The Project Gutenberg eBook of Scientific American Supplement, No. 647, May 26, 1888

Title: Scientific American Supplement, No. 647, May 26, 1888

Author: Various

Release date: December 31, 2008 [eBook #27667]

Language: English

Credits: Produced by Huub Bakker, Juliet Sutherland and the Online Distributed Proofreading Team at http://www.pgdp.net

SCIENTIFIC AMERICAN SUPPLEMENT NO. 647

NEW YORK, MAY 26, 1888

Scientific American Supplement. Vol. XXV., No. 647.

Scientific American established 1845

Scientific American Supplement, $5 a year.

Scientific American and Supplement, $7 a year.

TABLE OF CONTENTS.

INFLUENCE MACHINES.[1]

By MR. JAMES WIMSHURST.

I have the honor this evening of addressing a few remarks to you upon the subject of influence machines, and the manner in which I propose to treat the subject is to state as shortly as possible, first, the historical portion, and afterward to point out the prominent characteristics of the later and the more commonly known machines. The diagrams upon the screen will assist the eye to the general form of the typical machines, but I fear that want of time will prevent me from explaining each of them.

In 1762 Wilcke described a simple apparatus which produced electrical charges by influence, or induction, and following this the great Italian scientist Alexander Volta in 1775 gave the electrophorus the form which it retains to the present day. This apparatus may be viewed as containing the germ of the principle of all influence machines yet constructed.

Another step in the development was the invention of the doubler by Bennet in 1786. He constructed metal plates which were thickly varnished, and were supported by insulating handles, and which were manipulated so as to increase a small initial charge. It may be better for me to here explain the process of building up an increased charge by electrical influence, for the same principle holds in all of the many forms of influence machines.

This Volta electrophorus, and these three blackboards, will serve for the purpose. I first excite the electrophorus in the usual manner, and you see that it then influences a charge in its top plate; the charge in the resinous compound is known as negative, while the charge induced in its top plate is known as positive. I now show you by this electroscope that these charges are unlike in character. Both charges are, however, small, and Bennet used the following system to increase them.

Let these three boards represent Bennet's three plates. To plate No. 1 he imparted a positive charge, and with it he induced a negative charge in plate No. 2. Then with plate No. 2 he induced a positive charge in plate No. 3. He then placed the plates Nos. 1 and 3 together, by which combination he had two positive charges within practically the same space, and with these two charges he induced a double charge in plate No. 2. This process was continued until the desired degree of increase was obtained. I will not go through the process of actually building up a charge by such means, for it would take more time than I can spare.

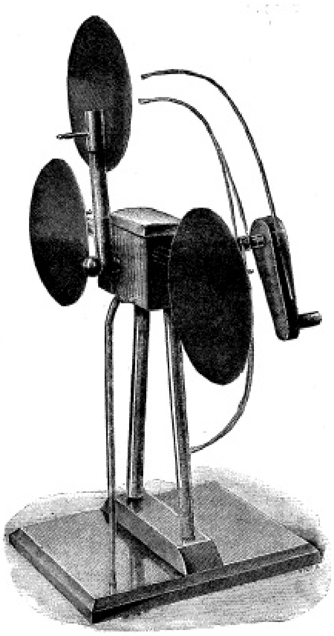


Fig. 11.

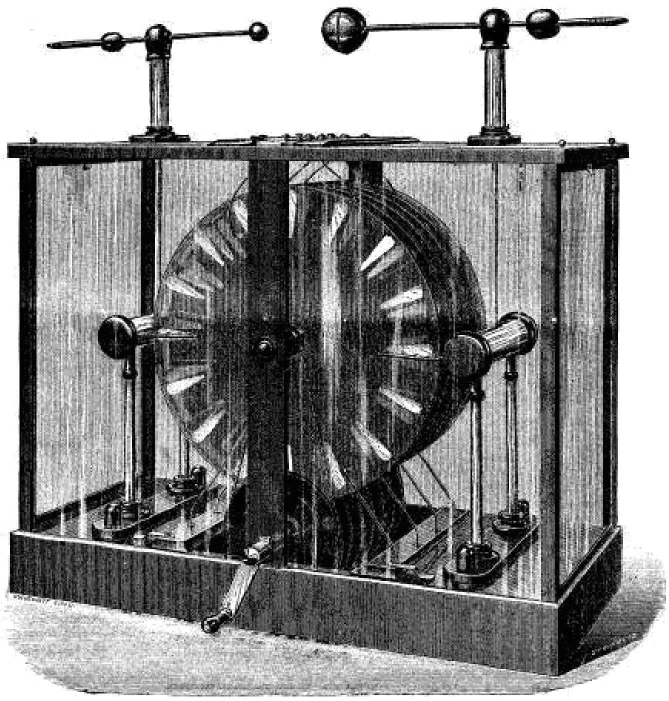
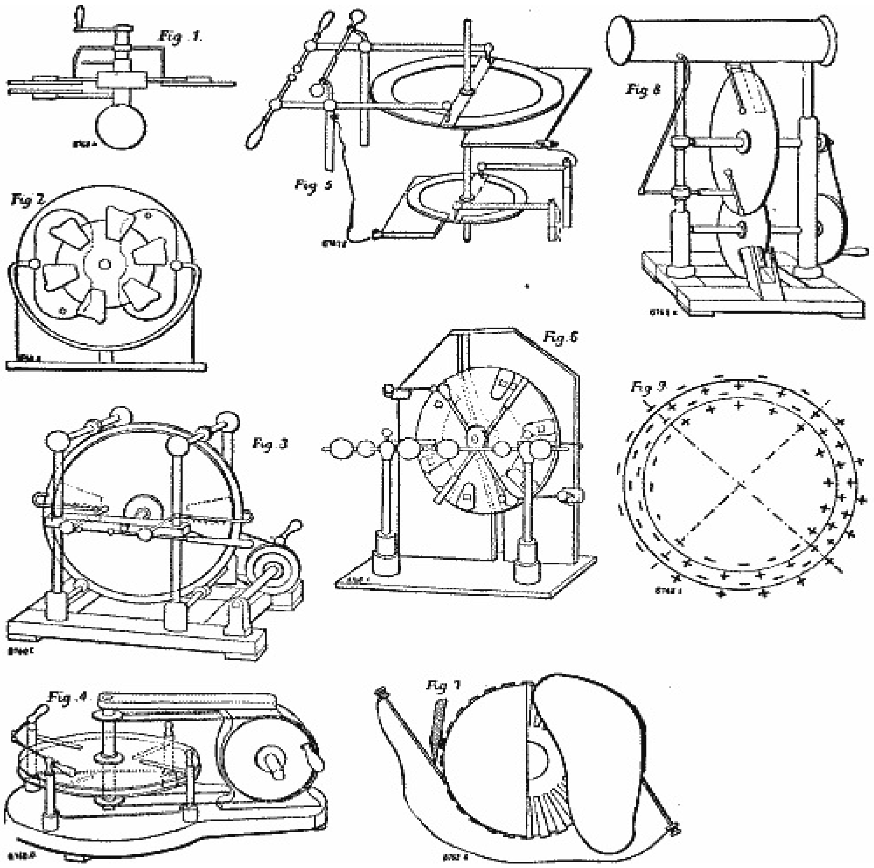


Fig. 12.

In 1787 Carvallo discovered the very important fact that metal plates when insulated always acquire slight charges of electricity; following up those two important discoveries of Bennet and Carvallo, Nicholson in 1788 constructed an apparatus having two disks of metal insulated and fixed in the same plane. Then by means of a spindle and handle, a third disk, also insulated, was made to revolve near to the two fixed disks, metallic touches being fixed in suitable positions. With this apparatus he found that small residual charges might readily be increased. It is in this simple apparatus that we have the parent of influence machines (see Fig. 1), and as it is now a hundred years since Nicholson described this machine in the Phil. Trans., I think it well worth showing a large sized Nicholson machine at work to-night (see Fig. 11, above).

In 1823 Ronalds described a machine in which the moving disk was attached to and worked by the pendulum of a clock. It was a modification of Nicholson's doubler, and he used it to supply electricity for telegraph working. For some years after these machines were invented no important advance appears to have been made, and I think this may be attributed to the great discoveries in galvanic electricity which were made about the commencement of this century by Galvani and Volta, followed in 1831 to 1857 by the magnificent discoveries of Faraday in electro-magnetism, electro-chemistry, and electro-optics, and no real improvement was made in influence machines till 1860, in which year Varley patented a form of machine shown in Fig. 2. It also was designed for telegraph working.



In 1865 the subject was taken up with vigor in Germany by Toepler, Holtz, and other eminent men. The most prominent of the machines made by them are figured in the diagrams (Figs. 3 to 6), but time will not admit of my giving an explanation of the many points of interest in them; it being my wish to show you at work such of the machines as I may be able, and to make some observations upon them.

In 1866 Bertsch invented a machine, but not of the multiplying type; and in 1867 Sir William Thomson invented the form of machine shown in Fig. 7, which, for the purpose of maintaining a constant potential in a Leyden jar, is exceedingly useful.

The Carre machine was invented in 1868, and in 1880 the Voss machine was introduced, since which time the latter has found a place in many laboratories. It closely resembles the Varley machine in appearance, and the Toepler machine in construction.

In condensing this part of my subject, I have had to omit many prominent names and much interesting subject matter, but I must state that in placing what I have before you, many of my scientific friends have been ready to help and to contribute, and, as an instance of this, I may mention that Prof. Sylvanus P. Thompson at once placed all his literature and even his private notes of reference at my service.

I will now endeavor to point out the more prominent features of the influence machines which I have present, and, in doing so, I must ask a moment's leave from the subject of my lecture to show you a small machine made by that eminent worker Faraday, which, apart from its value as his handiwork, so closely brings us face to face with the imperfect apparatus with which he and others of his day made their valuable researches.

The next machine which I take is a Holtz. It has one plate revolving, the second plate being fixed. The fixed plate, as you see, is so much cut away that it is very liable to breakage. Paper inductors are fixed upon the back of it, while opposite the inductors, and in front of the revolving plate, are combs. To work the machine (1) a specially dry atmosphere is required; (2) an initial charge is necessary; (3) when at work the amount of electricity passing through the terminals is great; (4) the direction of the current is apt to reverse; (5) when the terminals are opened beyond the sparking distance, the excitement rapidly dies away; (6) it does not part with free electricity from either of the terminals singly.

It has no metal on the revolving plates, nor any metal contacts; the electricity is collected by combs which take the place of brushes, and it is the break in the connection of this circuit which supplies a current for external use. On this point I cannot do better than quote an extract from page 339 of Sir William Thomson's "Papers on Electrostatics and Magnetism," which runs: "Holtz's now celebrated electric machine, which is closely analogous in principle to Varley's of 1860, is, I believe, a descendant of Nicholson's. Its great power depends upon the abolition by

Holtz of metallic carriers and metallic make-and-break-contacts. It differs from Varley's and mine by leaving the inductors to themselves, and using the current in the connecting arc."

In respect to the second form of Holtz machine (Fig. 4) I have very little information, for since it was brought to my notice nearly six years ago I have not been able to find either one of the machines or any person who had seen one. As will be seen by the diagram, it has two disks revolving in opposite directions, it has no metal sectors and no metal contacts. The "connecting arc circuit" is used for the terminal circuit. Altogether I can very well understand and fully appreciate the statement made by Professor Holtz in *Uppenborn's Journal* of May, 1881, wherein he writes that "for the purpose of demonstration I would rather be without such machines."

The first type of Holtz machine has now in many instances been made up in multiple form, within suitably constructed glass cases, but when so made up, great difficulty has been found in keeping each of the many plates to a like excitement. When differently excited, the one set of plates furnished positive electricity to the comb, while the next set of plates gave negative electricity; as a consequence, no electricity passed the terminal.

To overcome this objection, to dispense with the dangerously cut plates, and also to better neutralize the revolving plate, throughout its whole diameter, I made a large machine having twelve disks 2 ft. 7 in. in diameter, and in it I inserted plain rectangular slips of glass between the disks, which might readily be removed; these slips carried the paper inductors. To keep all the paper inductors on one side of the machine to a like excitement, I connected them together by a metal wire. The machine so made worked splendidly, and your late president, Mr. Spottiswoode, sent on two occasions to take note of my successful modifications. The machine is now ten years old, but still works perfectly. I will show you a smaller sized one at work.

The next machine for observations is the Carre (Fig. 8). It consists essentially or a disk of glass which is free to revolve without touch or friction. At one end of a diameter it moves near to the excited plate of a frictional machine, while at the opposite end of the diameter is a strip of insulting material, opposite which, and also opposite the excited amalgam plate, are combs for conducting the induced charges, and to which the terminals are metallically connected; the machine works well in ordinary atmosphere, and certainly is in many ways to be preferred to the simple frictional machine. In my experiments with it I found that the quantity of electricity might be more than doubled by adding a segment of glass between the amalgam cushions and the revolving plate. The current in this type of machine is constant.

The Voss machine has one fixed plate and one revolving plate. Upon the fixed plate are two inductors, while on the revolving plate are six circular carriers. Two brushes receive the first portions of the induced charges from the carriers, which portions are conveyed to the inductors. The combs collect the remaining portion of the induced charge for use as an outer circuit, while the metal rod with its two brushes neutralizes the plate surface in a line of its diagonal diameter. When at work it supplies a considerable amount of electricity. It is self-exciting in ordinary dry atmosphere. It freely parts with its electricity from either terminal, but when so used the current frequently changes its direction, hence there is no certainty that a full charge has been obtained, nor whether the charge is of positive or negative electricity.

I next come to the type of machine with which I am more closely associated, and I may preface my remarks by adding that the invention sprang solely from my experience gained by constantly using and experimenting with the many electrical machines which I possessed. It was from these I formed a working hypothesis which led me to make my first small machine. It excited itself when new with the first revolution. It so fully satisfied me with its performance that I had four others made, the first of which I presented to this Institution. Its construction is of a simple character. The two disks of glass revolve near to each other and in opposite directions. Each disk carries metallic sectors; each disk has its two brushes supported by metal rods, the rods to the two plates forming an angle of 90 deg. with each other. The external circuit is independent of the brushes, and is formed by the combs and terminals.

The machine is self-exciting under all conditions of atmosphere, owing probably to each plate being influenced by and influencing in turn its neighbor, hence there is the minimum surface for leakage. When excited, the direction of the current never changes; this circumstance is due, probably, to the circuit of the metallic sectors and the make and break contacts always being closed, while the combs and the external circuit are supplemental, and for external use only. The quantity of electricity is very large and the potential high. When suitably arranged, the length of spark produced is equal to nearly the radius of the disk. I have made them from 2 in. to 7 ft. in diameter, with equally satisfactory results. The diagram, Fig. 9, shows the distribution of the electricity upon the plate surfaces when the machine is fully excited. The inner circle of signs corresponds with the electricity upon the front surface of the disk. The two circles of signs between the two black rings refer to the electricity between the disks, while the outer circle of signs corresponds with the electricity upon the outer surface of the back disk. The diagram is the result of experiments which I cannot very well repeat here this evening, but in support of the distribution shown on the diagram, I will show you two disks at work made of a flexible material, which when driven in one direction close together at the top and the bottom, while in the horizontal diameter they are repelled. When driven in the reverse direction, the opposite action takes place.

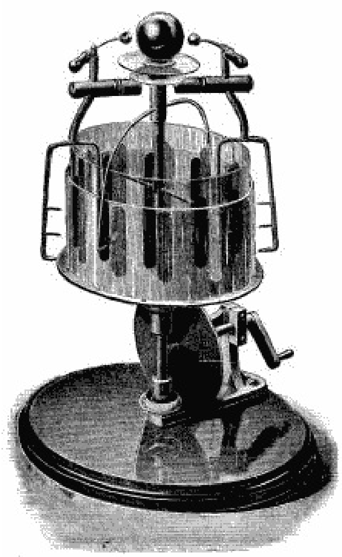


Fig. 10.

I have also experimented with the cylindrical form of the machine (see Fig. 10). The first of these I made in 1882, and it is before you. The cylinder gives inferior results to the simple disks, and is more complicated to adjust. You notice I neither use nor recommend vulcanite, and it is perhaps well to caution my hearers against the use of that material for the purpose, for it warps with age, and when left in the daylight it changes and becomes useless.

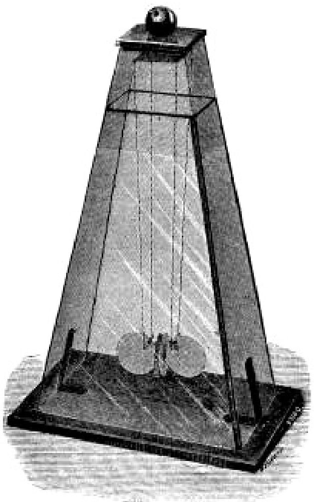


Fig. 13.

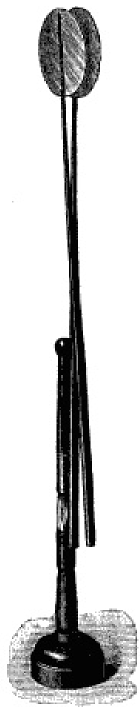


Fig. 14.

I have now only to speak of the larger machines. They are in all respects made up with the same plates, sectors, and brushes as were used by me in the first experimental machines, but for convenience sake they are fitted in numbers within a glass case. One machine has eight plates of 2 ft. 4 in. diameter; it has been in the possession of the Institution for about three years. A second, which has been made for this lecture, has twelve disks, each 2 ft. 6 in. in diameter. The length of spark from it is $13^5/_8$ in. (see Fig. 12). During the construction of the machine every care was taken to avoid electrical excitement in any of its parts, and after its completion several friends were present to witness the fitting of the brushes and the first start. When all was ready the terminals were connected to an electroscope, and the handle was moved so slowly that it occupied thirty seconds in moving one-half revolution, and at that point violent excitement appeared.

The machine has now been standing with its handle secured for about eight hours. No excitement is apparent, but still it may not be absolutely inert. Of this each one present must judge, but I will connect it with this electroscope (Figs. 13 and 14), and then move the handle slowly, so that you may see when the excitement commences and judge of its absolutely reliable behavior as an instrument for public demonstration. I may say that I have never, under any condition, found this type of machine to fail in its performance.

I now propose to show you the beautiful appearances of the discharge, and then, in order that you may judge of the relative capabilities of each of these three machines, we will work them all at the same time.

The large frictional machine which is in use for this comparison is so well known by you that a better standard could not be desired.

In conclusion, I may be permitted to say that it is fortunate I had not read the opinions of Sir William Thomson and Professor Holtz, as quoted in the earlier part of my lecture, previous to my own practical experiments. For had I read such opinions from such authorities, I should probably have accepted them without putting them to practical test. As the matter stands, I have done those things which they said I ought not to have done, and I have left undone those which they said I ought to have done, and by so doing I think you must freely admit that I have produced an electric generating machine of great power, and have placed in the hands of the physicist, for the purposes of public demonstration or original research, an instrument more reliable than anything hitherto produced.

[1]

Lecture delivered at the Royal Institution, April 27, 1888. For the above and for our illustrations we are indebted to *Engineering*.

VIOLET COPYING INK.—Dissolve 40 parts of extract of logwood, 5 of oxalic acid and 30 parts of sulphate of aluminium, without heat, in 800 parts of distilled water and 10 parts of glycerine; let stand twenty-four hours, then add a solution of 5 parts of bichromate of potassium in 100 parts of distilled water, and again set aside for twenty-four hours. Now raise the mixture once to boiling in a bright copper boiler, mix with it, while hot, 50 parts of wood vinegar, and when cold put into bottles. After a fortnight decant it from the sediment. In thin layers this ink is reddish violet; it writes dark violet and furnishes bluish violet copies.

SIBLEY COLLEGE LECTURES.—1887-88.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

THE EVOLUTION OF THE MODERN MILL.[1]

By C. J. H. WOODBURY, Boston, Mass.

The great factories of the textile industries in this country are fashioned after methods peculiarly adapted to the purposes for which they are designed, particularly as regards the most convenient placing of machinery, the distribution of power, the relation of the several processes to each other in the natural sequence of manufacture, and the arrangement of windows securing the most favorable lighting. The floors and roofs embody the most economical distribution of material, and the walls furnish examples of well known forms of masonry originating with this class of buildings.

These features of construction have not been produced by a stroke of genius on the part of any one man. There has been no Michael Angelo, no Sir Christopher Wren, whose epitaph bids the reader to look around for a monument; but the whole has been a matter of slow, steady growth, advancing by hair's breadth; and, as the result of continual efforts to adapt means to ends, an inorganic evolution has been effected, resulting in the survival of the fittest, and literally pushing the weaker to the wall.

This advance in methods has, like all inventions, resulted in the impairment of invested capital. There are hundreds of mill buildings, the wonder of their day, now used for storage because they cannot be employed to sufficient advantage in manufacturing purposes to compete with the facilities furnished by mills of later design. Thus their owners have been compelled to erect new buildings, and, as far as the original purpose of manufacturing is concerned, to abandon their old mills.

In the case of a certain cotton mill built about thirty years ago, and used for the manufacture of colored goods of fancy weave, the owners added to the plant by constructing a one story mill, which proved to be peculiarly adapted to this kind of manufacture, by reason of added stability, better light, and increased facilities for transferring the stock in process of manufacture; and they soon learned not only that the old mill could not compete with the new one, but that they could not afford to run it at any price; the annual saving in the cost of gas, as measured by the identical meter used to measure the supply to the old mill, being six per cent. on the cost of the new mill.

In another instance, one of two cordage mills burned, and a new mill of one story construction was erected in its place. The advantage of manufacture therein was so great that the owners of the property changed the remaining old mill into a storehouse; and now, as they wish to increase their business, it is to be torn down as a cumberer of the ground, to make room for a building of similar construction to the new mill.

It is true that such instances pertain more particularly to industries and lines of manufacture where competition is close and conditions are exacting. Still they apply in a greater or less degree to nearly every industrial process in which a considerable portion of the expense of manufacture consists in the application of organized labor to machines of a high degree of perfection.

These changes have been solely due to the differences in the conditions imposed by improvement in the methods of manufacture. The early mills of this country were driven by water power, and situated where that could be developed in the easiest manner. They were therefore placed in the narrow valleys of rapid watercourses. The method of applying water power in that day being strictly limited to placing the overshot or breast wheel in the race leading from the canal to the river, the mill was necessarily placed on a narrow strip of land between these two bodies of water, with the race-way running under the mill.

