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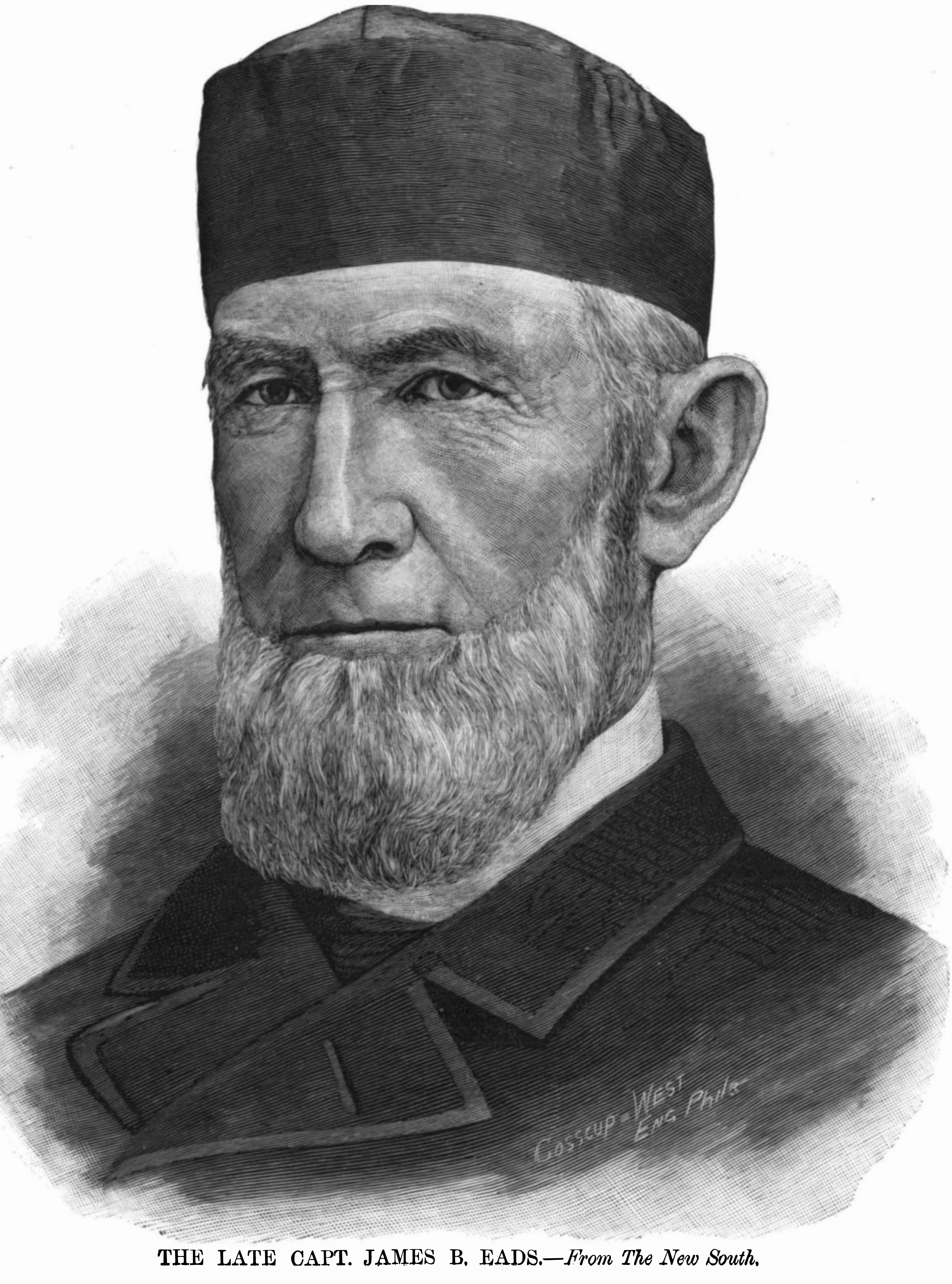
JAMES B. EADS.

THE man who devised and furnished our government with its first and most useful armored steamboats; who built the St. Louis bridge; who made one of the shallowest mouths of the Mississippi river permanently navigable for the use of ocean steamers; and who entertains other practical conceptions as grand as these, which, by his logical presentation, have won the unqualified indorsement of the ablest of his professional brethren, has a most evident title to recognition in scientific biography.

James Buchanan Eads was born in Lawrenceburg, Ind., May 23, 1820. "He very early," says Dr. Boynton, in the "History of the Navy during the Rebellion," "evinced such a love of machinery as attracted special notice." When only eight years old he watched with the greatest interest all the machinery to which he had access. When nine years old, the family removed to Louisville. The engine on board the boat excited so much admiration and wonder that the engineer was induced to explain to him the principal parts of the machine. So well did the lad profit by this one lesson in steam engineering that in little more than two years after he constructed a miniature engine which was worked by steam. When about ten years old, his father fitted for him a small workshop, and there he constructed models of saw mills, fire engines, steamboats, steam engines, electrical and other machines. One of the pastimes of his childhood was to take in pieces and put together again the family clock; and at twelve years he was able to do the same with a patent lever watch, with no tools but his pocket knife. When thirteen, misfortune overtook his father, and he had to withdraw from school and work his own way. His parents went to St. Louis in 1833 and he went with them. The steamer was burned in the night on the way there, and he landed barefooted and coatless, on the very spot now covered by the abutment of the great steel bridge which he designed and built. The only opening in the way of business that offered was to sell apples on the street, and by this means, for a few months, he sustained himself and assisted in supporting his mother and sisters. In time he obtained a situation with a mercantile firm, where he remained for five years. One of the heads of the house having an excellent library, gave him access to it, and he used his opportunity well to study subjects bearing upon



THE LATE CAPT. JAMES B. EADS.—*From The New South.*

mechanics, machinery, civil engineering, and physical science. In 1839 he obtained employment as a clerk or purser on a Mississippi river steamer. He again made the best use of his opportunity to acquire that complete knowledge of the great river which he was afterward able to turn to such good account in the noble enterprises he so fortunately carried into effect. In 1842 he constructed a diving bell boat to recover the cargoes of sunken steamers. This was followed with a boat of larger tonnage, provided with machinery for pumping out the sand and water and lifting the entire hull and cargo of the vessel. A company was formed to operate this device, and it soon had a business that covered the entire Mississippi river, from Balize to Galena, and even branched into some of its tributaries.

By his methods a great many valuable steamers were set afloat and restored to usefulness which it would not previously have been possible to save, as they would have been buried very soon beneath the river sands. It was while engaged in this business that he gained a thorough knowledge of the laws which control the flow of silt-bearing rivers, and of the Mississippi he was able to say years afterward that there was not a stretch in its bed fifty miles long, between St. Louis and New Orleans, in which he had not stood upon the bottom of the stream beneath the shelter of the diving bell.

In 1845 he sold out his interest in this company and established in St. Louis the first manufactory of glassware west of the Ohio river. Two years later this enterprise culminated in financial disaster, and left him, at the age of twenty-seven, burdened with debts to the amount of twenty-five thousand dollars. He then returned to the business of raising steamers, removing obstructions from the channel, and improving the harbor of St. Louis. By the great fire of 1849 twenty-nine steamers were burned at the landing of that city, and most of these wrecks had to be removed by him. The capital with which he started again at this business was supplied by his creditors, and amounted to only fifteen hundred dollars. Ten years later he had increased this modest sum to nearly half a million dollars, and had long previously paid off his creditors in full.

His first undertakings in this peculiar and instructive study of hydraulics occurred while he was constructing the first diving bell boat, not then completed. A barge loaded with about a hundred tons of pig lead was sunk upon the rapids of the Mississippi river, near Keokuk, in fifteen feet of water. A contract was made for the recovery of this lead. He had had no experience whatever with the submarine armor, or diving apparatus of any kind; but, engaging a diver from the Lakes, who was familiar with it, with an armor, an air pump, and a sailor skillful in the use of rigging, he started—at the time only twenty-two years of age—to the scene of the wreck. Obtaining a barge, this was promptly anchored over it, and preparations made for the diver to go to work; but the current was found so exceedingly rapid that it was impossible to use the armor with any safety. A belt around the diver's waist was attached by a cord to the bow of the boat to hold him against the current, and a ladder procured on which the diver undertook to descend, but it was impossible for him to control his body in the current. Determined not to be baffled, Mr. Eads immediately visited the town of Keokuk and purchased a forty gallon whisky barrel, with which to improvise a diving bell. With several pigs of lead secured around one end of the barrel by a network of ropes, and with that head taken out, a block and tackle attached to the network at the other end, and a temporary derrick erected, he was soon prepared to commence the recovery of the cargo. But the diver demurred and would not descend in this dangerous-looking apparatus. Mr. Eads then set an example which he has followed throughout all his varied experience as an engineer—which was, never to ask a man in his employ to go where he was unwilling to trust his own life. The bell thus suspended was held against the current by a rope which led up to the bow of the barge, and a strap across the lower end of the barrel was used as a seat for the diver in it. He at once got into the diving bell and ordered his men to lower him down. He had a trace chain attached to a lead line, the lower end of the trace chain having a ring in it, and with this he was readily enabled to form a loop, which was placed over one of the pigs of lead, and at a given signal it was hoisted up. A small cord sufficed to draw it back to him while he was still in the bell; and in this manner a number of the pigs, weighing seventy pounds each, were recovered before he started to come up—the air pump all the time supplying him with air. But, in the mean time, having cleared the space beneath the bell, the guy line moved it farther and farther up stream, in compliance with his signals, and instead of the line being slacked out again when his men commenced raising the bell, it was held so far forward that the derrick capsized, having no guy to hold it in the opposite direction. His assistants seized the block and tackle and pulled the whisky barrel up to the surface of the water by hand. But it was so weighted with the lead around it that they could not raise it higher. Not knowing what was the matter, he waited patiently, the air pump running with redoubled velocity, supplying him with plenty of air. He soon saw the fingers of a man under the chime of the barrel, and, recognizing this as an invitation, he seized the man's hand and got out from under the barrel, much to the delight of all on board. The derrick was then secured against any possible catastrophe occurring again, and, after a number of successful trips to the bottom, the diver was content to do the remainder of the work.

In 1856 Mr. Eads made a proposition to Congress to keep the channels of the Mississippi, Missouri, Ohio and Arkansas rivers clear of snags, wrecks, and other obstructions for a term of years. A bill embodying his plans was passed by the House of Representatives, but failed in the Senate for want of action by that body.

In 1857 his health compelled him to retire from business, and four years later he was called upon to render the most signal and brilliant services to his country in its time of extreme need. It was on the 17th of April, 1861, three days after the surrender of Fort Sumter, when Attorney-General Bates wrote to him from Washington: "Be not surprised if you are called here suddenly by telegram. If called, come instantly. Under a certain contingency, it will be necessary to have the aid of the most thorough knowledge of our Western rivers and the use of steam on them, and in that event I have advised that you be consulted."

The dispatch came shortly after the letter. Mr. Eads went immediately to Washington, and, after consulting with the President and cabinet, prepared the plan he was requested to submit to them for placing gunboats on the rivers, with suggestions as to the kind of boats best fitted for the service, and in regard to the location of batteries to be erected at several points on shore. Shortly afterward he was appointed, with Captain (afterward Rear-Admiral) John Rodgers, United States Navy, to carry into effect the recommendations which he had made, and at once to improvise three war vessels for service at Cairo. These were the Conestoga, Tyler and Lexington, and were the first of the large fleet that afterward covered the Mississippi river. The Quartermaster-General issued proposals soon after for the construction of seven ironclad gunboats. These were designed by Mr. Eads, and he undertook to build them in sixty-five days—a short enough time under the best of circumstances; but business was then disorganized and all industrial enterprises in a chaotic condition. The materials with which the work had to be done had to be manufactured. Yet these seven heavily plated vessels of about six hundred tons each were all finished according to contract, and another one still larger, a snag boat, was by alterations and heavy plating made ready with the others for their armament. "Thus one individual put into construction and pushed to completion within a hundred days a powerful squadron of eight steamers, aggregating five thousand tons, capable of steaming at nine knots per hour, large, heavily armed, fully equipped, and all ready for their armament of one hundred and seven large guns. The fact that such a work was done is nobler praise than any that can be bestowed by words"*

In 1862 Mr. Eads was commissioned to build six more armored iron gunboats, four of which were much larger than any of the eight preceding ones. These were likewise after his own designs, four of them having two turrets each and the smaller ones one turret each. These turrets were a modification of the Ericsson turrets, the government insisting upon these being placed upon them. He was, however, permitted to place one turret on each of two of these large gunboats after his own design, and costing about thirty-five thousand dollars each, but on the written condition that they should be replaced by Ericsson turrets if they were not found satisfactory. The guns in these two turrets were worked by steam, and this was the first time in the history of artillery practice when heavy guns were manipulated wholly by steam. These vessels all proved to be of lighter draught than had been stipulated, so that it was possible to add from half to three-quarters of an inch to their armor; and three of them exceeded very considerably the contract speed. While these fourteen ironclads were under way, Mr. Eads also had the construction of four heavy mortar boats and seven tinclad or musket proof boats. The kind of ironclads that Mr. Eads designed and constructed and the kind of work they did are recorded in the history of Grant and Halleck's campaigns, and of Farragut's capture of Mobile.

In the construction of a steel arch bridge at St. Louis, on which he was engaged from 1867 to 1874, Mr. Eads had to deal with problems which had not before confronted an engineer. The central arch of this structure has a clear span of five hundred and twenty feet, and pronounced by the "British Encyclopædia" the finest specimen of metal arch construction in the world. The side arches are five hundred and two feet each in span. All of the piers, in consequence of the shifting deposits beneath the river bed, were sunk clear through to the bed rock. This required them to be sunk much deeper than any piers ever built, and through a medium of the most treacherous character. New plans had to be devised to secure success. One pier, weighing forty-five thousand tons, was sunk to a depth of one hundred and thirty six feet below high water mark through ninety feet of sand and gravel; and another one, weighing forty thousand tons, to one hundred and thirty feet through eighty feet of deposit. The loss of life which occurred in the caisson of the east pier resulted from the fact that the situation at such a depth, with the air pressure it was necessary to endure, was entirely new, and there was no recorded experience by which operations could be guided safely.

The erection of the arches developed new problems. The arches had to be designed about two and a half inches longer than they are in their present position, because of the contraction which their weight causes throughout the arch. Each half of the arch was built out from the pier and suspended by guys passing through heavy masts erected on each pier, and the central tubes had to be specially fitted for insertion. The suggestion was made by his chief assistant to contract the tubes by boxing them up and covering them with iron. This Mr. Eads disapproved of, and devised telescopic tubes for the center of the arch, which could be shortened by an internal right and left hand screw plug, and afterward extended by powerful levers, to rotate this plug, steel bands being also provided to cover the plug, flush with the outside of the tube, when the tubes were properly distended. During his absence in London, the chief assistant, confident of his ability to close them with ice, and having been left with full authority, undertook to do so; but the attempt proved a failure after a trial of eight or ten days, and the telescopic tubes, which Mr. Eads had prepared, were then inserted without difficulty.

