing with unrepealable laws and in which opinion must eventually be sustained by proof; it is a profession in which you will perhaps always be either an employer or employee of other engineers; and finally it is a profession which like all of life is a most strenuous competition.

Have you an idea of the general laws of science on which your engineering education has been based? Have you some skill in the arts which serve this science? Have you lived these four years so that you will fit naturally into a life of action, where results will be demanded with sharp insistence? Have you learned to take orders and to give them, and meet all men with certain poise?

Have you made up your mind to stay in the game? To fight hard but squarely? To never be beaten? Then you are well prepared, and the future holds good promise.

DEPARTMENTAL NOTES.

MECHANICS DEPARTMENT.

An experimental study of automobile springs is under way in the testing laboratory. The main problem in view is the determination of the "action" of springs of various designs. These tests are conducted to ascertain the behaviour of a spring with respect to amount, rapidity and damping of vibrations after a suddenly applied load.

* * *

The effect of alternating stresses on metals has been investigated for the past two years by Mr. J. B. Kommers. Repeated stress tests similar to those of Wöhler are hardly suitable for commercial testing because of the time involved, and for this reason the present experiments were performed on a machine which stressed the materials beyond the elastic limit. Some of the variables studied were the effect of speed of alteration of stress, variation in the amount of the deflection of the specimen, variation in the condition of the surface of the specimen, and the effect of impact combined with deflection. A large number of tests were also made on special alloy steels and other materials for the purpose of determining a method of interpreting the results of tests made under a set of standard conditions. The results of the investigation will be published in the near future.

* * *

The junior mechanical engineers have practically finished the new testing laboratory course, mechanics 54. It consists of tests of machine parts among which are the following: Tensile tests of belts and belt joints or splices, hardness tests on metals by the schroscope and Brinell methods, tests of elliptical springs, tests of holding strength of set screws in shaft connections, study and tests of welds and methods of welding. Some of the results obtained will probably be considered of sufficient importance to merit publication in the future.

* * *

As departmental research, Mr. Miller is carrying on a study of mild steel welds made by the oxhydric and ox acetylene processes. In this special attention is being given to the microscopic structure in the welds.

* * *

The department has substituted Boyd's *Strength of Materials* for Merriman's *Mechanics of Materials*, which has been used for a number of years. This book will be used in courses 2 and 3. Prof. Maurer has also revised his text on statics and kinetics.

DEPARTMENT OF MINING AND METALLURGY.

The summer school mining trip this year will be made to the northwest. The class will meet at Butte, Montana, on June 19, and spend several days in that camp in underground and surface inspection work. After a visit to the Washoe concentrating and smelting plants, the remainder of the session will be held in the Coeur d' Alenes, studying mining and milling practices in the silver-lead mines near Mullan, Mace, Wallace and Kellogg. At the conclusion of the inspection work the members of the class will get positions with the mining companies for a month or more of work. A number of men will probably make trips to the fruit regions and to the Pacific Coast before returning to Madison in the fall.

CHEMICAL ENGINEERING DEPARTMENT.

Prof. C. F. Burgess attended the meeting of the American Electrochemical Society at Boston from April 18–20. Papers from members of this department were as follows: Prof. Watts on the "Effect of Various Substances on Corrosion of Iron by Sulphuric Acid;" Prof. Kowalke on the "Volatility of Zinc Oxide;" and Prof. Burgess on "Dry Cell Testing."

* * *

F. R. Zimmerman and J. E. Fuller, senior mechanical engineers, are doing thesis work under the direction of this department on the "Cutting Efficiency of High Speed Tool Steels" as influenced by variations of temperature and heat treatment. The tests are made under constant conditions and determine the amount of metal removed and the life of the tool as used in actual practice. The Northern Electrical Company furnished the motor used in the test and a number of the various tool manufacturing companies have furnished bars of tool steel.

ALUMNI NOTES.

Harry Gardner, '05, is Professor of Sanitary Engineering, University of Kansas, Lawrence, Kansas.

W. P. Zabel '09, is foreman of the tungsten wire department of the National Electric Lamp Association, Cleveland, Ohio.

In Los Angeles, California, a number of alumni are located. Among them are H. E. Bailey, '03, instructor in Machine Design, Los Angeles Polytechnic High School; J. W. Buchanan, '06, draftsman on the Los Angeles aqueduct; P. B. Rogers, '05, with the Engineers' Exploration Co.; A. T. Stewart, '04, assistant engineer, City Board of Public Utilities.

F. C. Youngblutt, '06, is at present assistant engineer with the U. S. Reclamation Service at Glendive, Montana.

F. W. Fratt, '82, is president of the Union Depot, Bridge & Terminal Railroad Co., 430 Midland Bldg., Kansas City, Mo.

S. E. Elmore, '06, is manager of the drag line excavator department of the Bucyrus Co., South Milwaukee, Wis.

F. M. Johnson, '06, Pastor Gomez, '09, W. J. Grodske, Jr., '08, R. H. Whinery, '05, and W. M. Conway, '06, are connected with the Bureau of Public Works, Manila, P. I.

F. A. Hitchcock, '10, is an instructor in Structural Engineering in Cornell University, Ithaca, New York.

T. G. Nee, '99, is chief engineer of the Mexican Telegraph and Telephone Co., Arco San Augustin, No. 8, Mexico City, Mexico.