To meet these conditions of location, which was limited to this strip of land, the mill must be narrow and short, and the requisite floor area must be obtained by adding to the number of stories. It was essential that the roof of such a mill should be strong and well braced in order to sustain the excessive stress brought to bear upon it. The old factory roof was a curious structure, with eaves springing out of the edge of hollow cornices, the roof rising sharply until about six feet above the attic floor, with an upright course of about three feet, filled with sashes reaching to a second roof, which, at a more moderate pitch than the first slope, trended to the ridge.

The attic was reduced to an approximately square room, by placing sheathing between the columns underneath the sashes, and ceiling underneath the collar beams above; thus forming a cock-loft above and concealed spaces at the sides which diminished the practically available floor space in the attic. This cock-loft and these concealed spaces became receptacles for rubbish and harbors for vermin, both of which were frequent causes of fire.

The floors of such a mill were similar in their arrangement to those of a dwelling. Joists connecting the beams supported the floor; and the under side was covered over by sheathing or lath and plaster, thus forming, as in the case of the roof, hollow spaces which were a source of danger. This method caused at the same time an extravagant distribution of material, by the prodigal use of lumber and the unnecessary thickness of such floors, and entailed an excessive amount of masonry in the walls.

Mills built after this manner were frequently in odd dimensions; and the machinery was necessarily placed in diversified arrangement, calling forth a similar degree of wasted skill as that used in making a Chinese puzzle conform to its given boundaries. Their area depended upon the topography of the site, and their height upon the owner's pocket book. There was in Massachusetts a mill with ten floors, built on land worth at that time ten cents or less per square foot, which has been torn down and a new mill rebuilt in its place, because, since the advent of modern mills, it has failed every owner by reason of the excessive expenditure necessary for the distribution of power, for supervision, and for the transfer of stock in process, in comparison with the mills of their competitors, built with greater ground area and less number of stories.

With the advent of the steam engine as prime mover in mills, and the introduction of the turbine wheel with its trunk, affording greater facilities in the application of water power, the character of these buildings changed very materially, though still retaining many of their old features. One of the first of these changes may be noticed in the consideration which millwrights gave to the problem of fixing upon the dimensions of a mill so as to arrange the machinery in the most convenient manner. Although the floors were still hollow, there was a better distribution of material, the joists being deeper, of longer span, and resting upon the beams, thus avoiding the pernicious method of wasting lumber, and guarding against fracture by tenoning joists into the upper side of beams.

But this secondary type of mills was not honest in the matter of design. The influence of architects who attempted effects not accordant with or subservient to the practical use of the property is apparent in such mills. The most frequent of these wooden efforts at classic architecture was the common practice of representing a diminutive Grecian temple surrounding a factory bell perched in mid air. There were also windows with Romanesque arches copied from churches, and Mansard roofs, exiled from their true function of decorating the home, covering a factory without an answering line anywhere on its flat walls.

I do not mean to criticise any of these elements of design in their proper place and environment; but utility is the fundamental element in design, and should be especially noticeable in a building constructed for industrial purposes, and used solely as a source of commercial profit in such applications. Its lines therefore fulfill their true function in design in such measure as they suggest stability and convenience; and this can be obtained in such structures without the adoption of bad proportions offensive to the taste. In fact, certain decorative effects have been made with good results; but these have been wholly subordinate to the fundamental idea of utility.

The endurance with which brick will withstand frost and fires, and the disintegrating forces of nature, in addition to its resistance to crushing and the facility of construction, constitute very important reasons for its value for building purposes. But the use of this has been too often limited to plain brick in plain walls, whose monotony portrayed no artistic effect beyond that furnished by a few geometrical designs of the most primitive form of ornament, and falling far short of what the practice of recent years has shown to be possible with this material.

Additions of cast iron serve as ornaments only in the phraseology of trade catalogues; and the mixture of stone with brick shows results in flaring contrasts, producing harsh dissonance in the effect. The facades of such buildings show that this is brick, this is stone, or this is cast iron; but they always fail to impress the beholder with the idea of harmonious design. The use of finer varieties of clay in terra cotta figures laid among the brickwork furnishes a field of architectural design hardly appreciated. The heavy mass of brick, divided by regular lines of demarkation, serves as the groundwork of such ornamentation, while the suitable introduction in the proper places of the same material in terra cotta imparts the most appropriate elements of beauty in design; for clay in both forms shows alike its capacity for utility and decoration. The absorption of light by both forms of this material abates reflection, and renders its proportions more clearly visible than any other substance used in building construction.

The modern mill has been evolved out of the various exacting conditions developed in the effort to reduce the cost of production to the lowest terms. These conditions comprise in a great measure questions of stability, repairs, insurance, distribution of power, and arrangement of machinery.

In presenting to your attention some of the salient features of modern mill construction, I do not assume to offer a general treatise upon the subject; but propose to confine myself to a consideration of some topics which may not have been brought to your notice, as they are still largely matters of personal experience which have not yet found their way into the books on the subject. Much of this, especially the drawings thrown on the screen, is obtained from the experience of the manufacturers' mutual insurance companies, with which I am connected. By way of explanation, I will say that these companies confine their work to writing upon industrial property; and there is not a mechanical process, or method of building, or use of raw material, which does not have its relation to the question of hazard by fire, by reason of the elements of relative danger which it embodies.

It is indeed fortunate that it has been found by experience that those methods of building which are most desirable for the underwriter are also equally advantageous for the manufacturer. There is no pretense made at demands to compass the erection of fireproof buildings. In fact, as I have once remarked, a fireproof mill is commercially impossible, whatever effort may be made to overcome the constructive difficulties in the way of erecting and operating a mill which shall be all that the name implies. The present practice is to build a mill of slow burning construction.

FOUNDATIONS.

In considering the elements of such buildings, I wish to devote a few words to the question of foundations, because in the excessive loads imposed by this class of buildings, and in the frequent necessity of constructing them upon sites where alluvial drift or quicksands form compressible foundations, there is afforded an opportunity for the widest range of engineering skill in dealing with the problem. In such instances, a settling of the building must be foreseen and provided for, in order that it may be uniform under the whole structure. This is generally accomplished by means of independent foundations under the various points of pressure, arranged so as to give a uniform intensity of pressure upon all parts of the foundation. It is considered important to limit the load upon such foundations to two tons a square foot, although loads frequently exceed this amount.

There is a large building in New York City which has recently been reconstructed, and the foundations rearranged, where the load reached to the enormous amount of six to ten tons per square foot. It was a frequent occurrence in the class of high mills spoken of to impose loads of so much greater intensity upon the wall foundation than upon the piers under the columns of the mill, that the floors became much lower at the walls than at the middle.

The stone for such foundations should be laid in cement rather than in mortar, not merely because cement offers so much greater resistance to crushing, but because its setting is due to chemical changes occurring simultaneously throughout the mass. The hardening of mortar, on the other hand, is due to the drying out of the water mechanically contained with it, and its final setting is caused by the action of the carbonic acid gas in the air.

Although quicksands are never to be desired, yet they will sustain heavy loads if suitably confined. When inclined rock strata are met with, all horizontal components of stress should be removed by cutting steps so that the foundation stones shall lie upon horizontal beds.

Foundations are frequently impaired by the slow, insidious action of springs or of water percolating from the canal which supplies the water power for the mill; and the proper diversion of such streams should be carefully provided for.

In the question of foundations, there is much of a general nature which is applicable to all structures; but, at the same time, each case requires independent consideration of the circumstances involved.

WALLS.

In addition to what has been said, there is but little for me to offer on the subject of walls beyond the general question of stability. In mill construction, walls of uniform thickness have been displaced by pilastered walls, about sixteen inches thick at the upper story, and increasing four inches in thickness with each story below.

The remainder of the walls is from four to six inches less in thickness than at the pilasters. Frequently the outside dimensions of these pilasters are somewhat increased, giving greater stability and artistic effect. By leaving hollow flues within them, and using these flues as conductors for heated air which may be forced in by a blower, such pilasters afford a means for the most efficient method of warming the building.

Consideration must be given to the contraction of brick masonry, especially when an extension or addition is to be made to an older building. This shrinkage amounts to about three-sixteenths of an inch to the rod, an item which is of considerable importance in the floors of high buildings, where the aggregate difference is very appreciable. Some degree of annoyance is caused by neglect to consider this element of shrinkage in reference to the window and door frames, which should have a slight space above them allowing for such contraction. This contraction is often the source of serious trouble in brick buildings with stone faces, the shrinkage of the brick imposing excessive stress on the stone. Instances of this are quite frequent, especially in large public buildings, notably the capitol at Hartford and the public building at Philadelphia, where the shivering of the joints of the stone work gave undue alarm, on the general assumption that it indicated a dangerous structural weakness. The difficulty has, I believe, been entirely remedied in both cases.

The limit of good practice on loads upon brickwork is eight to ten tons per square foot, although it is true that these loads are largely exceeded at times. It is not to be shown, however, that the limits of safety in regard to desirable construction should be confined to the use of masonry for any low buildings. Structures which may be said to be equal to those of brickwork, as far as commercial risk is concerned, can be built wholly or in part of wood so as to conform to all practical conditions of safety. This statement does not apply except to low buildings of one or possibly two stories in height, where the timber cannot be subjected to the intense blast of flame occurring when a high building is on fire.

Mr. George H. Corliss, the eminent engine builder, of Providence, first built a one-story machine shop, with brick walls extending only to the base of the windows, above this the windows being very close together, with solid timber construction between them.

Another method is to place upright posts reaching from the sill to the roof timbers, and to lay three-inch plank on the outside of such posts up to the line of the windows. A sheathing on the outside plank between the timbers is laid vertically and fastened to horizontal furring strips. In some instances a small amount of mortar is placed over each of the furring strips. The reason for this arrangement is to prevent the formation of vertical flues, which are such a potent factor in the extension of fires.

WINDOWS.

Light is often limited or misapplied on account of faulty position or size of windows. The use of pilastered walls permits the introduction of larger windows, which are in most instances virtually double windows, the two pairs of sashes being set in one frame separated by a mullion. A more recent arrangement, widely adopted in English practice, is to place a swinging sash at the top of the window, which can be opened, when necessary, to assist in the ventilation, while the main sashes of the window are permanently fixed.

Rough plate glass is used in such windows, because it gives a softer and more diffused light, which is preferred to that from ordinary clear glass. White glass may be rendered translucent by a coat of white zinc and turpentine.

The top of a window should be as near the ceiling as practicable, because light entering the upper portion of a room illuminates it more evenly, and with less sharply marked shadows, than where the windows are lower down.

The walls below the windows should be sloped, in order that there may be no opportunity to use them as a resting place for material which should be placed elsewhere.

FIRE WALLS.

Brick division walls should be built so as to constitute a fire wall wherever it is practicable to do so. Such walls should project at least three feet above the roof, and should be capped by stone, terra cotta, or sheet metal. They must form a complete cut-off of all combustible material, especially at the cornices.

FIRE DOORS.

All openings in such walls must be provided with such fireproof doors as will prove reliable in time of need. Experience with iron doors of various forms of construction show that they have been utterly unreliable in resisting the heat of even a small fire. They will warp and buckle so as to open the passageway and allow the fire to pass through the doorway into the next room.

A door made of wood, completely enveloped by sheets of tinned iron, and strongly fastened to the wall, has proved to resist fire better than any door which can be applied to general use. I have seen such doors in division walls where they had successfully resisted the flame which destroyed four stories of a building filled with combustible material, without imposing any injury upon the door except the removal of the tin on the sheet iron; and the doors were kept in further service without any repairs other than a coat of paint.

The reason for this resistance to fire is that the wood, being a poor conductor of heat, will not warp and buckle under heat, and cannot burn for lack of air to support combustion. A removal of the sheet metal on such a door after a fire in a mill shows that the surface of the wood is carbonized, not burned, reduced to charcoal, but not to ashes.

Many fire doors are constructed and hung in such a manner that it is doubtful whether they could withstand a fire serious enough to require their services.

The door should be made of two thicknesses of matched pine boards of well dried stock, and thoroughly fastened with clinched nails. It should be covered with heavy tin, secured by hanging strips, and the sheets lock-jointed to each other, with the edge sheets wrapping around, so that no seam will be left on the edge.

Sliding doors are preferable to swinging doors for many reasons, especially because they cannot be interfered with by objects on the floor. But, if swinging doors are used, care should be taken that the hinges and latches are very strong, and securely fastened directly to the walls, and not to furring or anything in turn attached to the walls. The portion of the fixtures attached to the doors must be fastened by carriage bolts, and not by wood screws.

Sliding on trucks is the preferable method of hanging sliding doors, inclined two and one half inches to the foot, and bolted to the wall. The trucks should be heavy "barn door hangers," bolted to the door; and a grooved door jamb, of wood, covered with tin similar to the door, should receive it when shut. A step of wood will hold the door against the wall when closed. A threshold in the doorway retards fire from passing under the door, and also prevents the flow of water from one room to another.

These doors are usually placed in pairs, and sometimes an automatic sprinkler is placed between them.

Fire doors should always be closed at night. In some well ordered establishments there is a printed notice over each door directing the night watchmen to close such doors after them. In a storage warehouse in Boston, the fire doors are connected with the watchman's electric clock system, so that all openings of fire doors are matters of record on the dial sheet.

Fire doors should certainly be closed at times of fire; yet, that such doors are open at night fires, or left open by fleeing help at day fires, is an old story with underwriters. A simple automatic device can be used to shut such doors. It consists of two round pieces of wood with a scarfed joint held by a ferrule, forming a strut which is placed on two pins, keeping the door open, as other sticks have long since served like purposes.

The peculiarity of this arrangement is that the ferrule is not homogeneous, but is made up of four segments of brass soldered together with the alloy fusible at 163 degrees Fahr., which is widely known for its use in automatic sprinklers. When the solder yields, the rod cripples, and the door rolls down the inclined rail and shuts. At any time the door can be closed by removing one end of the rod from one of the pins and allowing it to hang from the other pin.

MILL TOWERS.

Because of economic reasons for preserving the space within the walls of the mill so that it may be to the greatest extent available for the best arrangement of machinery, the stairways should be placed outside of the building. Such stairways should not be spiral stairways, but should be made in short straight runs with square landings, because in the spiral stairway the portion of the stairs near the center is of so much steeper pitch that it renders them dangerous when the help are crowding out of the mill.

The wear of stairs from the tread of many feet presents a difficult problem. A very common practice consists in covering each tread with a thin piece of cast iron marked with diagonal scores, and generally showing the name of the mill. These treads wear out in the course of time, but for this use they answer very well, although somewhat slippery.

A wood tread gives a more secure foothold upon the stairway; and in some instances stairs have been protected by covering the treads with boards of hard wood, containing grooves about three-eighths of an inch deep, and of similar width, with a space of half an inch between them. These boards are grooved on both sides and placed on the stairs. After the front edge is worn, they are turned around so as to present the other edge to the front, and, in course of time, turned from the exposed side to do service in two positions on the other side. In this manner these tread covers are exposed to wear in four different positions.

Mill towers, besides containing the stairways, also serve other purposes, as for cloak rooms for the help. They often contain a part of the fire protective apparatus, carrying standpipes with hydrants at each floor. For this use they are easily available, and furnish a line of retreat in case a fire spreads to an extent beyond the ability of the apparatus to cope with it. These towers also furnish an excellent foundation for the elevated tank necessary for the supply of water for the fire apparatus in places unprovided with an elevated reservoir.

In view of the terrible and deplorable accidents which have occurred by reason of lack of proper stairway facilities at panics caused in time of fire, I would repeat the words of the late Amos D. Lockwood, the most eminent mill engineer which this country has yet produced, when he said to the New England Cotton Manufacturers' Association, "You have no moral right to build a mill employing a large number of help, with only one tower containing the stairways for exit."

The statute laws of several of the States require fire escapes; but it is a matter of fact that they are rarely used, because people are not often cool enough to avail themselves of that opportunity of escape. I know of one instance where a number of girls jumped out of a fourth story window, because they did not think of the stairways, and did not dare to use the fire escape. In that instance, none of the group referred to tried to go down the stairs, which did furnish a perfectly safe means of exit to a number of others.

Most of the fire escapes are put up so as to conform to the letter of the law; and in such manner that no one but a sailor or an acrobat would be likely to trust himself to them. In crowded city buildings, and in other places where the ordinary means of escape are not in duplicate, it is essential that fire escapes should be provided; but it is a great deal better to make a mill building so that they shall not be necessary as a matter of fact, even if they are put up to conform to the requirements of statute law.

REAR TOWERS.

In addition to stairways, towers are placed at the rear of the mill, for the purpose of accommodating the elevators and sanitary arrangements. It is not desirable that elevators should be boxed or surrounded with anything that would result in the construction of a flue; but it is preferable that they pass directly through the floors, with the openings protected by automatic hatchways which close whenever the elevator car is absent. In the washroom, etc., in these towers, it is desirable to protect the wood floors by means of a thin layer of asphalt.

BASEMENT FLOORS.

There are difficulties connected with the floors on or near the ground, by reason of the dry rot incident to such places. Dry rot consists in the development of fungus growth from spores existing in the wood, and waiting only the proper conditions for their germination. The best condition for this germination is the exposure to a slight degree of warmth and dampness. There have been many methods of applying antiseptic processes for the preservation of wood; but, irrespective of their varying degrees of merit, they have not come into general use on account of their cost, odor, and solubility in water.

It is necessary that wood should be freely exposed to circulation of air, in order to preserve it under the ordinary conditions met with in buildings. Whenever wood is sealed up in any way by paint or varnish, unless absolutely seasoned, and in a condition not found in heavy merchantable timber, dry rot is almost sure to ensue. Whitewash is better.

There has recently been an instance of a very large building in New York proving unsafe by reason of the dry rot generated in timbers which have been completely sealed up by application of plaster of Paris outside of the wire lath and plaster originally adopted as a protection against fire. Wire lath and plaster is one of the best methods of protecting timber against fire; and, if the outside is not sealed by a plaster of stucco or some other impermeable substance, the mortar will afford sufficient facilities for ventilation to prevent the deposition of moisture, which will in turn generate dry rot.

Where beams pass into walls, ventilation should be assured by placing a board each side of the beam while the walls are being built up, and afterward withdrawing it. In the form of hollow walls referred to, it is a common practice to run the end of the beam into the flue thus formed, in order to secure ventilation.

I am well acquainted with a large mill property, one building of which was erected a short time before the failure of the corporation, which resulted in the whole plant remaining idle several years. After the lapse of about five years this establishment was again put into operation; but before the new mill could be safely filled with machinery, it was necessary to remove all the beams which entered walls and to substitute for them new ones, because the ends were so thoroughly rotted that it would have been dangerous to impose any further loads upon the floors. When floors are within a few feet of the ground, unless the site be remarkably dry, it is essential to provide for a circulation of air, which can be done very feasibly in a textile mill by laying drain pipe through the upper part of the underpinning, forming a number of holes leading into this space, and then making a flue from this space to the picker room or any other place requiring a large amount of air. The fans of the picker room, drawing their supply from underneath the building, produce a circulation of air which keeps the timber in good condition.

It is supposed by some that there is a difference in the quality of timber according to the season in which it is felled, preference being given to winter timber, on account of the greater amount of potash and phosphoric acid which it is said to contain at that time. In some parts of Europe it is a custom to specify that the lumber should have been made from rafted timber, on account of the action of the water in killing certain species of germs. Whatever may be the merits of either of these two theories, the commercial lumber of the northern part of this country is generally felled in winter and afterward rafted.

The action of lime in the preservation of wood has always been attended with the most excellent results; although not suited to places subject to the action of water, which dissolves the lime, leaving the timber practically in its original condition. The preservative action of lime upon wood is readily shown by the admirable condition in which laths are always found. I doubt if any one ever found a decayed lath in connection with plaster.

As an example of the action of lime as a preservative of lumber. I can cite an instance of a mill in New Hampshire where the basement floor was placed in 1856, the ledge in the cellar having been blasted out for the purpose. The rock was very seamy, and abounded in water issuing from springs or percolating from the canal supplying water to the mill. The rock was blasted away to a grade two feet below the floor, and most of the space filled up again by replacing the small pieces of stone, so arranged as to form blind drains for the removal of any water which might find its way under the floor.

Toward the top of this filling, finer stones were used, then about three inches of gravel, which was covered with two inches of sand and lime. Two years ago I was at this mill when some alterations requiring the removal of the floor were in progress, and found that the lumber was still in good, sound condition, except for a superficial decay on the under side of the floor plank.

But there are frequent instances where it is necessary to place the floor directly upon the earth, without any space or loose filling underneath it, in order to save room, or to secure a firm support for machinery. By way of information upon what has actually been accomplished in this direction, I will cite instances of three floors in such positions, all of which have to my knowledge fulfilled the purpose for which they were designed.

The first instance is that of a basement floor laid twenty-one years ago, a portion of which was made by excavating one foot below the floor, six inches of coarse stone being filled in, then five inches of coal tar concrete made up with coarse gravel, and finally about one inch of fine gravel concrete. Before the concrete was laid, heavy stakes were driven through the floor about three feet apart, to which the floor timbers were nailed and leveled up. The concrete was then filled in upon the floor timbers, and thoroughly tamped and rolled out to the level of the top of the floor timbers. The under side of the floor timbers was covered with hot coal tar.

This floor is still in good condition, and has not needed repairs caused by the decay of the timber. Another portion of the floor laid at the same time and in the same manner, with the exception that cement concrete was used in the place of the coal tar, was entirely rotted out in ten years.

Another floor was made in quite a similar manner. All soil and loam was removed from the interior of the building; the whole surface was brought up to the grade with a puddle of gravel and ashes; stakes two and a half by four inches, and thirty inches in length, were driven down; and nailing strips were secured to them. Over this puddled surface a coat of concrete eight inches thick was laid, the top being flush with the upper surface of the nailing strips. This concrete was made of pebbles about two inches in diameter, well coated with coal tar, and laid in place when hot. It was then packed together by being tamped and rolled, and a thin covering of the tarred sand placed upon the top, forming a smooth, hard surface. The first floor consisted of two inches of matched spruce, grooved on both sides, and fitted with hard pine splines, five-eighths by one and one-fourth inches. On the top of this a hard pine 1¼ inch floor was laid over a course of building paper.

Another method, which is certainly more novel than either of the others, consists in supporting a floor upon a bed of resin. The underlying earth was removed, and replaced with spent moulding sand, leaving trenches for the floor timbers, which were placed upon bricks laid without mortar. Melted resin was poured into the space alongside and underneath the timbers. The floor planks were then laid upon the timbers, the tops of which were about half an inch above the level of the sand. Holes were bored into the floor plank about four feet apart, and melted resin then poured into the holes, so as to interpose a layer of resin underneath the floor plank and beams. Upon this floor a top floor of hard wood was laid in the usual manner. This floor has been used for a number of years to support a large quantity of heavy machine tools, principally planers, without yielding or depreciation due to decay, and has proved to be most satisfactory.