In an address delivered at the opening of this bridge, July 4, 1874, Mr. Eads revealed that confidence in his resources and investigations which probably furnishes one of the keys to the secret of his success in this and his other enterprises. This secret consists in the fact that his courage is always equal to his convictions. Everything, he said on this occasion, which prudence, judgment, and the present state of science could suggest to him and his assistants had been carefully observed in its design and construction; every computation involving its safety had been made by different individuals, thoroughly competent to make them; they had been carefully revised, time and again, re-examined, verified, until the possibility of error nowhere existed.

A similar confidence was displayed in his plans for deepening the mouth of the Mississippi by jetties, in which he was opposed by nearly all of the United States engineers, and by a commission of seven of them. The commission in 1874 proposed to avoid the bars by building a canal from Fort St. Philip to Breton Bay. Mr. Eads' plan was to make the river itself deepen a channel through them. Congress naturally inclined to adopt the advice of its official experts, but Mr. Eads had faith enough in his plan to propose to do the work at his own expense and wait for his pay until he had demonstrated its success. It was hard to get permission to make even the experimental application of his views thus so liberally proposed; but a bill was finally passed to allow him to attempt the improvement of the South Pass, the smallest of the three, and not the one he had selected; and the depth on the bar of which was only eight feet. The cost of the work was to be five and a quarter million dollars; only half a million was to be paid after a channel twenty feet deep by 200 feet in width had been secured, another half million after a channel twenty-two feet deep, and other sums on the obtaining of channels of twenty-six and twenty-eight feet depth respectively, but, as a guarantee that the maintenance of the channel should not cost more than one hundred thousand dollars a year, the final million of the whole sum was to be withheld until a channel of thirty feet maximum depth had been kept throughout during twenty years. Congress, however, deeming these terms unnecessarily severe, with remarkable unanimity voted to pay him one and three-quarter million dollars in advance of his contract terms, after he had secured twenty-two feet depth.

The conception of the plan of the jetties was based upon a knowledge of the fact that the Mississippi river is a transporter of solid material, almost all of which is held in suspension by the mechanical effect of the current, and that the quantity of the matter which it is able to carry increases with the square of the velocity. The current of the river is caused by the fall of the water from a higher to a lower level, that is, by the force of gravity. The element which resists the current is the friction of its bed. This friction does not follow the law of solids, but increases or diminishes exactly as the width of the bed or wetted perimeter of its cross section is increased or diminished. Hence, if the stream be contracted, where it is too wide, to one-half its width, one-half of the frictional resistance will be gone, and the current will be more rapid, and, therefore, more able to carry a larger load of sediment. This it immediately takes up from its own bed, and thus causes a deepening. The result of the application of the jetty system to the South Pass has been a triumphant justification of its author's views.

On the 8th of July, four years after he commenced the work at the jetties, the United States inspecting officer reported the maximum depth of thirty feet had been secured throughout the jetty channel, and that the least width of the twenty-six feet channel through the jetties was two hundred feet. The balance due Mr. Eads upon his contract was then paid to him, and the million that was to be held as security for maintenance was considered as earned, and placed at interest for his benefit. The current of the river has maintained this depth ever since. The cost of the jetties was about half of the estimated cost of the proposed canal.

Mr. Eads had not commenced the jetties before he turned his attention to the improvement of eleven hundred miles of the Mississippi throughout its alluvial basin by the jetty system. On March 15, 1874, in a letter to the Hon. William Windom, chairman of the Senate Committee on Transportation Routes to the Seaboard, the first outline of this novel plan was suggested. In his review of the United States Levee Commission, February 19, 1876, Mr. Eads said:

"By the undercharge theory of the Delta Survey Report, caving banks are attributed to the direct action of the current against them, by which strata of sand underlying those of clay are supposed to be washed out. This is not correct. If the water be charged with sediment to its normal supporting capacity, it cannot take up more unless the rate of current be increased. Caving banks are caused wholly by the alternations in the velocity of the current. Alternations are inseparable from a curved channel, because the current in the bend is usually more rapid than on the point; but if the channel be nearly uniform in width, the caving caused by the curves will be very trifling. And, in proof of this, many abrupt bends exist in the lower part of the river where the whole force of the current has set for years directly against them without any important caving of the banks. The bend at Fort St. Philip is a notable instance, the great difference in the width of the flood channel constituting the real cause of the destruction and caving of the banks. This tends to great irregularities in the slope of the flood line, and, consequently, great changes in current velocity, by which a scouring and depositing action are alternately brought into very active operation. The whole of the river below Red river proves this. Caving banks are much less frequent there than above, because the flood width of the river is far more uniform. A correction of the *high water channel*, by reducing it to an approximate uniformity of width, would give uniformity to its slope and current, almost entirely preventing the caving of its banks, and through its present shallows, which now constitute the resting places for its snags, there would be a navigable depth, in *low water*, equal to that which now exists in its bends. By such correction the flood slope can be permanently lowered, and in this way the entire alluvial basin, from Vicksburg to Cairo, can be lifted, as it were, above all overflow, and levees in that part of the river rendered useless. *There can be no question of this fact, and it is well for those most deeply interested to ponder it carefully before rejecting it, for the increased value given to the territory thus reclaimed can scarcely be estimated.*"

Two years later, in a review of Humphreys and Abbot's "Report on the Physics and Hydraulics of the Mississippi River," published in Van Nostrand's *Engineering Magazine*, Mr. Eads elaborated this plan, and combated the declaration that the bed of the river is formed of blue clay and will not erode unless very slowly under the effect of the current, and likewise exposed the fallacy of the declaration that there is no relation between the quantity of sediment carried in the water and the velocity of its current.

Mr. Eads thus clearly outlined, in 1874, 1876, and 1878, one of the most magnificent plans which hydraulic engineering has ever undertaken. It is not simply to

* Boynton's "History of the Navy during the Rebellion."

save thirty thousand square miles of land as rich as the Delta of Egypt from devastating inundations, but to extend deep water from the Gulf of Mexico to the mouth of the Ohio, into the very heart of the Mississippi valley, while permanently locating this magnificent channel by practically putting an end to the caving of its banks. During the period we have referred to, Mr. Eads delivered addresses upon this subject in the chief cities of the river, published elaborate essays in which it was fully explained, and defended it against all attacks, until finally, in 1879, Congress authorized the creation of a commission to consider this plan, which is known as the "jetty system." The "outlet system" and the "levee system" were also examined by it, and in 1880 it reported in favor of the "jetty system," and recommended its adoption by Congress in its report, February 17, 1880. Mr. Eads was a member of the commission for two or three years. During this period several million dollars were voted by Congress to carry out the plan, which will be found described in the report referred to, as agreeing substantially with the quotations we have made. Two reaches of the river, Plum Point, twenty miles long, and Lake Providence, thirty-five miles long, were selected for improvement. The low water depth in the first reach was only five feet, the other reach (four hundred miles below) had a depth of only six feet. The permeable contraction works, constructed of piles and willows, which had been first used by Mr. Eads at the South Pass several years before, were put in position for one season in the period between two floods, and the effect produced by the works during the first flood that followed was simply marvelous. The depth was increased through the upper reach to twelve feet at low water, and through the lower reach to fifteen feet, and scores of millions of cubic yards of sediment were deposited between them by the checking of the current by the permeable works. Thus, new shore lines of an approximately uniform width were developed. In some places the deposit was thirty feet deep.

Mr. Eads was, during the time of this construction, in bad health, and for some time absent from the United States. Owing to the charge made by several prominent friends of the river (members of the Senate and House), that the commission had abandoned the leading feature of the system, the contraction works, and had changed it to a costly system of bank revetments, and the public declarations of Mr. Eads to the same effect, no further appropriations were made at the last session of Congress to continue this magnificent work. Enough has been done, however, to show the entire practicability of the plan.

Mr. Eads claims that this system of improvement designed by him is, in several respects, wholly different from any ever before proposed for the treatment of a river. It is, however, only applicable to rivers flowing through alluvial deposits.

The grandest work, however, contemplated by Mr. Eads is the ship railway which he proposes to construct across the isthmus of Tehuantepec, for the transportation of large ships fully laden from ocean to ocean. This he holds to be entirely practicable—because the railway can be built wherever the canal can, at one half the cost of the canal with locks, or one-quarter the cost of one at tide level, because it can be built in one-third or one-quarter of the time needed to build a canal, because four or five times the speed practicable on a canal can be secured, because more vessels can be carried in a day over the railway than through the canal, because the capacity of the railway can be increased to suit increased needs without disturbance, because it will cost less to maintain and operate it than to maintain and operate a canal, because it can be built and operated where the canal cannot be, because more accurate estimates can be made of the cost and time needed for its construction, and because its location is the very best of all those which are proposed on the American isthmus. It is not generally known, but it is, nevertheless, true, that the location of the ship railway and that of the Panama canal are about twelve hundred statute miles apart, the whole immense territory of Central America lying between the two. It is, therefore, far superior in climate and in position to any other location.

Besides these works, Mr. Eads has, at the request of the governments and individuals particularly interested, examined and reported upon the bar at the mouth of the St. John's river, Florida, the improvement of the Sacramento river, the improvement of the harbor of Toronto, the improvement of the port of Vera Cruz, the improvement of the harbor of Tampico, the improvement of the harbor of Galveston, and the estuary and port of the Mersey, England. He was president of the St. Louis Academy of Science for two terms, and made an inaugural address in which was embodied a review of the recent achievements of science, and, in another, the present knowledge of the laws of light. In 1881 he made an extemporary address before the British Association at York, upon the improvement of the Mississippi, and also upon the Tehuantepec ship railway, which were, by unanimous vote, ordered to be embodied in its report of the proceedings, and in June, 1881, he was awarded the Albert medal of the British Society of Arts, in token of its appreciation of the services he had rendered to the science of engineering—he being the first American upon whom this medal had been conferred. It is now his purpose to devote the remaining energies of his life, until the scheme is an accomplished fact, to the prosecution of the ship railway.—*Popular Science Monthly, New York.*

For another excellent sketch of the life of Capt. Eads, see SUPPLEMENT, No. 588.

THE FISH TORPEDO.

PERHAPS no invention ever gained a reputation so quickly and so cheaply as the Whitehead or fish torpedo. The idea of its construction was first suggested by an Austrian marine artillery officer, who is now dead. In the year 1864, Mr. Robert Whitehead, who was acting in the capacity of manager to an iron works at Fiume, a seaport in Austria, situated at the head of the Adriatic Gulf, took the matter up, and, after a long series of experiments, produced the Whitehead torpedo.

In the year 1870, Mr. Whitehead came to England, and put his invention before the British Admiralty. He was afforded a trial, and succeeded in destroying an old hulk which was moored at the mouth of the River Medway. From that date the fortune of the Whitehead torpedo, or, rather, of its inventor, may be said to have been made. He received at the time seventeen thousand pounds ($85,000) for the secret of his invention. Since that date nearly all the European governments have purchased Mr. Whitehead's secret, in addition to which a large and doubtless lucrative business has been carried on at Fiume in the manufacture of the weapons themselves.

The Whitehead torpedo consists mainly of a steel outer shell, which is from fourteen to sixteen inches in diameter in the center, and from thence it tapers to a point at each end. The length is either fourteen feet or nineteen feet. It is propelled by means of two screws, which are actuated by a small engine, as in an ordinary steamboat. In place, however, of the boiler and furnace, which, of course, would be impossible in such a position, there is a strong reservoir made of Whitworth fluid pressed steel. Into this air is pumped until it has reached a pressure of about 1,000 lb. to the square inch, although in the most recent Woolwich made torpedoes the pressure has been increased by 200 lb. additional, bringing it to 1,200 lb. to the square inch. In the front part of the weapon is placed the explosive charge. By making the bows bluffer, which, however, has not detracted from the speed, more storage room has been found for the charge, which now consists of 70 lb. of damp gun cotton. The original Woolwich Whitehead torpedo carried only 33 lb. of gun cotton.

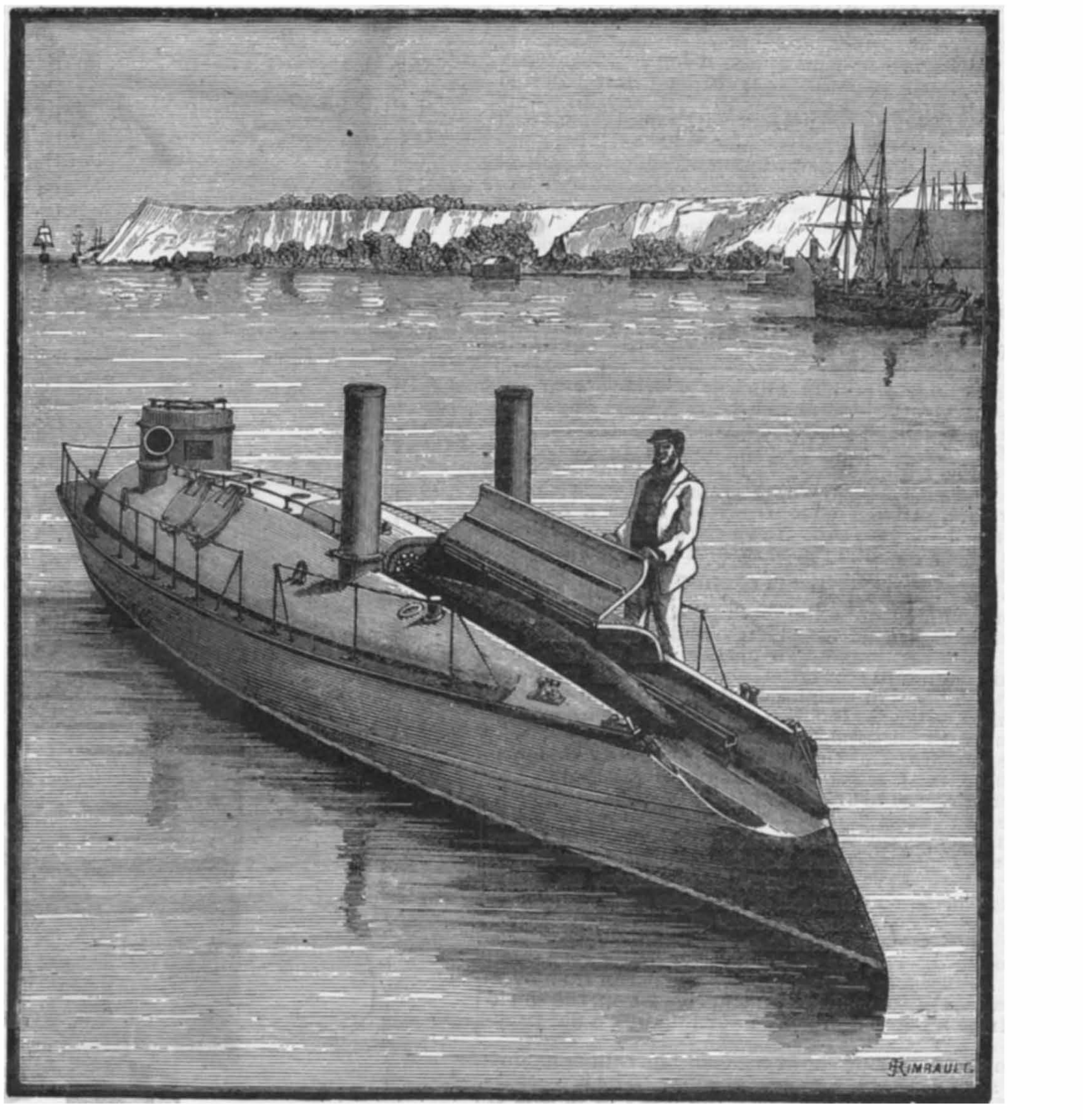
The great feature about the Whitehead torpedo is the mechanism by which the depth at which it travels in the water is provided for. It will be easily understood that if the specific gravity of the whole weapon were less than that of water, it would float at the surface, more or less out of water, while if the specific gravity were greater than water, it would certainly sink, for there are no half measures about flotation. It is this part of the apparatus which constitutes the secret, and so important was this considered that all persons who were intrusted with the details had to make a declaration that they would not make them known.