E. B. Miller, '06, is superintendent of the Davison Chemical Co., 601 Keyser Bldg., Baltimore, Md.

E. G. Merrick, '00, is a turbo-alternator designer, Cie Francaise Thomson Houston Lesquin lez Lille, Nord, France.

R. E. Robertson, '10, is with the U. S. A. Engineers, at La Crosse, Wis.

Altmont Delgado, '06, is a partner in the Kingston Industrial Works, Kingston, Jamaica, B. W. I.

C. A. Scribner, '08, is foreman of electrical installations for the Arnold Company, Chicago.

The University of Wisconsin

THE COLLEGE OF LETTERS AND SCIENCE offers a General Course in Liberal Arts; a Course in Commerce; a Course in Music; a Course in Journalism, Library Training Courses in connection with the Wisconsin Library School; a Course in Education; the Course for the Training of Teachers, and the Course in Chemistry.

THE COLLEGE OF MECHANICS AND ENGINEERING offers courses of four years in Mechanical Engineering, Electrical Engineering, Civil Engineering, Applied Electro-chemistry, Chemical Engineering, and Mining Engineering.

THE COLLEGE OF LAW offers a course extending over three years, which leads to the degree of Bachelor of Laws and which entitles graduates to admission to the Supreme Court of the state without examination.

THE COLLEGE OF AGRICULTURE offers (1) a course of four years in Agriculture; (2) a course of two years; (3) a short course of one or two years in Agriculture; (4) a Dairy Course; (5) a Farmers' Course; (6) a course in Home Economics, of four years.

THE COLLEGE OF MEDICINE offers a course of two years in Pre-clinical Medical Work, the equivalent of the first two years of the Standard Medical Course. After the successful completion of the two years' course in the College of Medicine, students can finish their medical studies in any medical school in two years.

THE GRADUATE SCHOOL offers courses of advanced instruction in all departments of the University.

THE UNIVERSITY EXTENSION DIVISION embraces the departments of Correspondence-Study, of Debating and Public Discussion, of Lectures and Information and general welfare. A municipal reference bureau, which is at the service of the people of the state is maintained, also a traveling Tuberculosis Exhibit and vocational institutes and conferences are held under these auspices.

SPECIAL COURSES IN THE COLLEGE OF LETTERS AND SCIENCE

THE COURSE IN COMMERCE, which extends over four years, is designed for the training of young men who desire to enter upon business careers.

THE COURSES IN PHARMACY are two in number; one extending over two years, and one over four years, and are designed to furnish a thoroughly scientific foundation for the pursuit of the profession of pharmacy.

THE COURSE FOR THE TRAINING OF TEACHERS, four years in length, is designed to prepare teachers for the secondary schools. It includes professional work in the departments of philosophy and education, and in the various subjects in the high schools, as well as observation work in the elementary and secondary schools of Madison.

A COURSE IN JOURNALISM provides two years' work in newspaper writing and practical journalism, together with courses in history, political economy, political science, English literature, and philosophy, a knowledge of which is necessary for journalism of the best type.

LIBRARY TRAINING COURSES are given in connection with the Wisconsin Library School, students taking the Library School Course during the junior and senior years of the University Course.

THE COURSE IN CHEMISTRY offers facilities for training for those who desire to become chemists. Six courses of study are given, namely, a general course, a course for industrial chemist, a course for agricultural chemist, a course for soil chemist, a course for physiological chemist and a course for food chemist.

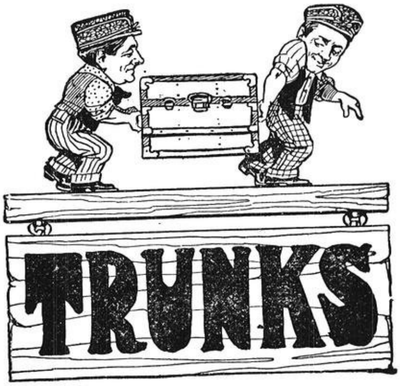
THE SCHOOL OF MUSIC gives courses of one, two, three, and four years, and also offers opportunity for instruction in music to all students of the University.

THE SUMMER SESSION embraces the Graduate School, and the Colleges of Letters and Science, Engineering, and Law. The session opens the fourth week in June and lasts for six weeks, except in the College of Law, which continues for ten weeks. The graduate and undergraduate work in Letters and Science is designed for high school teachers who desire increased academic and professional training and for regular graduates and undergraduates. The work in Law is open to those who have done two years' college work in Letters and Science or its equivalent. The Engineering courses range from advanced work for graduates to elementary courses for artisans.

THE LIBRARIES at the service of members of the University include the Library of the University of Wisconsin, the Library of the State Historical Society, the Library of the Wisconsin Academy of Sciences, Arts, and Letters, the State Law Library, and the Madison Free Public Library, which together contain about 380,000 bound books and over 195,000 pamphlets.

THE GYMNASIUM, Athletic Field, Boating Facilities, and Athletic Teams give opportunity for indoor and outdoor athletic training, and for courses in physical training under the guidance of the athletic director.

Detailed information on any subject connected with he University may be obtained by addressing **W. D. HIESTAND, Registrar, Madison, Wisconsin.**


TRUNKS