In some instances asphaltum or coal tar concrete floors are not covered with wood, although it is much more agreeable for the help to stand upon wooden floors. It should be remembered that all these compounds are readily softened by means of oil, and they should be protected from oil by a coat of paint when not covered with wood; the preferable method being to first apply a priming containing very little oil, or a coat of shellac, and follow with some paint mixed up with boiled linseed oil.

(*To be continued.*)

[1]

The lecture was illustrated by about fifty views on the screen, which cannot be reproduced here, showing photographs of mills and mechanical drawings of the methods of construction alluded to in the lecture.

THE MECHANICAL EQUIVALENT OF HEAT.

By De Volson Wood, Professor of Engineering in Stevens Institute of Technology.

It is clearly intimated by Mr. Hanssen, in his determination of the mechanical equivalent of heat, published in the Scientific American Supplement, No. 642, April 21, 1888, that his object is to determine the *absolute* value of this constant. With his data he finds it to be 771.89 foot pounds. But the determination by direct experiment gives a larger value. Thus, the most reliable experiments—those of Joule and Rowland—give values exceeding by several units that found by Hanssen. A committee of the British Association, appointed for this purpose, reported in 1876 that sixty of the most reliable of Joule's experiments gave the mean value 774.1. The experiments were made with water at a temperature of about 60° F., according to the mercurial thermometer, and reduced to its value at the temperature of melting ice, according to the formula given by Regnault for the variation of the specific heat of water at varying temperature under the constant pressure of one atmosphere. According to this formula the specific heat of water increases with the temperature above the melting point of ice, so that the equivalent would be somewhat less at 32° F. than at 60° F. It will be found in Regnault's *Relation des Experiences* that he experimented on water at high temperatures, but more recently Professor Rowland has found that the specific heat of water is *greater* at 40° F. than at 60° F., thus reversing between these limits the law given by Regnault; the increase, as given by the most probable values, being, roughly, about $^1/_{250}$ of its value at 60° F. The proper correction due to this cause would make the equivalent over 777 foot pounds, instead of 774.1. Professor Rowland's experiments, when reduced to the same thermometer, same temperature, and same latitude as Joule's, agreed very nearly with those of the latter, being about $^1/_{1000}$ part larger; so that the chief difference in the ultimate values consists in the reductions for temperature and latitude. The force of gravity being less for the lower latitudes, the number representing the mechanical equivalent will be greater for the latter, since the unit pound mass must fall through a greater number of feet to equal the same work; so that the equivalent will be greater at Paris than at Manchester. Professor Rowland also found that the degrees on the air thermometer from 40° F. upward to above 60° F. exceeded those on the mercurial thermometer throughout the corresponding range, and that from 40° to 41° the degree was between $^1/_{150}$ and $^1/_{200}$ of a degree larger on the air thermometer than on the mercurial. Although this fraction is too small to be observed by ordinary means, yet, if it exists, it cannot be ignored if absolute values are sought. Regnault employed the air thermometer in his experiments, while Joule used the mercurial thermometer, and if Joule's value 774.1 be increased by $^1/_{200}$ of itself in order to reduce it from the equivalent of the degree on the mercurial thermometer to that on the air thermometer, we get 778 foot pounds, nearly. Rowland found from his experiments that when reduced to the air thermometer and to the latitude of Baltimore, the equivalent was nearly 783, subject to small residual errors.

Nearly all writers upon this subject—except Rankine—have considered that the mechanical equivalent of heat, in British units, was the energy necessary to raise the temperature of one pound of water from 32° F. to 33° F., but Rankine defines it as the heat necessary to increase the temperature of one pound of water one degree Fahrenheit from that of maximum density, or from 39° F. to 40° F. For ordinary practice it is immaterial which of these definitions is used, for the errors resulting therefrom are much less than those resulting from ordinary observations. But when the value is to be determined by direct experiment at the standard temperature, Rankine's limits are much to be preferred; for it is so very difficult to determine exact values by observation when the substance is near the state bordering on a change of state of aggregation, as that of changing from water to ice. Observations made at about 60° F. were reduced by means of Regnault's law for the specific heat of water, as has been stated, which is expressed by the formula

$$c = 1 + \frac{4}{10^5} t + \frac{9}{10^7} t^2$$

in which t denotes the temperature according to the Centigrade scale. According to this law, the mechanical equivalent would not be 0.2 of a foot pound greater at 5° C. (41° F.) than at 0° C. (32° F.); hence, if this law were correct, it would make no practical difference whether the temperature were at 0° C. or 5° C. This law makes the *computed* value at 32° F. about 0.95 of a foot pound less than that determined by experiment at 60° F.; whereas Rowland's experiments make it *greater* at 40° F. by more than four foot pounds, for the air thermometer. In determining a *fixed* value to be used for scientific purposes, it is necessary to fix the place, the thermometer, and the particular degree on the thermometer. The place may be known by its latitude if reduced to the level of the sea. The air thermometer agrees most nearly with that of the ideally perfect gas thermometer, while the mercurial thermometer differs very much from it in some cases. Thus, Regnault found that when the air thermometer indicated 630° F. above the melting point of ice (or 662° F.), the mercurial thermometer indicated 651.9° above the same point (683.9° F.), a difference of 22° F. It is apparent that the air thermometer furnishes the best standard. As for the particular degree on the scale to be used for the standard, it is apparent, from the observations above made, that the temperature corresponding to that at or near the maximum density of water is more desirable than that at the melting point of ice. The fact, also, that the specific heats at constant pressure and at constant volume are the same at the point of maximum density, as shown by theory, is an additional argument in favor of selecting this point for the standard. It thus appears that the solution of this problem, which appears simple and very definite by Mr. Hanssen's method, becomes intricate and, to a limited degree, indeterminate when subjected to the refinements of direct experiment. If the constants used by Hanssen are absolutely correct, then his result must be unquestioned; but since physical constants are subject to certain residual errors, one would as soon think of finding the specific heat of air at constant volume, by using the value of the mechanical equivalent as one of the elements, and trusting the result, as he would to trust to the computed value of the mechanical equivalent without subjecting it to the test of a direct experiment. We will, therefore, examine the constants used to see if they are the exact values of the quantities they represent.

He says they are universally accepted as correct; and this may be true, when used for general purposes, and yet not be scientifically exact. He uses 0.2377 as the specific heat of air. This is the value, to four decimals, found by Regnault. Thus, Regnault gives for the mean value of the specific heat of air

Between —30° C	and +	10° C.	0.23771
" 0° C	"	100° C.	0.23741
" 0° C	"	200° C.	0.23751

And we know of no reason why one of these values should be used rather than another, except that the mean of a large range of temperatures may be more nearly correct than that of any other; and if this reason determines our choice, the number 0.2375 would be used instead of 0.2377. Although this difference is small, yet the former value would have reduced his result about 0.7 of a foot pound.

Again, he uses 0.1686 for the specific heat of air at constant volume. The value of this constant has never been found to any degree of accuracy by direct experiment, and we are still dependent upon the method established by La Place and Poisson, according to which the constant ratio of the specific heat of a gas at constant pressure to that at constant volume is found by means of the velocity of sound in the gas. The value of the ratio for air, as found in the days of La Place, was 1.41, and we have 0.2377 ÷ 1.41 = 0.1686, the value used by Clausius, Hanssen, and many others. But this ratio is not definitely known. Rankine in his later writings used 1.408, and Tait in a recent work gives 1.404, while some experiments give less than 1.4, and others more than 1.41.

An error of one foot in a thousand in determining the velocity of sound will affect the third decimal figure one or two units. A small difference in the assumed weight of a cubic foot of air also affects the result. M. Hanssen gives 0.080743 pound as the weight at 32° F. under the pressure of one atmosphere; while Rankine gives 0.080728 pound. In my own computations I use 1.406 as a more probable value of the constant sought. This will give for the specific heat of air at constant pressure

$$0.2375 \div 1.406 = 0.1689$$

This is only 0.0003 of a unit greater than the value used by Hanssen, but it would have given him nearly 775, instead of 771.89.

Again, he uses 491.4° F. for the absolute temperature of melting ice. The exact value of this constant is unknown; but the mean value as determined by Joule and Thomson, in their celebrated experiments with porous plugs, was 492.66° F. This value would slightly change his result. It will be seen from the above that a small change in the constants used may affect by several units the computed value of the mechanical equivalent. I have computed it, using 1.406 for the ratio of the specific heat of air at constant pressure to that at constant volume, 491.13° F. as the temperature of melting ice above the zero of the *air* thermometer, 26,214 feet for the height of a homogeneous atmosphere, and 0.2375 for the specific heat of air, and I find, by means of these constants, 778. If computed from the zero of the absolute scale, 492.66° F., I find 777 to the nearest integer. Recently I have used 778. If the value given by Rowland, about 783 according to the air thermometer at 39° F., should prove to be correct, it seems probable that the constant 1.406 used above would be reduced to about 1.403, or that the other constants must be changed by a small amount. The height of the homogeneous atmosphere used above, 26,214 feet, is the value used by Rankine as deduced from Regnault's figures, and only one foot less than the value used by Sir William Thomson; but the figures used by Mr. Hanssen give 26,210½ feet.

The method above called Hanssen's is really that of Dr. Mayer (the German professor), who in 1842 used it for determining the mechanical equivalent; but on account of erroneous data, the value found by him was much too small.

ECONOMY TRIALS OF A NON-CONDENSING STEAM ENGINE—SIMPLE, COMPOUND, AND TRIPLE.[1]

By Mr. P. W. Willans, M.I.C.E.

The author described a series of economy trials, non-condensing, made with one of his central valve triple expansion engines, with one crank, having three cylinders in line. By removing one or both of the upper pistons, the engine could be easily changed into a compound or into a simple engine at pleasure. Distinct groups of trials were thus carried out under conditions very favorable to a satisfactory comparison of results.

No jackets were used, and no addition had, therefore, to be made to the figures given for feed water consumption on that account. Most of the trials were conducted by the author, but check trials were made by Mr. MacFarlane Gray, Prof. Kennedy, Mr. Druitt Halpin, Professor Unwin, and Mr. Wilson Hartnell. The work theoretically due from a given quantity of steam at given pressure, exhausting into the atmosphere, was first considered.

By a formula deduced from the θ φ diagram of Mr. MacFarlane Gray, which agreed in results with the less simple formulas of Rankine and Clausius, the pound weight of steam of various pressures required theoretically per indicated horse power were ascertained. (See annexed table.)

A description was then given of the main series of trials, all at four hundred revolutions per minute, of the appliances used, and of the means taken to insure accuracy. A few of the results were embodied in the table. The missing quantity of feed water at cut off, which, in the simple trials, rose from 11.7 per cent. at 40 lb. absolute pressure to nearly 30 per cent. at 110 lb. and at 90 lb. was 24.8 per cent., was at 90 lb. only 5 per cent. in the compound trials. In the latter, at 160 lb., it increased to 17 per cent., but, on repeating the trial with triple expansion, it fell to 5.46 per cent. or to 4.43 per cent. in another trial not included in the table.

On the other hand, from the greater loss in passages, etc., the compound engine must always give a smaller diagram, considered with reference to the steam present at cut-off, than a simple engine, and a triple a smaller diagram than a compound engine. Nevertheless, even at 80 lb. absolute pressure, the compound engine had considerable advantage, not only from lessened initial condensation, but from smaller loss from clearances, and from reducing both the amount of leakage and the loss resulting from it. These gains became more apparent with increasing wear. The greater surface in a compound engine had not the injurious effect sometimes attributed to it, and the author showed how much less the theoretical diagram was reduced by the two small areas taken out of it in a compound engine than by the single large area abstracted in a simple engine. The trials completely confirmed the view that the compound engine owed its superiority to reduced range of temperature. At the unavoidably restricted pressures of the triple trials, the losses due to the new set of passages, etc., almost neutralized the saving in initial condensation, but with increased pressure—say to 200 lb. absolute—there would evidently be considerable economy. The figures of these trials showed that the loss of pressure due to passages was far greater with high than with low pressure steam, and that pipes and passages should be proportioned with reference to the weight of steam passing, and not for a particular velocity merely.

The author described a series of calorimetric tests upon a large scale (usually with over two tons of water), the results of which were stated to be very consistent. After comparing the dates of initial condensation in cases where the density of steam, the area of exposed surface, and the range of temperature were all variables, with other cases (1) where the density was constant and (2) where the surface was constant, the author concluded that, at four hundred revolutions per minute, the amount of initial condensation depended chiefly on the range of temperature in the cylinder, and not upon the density of the steam or upon the extent of surface, and that its cause was probably the alternate heating and cooling of a small body of water retained in the cylinder. The effect of water, intentionally introduced into the air cushion cylinder, corroborated the author's views, and he showed how small a quantity of water retained in the cylinder would account for the effects observed. At lower speeds surface might have more influence. The favorable economical effect of high rotative speed, *per se*, was very apparent.

In a trial with a compound engine, with 130 lb. absolute pressure, the missing quantity at cut-off rose from 11.7 per cent. at 405 revolutions to 29.66 per cent. at 130 revolutions, the consumption of feed water increasing from 20.35 lb. to 23.67 lb. This saving of 14 per cent. was due solely to increase of speed. Similar trials had been made with a simple engine. In one simple trial at slow speed the missing quantity rose to 44.5 per cent. of the whole feed water.

Intended mean admission pressure (Lb.)	40	90		110		130	150		160		170
Simple, Compound, or Triple.	S.	S.	C.	S.	C.	C.	C.	T.	C.	T.	T.
Actual mean admission pressure	40.88	92.65	87.54	106.3	109.3	130.6	149.9	151.9	158.5	158.1	172.5

(Lb.)											
Percentage ratio of actual mean pressure, referred to low pressure piston, to theoretical mean pressure	98.2	100	91.3	100.7	94.8	94.2	94.6	84.54	95.9	85.3	85.2
Indicated horse power	16.51	31.61	28.14	33.5	33	36.31	38.59	35.69	39.55	35.56	38.45
Feed water actually used per indicated H.P.H.— Simple (Lb.)	42.76	26.89	...	26	...	...	...	...	...	...	...
Compound (Lb.)	...	...	34.16	...	21.37	20.35	19.45	...	19.19	...	...
Triple (Lb.)	...	...	...	...	...	...	...	19.68	...	19.19	18.45
Steam required theoretically per 1 H.P.H. (Lb.)	34.67	19.24	19.86	17.9	17.65	16.25	15.23	15.16	14.87	14.9	14.36
Percentage efficiency	81.1	71.5	82.2	68.8	82.5	80	78.3	77	77.4	77.6	77.8
Percentage of feed water missing at cut off in high pressure cylinder	...	...	...	...	...	...	...	5.33	...	6.84	5.01
Ditto high pressure cylinder	...	...	5	...	9.5	11.7	15.1	14.84	17	12.06	15.33
Ditto low pressure cylinder	11.7	24.8	15.2	29.56	16.25	19.1	20.6	22.12	21.3	22.11	24.21
Percentage of feed water missing at end of stroke in low pressure cylinder	10.4	18.83	14.25	21.53	16.59	17.55	20.69	18.01	19.55	18.81	19.25

The author compared a series of compound trials, at different powers, with 130 lb. absolute pressure, and various ratios of expansion, with a series giving approximately the same powers at a constant ratio of expansion, but with varying pressures, being practically a trial of automatic expansion against throttling. Starting with 40 indicated horse power, 130 lb. absolute pressure, four expansions, and a consumption of 20.75 lb. of water, the plan of varying the expansion, as compared with throttling, showed a gain of about 7 per cent. at 30 indicated horse power, but of a very small percentage when below half power. If the engine had an ordinary slide valve, the greater friction, added to irregular motion, would probably neutralize the saving, while if the engine were one in which initial condensation assumed more usual proportions, the gain would be probably on the side of variable pressure. Even as it was, the diagrams showed that the missing quantity became enormously large as the expansion increased. Judging only by the feed water accounted for by the indicator, the automatic engine appeared greatly the more economical, but actual measurement of the feed water disproved this. The position of the automatic engine was, however, relatively more favorable when simple than when compound.

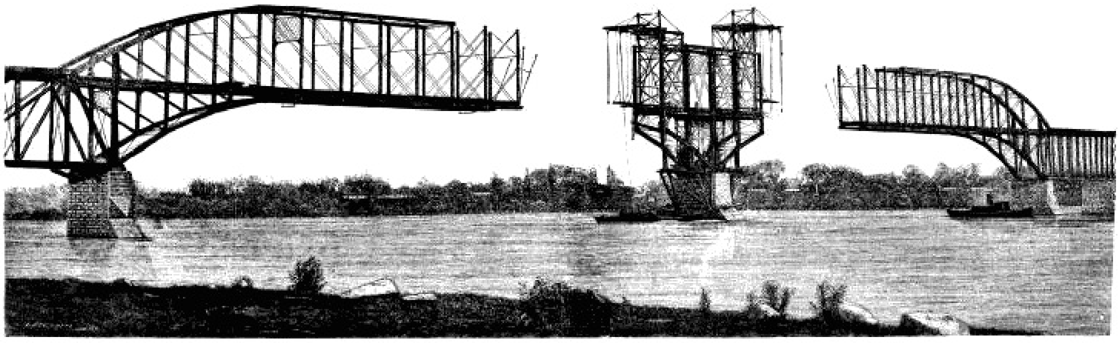
In conclusion, the author referred to a trial with a condensing engine, at 170 lb. absolute pressure, in which the feed water used was 15.1 lb., a result evidently capable of further improvement, and to an efficiency trial of a combined central valve engine and Siemens' dynamo, made for the Admiralty, at various powers. At the highest power the ratio of external electrical horse power to indicated horse power in the engine was 82.3 per cent. Taking the thermo-dynamic efficiency of the engine at 80 per cent., that of the combined apparatus would be nearly 66 per cent.

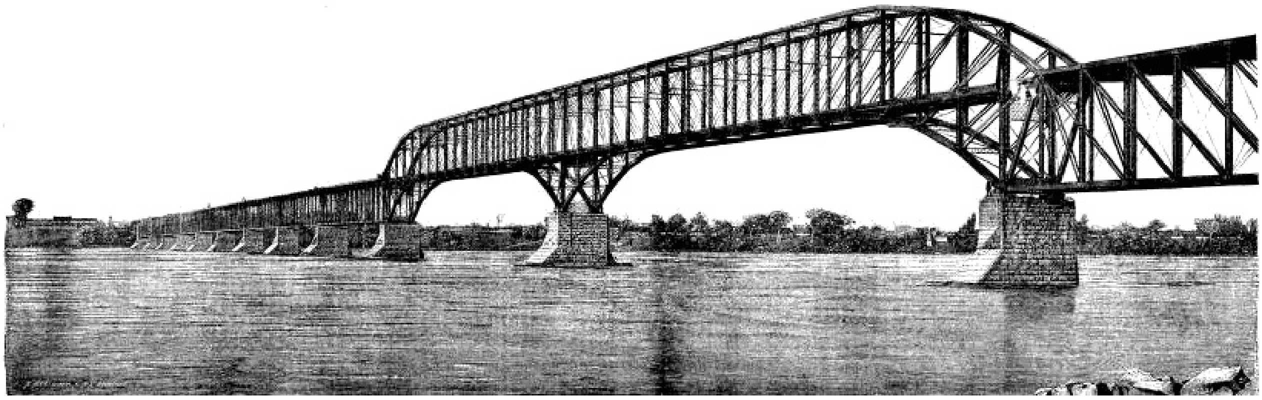
[1]

Abstract of paper read before the Institution of Civil Engineers, March 13.

RAILWAY BRIDGE AT LACHINE.

The subject of our large illustration this week is a large steel bridge carrying the Central Pacific Railway over the St. Lawrence River at Lachine, near Montreal. The main features of this really magnificent structure are the two great channel spans, each 408 feet long. It will be noticed that the design combines, in a very ingenious manner, an upper and a lower deck structure, the railway track being laid on the top of the girders forming the side spans, and on the lower flanges of the channel spans, which are crossed by continuous girders, 75 feet deep, over the central pier, and supported by brackets as shown. The upper of our two engravings shows the method of constructing the principal spans, which were built outward from the side piers, while the work on the center pier was extended on each side to meet. It was built at the works of the Dominion Bridge Company, Montreal, from the design of Mr. C. Shaler Smith, the well-known American bridge engineer.—*Engineering*.



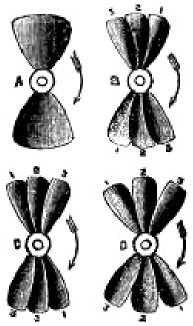


IMPROVED SCREW PROPELLER.

While the last few years have seen great advances made in the designs of steamships and of their engines, little or nothing has been done in the way of improving the screw propeller. As a general rule it would appear to be taken for granted that no radical improvement could be made in the form of the propeller, although various metals have been introduced in its manufacture with the view of increasing its efficiency. For sea-going steamers, however, the shape remains the same, the variation chiefly relating to the number of blades employed. A striking departure from ordinary practice, however, has of late been made by Mr. B. Dickinson, who has invented a screw propeller which, on practical trial, has given an efficiency far in advance of the ordinary screw. This new propeller we illustrate here in Figs. C and D, while Fig. A shows an ordinary propeller. The Dickinson propeller illustrated has six blades, giving a surface of 30 square feet; it is right handed, and has pitch of 15 ft. and a diameter of 10 ft. 6 in. The ordinary screw propeller shown at Fig. A is right handed and two bladed, with a pitch at the boss of 13 ft. 6 in. and at the tip of 15 ft. It has a diameter of 10 ft. 9 in. and 32 square ft. of surface. The projected area looking forward is 22 square ft. and the projected area looking athwartship 22.84 square feet. The most graphic way of illustrating the principle of Mr. Dickinson's propeller is to take a two bladed propeller of the ordinary type as shown at Fig. A in the annexed cuts, and divide into three sections as in Fig. B, then move section No. 1 to the line position on the shaft of No. 3, and No. 3 to that of No. 1, No. 2 remaining stationary. The effect of this interchange will be that (having regard to the circle of rotation) No. 3, the rearmost section, will rotate in advance of No. 2, and No. 2 in advance of No. 1 (see Fig. C). By this arrangement the water operated on escapes freely astern from every blade—that from No. 1 passing in the wake of No. 2, while that from Nos. 2 and 1 passes in the wake of No. 3. Fig. D represents the blades with a wider spread as practically used. The advantages claimed by Mr. Dickinson for his propeller, and which are sufficiently important to be given in detail, are:

1. That the blades of each section, when the vessel is in motion, necessarily cut solid, undisturbed water, each blade operating upon precisely the same quantity of water as an individual broad blade would do, though, of course, it parts with it in one-third of the time.