The Turkish government did not purchase this secret from Mr. Whitehead, but they became acquainted with it through a torpedo being fired at their ships by the Russians during the Russo-Turkish war. This weapon missed its mark and came ashore unexploded. It was taken possession of by the Turks, who thus had an opportunity of studying its mechanism without being under any engagement as to secrecy. Lieutenant Sleeman was at the time in the Ottoman navy, and in his book on the torpedo he thus describes this part of the weapon:

"The torpedo is maintained at the desired depth by means of a certain mechanical apparatus contained within the adjustment chamber, and which constitutes what is called the secret of the fish torpedo. This chamber is connected by screws to the foremost and after chambers of the torpedo in such a manner that by means of a number of holes bored round the circumference, the faces of the chamber are exposed to the pressure of the water, which varies with the depth to which the torpedo descends. Within the adjustment chamber is an endless strong spiral spring attached to the after face of the chamber, and so arranged that after being set to a certain tension, capable of resisting an equivalent pressure on the outside of the aforesaid face, any increase or decrease in this exterior pressure will cause the spiral spring to work a rod by which the horizontal rudders of the torpedo are regulated, and thus the desired depth for which the spring is set is maintained. The course of the torpedo is represented by a series of curves, above and below the line, corresponding to the depth set for. These curves gradually decrease, until, at one hundred yards' distance, they are so small that the path is almost identical with a straight line."

There is also fitted a swinging weight which assists the action.

The weapon can be adjusted to explode either by contact with the side of the attacked vessel or at the expiration of a certain time. It can be set to travel at any depth between five and fifteen feet. It can be arranged at will to either float or sink at the end of a run, so that if it were set for contact firing, and did not hit its mark, it could not be captured by the enemy. At the same time it can be recovered after a practice run in peace time. The standard speed for a modern Woolwich Whitehead torpedo is at the rate of twenty-four and a half knots an hour, and it will travel at this rate for six hundred yards. It is said, however, that twenty-six knots has been reached for this distance, while one torpedo ran for four hundred yards at the rate of twenty-seven knots an hour. It is needless to say that no vessel that ever yet floated can attain this speed. The method of ejecting the fish torpedo from a vessel is an important feature, and one on which its efficiency to a great extent depends. In those wonderful craft the torpedo boats, which are built solely for operating with this weapon, there are two methods of sending it on its errand of destruction. In the first a tube or gun is built into the structure of the vessel itself, the launching then being effected over the bow. Our illustration shows a torpedo boat constructed by Messrs. Yarrow & Co., the well-known builders of these craft. The torpedo may be plainly seen in its berth, but when the cover is shut it is snugly tucked away out of sight. In the larger boats of this class two torpedo tubes are placed side by side. The second method of firing is by torpedo tubes, or guns, as they are generally called, being mounted separately on deck. They are generally fixed on a turn-table, so that they can be turned to point toward the enemy without moving the boat. In the built-in system, the vessel itself must be maneuvered to point to the object—often no easy matter in a seaway.



YARROW TORPEDO BOAT, SHOWING WHITEHEAD TORPEDO IN POSITION.

The launching impulse can be given either by compressed air, steam, or gunpowder. There is a small cylinder at the rear of the tube, and in this a piston works, having a projecting piston rod which is arranged to strike the end of the torpedo when the launching is to be effected. On the compressed air or steam being admitted to the cylinder, or the gunpowder being exploded, the piston is thrust forward, and the impulse is thus given. The gunpowder method is the most recent, and is generally considered the most efficient system of launching.

The reputation of the Whitehead torpedo as an engine of destruction has been somewhat shaken of late, in consequence of experiments made at Portsmouth on H. M. S. Resistance, an obsolete ironclad which was condemned to a species of naval vivisection in the interests of science. It would take too much space to describe the trials that took place, but it will be sufficient to say that the torpedo failed to actually sink the ship, although exploded in contact with her side. This was altogether an unexpected result, and naval men have begun to think lately that they have been taking the enormous destructive powers with which the torpedo has been credited a little too much on trust. Whatever may be said, however, there is no doubt but that the

fish torpedo is a weapon of enormous possibilities, and no maritime nation can afford to neglect it. Whether these possibilities could be realized in actual warfare, we hope will remain forever a sealed b●●k.—*Scientific News.*

THE MAXIM GUN.

About two years ago this journal gave to its readers a description of the Maxim automatic gun, showing this invention in its primitive condition. Since that time, however, great changes have been made.

The original gun was interesting on account of its being the first ever constructed in the world in which the functions of loading and firing were performed by energy derived from the recoil. The gun as it existed at that time was rather too heavy and complicated, but it operated well and fired with great rapidity. The advent of this first gun created a great stir in military and scientific circles. Thousands flocked to see it and to witness its amazing rapidity of fire, and the inventor was pressed to fill orders from all quarters. He, however, steadily refused to allow a gun to go out of his possession, believing that he would be able to greatly reduce the number of parts, its weight, and its cost.

Among the first officers who visited the inventor's experimental factory was Lieutenant-General Sir Andrew Clarke, then Inspector-General of Fortifications. He advised the inventor to simplify his gun as much as possible, and said, "Do not give up until you make it so simple that it can all be taken apart, examined, and cleaned, with no other instruments than the hands." The inventor acting upon this advice designed a wholly new action, altogether different to that employed before, and indeed to that employed in any other gun, and this gun as made at present may be taken apart in three seconds, and put together again and fired in three seconds. If anything happens to the lock, the whole lock may be taken out and a new one replaced, in six seconds.

The gun as now simplified, and of which we present engravings, consists of an ordinary gun barrel, two thirds of which is inclosed in a tubular casing; the other third is inclosed in a rectangular steel case. Inside of this case the breech block or bolt operates; the main spring, the tumbler, the firing pin, and the sears are exactly like those employed in an ordinary one barrel pistol.

The cartridges, which are placed side by side in a belt, are fed into the gun at F, Fig. 2, by a bell crank lever, one end of which is attached to the barrel, and the other end to a slide which is provided with two fingers. As the barrel recoils, these fingers slide back and engage a new cartridge. After the recoil the gun is pushed forward into the firing position by the action of the coiled spring, shown in Fig. 1, and this action of the barrel moves a fresh cartridge into position. A transversely moving slide, D, which forms a part of the breech block, seizes the cartridges in the belt, draws them out, and deposits them one by one in the barrel.

One of our illustrations represents a gun of rifle caliber mounted on a light tripod, and provided with a shield constructed in such a manner that it may be folded to resist bullets, or opened and the top leaf turned backward over the gunner's head to resist arrows. This gun weighs 42 lb.; the tripod without the shield weighs 50 lb.; and the swivel which connects the gun with the tripod weighs 16 lb.

The mounting of this gun was expressly designed for the African traveler Mr. Henry M. Stanley. The rate of fire is 660 to 670 shots per minute.

The small tank shown on the shield is connected with the tube about the water jacket in such a manner that each recoil of the barrel admits a definite quantity of water, which cools the barrel and escapes as steam through orifices at the end of the tube near the muzzle of the gun. The actual amount of heat developed by firing one cartridge containing 85 grains of powder is 1½ units. It will, therefore, be seen that a very small quantity of water suffices to keep the barrel from overheating. For convenience in transportation, the shield and tripod may be quickly folded up into a flat package.

Another engraving shows a gun of 1 in. caliber mounted on a cone suitable for naval purposes. The projectiles are of hardened steel, and pass through 1 in. of iron at 100 yards range. This gun is intended as an anti-torpedo boat gun, and as it is mounted on a universal joint, it may be turned in any direction freely while firing. The rate of discharge is 280 shots per minute.

The following advantages are claimed for the automatic system of guns: Weight for weight, guns of this system fire vastly more rounds per minute than is possible with any other system. It requires but one gunner to operate them. The magazine being below the gun does not present a target to the enemy's fire like one placed above the gun, and, moreover, no one has to stand up to place the cartridges in a high magazine on the top of the gun.

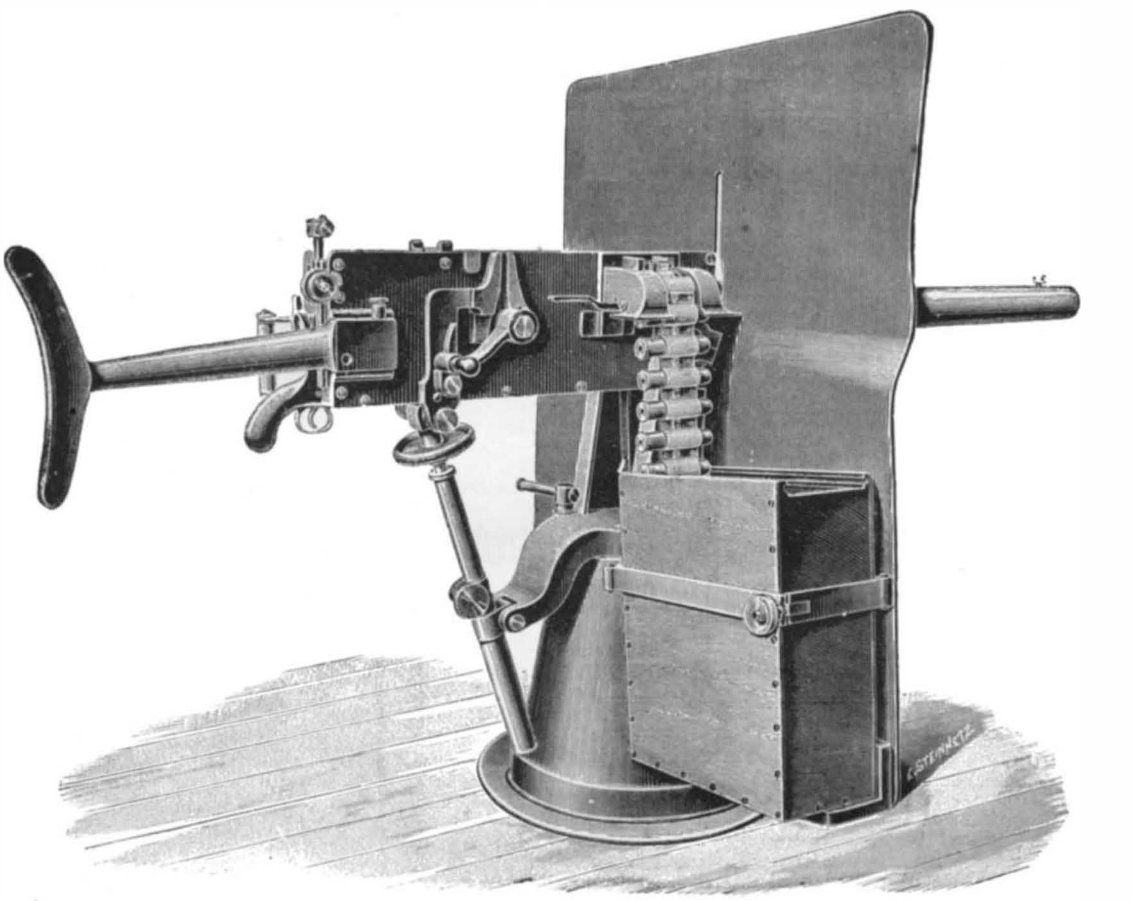
The magazine being below the gun and the cartridges placed in a tape, many more can be packed in the same space, and a much larger magazine employed than is possible with any other gun. In some cases over 2,000 rounds have been fired from a single belt out of a single magazine. There is no crank or handle to be operated by hand, and, consequently, no tendency for the gun to be disturbed while firing. As no external force is used to operate the gun, it may be mounted upon a very light mount or carriage, and may be trained in any direction while firing, with the greatest facility. The feed of cartridges is positive, and does not depend upon gravity. The extraction is unique. The cartridges are seized by both sides of the head by a slide which passes over them in a transverse direction, there being no spring employed. When a cartridge is fired, the shell is pulled out of the barrel by both sides, and is moved in a transverse direction by the slide. The uncertainty due to the ordinary spring extractors, which have given so much trouble to other machine guns, is, therefore, completely obviated. Another advantage, and by no means the least, is the fact that with the automatic system it is quite impossible that the breech should be unlocked and the cartridges withdrawn while in the act of exploding. The greatest enemy that machine guns operated by hand have to contend with is that all cartridges do not explode at the instant of being struck; a certain percentage of them "hang fire," for only a short time it is true, but sufficient, when the crank is being turned or the handle being worked at a high speed, to allow of the breech being opened while the cartridge is in the act of exploding. This always renders the gun *hors de combat*, and sometimes blows up the magazine. With the automatic system this cannot occur, because the force which opens the breech is derived from the cartridge which happens to be in the barrel at that time. If the cartridge is struck and does not explode at the very instant of being struck, the gun waits for it. When, however, the explosion does occur, the barrel recoils, and the empty shell is withdrawn exactly in the same manner as with cartridges which do not "hang fire."