2. That each sectional blade exerts the equivalent efficiency of the first or entering third portion of the breadth of an ordinary propeller blade, and that consequently the combined sections have greater effective power. It is now regarded by experts as an ascertained fact that the after or trailing portion of the broad blade is relatively non-



Figs. A-D.

effective as compared with the forward or entering portion.

3. When three blades are fitted, the spent water from No. 2 being delivered immediately in the wake of No. 3, and that from No. 1 in the wake of No. 2, has the effect of destroying or reducing to a minimum the back draught of sections Nos. 2 and 3, No. 1 alone being subject to this drawback. This is of greater importance than might at first thought appear, as in cases where there are three or four blades revolving in one plane, the water is drawn after the retreating blade, lessening the resistance to the face of the advancing one.

4. That by the subdivision of the blades, as arranged spirally, the water passing through within the radius of the propeller has its resisting capacity more thoroughly worked out than is possible with any propeller whose blades are all on the same plane. This view is confirmed by the visibly increased rotation of the water in the wake of the vessel.

5. That by broadening the blades or increasing the number of sections, the diameter of the propeller may be proportionately diminished without the sacrifice of engine power. This is often desirable with vessels of light draught, the complete immersion of the screw being at all times necessary to avoid waste of power.

6. The propeller being made and fitted on the shaft in sections, all that is necessary in case of accident is to replace the broken section. This in many cases could be done afloat.

7. The blades being arranged to take their water at different planes, there is the greater certainty of one or other of the sections operating upon what is termed the water of friction. This is considered an advantage.

8. Where it is desirable, the blades of the different sections can be made of varying breadth or pitch.

9. The principle of division into two or more sections applies equally to two, three, or four bladed ordinary propellers.

10. The adoption of this principle does not entail any alteration or enlargement of the screw space or bay as usually provided.

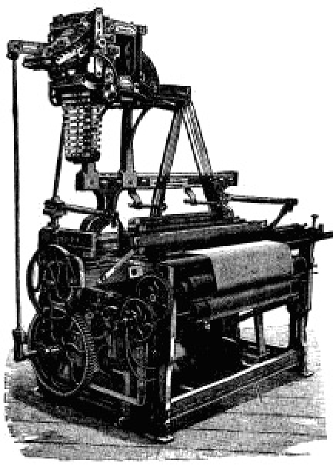
11. As a consequence of the freedom and rapidity with which the water operated upon escapes from the narrow blades, the depression at the stern of the vessel caused by the action of the ordinary propeller is greatly reduced.

12. The vibration caused by this propeller is so slight as to be hardly noticeable, thereby effecting a saving in the wear and tear of the engine and machinery. This may also be a consideration in promoting the comfort of passengers.

From a practical and working point of view we take Mr. Dickinson's chief claims to be, in the first place, the yielding of a greater speed per power employed, or an economy in obtaining an equal speed; in the second, increased, rapidity in maneuvering and stopping a vessel; and in the third, a reduction of vibration. In order to put these claims to a practical and reliable comparative test, Messrs. Weatherley, Mead & Hussey, of Saint Dunstan's Hill, London, placed at the inventor's disposal two of their new steamers, the Herongate and the Belle of Dunkerque. These are in every respect sister boats, and were built in 1887 by Messrs. Short Brothers, and engined by Mr. John Dickinson, of Sunderland. The Herongate was fitted about four months ago with the largest propeller yet made on Mr. B. Dickinson's principle, the Belle of Dunkerque having an ordinary four-bladed propeller of the latest improved type. Every precaution was taken to place the two vessels on the same footing for the purpose of a comparative test, which was recently carried out. Both vessels previously to the trial were placed on the gridiron, cleaned and painted, their boilers opened out and scaled, their steam gauges independently tested, and both vessels loaded with a similar cargo of pitch, the only difference being that the Herongate carried 11 tons more dead weight and had one inch more mean draught than the Belle of Dunkerque, while the former had been running continuously for nine months against the latter's two and a half months. On the day of the trial the vessels were lying in the Lower Hope reach, and it was decided to run them over the measured mile there with equal pressure of steam. The order of running having been arranged, the Herongate got under way first, the Belle of Dunkerque following over the same course. Steaming down against tide, the Herongate is said to have come round with remarkable ease and rapidity, and in turning on either helm, whether with or against tide, to have shown a decided advantage. Equally manifest, it is stated, was the superiority shown in bringing up the vessel by reversing, when running at full speed, thus confirming the very favorable reports previously received by the owners from their captains since the

Dickinson propeller was fitted to the Herongate. Those who were on board her state that the vibration was scarcely noticeable. From a statement submitted to us it is clear that the Herongate had the turn of the scale against her in dead weight and draught, vacuum, and diagrams taken, but notwithstanding (making allowance for one faulty run due to the variations in tide) she appears to have more than held her own in the matter of speed, with a saving of 4½ and 3¼ revolutions per minute at 140 lb. and 160 lb. steam pressure respectively. This is further confirmed by the results of a run made after the experiments were concluded, the two vessels being placed in line, and fairly started for a half hour's run over the flood with 150 lb. steam pressure. At the expiration of that time the Herongate was judged to be leading by at least half a length, her revolutions being 76, as against 80 in the Belle of Dunkerque. It was agreed by all present at these trials that the propeller had realized in full the three main working advantages claimed for it. This being the first Dickinson propeller fitted to a sea-going vessel of this size, it is quite within the limits of possibility that the present results may be improved upon in further practice. In any case we can but regard this propeller as a distinct and original departure in marine propulsion, and we congratulate Mr. Dickinson on his present success and promising future. Messrs. Weatherley, Mead & Hussey also deserve credit for their discernment, and for the spirited manner in which they have taken up Mr. Dickinson's ingenious invention. We understand that they are so satisfied with the results that they intend having one of their larger ocean-going steamers fitted with the Dickinson propeller.—*Iron*.

IMPROVED DOBBY.



IMPROVED DOBBY.

At the Manchester Royal Jubilee Exhibition, Messrs. Butterworth & Dickinson, Burnley, showed Catlow's patent dobby, which is illustrated above, as applied to a strong calico loom. This dobby is a double lift one, thus obtaining a wide shed, and the use of two lattice barrels connected by gearing so that they both revolve in the same direction. The jack lever is attached to the vertical levers, the top and bottom catches being worked respectively by the two barrels, and connected with the ends of the levers. To each of these catches a light blade spring is attached, which insures them being sprung upon the top of the knife, and thereby obtaining a certain lift. A series of wooden jacks or levers are employed, so as to give a varying lift to the front and back healds, in this way keeping the yarn in even tension, and preventing slack sheds. The healds are drawn down by means of a series of levers adjoining one another, and worked by means of a rocking bar driven from the tappet shaft. When the shed is being formed, the jacks are pushed down until it is fully open, and the warp is thus drawn down with the same certainty as the upward movement is made. —*Industries*.

[United States Consular Reports. Special Issue No. 10.]

SULPHUR MINES IN SICILY.

By Phillip Carroll, U. S. Consul, Palermo.

Sulphur, or brimstone, is a hard, brittle substance of various colors, from brilliant yellow to dark brown, without smell when cool, of a mild taste, and burns with a pale blue flame, emitting pungent and suffocating fumes. Its specific gravity is from 1.9 to 2.1.

Sulphur exists more or less in all known countries, but the island of Sicily, it is thought, is the only place where it is produced on a large scale, and consequently that island appears to command the market. Small quantities have been found in the north of Italy, the Grecian Archipelago, Russia, Austria, Poland, France, Spain, eastern shores of Egypt, Tunis, Iceland, Brazil, Central America, and the United States. Large quantities are said to exist in various countries of Asia, but it is understood to be impracticable to utilize the same, consequent upon the distance from any commercial port and the absence of rail or other roads.

Sulphur is of two kinds, one of which is of volcanic emanation, the other being closely allied to sedimentary rocks. The latter is found in Sicily, on the southern and central portions of the island. Mount Etna, situated in the east, seems to exert no influence in the formation of brimstone. There are various hypotheses relative to its natural formation. Dr. Philip Swarzenburg attributes it to the emanations of sulphur vapor expelled from metallic matter existing in the earth, consequent upon the fire in the latter, while Professors Hoffman and Bischoff ascribe it to the decomposition of sulphureted hydrogen. Hoffman believes the sulphureted hydrogen must have passed through the fissures of stratified rocks, but Bischoff is of opinion that the sulphureted hydrogen must have been the result of the decomposition of sulphate of lime in the presence of organic matter. The theory of others is that sulphur owes its origin to the combination of lacustrine deposits with vegetable matter, and others again suppose that it is due to the action of the sea upon animal remains. The huge banks of rock salt often met with in the vicinity of sulphur mines, and which in some places stretch for a distance of several miles, seem to indicate that the sea has worked its way into the subsoil. Fish and insects, which are frequently found in strata of tripoli, which lie under sulphur beds, induce the belief that lakes formerly existed in Sicily.

The following is a list of the various strata which form part of the crust of the earth in Sicily, according to Professor Mottura, an Italian geologist:

Pliocene.—Sandstone; coarse calcareous rock; marl.

Upper Miocene.—Calcareous marl; gypsum, etc.; sulphur embedded in calcareous limestone; silicious limestone; tripoli, containing fossils of fish, insects' eggs, etc.

Middle Miocene.—Sandstone containing quartz, intercalated with marl of a saltish taste.

Lower Miocene.—Rock salt; blue marl, containing petroleum and bitumen; flintstone; ferruginous clay, mixed with aragonite and bituminous schists; ferruginous and silicious sandstone.

Eocene.—Limestone, containing diaspores and shells.

At times one or another of the strata disappears, while the order of some is slightly reversed on account of the broken state of the crust. Upon the whole, however, the above has been generally observed in the various mines by the author referred to.

Sulphur mines have been operated in Sicily over three hundred years, but until the year 1820 its exportation was confined to narrow limits. At present the number of mines existing in Sicily is about three hundred, nearly two hundred of which, being operated on credit, are, it is understood, destined to an early demise. It is said that there are about 30,000,000 tons of sulphur in Sicily at present, and that the annual production amounts to about 400,000 tons. If this should be true, taking the foregoing as a basis, the supply will become exhausted in about seventy-five years.

In 1819 a law was passed in Italy, which is still in force, governing mining in Sicily, which provides that should a land owner discover ore in his property he would be the owner thereof, and should have the right to mine, operate, or rent the property to others for that purpose, but if he should decline to operate his mines or to rent them to others to be operated, the state would rent them on its own account.

Royalties vary from 12 to 45 per cent. They are paid according to the quality of the ore and the facilities for producing sulphur; 25 per cent. may, however, be taken as an average. There is a land tax of 36 per cent. of the net income, which is usually paid by the owners and lessees of the mines, in proportion to the quantity of sulphur which they produce. The export duty is 10 lire per ton. All mines are inspected by government officials once a year, and the owners are required to furnish the state with plans of the works and their progress, with a view to insure the safety of the workmen and to ascertain the extent of the property.

Those who rent their mines receive from 10 to 40 per cent. of the sulphur produced. Leases are valid for such period as the contracting parties may stipulate therein. The general limit, however, is nine years. The average lease is 25 per cent., 40 per cent. being paid only when the mines are very favorably situated and the production good. Some lessees prefer paying a considerable sum in cash in advance, at the beginning of the term of the lease, and giving 15 or 20 per cent. in sulphur annually thereafter, instead of a higher percentage.

The external indications of the presence of sulphur are the appearance of gypsum and sulphurous springs. These are indubitable signs of the presence of sulphur, and when discovered the process resorted to here, in order to reach the sulphur, is to bore a hole sufficiently large to admit a man, after which steps are constructed in the passage in order to facilitate the workmen in going to and fro. These steps extend across the passage, and are about 25 centimeters high and 35 broad. The inclination of the holes or passages varies from 30 to 50 degrees. Upon attaining the depth of several meters water is often met with, and in such considerable quantity that it is impossible to proceed. Hence it becomes necessary to either pump the water out or retreat in order to bore elsewhere. It is often necessary to bore several passages in order to discover the ore or seam of sulphur. When, however, it has been discovered the passages are made to follow its direction, whether upward or downward. As the direction of seams is in most cases irregular, that of the passages or galleries is likewise. Where the ore is rich and the matrix yielding, the miners break it by means of pick-axes and pikes, but when such is not the case gunpowder is resorted to, the ore in this case being carried to the surface by boys. The miners detach the ore from the surrounding material, and the cavities which ensue in consequence assume the appearance of vast caves, which are here and there supported by pillars of rock and ore in order to keep them from falling or giving way. In order to strengthen the galleries sterile rock is piled upon each side and cemented with gypsum. In extensive mines, however, these supports and linings are too weak, and not infrequently, as a result, the galleries and caverns give way, occasionally causing considerable havoc among the miners. Sulphur is found from the surface to a depth of 150 meters. The difficulties met with in operating mines are numerous, and among the greatest in this category are water, land slides, irregularity of seam, deleterious gases, hardness of rocks and matrices. Of these difficulties, water is the most frequently met with. Indeed, it is always present, and renders the constant use of pumps necessary. At one time miners were allowed to dig where they pleased so long as sulphur was extracted, the consequence being that in groups of mines, the extent and direction of which being unknown to their respective owners, one mine often fell into or upon another, thus causing destruction to life and property. It was largely for this reason, it is understood, that the government determined to require owners and lessees of mines to furnish plans thereof to proper authority, and directed that official inspection of the mines should be made at stated periods. In order to comply with the decree of the government it became necessary to employ mining engineers to draw the plans, etc., and those employed were generally foreigners. In the system of excavation described no steam power is employed. Pumping is performed by means of primitive wooden hand pumps, and when sufficient ore has been collected it is conveyed on the backs of boys to the surface—a slow, costly, and difficult procedure. This system may, however, be suitable to small mines, but in large mines there is no economy in hand labor; indeed, much is lost in time and expense by it. For this reason steam has been introduced into the larger and more important mines. The machinery employed is a hoisting apparatus, with a drum, around which a coil is wound, with the object of hoisting and lowering trucks in vertical shafts. Steam pumps serve to extract the water. The force of the hoisting apparatus varies from 15 to 50 horse power. The fuel consumed is English and French coal, the former being preferred, as it engenders greater heat. The cost of a ton of coal at the wharf is $4.40, whereas in the interior of the island it costs about $10. The shafts or pits are made in the ordinary way, great care being taken in lining them with masonry in order to guard against land slides. In level portions of the country vertical shafts are preferred, but where the mine is situated upon a hill a debouch may often be found below the sulphur seam, when an inclined plane is preferred, the ore being placed in trucks and allowed to run down the plane on rails until it reaches the exterior of the mine, where it suddenly and violently stops, and as a result the trucks are emptied of their load, when they are drawn up the plane to be refilled; and thus the process goes on indefinitely. In these mines a gutter is made in the inclined plane which carries off the water, thus dispensing with the necessity of a pump and the requisites to operate it. The galleries and inclined shafts are lined with beams of pine or larch, which are brought hither from Sardinia, as Sicily possesses very little timber. The mines are illuminated by means of iron oil lamps, the wicks of which are exposed. The lamps are imported from Germany. In certain cases an earthenware lamp, made on the island, and said to be a facsimile of those used by the Phœnicians, is employed. This lamp is made in the shape of a small bowl. It is filled with oil and a wick inserted, which hangs or extends outward, and is thus ignited, the flame being exposed to the air. Safety lamps are unknown, and those described are generally secure. Few explosions take place—only when confined carbonic hydrogen is met with in considerable quantities, and when the ventilation is not good. In this case the mine is easily ignited, and once on fire may burn for years. The only practical expedient for extinguishing the fire is to close all inlets and outlets in order to shut off the air. This, however, is difficult and takes time. Notwithstanding the closing of communications, the gases escape through the fissures and openings which obtain everywhere, and the ingress of air makes it next to impossible to extinguish the fire;

hence it burns indefinitely or until the mine is exhausted. Occasionally the burning of a mine results beneficially to its owners, in that it dispenses with the necessity of smelting, and produces natural, refined sulphur.

Galleries in extent are usually 1.20 by 1.80 meters, and when ore is not found and it becomes necessary to extend the galleries, laborers are paid in accordance with the progress they may make and the character of the rock, earth, etc., through which it may be necessary to cut, as follows:

Silicious limestone, 60 lire per meter; daily progress, 0.20 meter.

Gypsum, 50 lire per meter; daily progress, 0.30 meter.

Marl, 30 lire per meter; daily progress, 0.50 meter.

Clay, 15 lire per meter; daily progress, 1 meter.

Laborers working in the ore are paid 4.30 lire per ton. This includes digging, extracting, and illumination. In some mines, however, the laborers are paid when the sulphur is fused and ready for exportation. One ton of sulphur, or its equivalent (say from 40 to 50 lire), is the amount generally paid. In mines where this system obtains the administration is only responsible for their maintenance. Each miner produces on an average about 1½ tons of ore daily, and when the works are not more than 40 meters in depth he employs one boy to assist him, two boys when they reach 60 meters, and three when under 100 meters. These boys are from seven to sixteen years of age, and are paid from 0.85 to 1.50 lire per day by the miner who employs them. They carry from 1,000 to 1,500 pounds of ore daily, or in from six to eight hours. The food consumed by miners is very meager, and consists of bread, oil, wine, or water; occasionally cheese, macaroni, and vegetables are added to the above.

Mining laborers generally can neither read nor write, and when employed in mines distant from habitations or towns, live and sleep therein, or in the open air, depending on the season or the weather. In a few mines the laborers are, however, provided with suitable dwelling places, and a relief fund is in existence for the succor of the families of those who die in the service. This fund is greatly opposed by the miners, from whose wages from 1 to 2 per cent. is deducted for its maintenance. In the absence of a fund of this character, the sick or infirm are abandoned by their companions and left to die. Generally miners are inoffensive when fairly dealt with. They are said to be indolent and dishonest as a rule. The managers of mines receive from 3,000 to 5,000 lire per annum; chief miners from 1,500 to 2,500 lire; surveyors, 700 to 1,000 lire; and weighers and clerks, from 1,000 to 2,000 lire per annum. The total number of mining laborers in Sicily is estimated at about 25,000.

The ore for fusion of the first grade as to yield contains from 20 to 25 per cent. of sulphur, that of the second grade from 15 to 20 per cent., and of the third grade 10 to 15 per cent. The usual means adopted for extracting sulphur from the ore is heat, which attains the height of 400 degrees Centigrade, smelting with the kiln, which in Sicilian dialect is called a "calcarone." The "calcarone" is capable of smelting several thousand tons of ore at a time and is operated in the open air. Part of the sulphur is burned in the process of smelting in order to liquefy the remainder. "Calcaroni" are situated as closely to the mouth of a shaft as possible, and if practicable on the side of a hill, in order that when the process of smelting is complete, the sulphur may run down the hill in channels prepared for the purpose. The shop of a "calcarone" is circular and the floor has an inclination of from 10 to 15 degrees. A design of a "calcarone" is herewith inclosed. The circular wall is made of rude stone work, cemented together with gypsum. The thickness of the wall at the back is 0.50 meter, and from this it gradually becomes thicker until in front, where it is 1 meter, when the diameter is to be 10 meters. In front of the thickest part of the wall an opening is left, measuring 1.20 meters high and 0.25 meter broad.

Through this opening the liquid sulphur flows. Upon each side of this opening two walls are built at right angles with the circular wall, in order to strengthen the front of the kiln. These walls are 80 centimeters thick each and are roofed. A door is hinged to these walls, thus forming a small room in front of each kiln in which the keeper thereof resides from the commencement to the termination of the flow of sulphur. The inclined floor of the kiln is made of stone work and is covered with "ginesi," the name given to the refuse of a former process of smelting. The stone work is 20 centimeters thick, and the "ginesi" covering 25 centimeters, which gradually becomes thicker as it approaches its lowest extremity. The front part of the circular wall is 3.50 meters high and the back 1.80 meters. The interior of the wall is plastered with gypsum in order to render it impermeable.

The cost of a "calcarone" of about 500 tons capacity is 800 lire. The capacity varies from 40 to 5,000 tons, or more, depending upon circumstances. If a mine is enabled to smelt the whole year round, the smaller "calcaroni," being more easily managed, are preferred; the inverse is the case as to the larger "calcaroni," when this is impracticable. When a "calcarone" is situated within 100 meters of a cereal farm, its operation is prohibited by law during the summer, lest the fumes of the sulphur should destroy the crop.

When, however, the distance is greater from the farm or farms than 100 meters, smelting is permitted; but should any damage ensue to the crops as a result of the fumes, the owners of the "calcaroni" are required to liquidate it. Therefore the mines which are favorably situated smelt the entire year, and employ "calcaroni" of from 40 to 500 tons, as there is less risk of a process failing, which occasionally happens, and for the reason that the ore can be smelted as soon as it is extracted; whereas, when kilns or "calcaroni" are situated within or adjacent to the limit adverted to, they can only be operated five or six months in the year, consequent upon which the ore is necessarily stacked up all through the summer or until such time as smelting may be commenced without endangering the crops, when it becomes necessary to use "calcaroni" whose capacity amounts to several thousand tons. As intimated, these large "calcaroni" are not so manageable as those of smaller dimensions, and as a result many thousands of tons of sulphur are lost in the process of smelting, besides perhaps the loss of an entire year in labor. Again, the ore deteriorates or depreciates when long exposed to the air and rain, all of which, when practicable, render the kilns or "calcaroni" of the smaller capacity more advantageous and lucrative to those operating sulphur mines in Sicily. Smelting with a "calcarone" of 200 tons capacity consumes thirty days, one of 800 tons 60 days, and with a "calcarone" of 2,000 tons capacity from 90 to 120 days are consumed.

In loading or filling the "calcaroni," the larger blocks of ore are placed at the bottom as well as against the mouth, in order to keep the lower part of the kiln as cool as possible with a view of preventing the liquid sulphur from becoming ignited as it passes down to where it makes its exit, etc. The blocks of ore thus first placed in position are, for obvious reasons, the most sterile. After the foundation is thoroughly laid the building of the "pile" is proceeded with, the larger blocks being placed in the center to form, as it were, the backbone of the pile; the smaller blocks of ore are arranged on the outside of these and in the interstices. The shape or form of the pile when completed is similar to a truncated cone, and when burning the kiln looks like a small volcano. When the kiln has been filled with ore, the whole is covered with ginesi with a view of preventing the escape of the fumes. The ore is then ignited by means of bundles of straw, impregnated or saturated with sulphur, being held above the thin portion of the top of the kiln, which is at once closed with ginesi, and the "calcarone" is left to itself for about a week. During the burning process the flames gradually descend, and the sulphur contained in the ore is melted by the heat from above. In about seven or eight days sulphuric fumes and sublimed sulphur commence to escape, when it becomes necessary to add a new coat of ginesi to the covering and thus prevent the destruction of vegetation by the sulphur fumes. The mouth of the kiln, which has been left open in order to create a draught, is closed up about this time with gypsum plaster. When the sulphur is all liquefied it finds its way to the most depressed part of the kiln, and there, upon encountering the large sterile blocks, quite cold, already referred to, solidifies. It is again liquefied by means of burning straw, whereupon an iron trough is inserted into a mouth made in the kiln for the purpose, and the reliquefied sulphur runs into it, from which it is immediately collected into wooden moulds, called "gadite," and which have been kept cool by being submerged in water. Upon its becoming thoroughly cool the sulphur is taken out of the moulds referred to, and is now in solid blocks, each weighing about 100 weight. Two of these blocks constitute a load for a mule, and cost from 4 to 5 francs.

The above is the result when the operation succeeds; but this is not always the case. At times the sulphur becomes solidified before it reaches the mouth of the kiln, because of the heat not being sufficient to keep it liquid in its passage thereto, and other misfortunes not within control, and consequent upon the use of the larger kilns, or "calcaroni."

When the sulphur ceases to run from the kiln, the process is complete. The residue is left to cool, which consumes from one to two months. The cooling process could be accomplished in much less time by permitting the air to enter the kiln, but this would be destructive to vegetation, and even to life, consequent upon the fumes of the sulphur. The greatest heat at a given time in a kiln is calculated to be above 650 degrees Centigrade—that is, at the close of the process. This enormous heat is generally allowed to waste, whereas it is understood it could be utilized in many ways. A gentleman of the name of Gill is understood to have invented a recuperative kiln, which will, if generally adopted, utilize the heat of former processes named. A ton of ore containing about 25 per cent. of sulphur yields 300 pounds of sulphur. This is considered a good yield. When it yields 200 pounds it is considered medium, and poor when only 75 pounds. Laborers are paid 0.40 lire per ton for loading and unloading kilns, and from thirty to forty hands are employed at a time. The keeper of a kiln receives from 2 to 2.50 lire per day.

Notwithstanding the "calcarone" has many defects, it is the simplest and cheapest mode of smelting, and is preferred here to any other system requiring machinery and skilled labor to operate it.

The following are the principal furnaces in use here: Durand's; Hirzel; Gill and Kayser's system of fusion; Conby Bollman process; Thomas steam process of smelting; and Robert Gill's recuperative kilns.

There are seven qualities or grades of sulphur, viz.:

1. Sulphur almost chemically pure, of a very bright and yellow color.

Second Best.—Slightly inferior to the first quality; bright and yellow.

Second Good.—Contains 4 to 5 per cent. of earthy matter, but is of a bright yellow.

Second Current.—Dirty yellow, containing more earthy matter than that last named.

Third Best.—Brownish yellow; this tint depends on the amount of bitumen which it contains.

Third Good.—Light brown, containing much extraneous matter.

Third Current.—Brown and coarse.

These qualities are decided by color, not by test. The difference of price is from 3 to 10 francs per ton. Manufacturers prefer the third best, because of its containing more sulphuric acid and costing less than the sulphur of better quality.

Sulphur is conveyed to the seaboard by rail, in carts, or on mules or donkeys. Conveyance by cart, mule, or donkey is only resorted to when the distance is short or from mines to railroad stations. The tariff in the latter case is understood to be 1 lire per ton per mile. The railroad tariff is 0.12 per ton per kilometer; but it is contemplated, it is understood, to reduce this to 7 centimes in a short time. The price per ton of sulphur is as follows:

Grade.	At Porto Empedocle. Lire.	At Licata. Lire.	At Catania. Lire.
Second best	86.60	87.00	90.70
Second good	84.42	84.50	90.30
Second current	83.90	83.90	88.40
Third best	79.00	79.90	86.90
Third good	77.80	77.80	83.00
Third current	76.80	76.70	

Sulphur free on board, brokerage, shipment, export duty, and all other expenses included, costs 20 lire per ton in excess of the above prices. Nearly all the sulphur exported from Palermo emanates from the Lercara mines, in the province of Palermo, the price per ton being as follows: first quality, 91.60 lire; second quality, 88.40. Sulphur is usually conveyed in steamers to foreign countries from Sicilian ports. The average freight per ton to New York is about as follows: From Palermo, 8.70 lire; from Catania, 13.50 lire; from Girgenti, 16 lire. An additional charge of 2.50 lire is made when the sulphur may be destined for other ports in the United States.

Liebig once said that the degree of civilization of a nation and its wealth could be seen in its consumption of sulphuric acid. Now, although Italy produces immense quantities of sulphur, it cannot, on account of the scarcity of fuel, and other obvious reasons perhaps, compete with certain other countries in the manufacture and consumption of sulphuric acid.

Sulphur is employed in the manufacture of sulphuric acid, and the latter serves in the manufacture of sulphate of soda, chloridic acid, carbonate of soda, azodic acid, ether, stearine candles, purification of oils in connection with precious metals and electric batteries. Nordhausen's sulphuric acid is employed in the manufacture of indigo. Sulphate of soda is employed in the manufacture of artificial soda, glassware, cold mixtures, and medicines. Carbonate of soda is used in the manufacture of soap, bleaching wool, coloring and painting tissues, and in the manufacture of fine crystal ware and the preparation of borax. Chloric acid is used in the preparation of chlorides with bioxide of manganese, and with chlorides in the preparation of hypochlorides of lime, known in commerce under the name of bleaching powder, and improperly called chloride of lime, which is used as a disinfectant in contagious diseases, in bleaching stuffs, and in the manufacture of paper from vegetable fibers, and in the manufacture of gelatine extracted from bones, as well as in fermenting molasses and in the manufacture of sugar from beet root. Sulphur is also used in the preparation of gunpowder and oil of vitriol, and in the manufacture of matches and cultivation of the vine.

In the year 1838 the Neapolitan government granted a monopoly to a French company for the trade in sulphur. By the terms of the agreement the producers were required to sell their sulphur to the company at certain fixed prices, and the latter paid the government the sum of $350,000 annually in consideration of this requirement. This, however, was not a success, and tended to curtail the sulphur industry, and the government, discovering the agreement to be against its interests, annulled it, and established a free system of production, charging an export tax per ton only. At that time sulphuric acid was derived exclusively from sulphur. Hence the demand from all countries was great, and the prices paid for sulphur were high. It was about this period that the sulphur industry was at its zenith. The monopoly having been abolished, every mine did its utmost to produce as much sulphur as possible, and from the export duty exacted by the government there accrued to it a much larger revenue than that which it received during the period of the monopoly. The progress of science has, however, modified the state of things since then, as sulphur can now be obtained from pyrite or pyrite of iron. This discovery immediately caused the price of sulphur to fall, and the great demand therefore correspondingly ceased. In England, at the present time, it is understood that two-thirds of the sulphuric acid used is manufactured from pyrites. The decrease in prices caused many of the mines to suspend operations, and as a result the sulphur remained idle in stock. In 1884 an association was formed at Catania with a view to buying up sulphur thus stored away at the mines and various ports at low prices, and store it away until a favorable opportunity should present itself for the sale thereof. This had the effect of increasing the prices of sulphur in Sicily for some time, and the producers, discovering that the methods of the association increased the foreign demand for their produce as well as its prices, exported it directly themselves, thus breaking up the association referred to, as it was no longer a profitable concern.

The railroad system, which in later years has placed the most important parts of Sicily in communication with the seaboard, has been most beneficial to the sulphur industry. A great saving has been made in transporting it to the ports. This was formerly (as stated) accomplished by carts drawn by mules at an enormous expense, as the roads were wretched, and unless some person of distinction contemplated passing over them, repairs were unknown.

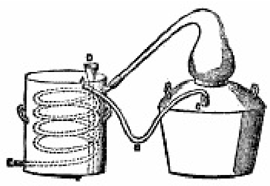
Palermo, March 20, 1888.

AN AUTOMATIC STILL.

By T. Maben.

The arrangement here described is one that may readily be adapted to, and is specially suited for, the old fashioned stills which are in frequent use among pharmacists for the purpose of distilling water. The idea is extremely simple, but I can testify to its thorough efficiency in actual practice. The still is of tinned copper, two gallon capacity, and the condenser is the usual worm surrounded with cold water.

The overflow of warm water from the condenser is not run into the waste pipe as in the ordinary course, but carried by means of a bent tube, A, B, C, to the supply pipe of the still. The bend at B acts as a trap, which prevents the escape of steam.



The advantages of this arrangement are obvious. It is perfectly simple, and can be adapted at no expense. It permits of a continuous supply of hot water to the still, so that the contents of the latter may always be kept boiling rapidly, and as a consequence it condenses the maximum amount of water with the minimum of loss of heat. If the supply of water at D be carefully regulated, it will be found that a continuous current will be passing into the still at a temperature of about 180° F., or, if practice suggest the desirability of running in the water at intervals, this can be easily arranged. It is necessary that the level at A should be two inches or thereabout higher than the level of the bend at C, otherwise there may not be sufficient head to force a free current of water against the pressure of steam. It will also be found that the still should only contain water to the extent of about one-fourth of its capacity when distillation is commenced, as the water in the condenser becomes heated much more rapidly than the same volume is vaporized. By this expedient a still of two gallons capacity will yield about half a dozen gallons per day, a much greater quantity than could ever be obtained under the old system, which required the still to be recharged with cold water every time one and a half gallons had been taken off.

The objection to all such continuous or automatic arrangements is, of course, that the condensed water contains all the free ammonia that may have existed in the water originally, but it is only in cases where the water is exceptionally impure that this disadvantage will become really serious. The method here outlined has, no doubt, occurred to many, and may probably be in regular use, but not having seen any previous mention of the idea, I have thought that it might be useful to some pharmacists who prepare their own distilled water.—*Phar. Jour.*

COTTON SEED OIL.

"Cotton seed oil," said Mr. A.E. Thornton, of the Atlanta mills, "is one of the most valuable of oils because it is a neutral oil, that is, neither acid nor alkali, and can be made to form the body of any other oil. It assimilates the properties of the oil with which it is mixed. For instance, olive oil. Cotton seed oil is taken and a little extract of olives put in. The cotton oil takes up the properties of the extract, and for all practical purposes it is every bit as good as the pure olive oil. Then it is used in sweet oil, hair oil, and, in fact, in nearly all others. A chemist cannot tell the prepared cotton oil from olive oil except by exposing a saucerful of each, and the olive oil becomes rancid much quicker than the cotton oil. The crude oil is worth thirty cents a gallon, and even as it is makes the finest of cooking lard, and enters into the composition of nearly all lard."

A visit to the mills showed how the oil is made. From the platform where the seed is unloaded it is thrown into an elevator and carried by a conveyor—an endless screw in a trough—to the warehouse. Then it is distributed by the conveyor uniformly over the length of the building—about 200 feet. The warehouse is nearly half filled now, and thousands and thousands of bushels are lying in store. Another elevator carries the seed up to the "sand screen." This is a revolving cylinder made of wire cloth, the meshes being small enough to retain the seed, which are inside the cylinder, but the sand and dirt escape. Now the seeds start down an inclined trough. There is something else to be taken out, and that is the screws and nails and rocks that were too large to be sifted out with the sand and dirt. There is a hole in the inclined trough, and up through that hole is blown a current of air by a suction fan. If it were not for the fan, the cotton seed, rocks, nails, and all would fall through. The current keeps up the cotton seed, and they go on over, but it is not strong enough to keep up the nails and pebbles, and they fall through. Now the seed, free of all else, is carried by another elevator and endless screw conveyor to the "linter." This is really nothing more than a cotton gin with an automatic feed.

"HULLER" AND "HEATERS."

Then the seed is carried to the "huller," where it is crushed or ground into a rough meal about as coarse as the ordinary corn "grits." The next step is to separate the hulls from the kernels, all the oil being in the kernel, so the crushed seed is carried to the "separator." This is very much on the style of a sand screen, being a revolving cylinder of wire cloth. The kernels, being smaller than the broken hulls, fall through the broken meshes, and upon this principle the hull is separated and carried direct to the furnace to be used as fuel. The kernels are ground as fine as meal, very much as grist is ground, between corrugated steel "rollers," and the damp, reddish colored meal is carried to the "heater."

The "heater" is one iron kettle within another, the six inch steam space between the kettles being connected direct with the boilers. There are four of these kettles side by side. The meal is brought into this room by an elevator, the first "heater" is filled, and for twenty minutes the meal is subjected to a "dry cook," a steam cook, the steam in the packet being under a pressure of forty-five pounds. Inside the inner kettle is a "stirrer," a revolving arm attached at right angles to a vertical shaft. The stirrer makes the heating uniform, and the high temperature drives off all the water in the meal, while the involatile oil all remains.

In five minutes the next heater is filled, in five minutes the next, etc.

Now there are four "heaters," and as the last heater is filled—at the end of twenty minutes—the first heater is emptied. Then at the end of five minutes the first heater is filled, and the one next to it is emptied, and the rotation is kept up, each heater full of meal being "dry-cooked" for twenty minutes.

Corresponding to the four heaters are four presses. Each press consists of six iron pans, shaped like baking pans, arranged one above the other, and about five inches apart. The pans are shallow, and around the edge of each is a semicircular trough, and at the lowest point of the trough is a funnel-shaped hole to enable the oil to run from one pan to the next lowest, and from the lowest pan to the "receiving tanks" below.

PRESSING OUT THE OIL.

As soon as a "heater" is ready to be emptied, the meal is taken out and put into six hair sacks, corresponding to the six pans in the press. There are six hair mats about one foot wide and six long, one side of each being coated with leather. The hair mat is about an inch thick. Now the hair sack, containing ten and a half to eleven pounds of heated steaming meal, is placed on one end of the mat, and the meal distributed so as to make a pad or cushion of uniform thickness. The pad of meal is not quite three feet long, a foot wide, and three inches thick, and the hair mat is folded over, sandwiching the pad and leaving the leather coating of the pad outside. In this form the six loads are put into the six pans, and by means of a powerful hydraulic press the pans are slowly pressed together. The oil begins trickling out at the side, slowly at first, and then suddenly it begins running freely. The pressure on the "loads" is 350 tons. After being pressed about five minutes, the pressure is eased off and the "loads" taken out. What had been a mushy pad three inches thick is a hard, compact cake about three-quarters of an inch thick, and the sack is literally glued to the cake. The crude oil has a reddish muddy color as it runs into the tanks.

To one side were lying great heaps of sacks of yellowish meal—the cakes which have been broken and ground up into meal. That, as explained above, forms the body of all fertilizers. The following is a summary of the work for the eight months' season at the Atlanta mills:

Fifteen thousand tons of seed used give:

Fifteen million pounds of hull.

Ten million three hundred and thirty-one thousand two hundred and fifty pounds of meal.

Four million six hundred and sixty-eight thousand seven hundred and fifty pounds of oil.

Three hundred thousand pounds of lint cotton.

The meal is worth at the rate of $6 for 700 pounds, or $88,603.58.

The oil is worth thirty cents a gallon, or seven and a half pounds, or $186,750.

The lint is worth $18,000, making a total of $293,353, and that doesn't include the 15,000,000 pounds of hull.—*Atlanta Constitution.*

MANUFACTURE OF PHOTOGRAPHIC SENSITIVE PLATES.

Quite recently Messrs. Marion & Company, London, began on their own account to manufacture sensitive photographic plates by machinery, and the operations are exceedingly delicate, for a single minute air bubble or speck of dust on a plate may mar the perfection of a picture. Their works for the purpose at Southgate were erected in the summer of 1886, and were designed throughout by Mr. Alexander Cowan.

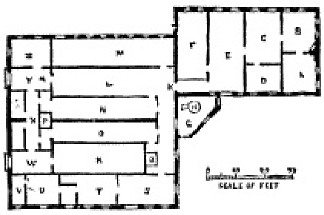


Fig. 1.

Buildings of this kind have to be specially constructed, because some of the operations have to be carried on in the absence of daylight, and in that kind of non-actinic illumination which does not act upon the particular description of sensitive photographic compound manipulated. Glass and other materials have therefore to pass from light to dark rooms through double doors or double sliding cupboards made for the purpose, and the workshops have to be so placed in relation to each other that the amount of lifting and the distance of carriage of material shall be reduced to a minimum. Moreover, the final drying of sensitive photographic plates takes place in absolute darkness. Fig. 1 is a ground plan of the chief portion of the works. In this cut, A is the manager's private office, B the counting house, C the manager's laboratory, and D his dark room for private experiment, which can thus be conducted without interfering with the regular work of the establishment. E is the carpenter's shop and packing room, F the albumen preparation room, G the engine room, with its two doors; the position of the engine is marked at H. The main building is entered through the door, K; the passage, L, is used for the storage of glass, and has openings in the wall on one side to permit the passage of glass into the cleaning room, M; this room is illuminated by daylight. The plates, after being cleaned, pass into the coating rooms, N and O, into which daylight is never admitted; the coating machine is in the room, N, and three hand coating tables in the room, O; both these rooms are illuminated by non-actinic light.

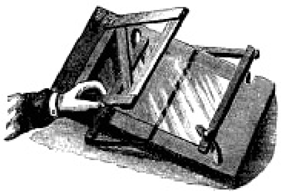


Fig. 2.

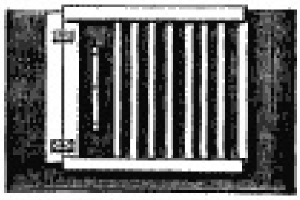


Fig. 3.

The walls of N and O are of brick, to keep these interior rooms as cool as possible in hot weather, for the making of photographic plates is more difficult in summer time, because the high temperature tends to prevent the rapid setting of the gelatine emulsion upon them. At the end of these rooms and communicating with both is the lift, P, by which the coated plates are carried to the drying rooms above, which there cover the entire area of the main building; they consist of two rooms measuring 60 ft. by 30 ft., and are each 30 ft. high at the highest part in the center of the building; these rooms are necessarily kept in absolute darkness, except while the plates are being stored therein or removed therefrom, and on such occasions non-actinic light is used. After the plates are dry, they come down the lift, Q, into the cutting and packing room, R, which is illuminated by non-actinic light. In the drying rooms the batches of plates are placed one after the other on tram lines at one end of the room, and are gradually pushed to the other end of the building, so that the first batches coated are the first to be ready to be taken off when dry, and to be sent down the lift, Q. The plates in R, when sufficiently packed to be safe from the action of daylight, are passed through specially constructed openings into the outside packing room, S, where they are labeled. The chemicals are kept in the room, T, where they are weighed and measured ready for the making of the photographic emulsion in the room, U. The next room, V, is for washing small experimental batches of emulsion, and W is the large washing room. The emulsion is then taken into the passage, X, communicating with the two coating rooms. A centrifugal machine in the room, Y, is used for extracting silver residues from waste materials, also for freeing the emulsion from all soluble salts. Washing and cleaning in general go on in the room, Z.

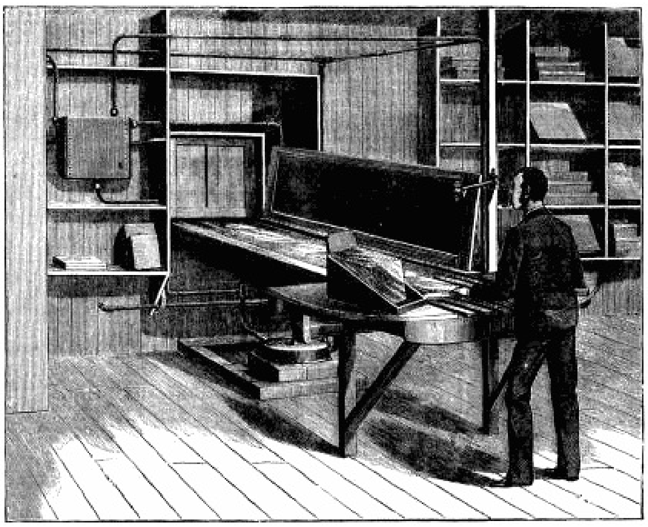


Fig. 4.—PLATE-WARMING MACHINE.

The glass for machine coating is cut to standard sizes at the starting, instead of being coated in large sheets and cut afterward—a practice somewhat common in this industry. The disadvantage of the ordinary plan is that minute fragments of glass are liable to settle upon the sensitive film and to cause spots and scratches during the packing operations; any defect of this kind renders a plate worthless to the photographer. When any breakages take place in the cutting, it is best that they should occur at the outset, and not after the plate has been coated with emulsion. The cutting when necessary is effected by the aid of a "cutting board," Fig. 2, invented by Mr. Cowan, and now largely in use in the photographic world. This appliance is used to divide into two equal parts, with absolute exactness, any plate within its capacity, and it is especially useful in dimly lighted rooms. It consists of four rods pivoted together at the corners and swinging on two centers, so that in the first position it is truly square, and in other positions of rhomboid form, the two outer bars approaching each other like those of a parallel ruler. The hinge flap comes down on the exact center of the plate, minus the thickness of the block holding the diamond. By this appliance plates can be cut in either direction. Fig. 3 represents a similar arrangement for cutting a number of very small plates out of one large one; in this the hinge flap is made in the form of a gridiron, and the bars are spaced at accurate distances, according to the size of the plate to be cut, so that a plate 10 in. square, receiving four cuts in each direction, will be divided into twenty-five small plates.