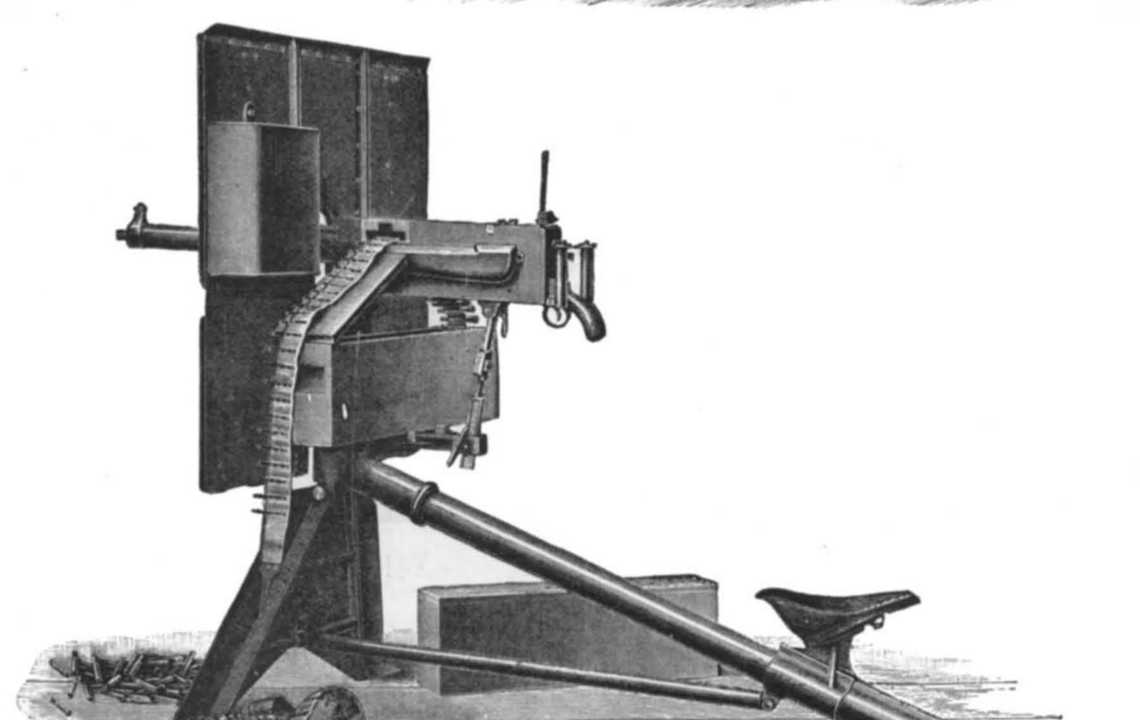
The British government was among the first to order one of these guns, and it was specified that it should not weigh over 100 lb., and that it should be able to fire 400 rounds in one minute, 600 rounds in two minutes, and 1,000 in four minutes.

Three guns were submitted by the inventor to a duly appointed committee. The first gun tested was fired rapidly at first, in order to come within the 400 in one minute; then the speed was reduced, and it fired its thousandth cartridge just inside of the four minutes. The second gun tested fired 400 shots in forty-five seconds, and finished the thousand rounds in three minutes twenty-two seconds. These two guns were provided with water jackets inclosing the barrel. The third gun was then tried, in which the supply of water was from the base. The gun fired 1,000 rounds in a minute and a half, and continuing to fire, it scored 2,115 rounds in three minutes forty-five seconds. The two first guns weighed 50 lb. each, and the last one 42 lb. After this remarkable record, the committee submitted the guns to the sand test, all parts being sprinkled with dry, sharp sand.

Sand was also sprinkled on the feed belt in the magazine. The rate of firing was greatly reduced; nevertheless, the gun fired at the rate of 400 shots per minute. The gunner then took the lock out, wiped it, and replaced it, when a box of 333 cartridges was fired in half a minute. The gun was next submitted to the rust test, and while still wet and full of dirty water, it was again fired at a much reduced speed, a box of 333 cartridges passing through in fifty seconds. The parts were then wiped and oiled, and a box of 333 cartridges was again fired in half a minute. These guns used the Gatling cartridge, having 85 grains of powder and 480 grains of lead. With the American service cartridge, which is shorter, the rate of firing would have been about 700 rounds per minute. It will be seen that for weight and rapidity of fire the guns went far beyond the requirements, while the sand and rust tests were most satisfactory. The committee made arrangements on the spot for the purchase of the three guns submitted.

Referring to the diagrams, Figs. 1 and 2, which illustrate the mechanism of the rifle caliber gun, the section Fig. 2 shows the position of the parts in firing position; directly an explosion has taken place, the whole of the breech block and the barrel attached to it are forced back inside the casing, consisting of two steel side plates, AA, a bottom plate, B, a hinged cover, C, and two gun metal end pieces, D and E, the latter with an extension, L, forming the water chamber for the steel barrel. This recoil at first forces the block, G, to slide back in the slots, *b*, provided in the side plates; this motion brings the curved bar, *c*, Fig. 1, into contact with the fixed curved piece, *a*. The curved lever, *c*, and the crank are thus given a gradually accelerated rotary motion of nearly half a revolution until the extended arm on the crank shown in Fig. 1 in front of the fixed piece, *a*, is stopped by the spring, *d*, and the whole mechanism is at once drawn back again by the coiled spring shown in Fig. 1, the chain at the end of which was wound over an eccentric cam on the block, G. These rear and forward movements of the internal mechanism of the gun perform all the operations necessary to place the weapon again into firing position; the cartridge extractor, *m*, draws the new cartridge out

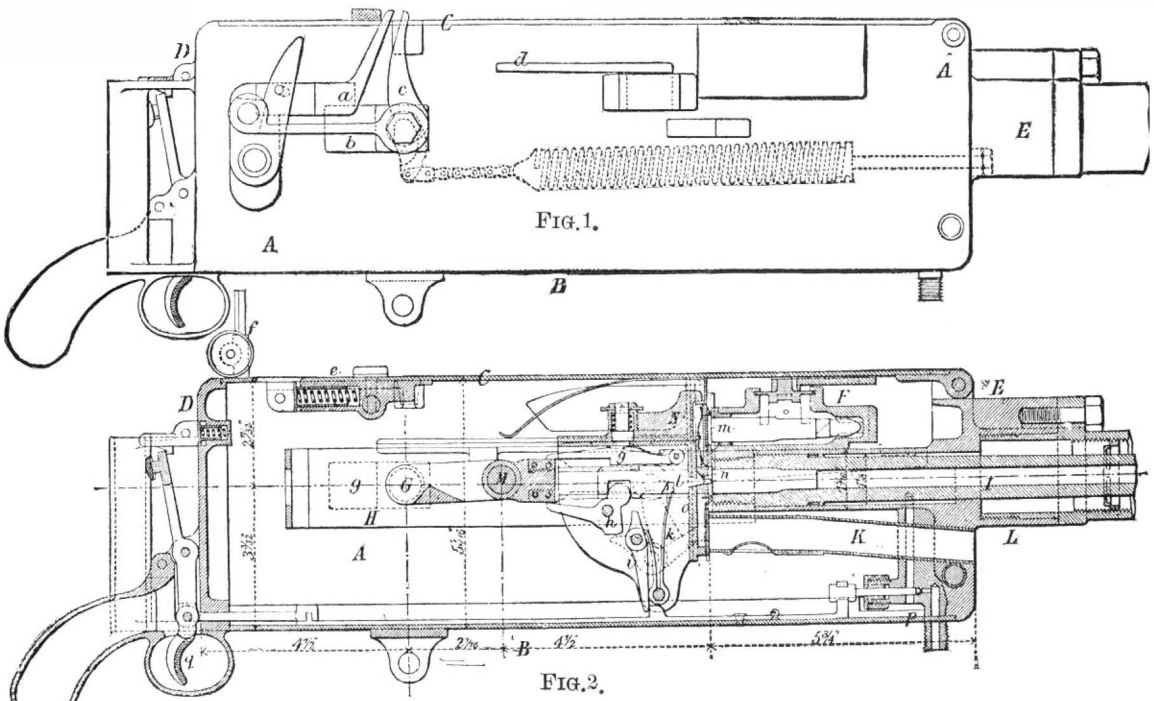




THE MAXIM GUN.

of the casing, F, while at the same moment the discharged cartridge is withdrawn from the barrel; when at the end of the backward movement the extractor device drops, bringing the empty case opposite the discharge tube, K, and the fresh cartridge opposite the breech of the barrel.

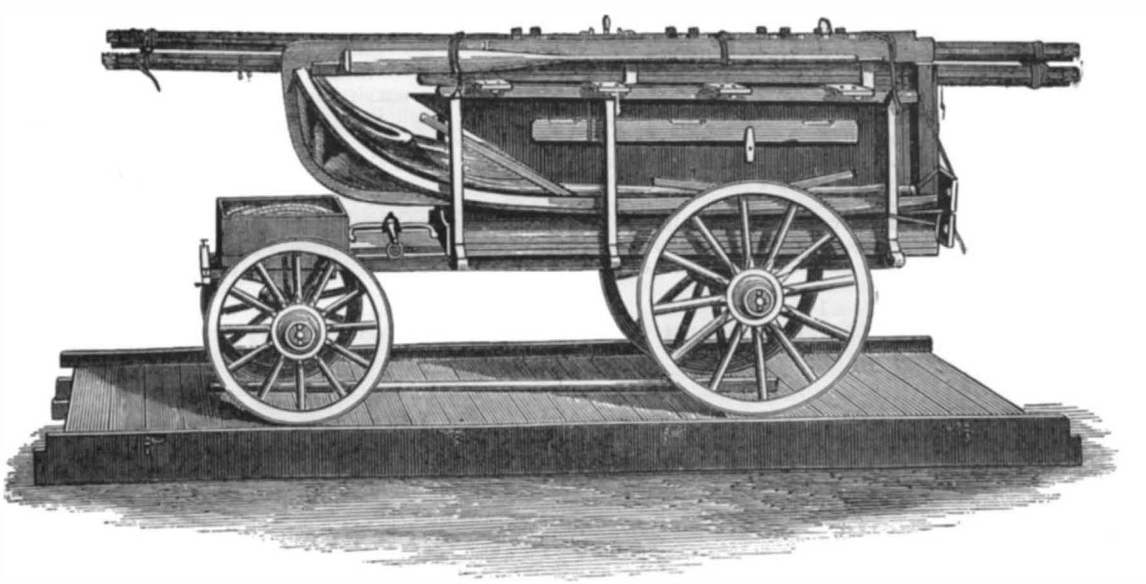
The gun would continue to discharge shot after shot almost continuously, if it were not prevented from firing by a finger on the bar hinged to the trigger, *q*, and lying on the bottom of the casing, B; but by pulling the trigger and fixing it in the firing position by means of the spring catch attached to the block, D, a continuous discharge of the gun will be the result. The trigger bar is extended, as shown, to the front end of the casing at *p*, where it works a valve, opening at every action of the trigger to admit a small amount of water to the cooling chamber round the gun barrel; the screwed nipple, *p*, is connected to a water reservoir, and several methods for the automatic supply of water to the chamber have been devised by Mr. Maxim, to which we shall refer in a future article. In our illustration, *f* is the sight shown somewhat shortened, and *e* represents a spring catch which holds down the hinged lever, *c*, and can only be opened when the gun is in the non-firing position; the whole breech block can be taken out, cleaned, and returned in a few seconds.—*Engineering.*



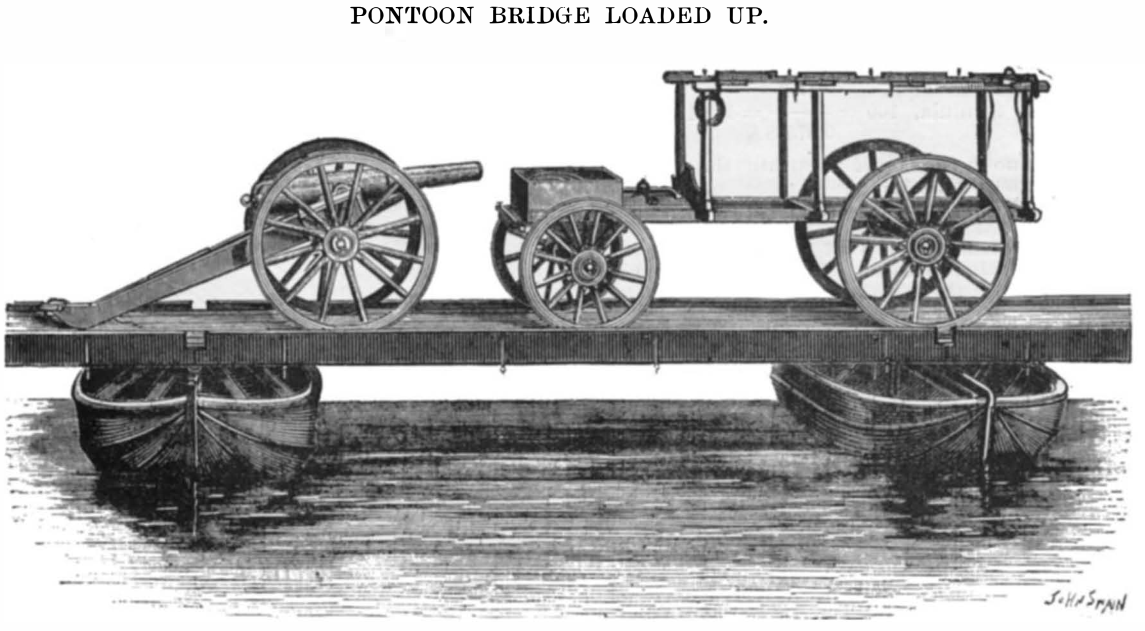
THE MAXIM GUN.

THE BERTHON PONTOON BRIDGE.

SIR HOWARD DOUGLAS, in his celebrated and standard work on "Military Bridges," expressed the opinion that if the Berthon boats could be made light enough they would be admirably adapted to the purpose of pontoons for bridges. This condition is now fulfilled, for they are actually only about half the weight of those in general use. The new collapsible pontoon possesses several very great advantages: 1. Being duplex—*i. e.*, divided transversely into two halves—its length when carried is reduced to half that of ordinary pontoons. 2. Though much wider, it shuts into one-seventh part of its beam—*i. e.*, a pontoon which is 7 ft. wide when open is only 1 ft. when shut. 3. For light bridges the halves may be used singly, and so double the length of bridge that might be formed of any number of whole pontoons. Our first engraving represents a carriage loaded with one complete unit of a pontoon train, consisting of one duplex pontoon 26 ft. by 7 ft., six balks, 20 ft. long, twenty chesses—planks—10 ft. by 1 ft., twelve bearers, oars, cables, anchor, etc. Total weight, including the carriage, 2 tons 4 cwt. Our second engraving represents the carriage unloaded and standing on the light bridge. To make the above more clear, let it be understood that each carriage load comprises a pontoon and all kinds of superstructure for a heavy bridge 20 ft. long and 10 ft. wide, or a light bridge 40 ft. long, 5 ft. 4 in. wide, which admits of guns and military wagons being drawn across by hand, the horses following singly. By order of the Ministre de la Guerre, in Paris, several officers of the French army went to Romsey a few weeks ago to see these bridges thrown across the river Test and crowded with men and wagons; and there is no doubt of their adoption. The displacement of each 26 ft. by 7 ft. pontoon is ten tons.—*The Engineer.*



PONTOON BRIDGE LOADED UP.



PONTOON BRIDGE IN PLACE.

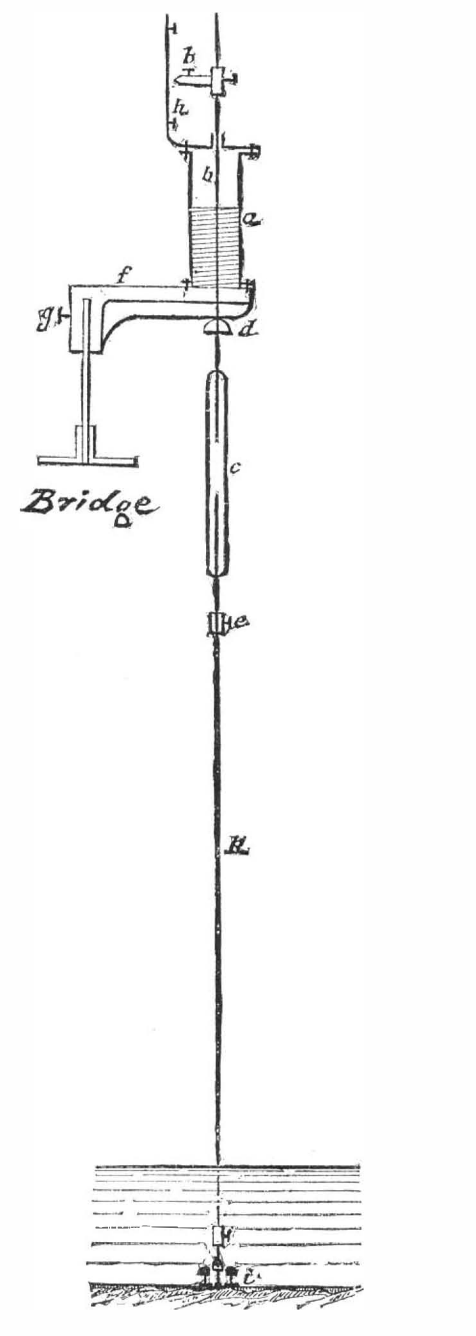
THE BERTHON PONTOON BRIDGE.

APPARATUS FOR MEASURING BRIDGE DEFLECTIONS.

THE accurate measurement of the deflection of metallic bridges, under the weight of railway trains, is a matter of much importance. In cases in which bridges are thrown over deep ravines, it is quite difficult to use ordinary leveling apparatus, and, on another hand, the data that such apparatus furnish are forcedly inaccurate.

It was for the purpose of remedying such inconveniences that Mr. Frau, chief engineer of the Palatinate Railways, was led to devise a simple apparatus, which is illustrated herewith, and which is now in use on several German lines.

Mr. Frau's apparatus consists essentially of a hollow iron cylinder, *a*, containing a strong spiral spring and resting upon an iron plate, *f*, fixed to the bridge by a



APPARATUS FOR MEASURING BRIDGE DEFLECTIONS. (Scale 1-10.)

screw, *g*. This cylinder is traversed by a rod, *t*, that carries at the upper extremity a pencil, *b*, whose point traces the deflections of the bridge upon a tablet, *h*, fixed to the cylinder.

The other extremity of the rod, *t*, which carries a clamp, *e*, seizes the upper extremity of a wire, *k*, which at the lower extremity is held by rails or other heavy bodies, *i*, deposited at the bottom of the river. A traction apparatus, *c*, permits of tautening the wire, *k*, until the pencil, *b*, upon the spiral spring being compressed, descends to a point marked as zero. When heavy loads are carried over a bridge, its girders bend, and the cylinder, *a*, descends with them. The tablet, *h*, follows these motions, and the pencil, which remains immovable under the action of the initial tension of the rod, *t*, traces upon the tablet a curve that represents the true extent of the bridge's deflections.—*Annales Industrielles.*

COTTON is not a fiber, but a plant hair. It holds to be spun into a thread because of peculiar twists in each hair, shown under the microscope, especially in polarized light. Linen thread may be spun because the flax fibers have certain roughnesses on their surfaces, which enable them to cling together. Hence it is impossible to make as fine linen as cotton cloth, but it is much stronger.

LIMITING NUMBERS OF TEETH.

By GEORGE B. GRANT, Boston.

THERE is nothing in the theory of gear wheels, unless it is the skew bevel gear, which so confuses the student as the determination of the limiting numbers of teeth when small pinions must be used. The doctors disagree, badly, on this difficult subject, and any attempt to decide between them, or to examine their work by the aid of the methods they give, leads to a maze of trigonometrical computation that is tedious and bewildering. The mere statement of the problem and conditions is simple enough, but to express the limits in figures is altogether another matter.

The general problem, without regard to the form of tooth in use, is as follows. A gear having d teeth, radius O D, Fig. 1, drives a gear, radius O F, having f teeth. The driver is limited to a certain arc of recess, O R, which is given in terms of the pitch, O P, and the thickness of the tooth on the pitch line is limited to a certain amount, 2 T R, which is also given in terms of the pitch.

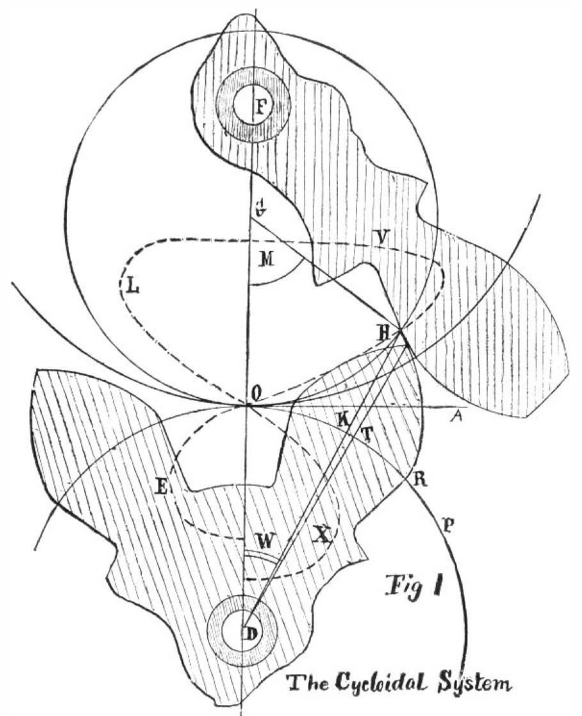


Fig 1
The Cycloidal System

When the given arc of recess has been taken up, the point of contact is at H, on the line of action, the broken line, O H V, and the whole problem is to so determine this line of action that the radial line, H D, shall cut off a distance, R K, on the pitch line of the driver which is not greater than the half tooth arc, R T. For if R K is greater than R T, as it is in the figure, the point of the tooth will have left the line of contact before the given recess has been taken up, and the action will be impossible.

It is seen that the position of the point, H, is completely determined, for a given driver and a line of action of given form, by the given arc of recess and the given tooth arc, and that in all cases the limit is fixed by these data.

By the theory of the gear tooth, the form and size of the line of action, O E X, for the approaching action, is in general independent of the form and size of the line, O H V, for the receding action; but if the gears are to belong to an interchangeable set, the lines must be equal to each other.

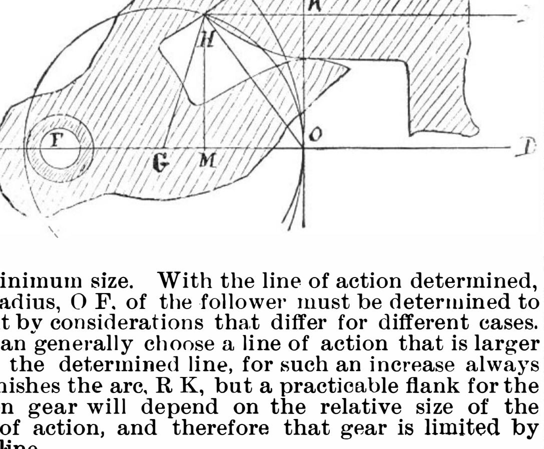
Therefore the action on the approach need not be considered at all unless the condition of interchangeability is introduced, and not then, unless there is some peculiarity of that action. The influence of either the approaching or the receding action, on the limit, is always peculiar to itself, and any limit that either may set is separate from the limit that is set by the other. When both limits exist, both must be considered, and the highest one is the real limit.

Let the diametral pitch be unity, so that the radius, D O, is equal to $\frac{d}{2}$, the arc of recess be assumed at a times the circular pitch, O P, and the tooth arc, 2 R T, be assumed at b times the circular pitch. Then we always have the angle O D T = O D K = H D G=

$$W = \frac{360}{d}\left(a - \frac{b}{2}\right)^\circ \qquad (1)$$

The form of the tooth that may be under discussion will determine the form of the line of action, O H V L O X E, and the solution of the problem will determine its minimum size. With the line of action determined, the radius, O F, of the follower must be determined to suit it by considerations that differ for different cases. We can generally choose a line of action that is larger than the determined line, for such an increase always diminishes the arc, R K, but a practicable flank for the driven gear will depend on the relative size of the line of action, and therefore that gear is limited by that line.

Fig 2
Cycloidal Rack Drives



CYCLOIDAL SYSTEM.

When the teeth are cycloidal, the line of action is a circle with center at G (Fig. 1), and, to secure flanks on the driven gear that are not too much undercurved, the diameter of the circle of action is fixed in certain terms of that of the driven gear, generally at not less than half of it.

Let O G be assumed at q times O F, and we shall have the angle

$$M = H\,G\,D = \left(\frac{360}{f} \cdot \frac{a}{q}\right)^\circ \qquad (2)$$

From the triangle G H D we have

$$\frac{G\,H}{G\,D} = \frac{\sin H\,D\,G}{\sin (H\,D\,G + H\,G\,D)}$$

and from this we get

$$f = \frac{d}{q\left(\frac{\sin (W + M)}{\sin W} - 1\right)} \qquad (3)$$

The general solution is apparently impossible, for both f and d are so involved in the formula that neither one can be expressed directly in terms of the other by known trigonometrical process.

We must therefore be satisfied with a special solution for each case by itself, and this can be obtained in at least three ways. By a graphical, or its equivalent, a mechanical construction, by a numerical process, depending on Rankine's approximation to the length of the circular arc, and by a tentative process of trial and error.

Professor Willis evidently used a mechanical method, for after stating the impossibility of the direct solution, he says that he derives his values by an apparatus "on a large scale with movable rulers." His values are exact to the nearest integer when the two gears are nearly the same size, are near enough for ordinary practical purposes, in most cases, and a delicately constructed apparatus would undoubtedly improve upon them.

Professor MacCord makes use of Rankine's approximation, and gets the value to the nearest integer, but the process is exceedingly laborious and difficult to follow. It serves the purpose of the original computation of tables, but not of casual computation, study, or examination.

I do not think that the method of trial and error has been applied to the cycloidal system, although MacCord makes use of a process of that nature in connection with the involute system, and I will explain its application by an example.

Suppose the driver to be given and the follower required. Let the arc of recess be equal to the pitch, the tooth equal to the space, and let the flanks of the follower be radial.

This gives $a = 1$, $b = \frac{1}{2}$, $q = \frac{1}{2}$, and formula (3) becomes

$$f = \frac{2\,d}{\dfrac{\sin\left(\frac{270^\circ}{d} + \frac{720^\circ}{f}\right)}{\sin \frac{270^\circ}{d}} - 1} \qquad (4)$$

Given $d = 6$. Assume for the first trial $f = 160$. Then $\frac{270^\circ}{6} = 45^\circ$, $\frac{720^\circ}{160} = 4^\circ\,30'$ $\frac{\sin 49^\circ\,30'}{\sin 45^\circ} - 1 = 0{\cdot}07538$

and from the formula, $160 = \frac{2 \times 6}{0{\cdot}07538} = 159{\cdot}193$. The computed value being more accurate than the assumed value, 160 is too high.

Assuming it lower, at 140, we have 140 = 140·171, and 140 is too low.

As the error from 160 is 0·807, and that from 140 is 0·171, the true value, between those values, will be in position in about the proportion of the errors. Its distance above 140 will be to its distance below 160 about as the error for 140 is to the error for 160, so that we can use $f = 140 + \frac{0{\cdot}171(160-140)}{0{\cdot}171 + 0{\cdot}807} = 143{\cdot}5$.

It would be sufficient for all practical purposes if 144 was assumed to be the next larger integer, without further search.

If the exact integer must be determined, try both integers adjacent to 143·5, 144 and 143. For f = 144 we get 144 = 143·961, and for f = 143 we get 143 = 143·027, showing that the true value is above 143 and below 144, the latter being undoubtedly its tabular value.

Its indicated value from the last pair of errors is 143·491, and a third trial, for 143·4 and 143·5, would fix its position still more accurately, if further accuracy was desirable.

If the first pair of assumed values are anywhere near correct, they will give an approximation that is close enough for use, and each pair of computations will give a nearer approach to the truth. The work is very simple in character, and when extreme accuracy is not sought, there is very little of it.

The method is practically the same when the problem is reversed and we have to find the driver for a given follower.

When either d or f is infinite, that is, when a rack drives or is driven, a vanishing fraction occurs, and it is easier to find another formula than to reduce the fraction.

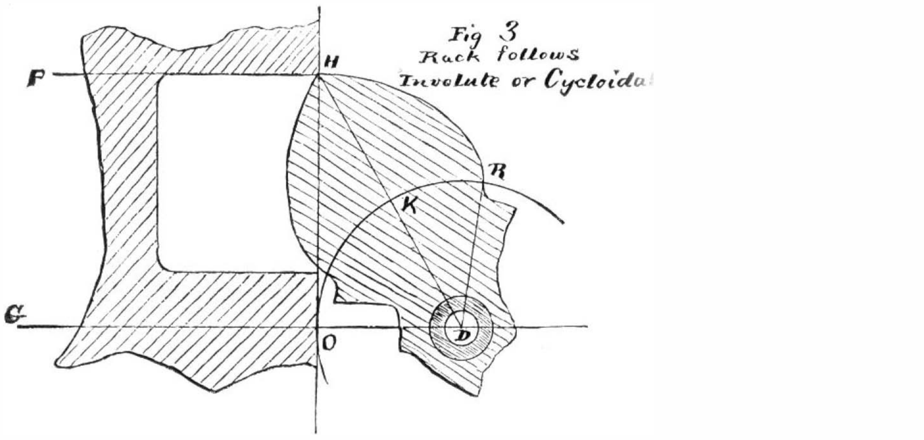
In Fig. 2 the rack drives, and we have $H\,G = \frac{K\,O}{\sin H\,G\,D}$ from which

$$f = \frac{2\,\pi\left(a - \frac{b}{2}\right)}{q \sin\left(\frac{360}{f}\,\frac{a}{q}\right)^\circ} \qquad (5)$$

In Fig. 3 the rack follows, and we have $O\,D = \frac{H\,O}{\tan H\,D\,G}$ from which

$$d = \frac{2\,a\,\pi}{\tan \frac{360}{d}\left(a - \frac{b}{2}\right)^\circ} \qquad (6)$$

and these two formulas are easily worked.



There is another problem that the same process will solve. Given both gears d and f, the half tooth $\frac{b}{2}\pi$, and the proportion q, to find a for the arc of recess for a pointed tooth.

For an example, take the tooth equal to the space, the flank of the driven gear to be radial, d = 15, and f = 16, and formula (3) gives

$$2{\cdot}875 = \frac{\sin\ (69\,a{-}6)^\circ}{\sin\ (24\,a{-}6)^\circ} \qquad (7)$$

A trial of a = 1 gives 2·883 = 2·875, an error of 0·008, that shows one to be a very little too small. A trial of a = 1·1 gives 2·694 = 2·875, an error of 0·181, that shows 1·1 to be too large, and the two errors fix it at about 1·004.