Before being cleaned all sharp edges are roughly taken off those plates intended for machine coating by girls, who rub the edges and corners of the plates upon a stone; the plates are then cleaned by any suitable method in use among photographers. The plates, now ready for the coating room, have to be warmed to the temperature of the emulsion, say from 80 deg. F. to 100 deg. F., before they pass to the coating machine, the inventor of which, Mr. Cadett, having come to the conclusion that, if the plates are not of the proper temperature, the coating given will be uneven over various parts of the surface. The plate-warming machine is represented in Fig. 4; it was designed by Mr. A. Cowan, and made by his son, Mr. A. R. Cowan. It consists of a trough 7 ft. long by 3 in. deep, forming a flat tank, through which hot water passes by means of the circulating system shown in the engraving. To facilitate the traveling of the glass plates without friction the top of the tank is a sheet of plate glass bedded on a sand bath. An assistant at one end places the glasses one after the other on the warm glass slab, and by means of a movable slide pushes them one at a time under the cover, which cover is represented raised in the engraving to show the interior of the machine. After having put one glass plate on the slide, another cannot be added until the man in the dark room at the other end of the slide has taken off the farthest warmed plate, because the slide has a reciprocating movement. This heating apparatus is built at right angles to the coating machine in the next room, in order to be conveniently placed in the present building; but it is intended in future to use it as a part of the coating machine itself, and to drive it at the same speed and with the same gearing, so that the cold plates will be put on by hand at one end, get warmed as they pass into the dark room, at the other end of which they will be delivered by the machine in coated condition. Underneath the heating table is a copper boiler, with its Bunsen's burner of three concentric rings to get up the temperature quickly and to give the power of keeping the water under the heating slab at a definite temperature, as indicated by a thermometer. The cold water tank of the system is represented against the wall in the cut.

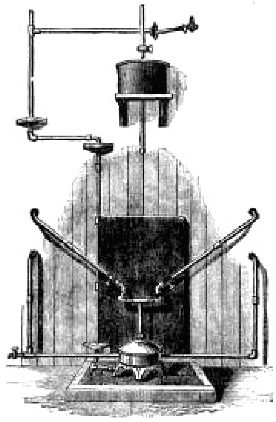


Fig. 5.

Fig. 5 represents the hot water circulating system outside the coating rooms for keeping the gelatine emulsions in these dimly lighted regions at a given temperature, without liberating the products of combustion where the emulsion is manipulated. The temperature is regulated automatically. It will be noticed where the pipes enter the two coating rooms, and Fig. 6 shows the copper inside one of them heated by the apparatus just described. The emulsion vessel in the copper is surrounded by warm water, and the copper itself is jacketed and connected with the hot water pipes, so forming part of the circulating system.

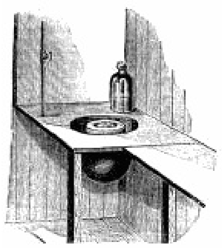


Fig. 6.

Fig. 7 is a general view of the coating machine recently invented by Mr. Cadett, of the Greville Works, Ashtead, Surrey. The plates warmed in the light room, as already described, are delivered near the end of the coating table, where they are picked off a gridiron-like platform, represented on the right hand side of the cut, and are placed by an assistant one by one upon the parallel gauges shown at the beginning of the machine proper; they are then carried on endless cords under the coating trough described farther on. After they have been coated they are carried onward upon a series of four broad endless bands of absorbent cotton—Turkish toweling answers well—and this cotton is kept constantly soaked with cold water, which flows over sheets of accurately leveled plate glass below and in contact with the toweling; the backs of the plates being thus kept in contact with fresh cold water, the emulsion upon them is soon cooled down and is firmly set by the time the plates have reached the end of the series of four wet tables. They are then received upon one over which dry toweling travels, which absorbs most of the moisture which may be clinging to the backs of the plates; very little wet comes off the backs, so that during a day's work it is not necessary to adopt special means to redry this last endless band. What are technically known as "whole plates," which are 8½ in. by 6½ in., are placed touching each other end to end as they enter the machine, and they travel through it at the rate of 720 per hour; smaller sizes are coated in proportion, the smaller the plates the larger is the number coated in a given time. The smaller plates pass through the machine in two parallel rows, instead of in a single row, so that quarter plates, 4¼ in. by 3¼ in., are delivered at the end of the machine at the rate of 2,800 per hour, keeping two attendants well employed in picking them up and placing them in racks as quickly as they can do the work. The double row of cords for carrying two lines of small plates through the machine is represented in the engraving. Although the plates touch each other at their edges on entering the machine, they are separated from each other by short intervals after

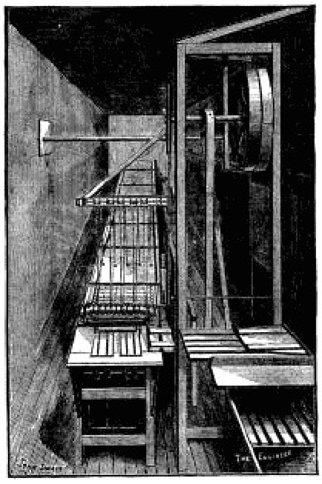


Fig. 7.—GENERAL VIEW OF COATING MACHINE.

being coated; this is effected by differential gearing. The water flowing over the tables for cooling the plates is caught in receptacles below and carried away by pipes. Between each of the tables is a little roller to enable small plates to travel without tilting over the necessary gap between each pair of bands.

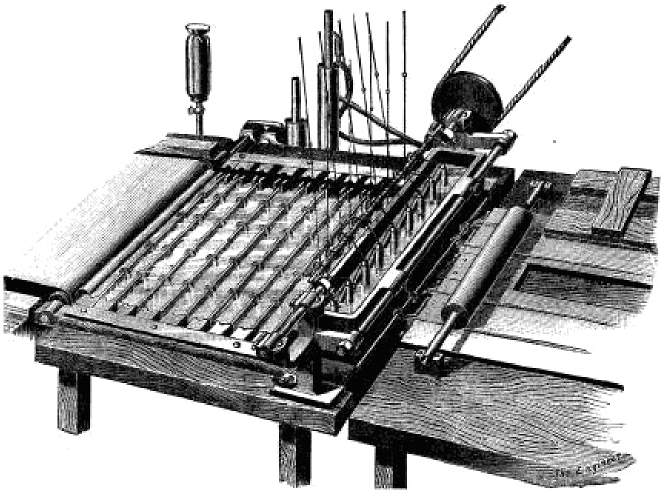


FIG. 8.

The feeding trough of Cadett's machine is represented in Fig. 8. The plates, cleaned as already described, are carried upon the cords under a brass roller, the weight of which causes sufficient friction to keep the plates from tilting; they next pass under a soft camel's hair brush to remove anything in the shape of dust or grit, and are then coated. They afterward pass over a series of accurately leveled wheels running in a tank of water kept exact by an automatic regulator at a temperature of from 80 deg. Fah. to 100 deg. Fah., by means of a small hot water circulating system. The emulsion trough is jacketed with hot water at a constant temperature. This trough is silver plated inside, because most metals in common use would spoil the emulsion by chemical action. The trough is 16 in. long; it somewhat tapers toward the bottom, and contains a series of silver pumps shown in the cut; the whole of this series of pumps is connected with one long adjustable crank when plates of the largest size have to be coated; when coating plates of smaller sizes some of the pumps are detached. A chief object of the machine is to deliver a carefully measured quantity of emulsion upon each plate, and this is done by means of pumps, in order that the quantity of emulsion delivered shall not be affected by changes in the level of the emulsion in the trough; the quantity delivered is thus independent of variations due to gravity or to the speed of the machine. These pumps draw the emulsion from a sufficient depth in the trough to avoid danger from the presence of air bubbles, and the bottom of the trough is so shaped that should by chance any sedimentary matter be present, it has a tendency to travel downward, away from the bottoms of the pumps. There is a steady flow of emulsion from the pumps to the delivery pipes, then it passes down a guide plate of the exact width of the plate to be coated. Immediately in front of the guide plate is a fixed silver cylinder, kept out of contact with the plate by the thickness of a piece of fine and very hard hempen cord, which can be renewed from time to time. These cords keep the cylinder from scraping the emulsion off the plate, and they help to distribute it in an even layer. There would be two lines upon each plate where it is touched by the cords, were not the emulsion so fluid as to flow over the cut-like lines made and close them up.

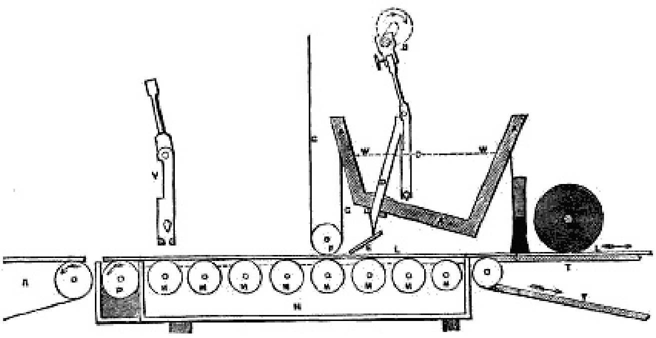


FIG. 9.

The silver cylinder to a certain extent overcomes the effects of irregularities in the glass plates, for the cylinder is jointed somewhat in the cup and ball fashion, and is made in two or more parts, which parts are held together by lengths of India rubber.

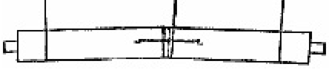


FIG. 10.

The arrangement is shown in section in Fig. 9, in which A is the hot water jacket of the emulsion vessel; B, the crank driving the pumps; C, a pump with piston in position; D, delivery tube of the pump; E, the silver guide plate to conduct the emulsion down to the glass; F, the spreading cylinder; G, the cords regulating the distance of the cylinder from the glass plates; H, soft camel's hair brush; K, friction roller; L L L, three plates passing under the emulsion tank; M, knife edged wheels in the hot water tank, N; the "plucking roller," P, has a hot water tank of its own, and travels at slightly greater speed than the other rollers; R is the beginning of the cooling bands; T, the driving cords; and W, a level of the emulsion in the trough. Y represents one of the bucket pistons of the pumps, detached. The construction of the crank itself is such that, by adjustment of the connecting rods, more or less emulsion may be put upon the plates. Mr. Cowan, however, intends to adjust the pumps once for all, and to regulate the amount of emulsion delivered upon the plates by means of driving wheels of different diameters upon the cranks.

Fig. 10 is a section of the hollow spreading cylinder, made of sheet silver as thin as paper, so that its weight is light. For coating large plates it is divided in the center, so as to adapt itself somewhat to irregularities in the surface of each plate. In this case it is supported by a third and central thread, as represented in the cut. Otherwise the cylinder would touch the center of the plate. Its two halves are held together by a slip of India rubber.—*The Engineer*.

THE USE OF AMMONIA AS A REFRIGERATING AGENT.[1]

By Mr. T.B. Lightfoot, M.I.C.E.

Within the last few years considerable progress has been made in the application of refrigerating processes to industrial purposes, and the demand for refrigerating apparatus thus created has led to the production of machines employing various substances as the refrigerating agent. In a paper read by the author before the Institution of Mechanical Engineers, in May, 1886, these systems were shortly described, and general comparisons given as to their respective merits, scope of application, and cost of working. In the present paper it is proposed to deal entirely with the use of ammonia as a refrigerating agent, and to deal with it in a more full and comprehensive manner than was possible in a paper devoted to the consideration of a number of different systems and apparatus. In the United States and in Germany, as well as to some extent elsewhere, ammonia has been very generally employed for refrigerating purposes during the last ten years or so. In this country, however, its application has been extremely limited; and even at the present time there are but few ammonia machines successfully at work in Great Britain. No doubt this is, to a large extent, due to the fact that in the United States and in Germany there existed certain stimulating causes, both as regards climate and manufactures, while in this country, on the other hand, these causes were present only in a modified degree, or were absent altogether. The consequence was that up to a comparatively recent date the only machine manufactured on anything like a commercial scale was the original Harrison's ether machine, first produced by Siebe, about the year 1857—a machine which, though answering its purpose as a refrigerator, was both costly to make and costly to work. In 1878 the desirability of supplementing our then existing meat supply by means of the large stocks in our colonies and abroad led to the rapid development of the special class of refrigerating apparatus commonly known as the dry air refrigerator, which, in the first instance, was specially designed for use on board ship, where it was considered undesirable to employ chemical refrigerants. Owing to their simplicity, and perhaps also to their novelty, these cold air machines have very frequently been applied on land, under circumstances in which the same result could have been obtained with much greater economy by the use of ammonia or some other chemical agent. Recently, however, more attention has been directed to the question of economy, and consideration is now being given to the applicability of certain machines to certain special purposes, with the result that ammonia—which is the agent that, in our present state of knowledge, gives as a rule the best results for large installations, while on land at any rate its application for all refrigerating purposes presents no unusual difficulties—promises to become largely adopted. It is hoped, therefore, that the following paper respecting its use will be of interest.

In all cases where a liquid is employed, the refrigerating action is produced by the change in physical state from the liquid to the vaporous form. It is, of course, well known that such a change can only be brought about by the acquirement of heat; and for the purpose of refrigeration (by which must be understood the abstraction of heat at temperatures below the normal) it is obvious that, other things being equal, that liquid is the best which has the highest heat of vaporization, because with it the least quantity has to be dealt with in order to produce a given result. In fact, however, liquids vary, not only in the amount of heat required to vaporize them (this amount also varying according to the temperature or pressure at which vaporization occurs), but also in the conditions under which such change can be effected. For instance, water has an extremely high latent heat, but as its boiling point at atmospheric pressure is also high, evaporation at such temperatures as would enable it to be used for refrigerating purposes can only be effected under an almost perfect vacuum. The boiling point of anhydrous ammonia, on the other hand, is 37½° below zero F. at atmospheric pressure, and therefore for all ordinary cooling purposes its evaporation can take place at pressures considerably above that of our atmosphere. Some other agents used for refrigerating purposes are methylic ether, Pictet's liquid, sulphur dioxide, and ether. In this connection it should be stated that Pictet's liquid is a compound of carbon dioxide and sulphur dioxide, and is said to possess the property of having vapor tensions not only much below those of pure carbon dioxide at equal temperatures, but even below those of pure sulphur dioxide at temperatures above 78° F. The considerations, therefore, which chiefly influence the selection of a liquid refrigerating agent are:

1. The amount of heat required to effect the change from the liquid to the vaporous state, commonly called the latent heat of vaporization.

2. The temperatures and pressures at which such change can be effected.

This latter attribute is of twofold importance; for, in order to avoid the renewal of the agent, it is necessary to deprive it of the heat acquired during vaporization, under such conditions as will cause it to assume the liquid form, and thus become again available for refrigeration. As this rejection of heat can only take place if the temperature of the vapor is somewhat above that of the cooling body which receives the heat, and which, for obvious reasons, is in all cases water, the liquefying pressure at the temperature of the cooling water, and the facility with which this pressure can be reached and maintained, is of great importance in the practical working of any refrigerating apparatus. Ammonia in its anhydrous form, the use of which is specially dealt with in this paper, is a liquid having at atmospheric pressure a latent heat of vaporization of 900, and a boiling point at the same pressure of 37½° below zero F. Water being unity, the specific gravity of the liquid at a temperature of 40° F. is 0.76, and the specific gravity of its vapor is 0.59, air being unity. In the use of ammonia, two distinct systems are employed. So far, however, as the mere evaporating or refrigerating part of the process is concerned, it is the same in both. The object is to evaporate the liquid anhydrous ammonia at such tension and in such quantity as will produce the required cooling effect. The actual tension under which this evaporation should be effected in any particular case depends entirely upon the temperature at which the acquirement of heat is to take place, or, in other words, on the temperature of the material to be cooled. The higher the temperature, the higher may be the evaporating pressure, and therefore the higher is the density of the vapor, the greater the weight of liquid evaporated in a given time, and the greater the amount of heat abstracted. On the other hand, it must be remembered that, as in the case of water, the lower the temperature of the evaporating liquid, the higher is the heat of vaporization. It is in the method of securing the rejection of heat during condensation of the vapor that the two systems diverge, and it will be convenient to consider each of these separately.

The Absorption Process.—The principle employed in this process is physical rather than mechanical. Ordinary ammonia liquor of commerce of 0.880 specific gravity, which contains about 38 per cent. by weight of pure ammonia and 62 per cent. of water, is introduced into a vessel named the generator. This vessel is heated by means of steam circulating through coils of iron piping, and a mixed vapor of ammonia and water is driven off. This mixed vapor is then passed into a second vessel, in order to be subjected to the cooling action of water. And here, owing to the difference between the boiling points of water and ammonia, fractional condensation takes place, the bulk of the water, which condenses first, being caught and run back to the generator, while the ammonia in a nearly anhydrous state is condensed and collected in the lower part of the vessel.

This process of fractional condensation is due to Rees Reece, and forms an important feature in the modern absorption machine. Prior to the introduction of this invention, the water evaporated in the generator was condensed with the ammonia, and interfered very seriously with the efficiency of the process by reducing the power of the refrigerating agent by raising its boiling point. In the improved form of apparatus, ammonia is obtained in a nearly anhydrous condition, and in this state passes on to the refrigerator. In this vessel, which is in communication with another vessel called the absorber, containing cold water or very weak ammonia liquor, evaporation takes place, owing to the readiness with which cold water or weak liquor absorbs the ammonia, water at 59° Fahr. absorbing 727 times its volume of ammonia vapor. The heat necessary to effect this vaporization is abstracted from brine or other liquid, which is circulated through the refrigerator by means of a pump. Owing to the absorption of ammonia, the weak liquor in the absorber becomes strengthened, and it is then pumped back into the generating vessel to be again dealt with as above described.

The absorption apparatus, as applied for cooling purposes, consists of a generator, which is a vessel of cast iron containing coils of iron piping to which steam at any convenient pressure is supplied; an analyzer, in which a portion of the water vapor is condensed, and from which it flows back immediately into the generator; a rectifier and condenser, in the upper portion of which a further condensation of water vapor and a little ammonia takes place, the liquid thus formed passing back by a pipe to the analyzer and thence to the generator, while in the lower portion the ammonia vapor is condensed and collected; and a refrigerator or cooler, into which the nearly anhydrous liquid obtained in the condenser is admitted by a pipe and regulating valve, and allowed to evaporate, the upper portion being in communication with the absorber.

Through this vessel weak liquor, which has been deprived of its ammonia in the generator, is continually circulated, after being first cooled in an economizer by an opposite current of strong cold liquor passing from the absorber to the generator, while, in addition, the liquor in the absorber, which would become heated by the liberation of heat due to the absorption and consequent liquefaction of the ammonia vapor, is still further cooled by the circulation of cold water. As the pressure in the absorber is much lower than that in the generator, the strong liquor has to be pumped into the latter vessel, and for this purpose pumps are provided. Though of necessity the various operations have been described separately, the process is a continuous one, strong liquor from the absorber being constantly pumped into the generator through the heater or economizer, while nearly anhydrous liquid ammonia is being continually formed in the condenser, then evaporated in the refrigerator and absorbed by the cool weak liquor passing through the absorber.

Putting aside the effect of losses from radiation, etc., all the heat expended in the generator will be taken up by the water passing through the condenser, less that portion due to the condensation of the water vapor in the analyzer, and plus the amount due to the difference between the temperature of the liquid as it enters the generator and the temperature at which it leaves the condenser. In the refrigerator the liquid ammonia, in becoming vaporized, will take up the precise quantity of heat that was given off during its cooling and liquefaction in the condenser, plus the amount due to the difference in heat of vaporization, owing to the lower pressure at which the change of state takes place in the refrigerator, and less the small amount due to the difference in temperature between the vapor entering the condenser and that leaving the refrigerator, less also the amount necessary to cool the liquid ammonia to the refrigerator temperature. When the vapor enters into solution with the weak liquor in the absorber, the heat taken up in the refrigerator is imparted to the cooling water, subject also to corrections for differences of pressure and temperature. The sources of loss in such an apparatus are:

a. Radiation and conduction of heat from all vessels and pipes above normal temperature, which can, to a large extent, be prevented by lagging.

b. Conduction of heat from without into all vessels and pipes that are below normal temperature, which can also to a large extent be prevented by lagging.

c. Inefficiency of economizer, by reason of which heat obtained by the expenditure of steam in the generator is passed on to the absorber and there uselessly imparted to the cooling water.

d. The entrance of water into the refrigerator, due to the liquid being not perfectly anhydrous.

e. The useless evaporation of water in the generator. With regard to the amount of heat used, it will have been seen that the whole of that required to vaporize the ammonia, and whatever water vapor passes off from the generator, has to be supplied from without. Owing to the fact that the heating takes place by means of coils, the steam passed through may be condensed, and thus each pound can be made to give up some 950 units of heat. With the absorption process worked by an efficient boiler, it may be taken that 200,000 thermal units per hour may be eliminated by the consumption of about 100 lb. of coal per hour, with a brine temperature in the refrigerator of about 20° Fahr.

Compression Process.—In this process ammonia is used in its anhydrous form. So far as the action of the refrigerator is concerned, it is precisely the same as it is in the case of the absorption apparatus, but instead of the vapor being liquefied by absorption by water, it is drawn from the refrigerator by a pump, by means of which it is compressed and delivered into the condenser at such pressure as to cause its liquefaction at the temperature of the cooling water. It must be borne in mind, however, that allowance must be made for the rise of temperature of the water passing through the condenser, and also for the difference in temperature necessary in order to permit the transfer of heat from one side of the cooling surface to the other. In a compression machine the work applied to the pump may be accounted for as follows:

a. Friction.

b. Heat rejected during compression and discharge.

c. Heat acquired by the ammonia in passing through the pump.

d. Work expended in discharging the compressed vapor from the pump.

But against this must be set the useful mechanical work performed by the vapor entering the pump. The heat rejected in the condenser is the heat of vaporization taken up in the refrigerator, less the amount due to the higher pressure at which the change in physical state occurs, plus the heat acquired in the pump, and less the amount due to the difference between the temperature at which the vapor is liquefied in the condenser and that at which it entered the pump. An ammonia compression machine, as applied to ice making, contains ice-making tanks, in which is circulated a brine mixture, uncongealable at any temperature likely to be reached during the process. This brine also circulates around coils of wrought iron pipes, in which the liquid ammonia passing from the condenser is vaporized, the heat required for this vaporization being obtained from the brine. A pump draws off the ammonia vapor from the refrigerator coils, and compresses it into the condenser, where, by means of the combined action of pressure and cooling by water, it assumes a liquid form, and is ready to be again passed on to the refrigerator for evaporation. The ammonia compression process is more economical than the absorption process, and with a good boiler and engine about 240,000 thermal units per hour can be eliminated by the expenditure of 100 lb. of coal per hour, with a brine temperature in the refrigerator of about 20° Fahr.

GENERAL CONSIDERATIONS.

From what has been said, it will have been seen that, so far as the mere application is concerned, there is no difference whatever between the absorption and compression processes. The following considerations, therefore, which chiefly relate to the application of refrigerating apparatus, will be dealt with quite independent of either system. The application of refrigerating apparatus may roughly be divided into the following heads:

a. Ice making.

b. The cooling of liquids.

c. The cooling of stores and rooms.