The angle of obliquity for cycloidal teeth varies from zero at O to a maximum at H, Fig. 1. The value of the maximum angle being

$$A\,O\,H = \frac{1}{2}\,O\,G\,H = \frac{1}{2}\,M$$

INTERCHANGEABLE INVOLUTE SYSTEM.

When the involute form of tooth is used the problem is different and a direct solution can be obtained, for the diameter of the driven gear can be expressed in terms of the fixed data of the driving gear. When the involute is interchangeable, the problem further complicated by the interference of the cusp point on the approach.

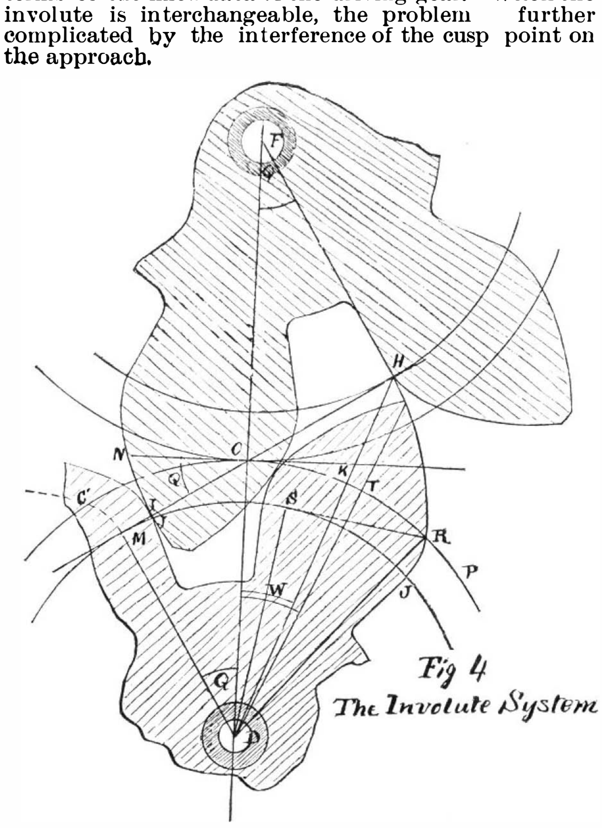


Fig 4
The Involute System

Willis did not attempt to obtain the limiting values for involute teeth, but MacCord has given us an accurate table that was computed by a tentative numerical process that he admits is tedious, and that an examination will show to be exceedingly so.

The direct solution can be obtained as follows. Consider first the action on the recess.

As in the case of cycloidal teeth, a given driver of d teeth has a tooth, 2 T R, Fig. 4, that is b times, and an

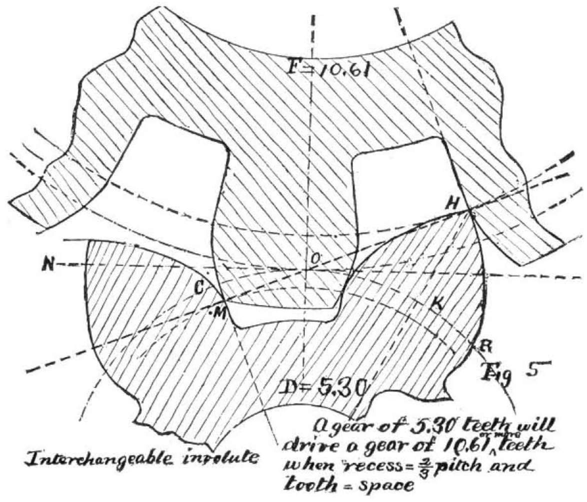
arc of recess, O R, that is a times the circular pitch, O P.

In the case of the interchangeable involute the line of action is a single straight line, M O H, and if we know the angle of obliquity, Q = N O M = O D M = O F H, of that line of action to the pitch line, the smallest possible follower, O F, is determined. Therefore, the problem is reduced to the finding of an angle of obliquity, Q, that shall make K R equal to T R.

When K R and T R are equal, K O and T O are equal, the angle O D K is fixed by the given values, and again we have

$$W = \frac{360}{d}\left(a - \frac{b}{2}\right)^{\circ} \qquad (1)$$

Draw the line D M perpendicular to O M, draw the base circle, M S J, and lay off R S equal to O M. We have M O H equal to M S R, and as R S is equal to O M, O H must be equal to M S.



The arc of the angle M D S is equal to that of the angle O D R, which is equal to $\frac{OR}{OD}$. Therefore, $OH = MS = \frac{OR}{OD} MD$. But $MD = OD \cos ODM = OD \cos Q$, and we have $OH = OR \cos Q = a\,\pi \cos Q$.

From the triangle O D H we have $\frac{OH}{OD} = \frac{\sin ODK}{\sin OHD}$, and from that

$$\cos Q = \frac{d \sin W}{2\,a\,\pi \cos (Q + W)} \qquad (8)$$

From this formula the value of Q can easily be determined by the tentative process above described, but a direct and exact process is to be preferred.

Expanding cos (Q + W), the formula becomes

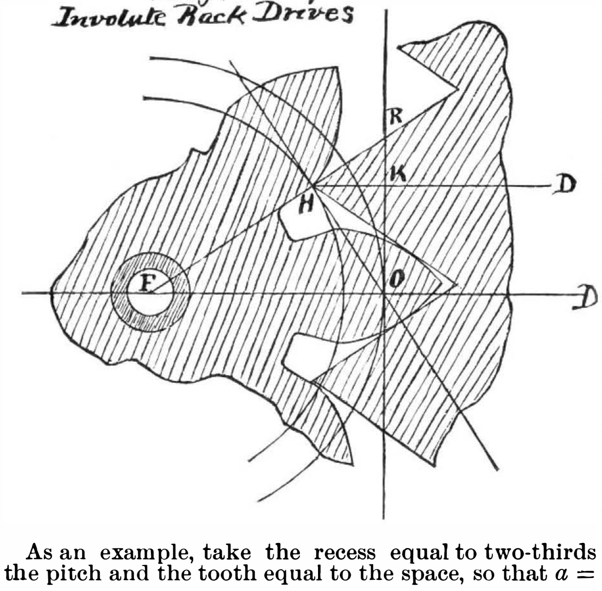
$$\cos Q = \sqrt{\frac{\left(\frac{d}{2\,a\,\pi}\right)\cot W + \frac{1}{2} + \sqrt{\left(\frac{d}{2\,a\,\pi}\right)\cot W - \left(\frac{d}{2\,a\,\pi}\right)^2 + \frac{1}{4}}}{1 + \cot^2 W}} \qquad (9)$$

an expression that is easily worked by the aid of logarithms. Knowing Q, the minimum follower is fixed by

$$f = 2\,a\,\pi \cot Q. \qquad (10)$$

To test the accuracy of a limit already found, equation (8) and the tentative process is the easiest, for one application is then sufficient, but to determine an unknown value, equation (9) is the best.

Fig. 6
Involute Rack Drives



As an example, take the recess equal to two-thirds the pitch and the tooth equal to the space, so that a = ⅔, b = ½. Given $d = 9$, then $\left(\frac{d}{2\,a\pi}\right)^2 = 4{\cdot}61645$, $W = \frac{150^{\circ}}{d} = 16^{\circ}\ 40'$, $\frac{d}{2\,a\pi} \cot W = 7{\cdot}17680$.

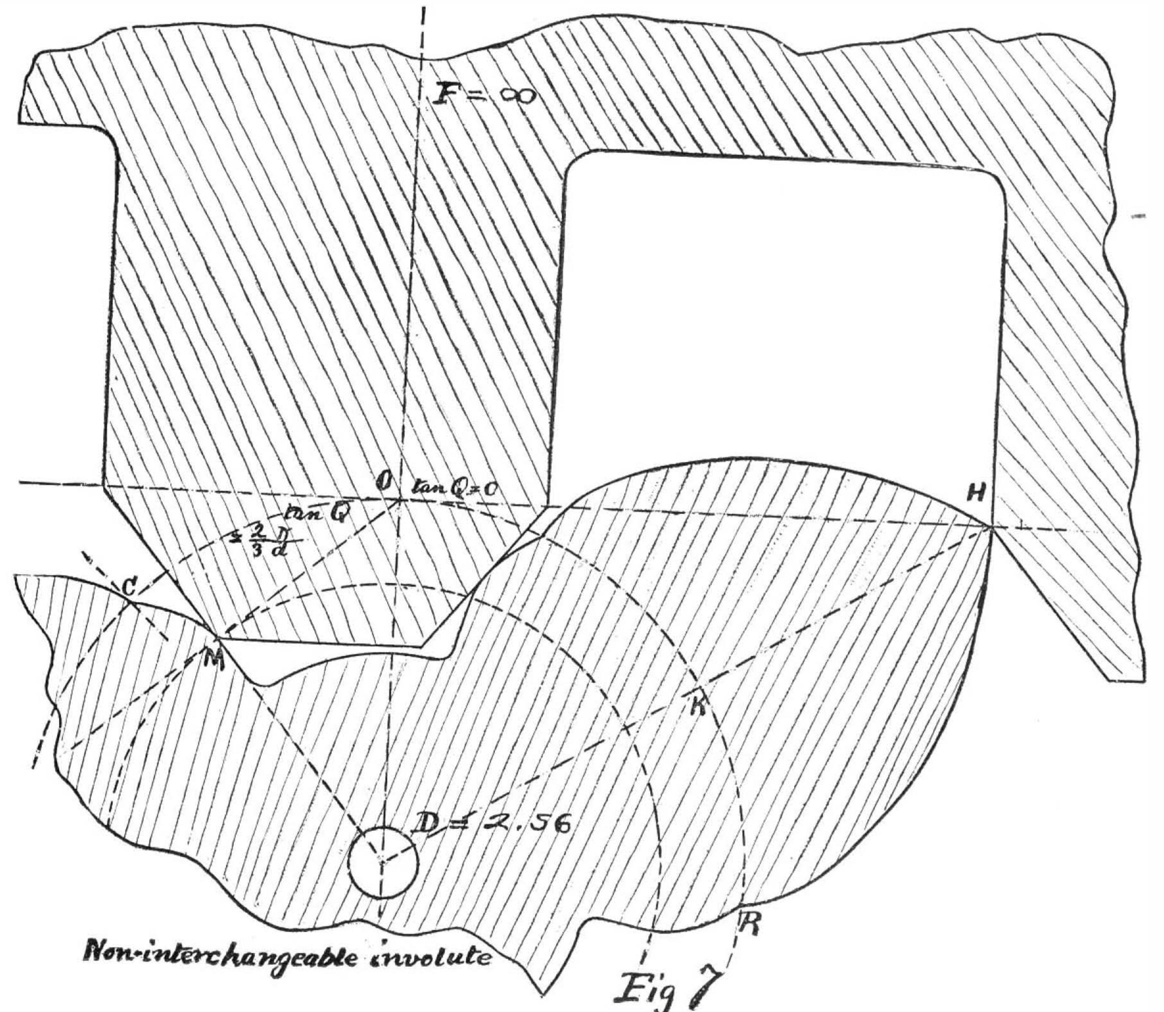
$$\cos Q = \sqrt{\frac{7{\cdot}17680 + 0{\cdot}5 + \sqrt{7{\cdot}17680 - 4{\cdot}61645 + 0{\cdot}25}}{12{\cdot}1572}}$$

$Q = 28^{\circ}\ 42'\ 3''$, and $f = 7{\cdot}65$.

MacCord gives $Q = 27^{\circ}\ 38'\ 12''$, but the error, which is certainly much more than the "one millionth part of the radius of the base circle," does not affect the tabular number, 8.

Trying this value of Q in (8), one trial gives $28^{\circ}\ 42'\ 0'' = 28^{\circ}\ 42'\ 3''$, the two agree as near as need be, and the accuracy of the numerical work is proved.

But the above solution settles the problem only so far as the recess is concerned, and the approach may interfere with the result as found by it. The given recess and tooth will fix a maximum for the angle of obliquity, the approach will fix a minimum value for it, and the maximum must not be less than the minimum.



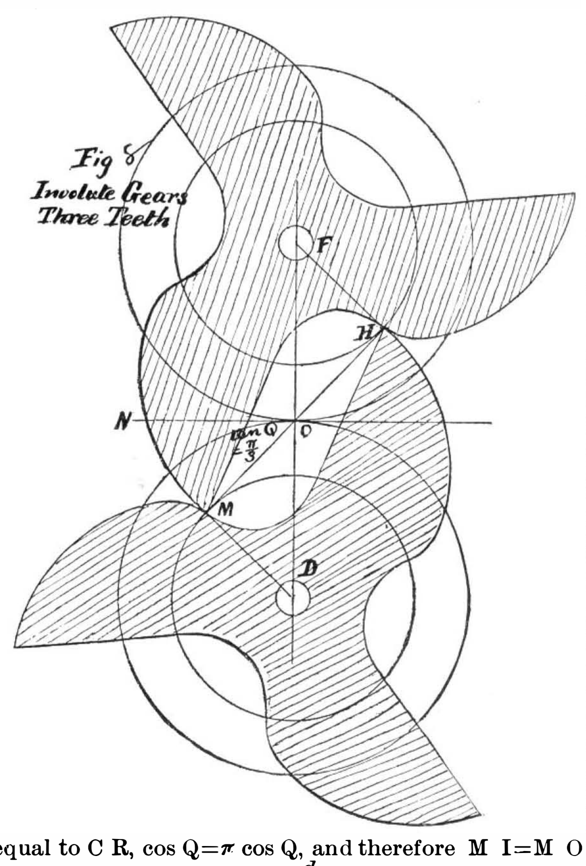
A 2.56 toothed involute gear will drive a rack when recess = 2/3 pitch and tooth = space

When that case occurs, the action is evidently impossible.

The whole arc of action is from C′ to R, for the driving tooth cannot begin to act until its cusp point or foot, J, which is its first acting point, arrives at the line of action at M, and it ceases to act when its allowed recess, O R, has been used.

Plainly this arc of action cannot be less than the circular pitch, for there must be always at least one pair of teeth in action, and if the largest possible arc of approach, C′ O, is less than $\pi - O\,R = \pi - a\pi$, the action is impossible, even when the conditions on the recess are favorable.

The distance, I H, is equal to the arc J J, which is



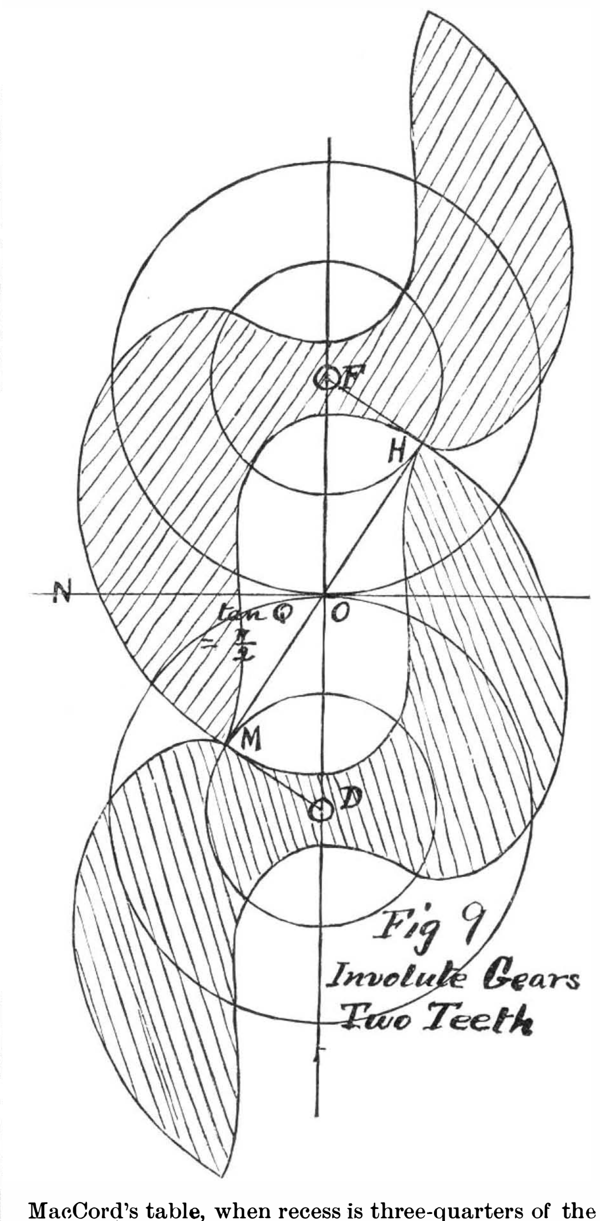
equal to C R, $\cos Q = \pi \cos Q$, and therefore $M\,I = M\,O - I\,O = M\,O - (I\,H - O\,H) = \frac{d}{2} \cdot \sin Q - \pi \cos Q\ (1 - a)$.

When M I is zero, it determines a minimum angle for Q, for any smaller value will bring M inside of I, and make the arc of action less than the circular pitch. If M I = O

$$\tan Q = \frac{2\,\pi}{d} \cdot (1 - a) \qquad (11)$$

The value of d that makes Q from (9), equal to Q from (11), fixes the lower limit of the series, and gives a number of teeth that cannot be decreased without changing the arc of recess. This smallest gear will work with gears of all sizes from a rack to the gear that is fixed by (11), but a smaller gear cannot be used at all.

When the arc of recess is equal to the pitch, the action can be all recess, there need be no flanks on the driver, there can be no limit set by the approach, and (9) always fixes the minimum gear in that case. But when the arc of recess is less than the pitch, there must be some approach to make out the full arc of action, and then that approach will fix the lower limit of the series.

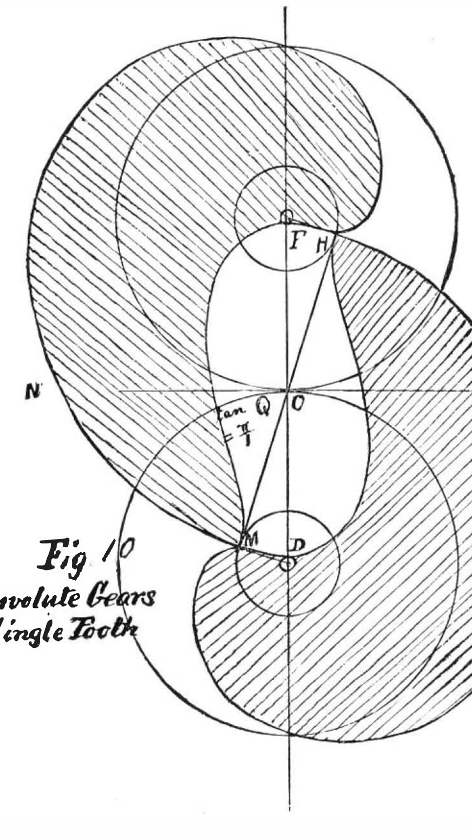


MacCord's table, when recess is three-quarters of the pitch, makes a pinion of 5·46 drive nothing less than a rack, when in fact it will drive anything from a gear of 16·39 teeth to a rack. Similarly, when recess equals

two-thirds the pitch, he finds that 5·30 teeth will drive nothing less than a rack, when it can really drive any gear with 10·61 or more teeth, as shown by Fig. 5.

When the involute rack is the follower, we have the case of Fig. 3 repeated, and formula (6) will apply, for the infinite cycloid is an inferior species of involute. When the recess is equal to the pitch, the lower limit for the driving gear is the same for both forms of tooth, but when the recess is less than the pitch, the lower limit, the gear that will drive nothing smaller than a rack, cannot be reached on account of the limit set by the approach.

In the case represented by Fig. 3, the action on the flank of the rack is concentrated on the single point, H, and can hardly be said to be practicable, although the mathematical requirement is perfectly met.



When the involute rack drives, we have the case of Fig. 6, in which O K = O H cos Q = $a\pi$ cos Q, O K = $(a - \frac{b}{2})\pi$, and

$$\cos Q = \sqrt{1 - \frac{b}{2a}} \qquad (12)$$

NON-INTERCHANGEABLE INVOLUTE SYSTEM.

The preceding matter has been confined to the interchangeable involute because the subject is generally treated in that way, and not because that is the proper way to treat it.

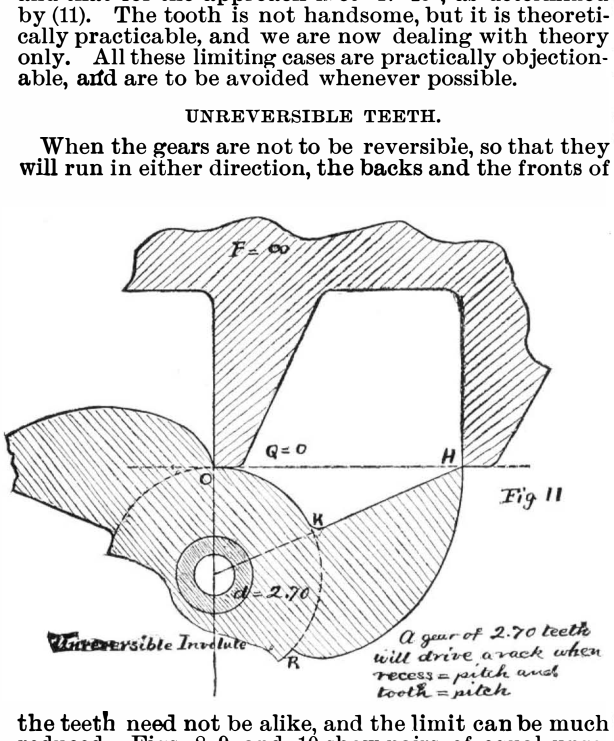
As before stated, there is no necessity that the angle of obliquity shall be the same on the approach as on the recess, unless the gears belong to a set that must be interchangeable, and a fair comparison of involute teeth with non-interchangeable cycloidal teeth requires them to be put on the same footing.

When the action on the approach sets a limit that is greater than the limit set by the recess, we can change the angle of obliquity on the approach side until the limit it sets is as low as required. The gears will not then be interchangeable, but the perfection of their action will not be otherwise interfered with.

Fig. 7 shows a 2·56 toothed pinion, the smallest pinion that will meet the conditions on the recess side, driving a rack. The angle of obliquity for the recess is zero, and that for the approach is 39° 17′ 15″, as determined by (11). The tooth is not handsome, but it is theoretically practicable, and we are now dealing with theory only. All these limiting cases are practically objectionable, and are to be avoided whenever possible.

UNREVERSIBLE TEETH.

When the gears are not to be reversible, so that they will run in either direction, the backs and the fronts of



the teeth need not be alike, and the limit can be much reduced. Figs. 8, 9, and 10 show pairs of equal unreversible involute gears having three, two, and one teeth respectively. The gears are mathematically complete and perfect, but the angle of obliquity is so great and the sliding action so excessive, that they are almost wholly impracticable from a mechanical point of view. They have an application as vanes in rotary engines, pumps, and blowers.

In all cases, the fact that the gears need not be reversible allows a much wider half tooth arc, R K, than would otherwise be possible, and reduces the limit, for the proportion, b, of the tooth to the pitch may then be increased.

For example, when the recess equals the pitch and the tooth equals half the pitch, the smallest pinion has 5·58 teeth, but when the tooth is equal to the pitch and but half of it is expected to act, the limit may be reduced to 2·70, as shown by Fig. 11.

The subject of the limiting numbers of teeth is not only a difficult one, but it is also an extensive one, and its full discussion with complete tables of results would require much more space and attention than its importance warrants. I have here given the main principles that are to be kept in view in the settlement of any case that may arise, and have endeavored to show how the subject can be studied without the great expense of time and labor required by the processes to be found in the present standard works on the principles of mechanism.

INVENTION OF THE TURBINE.

WAS M. FOURNEYRON, OF FRANCE, THE FIRST TO INVENT AND PUT TO PRACTICAL USE THE OUTWARD FLOW TURBINE WATER WHEEL?

By GEORGE WALKER, M.E.

FROM knowledge gained by my own personal observation and experience, in my early years, I am of the opinion that said wheel, which in those days was termed "the side vent reactor," was first invented and put to practical use in the United States of North America.

Deeming the SCIENTIFIC AMERICAN justly entitled to the prerogative of chief exponent of American inventions, I hereby offer my testimony in that behalf, for publication therein.

In the year 1819, when I was but a boy, a neighboring Englishman, by the name of Thomas Overton, resident of the township of Ulster, in the county of Bradford and State of Pennsylvania, had a grist mill and a saw mill built on a branch of the Susquehanna river, which abruptly deviated westerly from, and in like manner returned easterly to, the main course of that river, after bounding about two thirds of the outlines of a large island situate in said township of Ulster. The mills were located about midway of the course of the deviating branch of the river, and a head of water, varying from two to four feet, was secured by a wing dam, part way across the main river at the head of the island, and a dam across the branch at the mills.

The name of the superintending millwright was Peter Kelse or Kelce. I believe the former is the correct orthography of the name. (It was monosyllabic.)

Four outward flow or "side vent reaction" turbine water wheels were put into those mills, at the time they were built. Two about six feet diameter in the grist mill, each driving a run of stones, and two in the saw mill, one of which was about six feet diameter, to drive the saw, and one about three feet diameter, to gig back the log carriage. These wheels were made entirely of wood, excepting the iron bolts by which the parts were bolted and held together.

They were hung on vertical wooden shafts, and placed in circular openings, in the bottoms of square apartments or bays, on the stream side of the main flume.

In the partition between the flume and each wheel bay was a large rectangular gateway, through which, when the gates were hoisted, the water made its way, plunging into the wheel, across its diameter, against and past the right and left of the shaft, without regard or favor to the direction of the revolution of the wheel. The water discharged from the wheel below the floor of the bay, and passed out into the tail race.

The idea then was that the wheel operated entirely by reaction, and under those conditions it did. Therefore it was deemed immaterial in what direction the water entered it, only so that the gateage was large enough to keep the water over the wheel about as high as that in the main flume, so that no material loss of head should obtain.

A few years after the erection of those mills, tub gates, open at top and bottom, and considerably higher than the water in the flume, were built around the wheels, so that when they were hoisted the water entered the wheels all around, converging toward the center, which materially improved the power of the wheels.

As I am relating facts and circumstances that transpired a long time ago, and which in part are in controversion of the historically accredited honor bestowed upon M. Fourneyron, of France, as the first inventor of the outward flow turbine, and believing there is no other man living who could substantiate my statements, I deem it necessary and justifiable to be somewhat reminiscent, for the purpose of substantiating their verity as best I can, unaided, asking, as a favor, that if any person, knowing facts corroborative of any of my statements herein, should read this article, he would make a statement in that behalf through the SCIENTIFIC AMERICAN, or by letter to me.

When the frames of those mills were raised, I witnessed the operation from a favorable position. In the fall of the same season a brother of mine made his advent into this mundane sphere, by which, and other coincidences, I can positively fix the date of the erection of those mills in the year 1819, the date of that brother's birth, at which time we resided about three-quarters of a mile from the mills. In the spring of 1821 we moved, and took up our residence in the immediate vicinity of the mills, and remained in that vicinity until the year 1832, during all which time I was familiar with the mills in all their details.

I frequently witnessed the taking up of some of the water wheels, for repairs of the blacksmith, made steel steps and other parts. In the year 1829, I helped make a general repair of the water works of both mills, including the construction of a new water wheel of the same kind, to take the place of the old saw mill wheel. At that time my father was copartner in the ownership of the mills. Up to that time there had been no change of water wheels, as I positively know.

The fact that those wheels successfully performed the work they were designed to, for so many years, is strong presumptive evidence that they were not, at the time of the erection of those mills, experimental with the builder. About the year 1823 or 1824 I discovered among some drift wood, brought down by a freshet in the river, a piece of the broken wooden rim of a water wheel, of the kind in those mills. It was about two feet long, and in one side were mortises for iron vanes or buckets (as indicated by rust), about ¼ in. thick. My attention was particularly attracted to the narrowness of the issues, the thinness of the vanes and their large angle of deviation from the tangent of the wheel, as compared with those in the mills. This showed that that kind of wheels had been known for a time, further up the river; probably in the State of New York.

It was about the time of Fourneyron's experiments, and preceding the construction of his first practical wheel some three or four years.

The water wheels in those mills were the only kind that I knew of for several years.

I operated the grist mill as miller for some time in the years 1829–30, and in after years had frequent occasion as millwright to construct such wheels for low head water mills.

This train of varied experiences with those wheels fixed the whole matter, in general and in detail, vividly clear in my memory.

Now, the interesting question arises as to how long the invention antedates the year 1819, the time of construction of the "Overton Mills."

Can the records of the Patent Office show?

Joseph Glynn, in a treatise on the power of water, says: "M. Fourneyron, who began his experiments in 1823, erected his first turbine in 1827, at Pont sur l'Ognon, in France. The result far exceeded his expectations, but he had much prejudice to contend with, and it was not until 1834 that he constructed another, at Franche Comte, at the iron works of M. Caron, to blow a furnace."

The "American Cyclopedia," vol xvi., p. 43, says: "The turbine was introduced into general use by Fourneyron in France in 1827, and soon after by Fairbairn in England, and by Boyden in the United States."

Granting the truth of these historical statements, and mine as well, shows that the wheels in the Overton Mills had been in actual use four years in this country at the time of Fourneyron's experiments in 1823, and eight years at the time he erected his "first turbine in 1827."

That this wheel was first invented and put in use in the United States, I have no shadow of doubt; and that M. Fourneyron either *reinvented* it, or obtained a knowledge of it from this country, and claimed it as his own, may be equally true. And, considering the related circumstances, the latter supposition should not be considered extremely improbable; as I will proceed to show.