Ice Making.—For this purpose two methods are employed, known as the can and cell systems respectively. In the former, moulds of tinned sheet copper or galvanized steel of the desired size are filled with the water to be frozen, and suspended in a tank through which brine cooled to a low temperature in the refrigerator is circulated. As soon as the water is completely frozen, the moulds are removed, and dipped for a long time into warm water, which loosens the blocks of ice and enables them to be turned out. The thickness of the blocks exercises an important influence upon the number of moulds required for a given output, as a block 9 in. thick will take four or five times as long to freeze solid as one of only 3 in. In the cell system a series of cellular walls of wrought or cast iron are placed in a tank, the distance between each pair of walls being from 12 to 16 in., according to the thickness of the block required. This space is filled with the water to be frozen. Cold brine circulates through the cells, and the ice forms on the outer surfaces, gradually increasing in thickness until the two opposite layers meet and join together. If thinner blocks are required, the freezing process may be stopped at any time and the ice removed. In order to detach the ice it is customary to cut off the supply of cold brine and circulate brine at a higher temperature through the cells. Ice frozen by either of the above described methods from ordinary water is more or less opaque, owing to the air liberated during the freezing process, little bubbles of which are caught in the ice as it forms, and in order to produce transparent ice it is necessary that the water should be agitated during the freezing process in such a way as to permit the air bubbles to escape. With the can system this is generally accomplished by means of arms having a vertical or horizontal movement. These arms are either withdrawn as the ice forms, leaving the block solid, or they are made to work backward and forward in the center of the moulds, dividing the block vertically into two pieces. With the cell system agitation is generally effected by making a communication between the bottom of each water space and a chamber below, in which a paddle or wood piston is caused to reciprocate. The movement thus given to the water in the chamber is communicated to that in the process of being frozen, and the small bubbles of air are in this way detached and set free. The ice which first forms on the sides of the moulds or cells is, as a rule, sufficiently transparent even without agitation. The opacity increases toward the center, where the opposing layers join, and it is, therefore, more necessary to agitate toward the end of the freezing process than at the commencement. As the capacity for holding air in solution decreases if the temperature of the water is raised, less agitation is needed in hot than in temperate climates. Experiments have been made from time to time with the view of producing transparent ice from distilled water, and so dispensing with agitation. In this case the cost of distilling the water will have to be added to the ordinary working expenses.

Cooling of Liquids.—In breweries, distilleries, butter factories, and other places where it is desired to have a supply of water or brine for cooling and other purposes at a comparatively low temperature, refrigerating machines may be advantageously applied. In this case the liquid is passed through the refrigerator and then utilized in any convenient manner.

Cooling of Rooms.—For this purpose the usual plan is to employ a circulation of cold brine through rows of iron piping, placed either on the ceiling or on the walls of the rooms to be cooled. In this, as in the other cases where brine is used, it is employed merely as a medium for taking up heat at one place and transferring it to the ammonia in the refrigerator, the ammonia in turn completing the operation by giving up the heat to the cooling water during liquefaction in the condenser. The brine pipes cool the adjacent air, which, in consequence of its greater specific gravity, descends, being replaced by warmer air, which in turn becomes cold, and so the process goes on. Assuming the air to be sufficiently saturated, which is generally the case, some of the moisture in it is condensed and frozen on the surface of the pipes; and if the air is renewed in whole or in part from the outside, or if the contents of the chamber are wet, the deposit of ice in the pipes will in time become so thick as to necessitate its being thawed off. This is accomplished by turning a current of warm brine through the pipes. Another method has been proposed, in which the brine pipes are placed in a separate compartment, air being circulated through this compartment to the rooms, and back again to the cooling pipes in a closed cycle by means of a fan. This plan was tried on a large scale by Mr. Chambers at the Victoria Docks, but for some reason or other was abandoned. One difficulty is the collection of ice from the moisture deposited from the air, which clogs up the spaces between the pipes, besides diminishing their cooling power. This, in some cases, can be partially obviated by using the same air over again, but in most instances special means would have to be provided for frequent thawing off, the pipes having, on account of economy of space and convenience, to be placed so close together, and to be so confined in surface, that they are much more liable to have their action interfered with than when placed on the roof or walls of the room.

In addition to the foregoing there are, of course, many other applications of ammonia refrigerating machines of a more or less special nature, of which time will not permit even a passing reference. Many of these are embraced in the second class, cold water or brine being used for the cooling of candles, the separation of paraffin, the crystallization of salts, and for many other purposes. In the same way cold brine has been used with great success for freezing quicksand in the sinking of shafts, the excavation being carried out and the watertight tubing or lining put in while the material is in a solid state. In a paper such as this it would be quite impracticable to enter into details of construction, and the author has therefore confined himself chiefly to principles of working. In conclusion, however, it may be added that in ammonia machines, whether on the absorption or compression systems, no copper or alloy of copper can be used in parts subjected to the action of the ammonia. Cast or wrought iron and steel may, however, be used, provided the quality is good, but special care must be taken in the construction of those parts of absorption machines which are subjected to a high temperature. In both classes of apparatus first-class materials and workmanship are most absolute essentials.

[1]

Paper lately read before the Civil and Mechanical Engineers' Society.

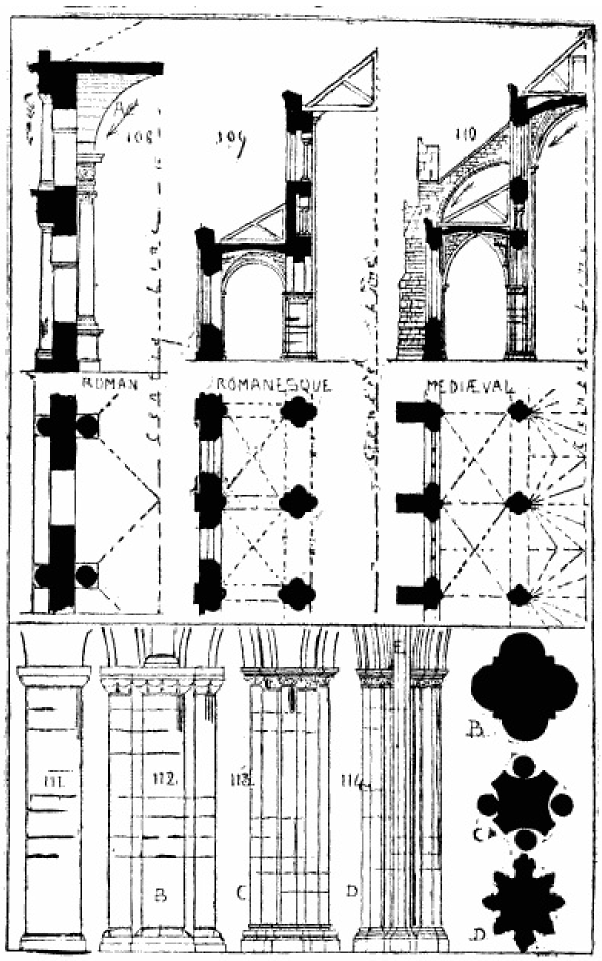
[Continued from SUPPLEMENT, No. 646, p. 10319.]

ELEMENTS OF ARCHITECTURAL DESIGN.[1]

By H. H. STATHAM.

III.—CONTINUED.

The Romans, in their arched constructions, habitually strengthened the point against which the vault thrust by adding columnar features to the walls, as shown in Fig. 108; thus again making a false use of the column in a way in which it was never contemplated by those who originally developed its form. In Romanesque architecture the column was no longer used for this purpose; its place was taken by a flat pilaster-like projection of the wall (plan and section, Fig. 109), which gave sufficient strength for the not very ambitious vaulted roofs of this period, where often in fact only the aisles were vaulted, and the center compartment covered with a wooden roof. At first this pilaster-like form bore a reminiscence of a classic capital as its termination; a moulded capping under the eaves of the building. Next this capping was almost insensibly dropped, and the buttress became a mere flat strip of wall. As the vaulting became bolder and more ambitious, the buttress had to be made more massive and of greater projection, to afford sufficient abutment to the vault, more especially toward the lower part, where the thrust of the roof is carried to the ground. Hence arose the tendency to increase the projection of the buttress gradually downward, and this was done by successive slopes or "set-offs," as they are termed, which assisted (whether intentionally or not in the first instance) in further aiding the correct architectural expression of the buttress. Then the vaulting of the center aisle was carried so high and treated in so bold a manner, with a progressive diminution of the wall piers (as the taste for large traceried windows developed more and more), that a flying buttress (see section, Fig. 110) was necessary to take the thrust across to the exterior buttresses, and these again, under this additional stress, were further increased in projection, and were at the same time made narrower (to allow for all the window space that was wanted between them), until the result was that the masses of wall, which in the Romanesque building were placed longitudinally and parallel to the axis of the building, have all turned about (Fig. 110, plan) and placed themselves with their edges to the building to resist the thrust of the roofing. The same amount of wall is there as in the Romanesque building, but it is arranged in quite a new manner, in order to meet the new constructive conditions of the complete Gothic building.



Figs. 108-114.

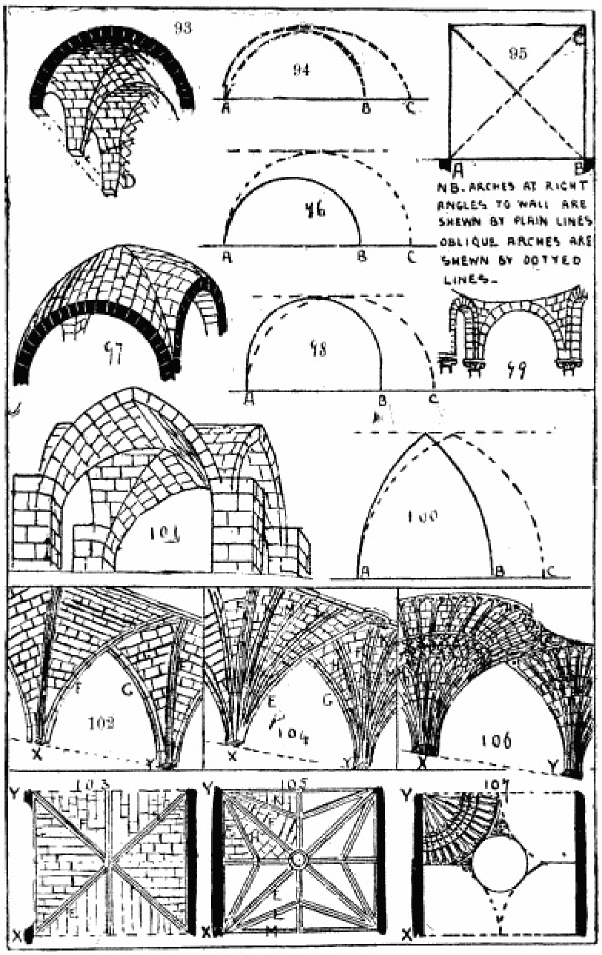
It will be seen thus how completely this important and characteristic feature of Gothic architecture, the buttress, is the outcome of practical conditions of construction. It is treated decoratively, but it is itself a necessary engineering expedient in the construction. The application of the same principle, and its effect upon architectural expression, may be seen in some other examples besides that of the buttress in its usual shape and position. The whole arrangement and disposition of an arched building is affected by the necessity of providing counterforts to resist the thrust of arches. The position of the central tower, for instance, in so many cathedrals and churches, at the intersection of the nave and transepts, is not only the result of a feeling for architectural effect and the centralizing of the composition, it is the position in which also the tower has the cross walls of nave and transepts abutting against it in all four directions: if the tower is to be placed over the central roof at all, it could only be over this point of the plan. In the Norman buildings, which in some respects were finer constructions than those of later Gothic, the desire to provide a firm abutment for the arches carrying the tower had a most marked effect on the architectural expression of the interior. At Tewkesbury, for instance, while the lower piers are designed in the usual way toward the north and south sides (viz., as portions of a pier of nearly square proportion standing under the angle of the tower), in the east and west direction the tower piers run out into great solid masses of wall, in order to insure a sufficient abutment for the tower arches. On the north and south sides the solid transept walls were available immediately on the other side of the low arch of the side aisle, but on the east and west sides there were only the nave and choir arcades to take the thrust of the north and south tower arches, and so the Normans took care to interpose a massive piece of wall between, in order that the thrust of the tower arches might be neutralized before it could operate against the less solid arcaded portions of the walls. This expedient, this great mass of wall introduced solely for constructive reasons, adds greatly to the grandeur of the interior architectural effect. The true constructive and architectural perception of the Normans in this treatment of the lower piers is illustrated by the curious contrast presented at Salisbury. There the tower piers are rather small, the style is later, and the massive building of the Normans had given way to a more graceful but less monumental manner of building. Still the abutment of the tower arches was probably sufficient for the weight of the tower as at first built; but when the lofty spire was put on the top of this, its vertical weight, pressing upon the tower arches and increasing their horizontal thrust, actually thrust the nave and choir arcades out of the perpendicular toward the west and east respectively, and there they are leaning at a very perceptible angle away from the center of the church—the architectural expression, in a very significant form, of the neglect of balance of mass in construction.

But while the buttress in Gothic architecture has been in process of development, what has the vault been doing? We left it (Fig. 92) in the condition of a round wagon vault, intersected by another similar vault at right angles. By that method of treatment we got rid of the continuous thrust on the walls. But there were many difficulties to be faced in the construction of vaulting after this first step had been taken, difficulties which arose chiefly from the rigid and unmanageable proportions of the circular arch, and which could not be even partially solved till the introduction of the pointed arch. The pointed arch is the other most marked and characteristic feature of Gothic architecture, and, like the buttress, it will be seen that it arose entirely out of constructive difficulties.

These difficulties were of two kinds; the first arose from the tendency of the round arch, when on a large scale and heavily weighted, to sink at the crown if there is even any very slight settlement of the abutments. If we turn again to diagram 77, and observe the nearly vertical line formed there by the joints of the keystone, and if we suppose the scale of that arch very much increased without increasing the width of each voussoir, and suppose it built in two or three rings one over the other (which is really the constructive method of a Gothic arch), we shall see that these joints in the uppermost portion of the arch must in that case become still more nearly vertical; in other words, the voussoirs almost lose the wedge shape which is necessary to keep them in their places, and a very slight movement or settlement of the abutments is sufficient to make the arch stones lose some of their grip on each other and sink more or less, leaving the arch flat at the crown. There can be no doubt that it was the observance of this partial failure of the round arch (partly owing probably to their own careless way of preparing the foundations for their piers—for the mediæval builders were very bad engineers in that respect) which induced the builders of the early transitional abbeys, such as Furness and Fountains and Kirkstall, to build the large arches of the nave pointed, though they still retain the circular-headed form for the smaller arches in the same buildings, which were not so constructively important. This is one of the constructive reasons which led to the adoption of the pointed arch in mediæval architecture, and one which is easily stated and easily understood. The other influence is one arising out of the lengthened conflict with the practical difficulties of vaulting, and is a rather more complicated matter, which we must now endeavor to follow out.

Looking at Fig. 92, it will be seen that in addition to the perspective sketch of the intersecting arches, there is drawn under it a plan, which represents the four points of the abutment of the arches (identified in plan and perspective sketch as A, B, C, D), and the lines which are taken by the various arches shown by dotted lines. Looking at the perspective sketch, it will be apparent that the intersection of the two cross vaults produces two intersecting arches, the upper line of which is shown in the perspective sketch (marked *e* and *f*); underneath, this intersection of the two arches, which forms a furrow in the upper side of the construction, forms an edge which traverses the space occupied by the plan of the vaulting as two oblique arches, running from A to C and from B to D on the plan. Although these are only lines formed by the intersection of two cross arches, still they make decided arches to the eye, and form prominent lines in the system of vaulting; and in a later period of vaulting they were treated as prominent lines and strongly emphasized by mouldings; but in the Roman and early Romanesque vaults they were simply left as edges, the eye being directed rather to the vaulting surfaces than to the edges. The importance of this distinction between the vaulting surfaces and their meeting edges or *groins*[2] will be seen just now. The edges, nevertheless, as was observed, do form arches, and we have therefore a system of cross arches (A B and C D[3] Fig. 95), two wall arches (A, D and B C), and two oblique arches (A C and B D), which divide the space into four equal triangular portions; this kind of vaulting being hence called *quadripartite* vaulting. In this and the other diagrams of arches on this page, the cross arches are all shown in positive lines, and the oblique arches in dotted lines.

We have here a system in which four semicircular arches of the width of A B are combined with two oblique arches of the width of A C, springing from the same level and supposed to rise to the same height. But if we draw out the lines of these two arches in a comparative elevation, so as to compare their curves together, we at once find we are in a difficulty. The intersection of the two circular arches produces an ellipse with a very flat crown, and very liable to fail. If we attempt to make the oblique arch a segment only of a large circle, as in the dotted line at 94, so as to keep it the same level as the other without being so flat at the top, the crown of the arch is safer, but this can only be done at the cost of getting a queer twist in the line of the oblique arch, as shown at D, Fig. 93. The like result of a twist of the line of the oblique arch would occur if the two sides of the space we are vaulting over were of different lengths, *i.e.*, if the vaulting space were otherwise than a square, as long as we are using circular arches. If we attempt to make the oblique arches complete circles, as at Fig. 96, we see that they must necessarily rise higher than the cross and side arches, so that the roof would be in a succession of domical forms, as at Fig. 97. There is the further expedient of "stilting" the cross arches, that is, making the real arch spring from a point above the impost and building the lower portion of it vertical, as shown in Fig. 98. This device of stilting the smaller arches to raise their crowns to the level of those of the larger arches was in constant use in Byzantine and early Romanesque architecture, in the kind of manner shown in the sketch, Fig. 99; and a very clumsy and makeshift method of dealing with the problem it is; but something of the kind was inevitable as long as nothing but the round arch was available for covering contiguous spaces of different widths. The whole of these difficulties were approximately got over in theory, and almost entirely in practice, by the adoption of the pointed arch. By its means, as will be seen in Fig. 100, arches over spaces of different widths could be carried to the same height, yet with little difference in their curves at the springing, and without the necessity of employing a dangerously flat elliptical form in the oblique arch. A sketch of the Gothic vault in this form, and as the intersection of the surfaces of pointed vaults, is shown in Fig. 101.



Figs. 93-107.

But now another and most important change was to come over the vault. The mediæval architects were not satisfied with the mere edge left by the Romans in their vaults, and even before the full Gothic period the Roman builders had emphasized their oblique arches in many cases by ponderous courses of moulded or unmoulded stone in the form of vaulting ribs. These, in the case of Norman building, were probably not merely put for the purpose of architectural expression, but also because they afforded an opportunity of concealing behind the lines of a regularly curved groin rib the irregular curves which were really formed by the junction of the vaulting surfaces. But when the vault become more manageable in its curves after the adoption of the pointed arch, the groin rib became adopted in the early pointed vaulting as a means of giving expression and carrying up the lines of the architectural design. On its edge were stones moulded with the deep undercut hollows of early English moulding, defining the curves of the oblique as well as of the cross arches with strongly marked lines, and, moreover, falling on a level with each other in architectural importance; the oblique vault of the arch is no longer a secondary line in the vaulting design; on the contrary, the cross arches are usually omitted, as shown in Figs. 102 and 103 (view and plan of an early Gothic quadripartite vault); so that the cross rib, which, in the early Romanesque wagon vault (Fig. 90), was the one marked line on the vaulting surface, has now been obliterated, and the line of the oblique arch (E F, Figs. 102, 103) has taken its place.

The effect of the strongly marked lines of the groin ribs, radiating from the cap of the shaft which was their architectural support, seems to have been so far attractive to the mediæval builders that they soon endeavored to improve upon it and carry it further by multiplying the groin ribs. One of the stages of this progress is shown in Figs. 104, 105. Here it will be seen that the cross rib is again shown, and that intermediate ribs have been introduced between it and the oblique rib. The richness of effect of the vault is much heightened thereby; but a very important modification in the mode of constructing it has been introduced. As the groin ribs become multiplied, it came to be seen that it was easier to construct them first, and fill in the spaces afterward; accordingly the groin, instead of being, as it was in the early days of vaulting, merely the line formed by the meeting of two arch surfaces, became a kind of stone scaffolding or frame work, between which the vaulting surfaces were filled in with lighter material. This arrangement of course made an immense difference in the whole principle of constructing the vault, and rendered it much more ductile in the hands of the builder, more capable of taking any form which he wished to impose on it, than when the vault was regarded and built as an intersection of surfaces. There was still one difficulty, however, one slight failure both practical and theoretical in the vault architecture, which for a long time much exercised the minds of the builders. The ribs of the vaulting being all of unequal length, they had to assume different curves almost immediately on rising from the impost; and as the mouldings of the ribs have to be run into each other ("mitered" is the technical term) on the impost, there not being room to receive them all separately, it was almost impossible to get them to make their divergence from each other in a completely symmetrical manner; the shorter ribs with the quicker curves parted from each other at a lower point than the larger ones, and the "miters" occurred at unequal heights. The effort to get over this unsatisfactory and irregular junction of the ribs at the springing was made first by setting back the feet of the shorter ribs on the impost capping, somewhat in the rear of the feet of the larger ribs, so as to throw their parting point higher up; but this also was only a makeshift, which it was hoped the eye would pass over; and in fact it is rarely noticeable except to those who know about it and look for it. Still the defect was there, and was not got over until the idea occurred of making all the ribs of the same curvature and the same length, and intercepting them all by a circle at the apex of the vault, as shown in Figs. 106, 107; the space between the circles at the apex of the vault being practically a nearly flat surface or *plafond* held in its place by the arches surrounding it; though, for effect, it is often treated otherwise in external appearance, being decorated by pendants giving a reversed curve at this point, but which of course are only ornamental features hung from the roof. If we look again at Fig. 104, we shall see that this was a very natural transition after all, for the arrangement of the ribs and vaulting surfaces in that example is manifestly suggestive of a form radiating round the central point of springing, though it only suggests that, and does not completely realize it. But here came a further and very curious change in the method of building the vault, for as the ribs were made more numerous, for richness of effect, in this form of vaulting, it was discovered that it was much easier to build the whole as a solid face of masonry, working the ribs on the face of it. Thus the ribs, which in the intermediate period were the constructive framework of the vault, in the final form of fan vaulting came back to their original use as merely a form of architectural expression, meant to carry on the architectural lines of the design; and they perform, on a larger scale and with a different expression, much the same kind of function which the fluting lines performed in the Greek column. The fan vault is therefore a kind of inverted dome, built up in courses on much the same principle as a dome, but a convex curve internally, instead of a concave one, the whole forming a series of inverted conoid forms abutting against the wall at the foot and against each other at their upper margins. This form of roof is wonderfully rich in effect, and has the appearance of being a piece of purely artistic work done for the pleasure of seeing it; yet, as we have seen, it is in reality, like almost everything good in architecture, the logical outcome of a contention with structural problems.

We have already noticed the suggestion, in early Gothic or Romanesque, of the dividing up of a pier into a multiple pier, of which each part supports a special member of the superstructure, as indicated in Fig. 90. The Gothic pier, in its development in this respect, affords a striking example of that influence of the superstructure on the plan which has before been referred to. The peculiar manner of building the arch in Gothic work led almost inevitably to this breaking up of the pier into various members. The Roman arch was on its lower surface a simple flat section, the decorative treatment in the way of mouldings being round the circumference, and not on the under side or *soffit* of the arch, and in early Romanesque work this method was still followed. The mediæval builders, partly in the first instance because they built with smaller stones, adopted at an early period the plan of building an arch in two or more courses or rings, one below and recessed within the other. As the process of moulding the arch stones became more elaborated, and a larger number of subarches one within another were introduced, this characteristic form of subarches became almost lost to the eye in the multiplicity of the mouldings used. But up to nearly the latest period of Gothic architecture this form may still be traced, if looked for, as the basis of the arrangement of the mouldings, which are all formed by cutting out of so many square sections, recessed one within the other. This will be more fully described in the next lecture. We are now speaking more especially of the pier as affected by this method of building the arches in recessed orders. If we consider the effect of bringing down on the top of a square capital an arch composed of two rings of squared stones, the lower one only half the width (say) of the upper one, it will be apparent that on the square capital the arch stones would leave a portion of the capital at each angle bare, and supporting nothing.[4] This looks awkward and illogical, and accordingly the pier is modified so as to suit the shape of the arch. Figs. 111, 112, 113, and 114, with the plans, B C D, accompanying them, illustrate this development of the pier. Fig. 111 is a simple cylindrical pier with a coarsely formed capital, a kind of reminiscence of the Doric capital, with a plain Romanesque arch starting from it. Fig. 112, shown in plan at B, is the kind of form (varied in different examples) which the pier assumed in Norman and early French work, when the arch had been divided into two recessed orders. The double lines of the arch are seen springing from the cap each way, in the elevation of the pier. If we look at the plan of the pier, we see that, in place of the single cylinder, it is now a square with four smaller half cylinders, one on each face. Of these, those on the right and left of the plan support the subarches of the arcade; the one on the lower side, which we will suppose to be looking toward the nave, supports the shaft which carries the nave vaulting, and which stands on the main capital with a small base of its own, as seen in Fig. 112—a common feature in early work; and the half column on the upper side of the plan supports the vaulting rib of the aisle. In Fig. 113 and plan C, which represents a pier of nearly a century later, we see that the pier is broken up by perfectly detached shafts, each with its own capital, and each carrying a group of arch mouldings, which latter have become more elaborated. Fig. 114 and plan D show a late Gothic fourteenth century pier, in which the separate shafts have been abandoned, or rather absorbed into the body of the pier, and the pier is formed of a number of moulded projections, with hollows giving deep shadows between them, and the capitals of the various members run into one another, forming a complete cap round the pier. This pier shows a remarkable contrast in every way to B, yet it is a direct development from the latter. In this late form of pier, it will be observed that the projection, E, which carries the vaulting ribs of the nave, instead of springing from the capital, as in the early example, Fig. 111, springs from the floor, and runs right up past the capital; thus the plan of the vaulting is brought, as it were, down on to the floor, and the connection between the roofing of its building and its plan is as complete as can well be. In Fig. 113 the vaulting shaft is supposed to stop short of the capital and to spring from a corbel in the wall, situated above the limit of the drawing. This was a common arrangement in the "Early English" and "Early Decorated" periods of Gothic, but it is not so logical and complete, or so satisfactory either to the eye or to the judgment, as starting the vaulting shaft from the floor line. The connection between the roofing and the plan may be further seen by looking at the portion of a mediæval plan given under Fig. 110, where the dotted lines represent the course of the groin ribs of the roof above. It will be seen how completely these depend upon the plan, so that it is necessary to determine how the roof in a vaulted building is to be arranged before setting out the ground plan.

Thus we see that the Gothic cathedral, entirely different in its form from that of the Greek temple, illustrates, perhaps, even more completely than the Greek style, the same principle of correct and truthful expression of the construction of the building, and that all the main features which give to the style its most striking and picturesque effects are not arbitrarily adopted forms, but are the result of a continuous architectural development based on the development of the construction. The decorative details of the Gothic style, though differing exceedingly from those of the Greek, are, like the latter, conventional adaptations of suggestions from nature; and in this respect again, as well as in the character of the mouldings, we find both sides illustrating the same general principle in the design of ornament, in its relation to position, climate, and material; but this part of the subject will be more fully treated of in the next lecture.

We have now arrived at a style of architectural construction and expression which seems so different from that of Greek architecture, which we considered in the last lecture, that it is difficult to realize at first that the one is, in regard to some of its most important features, a lineal descendant of the other. Yet this is unquestionably the case. The long thin shaft of Gothic architecture is descended, through a long series of modifications, from the single cylindrical column of the Greek; and the carved mediæval capital, again, is to be traced back to the Greek Corinthian capital, through examples in early French architecture, of which a tolerably complete series of modifications could be collected, showing the gradual change from the first deviations of the early Gothic capital from its classical model, while it still retained the square abacus and the scroll under the angle and the symmetrical disposition of the leaves, down to the free and unconstrained treatment of the later Gothic capital. Yet with these decided relations in derivation, what a difference in the two manners of building! The Greek building is comparatively small in scale, symmetrical and balanced in its main design, highly finished in its details in accordance with a preconceived theory. The Gothic building is much more extensive in scale, is not necessarily symmetrical in its main design, and the decorative details appear as if worked according to the individual taste and pleasure of each carver, and not upon any preconceived theory of form or proportion. In the Greek building all the predominant lines are horizontal; in the mediæval building they are vertical. In the Greek building every opening is covered by a lintel; in the Gothic building every opening is covered by an arch. No two styles, it might be said, could be more strongly contrasted in their general characteristics and appearance. Yet this very contrast only serves to emphasize the more strongly the main point which I have been wishing to keep prominent in these lectures—that architectural design, rightly considered, is based on and is the expression of plan and construction. In Greek columnar architecture the salient feature of the style is the support of a cross lintel by a vertical pillar; and the main effort of the architectural designer is concentrated on developing the expression of the functions of these two essential portions of the structure. The whole of the openings being bridged by horizontal lintels, the whole of the main lines of the superstructure are horizontal, and their horizontal status is as strongly marked as possible by the terminating lines of the cornice—the whole of the pressures of the superstructure are simply vertical, and the whole of the lines of design of the supports are laid out so as to emphasize the idea of resistance to vertical pressure. The Greek column, too, has only one simple office to perform, that of supporting a single mass of the superstructure, exercising a single pressure in the same direction. In the Gothic building the main pressures are oblique and not vertical, and the main feature of the exterior substructure, the buttress, is designed to express resistance to an oblique pressure; and no real progress was made with the development of the arched style until the false use of the apparent column or pilaster as a buttress was got rid of, and the true buttress form evolved. On the interior piers of the arcade there is a resolution of pressures which practically results in a vertical pressure, and the pier remains vertical; but the pressure upon it being the resultant of a complex collection of pressures, each of these has, in complete Gothic, its own apparent vertical supporting feature, so that the plan of the substructure becomes a logical representation of the main features and pressures of the superstructure. The main tendency of the pointed arched building is toward vertically, and this vertical tendency is strongly emphasized and assisted by the breaking up of the really solid mass of the pier into a number of slender shafts, which, by their strongly marked parallel lines, lead the eye upward toward the closing-in lines of the arcade and of the vaulted roof which forms the culmination of the whole. The Greek column is also assisted in its vertical expression by the lines of the fluting; but as the object of these is only to emphasize the one office of the one column, they are strictly subordinate to the main form, are in fact merely a kind of decorative treatment of it in accordance with its function. In the Gothic pier the object is to express complexity of function, and the pier, instead of being a single fluted column, is broken up into a variety of connected columnar forms, each expressive of its own function in the design. It may be observed also that the Gothic building, like the Greek, falls into certain main divisions arising out of the practical conditions of its construction, and which form a kind of "order" analogous to the classic order in a sense, though not governed by such strict conventional rules. The classic order has its columnar support, its beam, its frieze for decorative treatment. The Gothic order has its columnar support, its arch (in place of the beam), its decoratively treated stage (the triforium), occupying the space against which the aisle roof abuts, and its clerestory, or window stage. All these arise as naturally out of the conditions and historical development of the structure in the Gothic case as in the Greek one, but the Greek order is an external, the Gothic an internal one. The two styles are based on constructive conditions totally different the one from the other; their expression and character are totally different. But this very difference is the most emphatic declaration of the same principle, that architectural design is the logical, but decorative, expression of plan and construction.

[1]

Delivered before the Society of Arts, London, December 13, 1887. From the *Journal* of the Society.

[2]

A *groin* is the edge line formed by the meeting and intersection of any two arched surfaces. When this edge line is covered and emphasized by a band of moulded stones forming an arch, as it were, on this edge, this is called a *groin rib*.

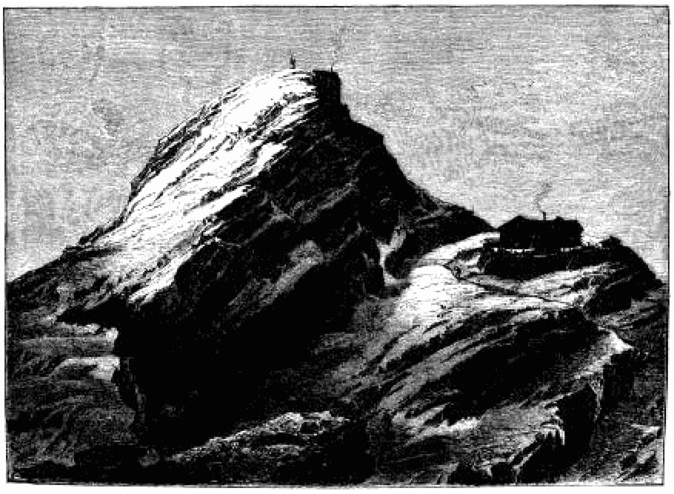
[3]

The "D" seems to have been accidentally omitted in this diagram; it is of course the fourth angle of the plan.

[4]

This was illustrated by diagrams on the wall at the delivery of the lecture.

THE METEOROLOGICAL STATION ON MT. SANTIS.



THE METEOROLOGICAL STATION ON MT. SANTIS.

At the second International Meteorological Congress, in 1879, the erection of an observatory on the top of a high mountain was considered. The Swiss Meteorological Commission undertook to carry out the project, and sent out circulars to different associations, governments, and private individuals requesting single or yearly contributions to aid in defraying the expense of the station. In December, 1881, an extra credit of about $1,000 was granted by the Bundesversammlung for the initial work on the station, which was temporarily placed in the Santis Hotel, and a telegraph was put up between that place and Weisbad in August, 1882, so that on September 1 of the same year the meteorological observations were begun.

At the end of August, 1885, this temporary arrangement expired, and the enterprise could not be carried on unless the support of the same was undertaken by the Union. On March 27, 1885, the Bundesversammlung decided to take the necessary steps. Mr. Fritz Brunner, who died May 1, 1885, left a large legacy for the enterprise, making it possible to build a special observatory.

For this purpose the northeast corner of the highest rocky peak was blasted out and the building was so placed that the wall of rock at the rear formed an excellent protection from the high west winds. By the first of October, last year, the building was ready for occupancy, and there was a quiet opening at which Mr. Potch, director of the Blue Hill Observatory, near Boston, and others were present.

The building is 26 feet long, 19 feet deep, and 30 feet high, and is very solid and massive, having been built of the limestone blasted from the rock. It consists of a ground floor containing the telegraph office, the observers' work room, and the kitchen and store rooms; the first story, in which are the living and sleeping rooms for the observers and their assistants; and the second story, living and sleeping rooms for visiting scientists who come to make special observations, and a reserve room. The barometer and barograph are placed in the second story, at a height of about 8,202 feet above the level of the sea, whereas in the hotel they were only about 8,093 feet above the sea level. The flat roof, of wood and cement, which extends very little above the plateau of the mountain top, is admirably adapted for making observations in the open air. All the rooms in the house are ceiled with wood, and the walls and floors of the ground floor and first story and the ceilings of the second story are covered with insulating material. The cost of the building, including the equipments, amounted to about $11,200.

The fact that since the erection of the Santis station there has been a still higher station constructed on Sonnblick (10,137 feet high) does not decrease the value of the former, for the greater the number of such elevated stations, the better will be the meteorological investigations of the upper air currents. The present observer at Santis is Mr. C. Saxer, who has endured the hardships and privations of a long winter at the station.

The anemometer house, which is shown in our illustration, is connected with the main house by a tunnel. Several times during the day records are taken of the barometer, the thermometer, the weather vane, as well as notes in regard to the condition of the weather, the clouds, fall of rain or snow, etc. A registering aneroid barometer marks the pressure of the atmosphere hourly, and two turning thermometers register the temperature at midnight and at four o'clock in the morning.—*Illustrirte Zeitung.*

THE CARE OF THE EYES.[1]

By Prof. David Webster, M.D.

"The light of the body is the eye." Of all our senses, sight, hearing, touch, taste, and smell, the sight is that which seems to us the most important. Through the eye, the organ of vision, we gain more information and experience more pleasure, perhaps, than through any or all our other organs of sense. Indeed, we are apt to depreciate the value of our other senses when comparing them to the eyesight. It is not uncommon to hear a person say, "I would rather die than be blind." But no one says, "I would rather die than lose my hearing." As a matter of fact, the person who is totally blind generally appears to be more cheerful, happier, than one who is totally deaf. Deaf mutes are often dull, morose, quick tempered, obstinate, self-willed, and difficult to get along with, while the blind are not infrequently distinguished for qualities quite the reverse. It is worthy of remark that the eye is that organ of sense which is most ornamental as well as useful, and the deprivation of which constitutes the most visible deformity. But it is unnecessary to enter into a comparison of the relative value of our senses or the relative misfortune of our loss of any one of them. We need them all in our daily struggle for existence, and it is necessary to our physical and mental well-being, as well as to our success in life, that we preserve them all in as high a degree of perfection as possible. We must not lose sight of the fact that all our organs of sense are parts of one body, and that whatever we do to improve or preserve the health of our eyes cannot do harm to any other organ. We shall be able to "take care of our eyes" more intelligently if we know something of their structure and how they perform their functions. The eye is a hollow globe filled with transparent material and set in a bony cavity of the skull, which, with the eyelids and eyelashes, protect it from injury. It is moved at will in every direction by six muscles which are attached to its surface, and is lubricated and kept moist by the secretions of the tear gland and other glands, which secretions, having done their work, are carried down into the nose by a passage especially made for the purpose—the tear duct. We are all familiar with the fact that our eyes are "to see with," but in order to be able to take care of our eyes intelligently, it is necessary to understand as far as possible how to see with them.

THE BACK WALL OF THE EYE.

It is a remarkable fact that every object we see has its picture formed upon the back wall of our eyes. The eye is a darkened chamber, and the whole of the front part of it acts as a lens to bring the rays of light coming from objects we wish to see to a focus on its back wall, thus forming a picture there as distinct as the picture formed in the camera obscura of the photographer. This has not only been proved by the laws of optics, but has been actually demonstrated in the eyes of rabbits and other animals. Experimenters have held an object before the eye of a rabbit for a few moments, and have then killed the animal and removed the eye as quickly as possible, and laid its back wall bare, and have distinctly seen there the picture of the object upon which the eye had been fixed. It is a truly wonderful fact that these pictures upon the back wall of the eye can be changed so rapidly that the picture of the object last looked at disappears in an instant and makes way for the picture of the next. We know that the picture formed on the back wall of the eye is carried back to the brain by the optic nerve, but there our knowledge stops. Science cannot tell us how the brain, and through it the mind, completes the act of seeing. It is there that the finite and the infinite touch, and, as our minds are finite, we cannot comprehend the infinite.

But there is enough that we can understand, and it shall be my endeavor in this paper to make some plain statements that will help as a guide in the preservation of those wonderful and useful organs.

FAR AND NEAR SIGHTEDNESS.

We have to use our eyes for near and far distant vision. In gathering pictures of distant objects the normally shaped eye puts forth little or no effort. It is the near work, such as reading, sewing, or drawing, that puts a real muscular strain upon the eyes. There are certain rules that apply to the use of the eyes for such near work regardless of the age of the person.

READING.

1. In reading, a book or newspaper should be held at a distance of from ten to fifteen inches from the eyes. It is hardly necessary to caution anybody not to hold the print further away than fifteen inches. The only objection to holding ordinary print too far away is that in so doing the pictures formed on the back wall of the eye are too small to be readily and easily perceived, and the close attention consequently necessary causes both the eyes and the brain to tire. Most persons quickly find this out themselves, and the tendency is rather to hold the book too near, for the nearer the object to the eye, the larger its picture upon the retina, or back eye wall. But here we encounter another danger. The nearer the object the eyes are concentrated upon, the

greater the muscular effort necessary; so that by holding the book too near, the labor of reading is greatly increased, and the long persistence in such a habit is likely to produce weak eyes, and may, in some instances, lead to real near-sightedness. When children are observed to have acquired this habit and cannot be persuaded out of it, they should always be taken to a physician skilled in the treatment of the eye for examination and advice. A little attention at such a time may save them from a whole lifetime of trouble with their eyes. Of course, the larger the print, the farther it may be held from the eyes.

POSITION.

2. The position of the person with regard to the light should be so that the latter will fall upon the page he is reading, and not upon his eyes. It is generally considered most convenient to have the light shine over the left shoulder, so that in turning the leaves of the book, the shadow of the hand upon the page is avoided. It is not always possible to do this, however, and, at the same time, to get plenty of light upon the page. When one finds himself compelled to face the light in reading, or in standing at a desk bookkeeping, he should always contrive to shade his eyes from a direct light. This may be done with a large eye shade projecting from the brow. A friend of mine, a physician, is very fond of reading by a kerosene lamp, the lamp being placed on a table by his side, and the direct light kept from his eyes by means of a piece of cardboard stuck up by the lamp chimney.

PROPER LIGHT.

3. The illumination should always be sufficient. Nothing is more injurious to the eyes than reading by a poor light. Many persons strain their eyes by reading on into the twilight as long as they possibly can. They become interested and do not like to leave off. Some read in the evening at too great a distance from the source of light, forgetting that the quantity of light diminishes as the square of the distance from the source of light increases. Thus, at four feet, one gets only one-sixteenth part of the light upon his page that he would at one foot. It is the duty of parents and others who have charge of children to see to it that they do not injure their eyes by reading by insufficient light, either daylight or artificial light. There is a common notion that electric light is bad for the eyes. The only foundation I can think of for such a notion is that it is trying to the eyes to gaze directly at the bright electric light. It is bad to gaze long at any source of light, and the brighter the source of light gazed at, the worse for the eyes, the sun being the worst of all. I have seen more than one person whose eyes were permanently injured by gazing at the sun, during an eclipse or otherwise. As a matter of fact, nothing short of sunlight is better than the incandescent electric light to read by or to work by.

READING IN BED.

As to reading while lying down in bed or on a lounge, I can see no objection to it so far as the eyes are concerned, provided the book is held in such a position that the eyes do not have to be rolled down too far. Unless the head is raised very high by pillows, however, it will be found very fatiguing to hold the book high enough, not to mention the danger of falling asleep, and of upsetting the lamp or candle, and thus setting the bed on fire. Many persons permanently weaken their eyes by reading to pass away the tedious hours during recovery from severe illness. The muscles of the eyes partake of the general weakness and are easily overtaxed. Persons in this condition may be read to, but should avoid the active use of their own eyes.

READING IN RAIL CARS.

Reading while in the rail cars or in omnibuses is to be avoided. The rapid shaking, trembling or oscillating motion of the cars makes it very difficult to keep the eyes fixed upon the words, and is very tiresome. I have seen many persons who attributed the failure of their eyes to the daily habit of reading while riding to and from the city. Children should be cautioned against reading with the head inclined forward. The stooping position encourages a rush of blood to the head, and consequently the eyes become congested, and the foundations for near-sightedness are laid.

(*To be continued.*)

[1]

From a paper by David Webster. M.D., professor of ophthalmology in the New York Polyclinic and surgeon to the Manhattan Eye and Ear Hospital, New York.

TESTING INDIGO DYES.

The author deals with the question whether a sample of goods is dyed with indigo alone or with a mixture of indigo and other blue coloring matters. His method may be summarized as follows: Threads of the material in question should give up no coloring matter to boiling water. Alcohol at 50 and at 95 per cent. (by volume) ought to extract no color, even if gently warmed (not boiled). Solution of oxalic acid saturated in the cold, solution of borax, solution of alum at 10 per cent., and solution of ammonium molybdate at $33^{1}/_{3}$ per cent. ought not to extract any coloring matter at a boiling heat. The borax extract, if subsequently treated with hydrochloric acid, should not turn red, nor become blue on the further addition of ferric chloride. Solutions of stannous chloride and ferric chloride with the aid of heat ought entirely to destroy the blue coloring matter. Glacial acetic acid on repeated boiling should entirely dissolve the coloring matter. If the acetic extracts are mixed with two volumes of ether and water is added, so as to separate out the ether, the water should appear as a slightly blue solution, the main bulk of the indigo remaining in suspension at the surface of contact of the ethereal and watery stratum. This acid watery stratum should be colorless, and should not assume any color if a little strong hydrochloric acid is allowed to fall into it through the ether. No sulphureted hydrogen should be evolved on boiling the yarn or cloth in strong hydrochloric acid. On prolonged boiling, supersaturation with strong potassa in excess, heating and adding a few drops of chloroform, no isonitrile should be formed.—*W. Lenz*.

MUNN & CO.,
361 Broadway, New York.
Branch Office, 622 and 624 F St., Washington, D.C.

Transcriber's Notes

1. Simple and obvious typographical errors have been corrected.

2. In the article "Manufacture of Photosensitive Plates", the original text referred to room U twice. The first instance has been changed to room T.

3. In the article "An Improved Screw Propeller", the text refers to the propeller in figure A as being four bladed and also two bladed. It is clearly two bladed and the reference to it being four-bladed has been corrected.