Mr. Overton was at that time an active business man. He was farmer, merchant and mill owner. His associations were mainly with the aristocratic classes, though he had an aptitude for congeniality in almost any society. He frequently visited Philadelphia, to purchase goods, where, at hotels and other places, he would be liable to meet with foreigners; and if drawn into conversation about his mills, would be likely to describe the wonderful new water wheels that operated them; by which persons possessed of the requisite comprehension of mechanical and scientific subjects may have obtained sufficient knowledge of their construction and principles of operation to construct, experiment, and develop them into condition for practical use.

Hamburg, Erie Co., N. Y., March 26, 1887.

MANAGEMENT OF BOILERS.

AT a recent meeting of the Liverpool Section of the Society of Chemical Industry, Mr. V. C. Driffield, managing engineer at the works of Messrs. Gaskell, Deacon & Co., Widnes, read a paper on "The Management of Boilers." He commenced by saying that, in all chemical industries, it was necessary to adopt steam in one form or another, and it was with reference to a number of practical points in connection with the generators of steam that he wished to draw the attention of the members. And, as he did not intend to discuss the relative merits of different types of steam boilers, his remarks would be confined to those in general use at chemical works, viz., Cornish or Lancashire boilers. Referring to the ordinary causes of wear and tear in a boiler, he said that incrustation was the greatest source of evil, causing overheating and subsequent collapse of flue, or other dangerous results. And, describing the chemical action and constituents of the various substances tending to form incrustation, he gave the following chemical analysis of the original water and of the subsequent deposits:

	Feed Water, Grains per Gal.	Mud from Heater.	Mud from Boiler.	Boiler Scale.
$CaSo_4$.......	2·14	....	....	0·51
$CaCO_2$.......	19 68	93·7	62·5	39·35
$MgCO_2$.......	4 23	5 8	1·7	....
MgH_2O_2......	....		32·7	44·92
Na_2CO_3......	....	0·5	3·1	3·01
S_1O_2.........	1·92	....	....	10·7
Al_2O_2 } Fe_2O_3 }	0·46	....	....	1·21
NaCl.........	9·16	....	....	....
Total solids..	37·59	100·0	100·0	99·7

After mentioning a number of "nostrums" for anti-incrustation, and while admitting that Dr. Clarke's process of softening water was advantageous to the boiler, he said his experience had proved that carbonate of soda was one of the best, and he had tried it very successfully upon the forty boilers now under his charge. Caustic soda, although very effective, had a tendency to act injuriously on the boiler fittings. He said tallow should not on any account be used, as it, in combination with the water, turned into a soapy paste, containing fatty acids. He was once under the impression that distilled water in one of his boilers was the cause of the internal corrosion; but, upon changing it,

he found an abnormal amount of chlorine, which was the cause of the mischief. He stated that a layer of incrustation one-sixteenth of an inch thick was equivalent to a loss of twenty per cent. in the fuel, besides rendering inspection both difficult and unsatisfactory. He then discussed the different forms of feed heaters, and gave it as his opinion that the most satisfactory way of heating the water was by injecting exhaust steam direct into it, and allowing it to mix with the water, in preference to using coils of pipes of water in the flue, or coils of steam pipes in the water. He described an arrangement adopted in his boilers, by which the exhaust steam plays on a circular diaphragm at the top of a cylindrical tank, meeting the water, heating it, and condensing, and then falling on to another plate, through perforated holes, into the hollow receiver, from which it is pumped. He then spoke of the corrosion at the front of the boiler bottoms being due to the damp surroundings, leaks from blow off cocks, gauge cocks, etc., and suggested various arrangements for remedying these defects, such as improved slack bunkers, troughs for all underground pipes, and expansion joints. He referred to the grooving of the flues and front angle irons being due to too much rigidity in the gusset plates. And, speaking of the question of the return flue under the boiler, he advocated the plan of the gases being returned up the sides, to enable the coldest water in the boiler to have the greatest heat. He was of opinion that cross flues in a boiler, although they undoubtedly strengthened the flues, threw a kind of shadow, and deflected the hot gases from where they were most wanted. After speaking of different kinds of boiler mountings, and the best for each particular service, he advocated strongly the keeping of a daily report of the periodical conditions of the boiler, height of water, etc., taken at different intervals during the day by an inspector, and also advocated the offering of a bonus to the boiler foreman, depending upon the returns of the boiler insurance inspector's report. He concluded by saying that many things are done for effective and good management of boilers, but there was nothing like watchfulness and care.

GLASS.*

By SYDNEY LUPTON, M.A.

THE lecturer referred at the outset to the story told by Pliny that glass was accidentally discovered by some Phœnician sailors, whose ship, containing a cargo of natron, or carbonate of soda, went ashore at the mouth of the Belus, a river in Galilee. They lighted a fire on the sand, and supported their cooking-pot on lumps of the natron. The heat of the fire melted the carbonate of soda and sand together, and formed a rough kind of glass. Like so many stories in the ancient writers, this is an entire fiction, which probably arose from the fact that the sand of the Belus is very pure, and was much used in Pliny's own time, A. D. 80, for glass making. The discovery of glass, like so many valuable discoveries, was probably made in Egypt, and spread thence to Sidon, Greece, and Rome. The earliest specimen of the glass in the British Museum is probably a small light blue amulet in the shape of a lion, bearing the name of Nuantef IV., a monarch of the 11th dynasty, who reigned, according to Lepsius, about 2400 B.C. It is doubtful if the Assyrians discovered the art of glass making for themselves or derived it from Egypt. The British Museum possesses a remarkable glass vase engraved with the name of Sargon, who reigned over Assyria about B. C. 721.

Ælian states that the sarcophagus of Belus, the founder of the Assyrian empire, was made of glass. There is great difficulty in ascertaining when glass was first known to the Greeks, as the same word (ὕαλος) expresses glass, rock crystal, or any other transparent stone. Under the early emperors the manufacture of glass attained great perfection at Rome, and valuable articles were imported from Alexandria and other places. Colorless, well-worked glass was very valuable. Thus Nero, A.D. 60, gave 50,000*l.* for two glass vases of no great size. Sheet glass, used either for mirrors or in windows, has been found in Herculaneum and Pompeii, A.D. 79. Egyptian artists were able at the same time to imitate in glass the highly prized "*vasa murrhina*," or vessels made of purple Derbyshire spar. The celebrated Portland vase, now in the British Museum, was found in 1560 in a sarcophagus at Monte del Grano, about two and a half miles from Rome. It is about ten inches high and seven inches across, with two handles composed of dark blue semi-transparent glass, ornamented with raised figures in white enamel, like a cameo.

The manufacture of glass gradually extended itself over the whole known world; and a glass cup ornamented with an engraving of a chariot race has been found near Colchester, which belonged to the Roman period, A.D. 400. After the departure of the Romans, the art of glass making, like so many other arts, was apparently lost in England for 250 years, when, according to Bede, Abbot Benedict in A.D. 674 brought over foreign workmen to glaze his newly founded church and monastery of Wearmouth (Sunderland). But for many years glass continued so valuable that even kings possessed but one set of windows, which they had to carry with them from one palace to another. In the fifteenth century Venice began to be specially celebrated for the excellence and beauty of its beads and glass vessels, the latter being specially valued in those troublous times from the belief that they broke into fragments as soon as any poison was poured into them. We owe to the Venetians also the method of making plate glass. Rather later Bohemia became celebrated for its ruby and other hard glass. Early in the sixteenth century the manufacture of glass was introduced by foreigners into Sussex and Surrey, and about the middle of that century glass houses were established in the Crutched Friars and in the Savoy, on the banks of the Thames.

The progress of the manufacture of glass for the last 300 years has been marked by increased cheapness of production and power of producing large articles. But the artistic beauty of shape so noticeable in old glass has until quite recently deteriorated, and is now only restored by those manufacturers, such as Salviati, who condescend to imitate their ancestors. The modern colored glass, also, is generally inferior in depth and softness of tint to ancient specimens.

* Abstract of a recent lecture before the Leeds Philosophical Society.

From this brief historical outline, Mr. Lupton passed on to the glass of to-day and its varieties. Dealing, in the next place, with the chemistry of the subject, he drew attention to the ingredients used in the manufacture of glass, and their relative proportions, and, with the view of showing the chief processes involved, took for illustration four examples: a beer bottle, a sheet of British plate or blown window glass, a salt cellar, and a sheet of plate glass. In the case of the beer bottle, the fused glass is allowed to cool until it becomes sticky, when the workman collects a quantity on the end of his blowpipe, a narrow iron tube about four feet long. He blows the glass into a thick, small bulb, which is placed in a hinged iron mould. The glass is then blown out until it fills the mould, and makes a bottle of the required size. An iron rod, the puntil, is now attached by hot glass to the bottom of the bottle, which is too often pressed inward to give a false appearance of size. The neck is cracked off by a cold iron or wet stick, and a weld of hot glass smoothed round the top. The bottle is then cracked off from the puntil and taken to the annealing oven.

In the case of window glass the workman collects from 15 to 20 lb. of glass on his blowpipe, and then by blowing and swinging the bulb over a pit he makes it into a cylinder. This cylinder is then placed on a table, the ends are cut off, and the cylinder is split by a wet stick. The cracked cylinder is placed in a furnace with a smooth hearth, and as the glass softens, it is gradually opened out by wooden poles into a sheet, usually about four feet long and three feet wide. In the case of salt cellars and similar articles, the very successful recent introduction of pressed glass has for many articles replaced skilled by unskilled labor, and expensive by cheap materials.

Instead of the somewhat expensive lead glass, a mixture of sodium and barium silicates is used for transparent, and of sand cryolite and zinc oxide for white opaque objects. The molten glass is run into an iron or gun metal mould, which is shut and squeezed in a press. The finer quality of articles must be reheated nearly to the melting point to remove accidental roughnesses. The hotter the mould the less is the reheating required. Plate glass is made by running the metal upon a smooth cast iron table, with a ledge of the required height round it. A heavy cast iron roller is then run over the upper surface. If the roller be grooved, we get the common translucent sheets. The finer plates must be most carefully ground and polished.

All varieties of glass must be "annealed" or heated nearly to the melting point, and allowed to cool extremely slow, or they become so brittle as to fly to pieces spontaneously or at the slightest touch. After annealing, by far the larger quantity of glass is ready for the market; but much has still to be "cut" or "engraved" for ornamental or useful purposes. Thus lines and other marks may be cut into the surface of the glass, or the general surface may be cut away so as to leave certain figures in relief. Three methods are in use:

1. Rough cutting is done by rapidly revolving iron wheels, supplied with a mixture of sand and water. Finer engraving is done by copper wheels, moistened with emery and water or oil; while the article is finally polished by wheels of lead, wood, or cork, covered with powdered pumice, putty powder, or rouge.

2. Etching is done by hydrogen fluoride, the powerful corrosive acid obtained by heating Derbyshire spar or cryolite with sulphuric acid. Glass was thus etched by Schwankhart, of Nuremberg, about 1760, and the acid itself was obtained and investigated by Scheele a few years later. The glass is covered with some substance, such as wax or pitch, upon which the acid will not act, and the required lines are scratched with a needle through the wax to the surface of the glass. The whole is then covered with solution of hydrogen fluoride, or exposed to the acid vapor, when the parts unprotected by the wax are eaten away more deeply the longer they are exposed to the action.

3. In 1871 General Tilghman, of Philadelphia, proposed an entirely new method of grinding or cutting glass and other hard substances. A jet of sharp quartz sand or emery is impelled at a great velocity against the object by a jet of steam or air issuing from a nozzle under considerable pressure. It is found that while a hard surface, such as glass, is rapidly cut by the blast, a soft elastic surface like pitch, or the skin, is unacted on. Hence, if certain parts of the glass are coated with pitch, they remain unacted on, while the exposed portions are cut into any designs or letters which may be desired.

Besides engraving, the aid of color is often called in to ornament glass. Much of the ancient glass, especially if it has been buried in the ground, is found to have a peculiar play of the colors of the rainbow over the surface, a phenomenon known as iridescence. It was long supposed that the ancients had some method of producing this appearance which had been lost in the lapse of ages, but it was found that the same effect could be produced on modern glass by the unsavory process of burying it for a few years in an old drain. Analysis showed that the surface of iridescent glass had been disintegrated, that most of the soda and lime had gone, and that what remained was nearly pure silica. The colors then are due to the breaking up of sunlight by repeated refractions and reflections at the surfaces of very thin minute plates of silica, of which the surface of the glass is composed—a well known phenomenon which had been admirably investigated by Newton some 200 years ago. The same effect is now produced by exposing the article to the vapor of stannous chloride, or by heating it in a closed vessel with a solution of hydrochloric acid.

The white opaque glass so much in fashion for lamp shades and other purposes may be obtained by the use of cryolite. It is also made by mixing aluminate of soda, sulphate of alumina, sulphate or phosphate of lime with ordinary glass. The white enamel used by jewelers is made by mixing oxide of tin, putty powder, with a fine glass. Many of the easily oxidizable metals dissolve readily in glass, and impart to it a characteristic color. Thus copper gives red or blue green; iron, bottle green or yellow; cobalt, blue; manganese, violet; and chromium, bright green. These facts were known in very early times, and many of the old painted windows have a richness and softness of color which cannot now be attained. A mosaic window is made by cutting pieces of glass of the required shapes from sheets of glass of the different colors, and then joining the various bits of glass together by lead. The process is tedious. It is difficult to shade, and the lead more or less interferes with the beauty and unity of the picture. Hence, in recent years another method has been in vogue. A sheet of colorless glass of the size required for the entire window has the design painted on it with finely powdered fusible glass of the required colors ground up with turpentine or oil of cloves. On heating the whole plate to low redness the colored glass melts and attaches itself to the less fusible colorless sheet. These windows are far cheaper and at first more artistic than the former ones, but the colors are not so good as if they went all through the body of the glass, and the soft colored glass is also very liable to be acted on and spoiled by the air.

Many attempts have been made to render glass pliable (and, according to Petronius, Tiberius cut off the head of an artist who succeeded in doing so), or to increase the strength and hardness of the article. Rather more than two hundred years ago, Prince Rupert showed the newly founded Royal Society that when fairly clear molten green glass is dropped into cold water, it assumes a curious pear-shaped form with a long tail. These globules, now known as Rupert's drops, are extremely hard, and may be hammered without breaking. If, however, the surface of the drop be scratched or the tail broken, the whole falls more or less completely to powder with a slight noise and pale flashes of light.

No practical use was made of this discovery until 1875, when M. De la Bastie brought out a partially successful toughening process. The glass object, made in the ordinary way, was heated until it softened, and then plunged into a bath of tallow heated to 160° F. Pieper subsequently proposed superheated steam instead of the tallow. The glass is thus cooled rapidly to a certain point, and afterward more slowly. It remains much like ordinary glass in appearance, except that the edges are all rounded. It becomes slightly more dense, so hard that it cannot be cut by a diamond, has a peculiar ring when struck, and is much more tough. Thus, a rod of glass which in its ordinary annealed condition will bear a pull of 3,000 lb., after De la Bastie's process will carry 8,500 lb., and after Pieper's 10,000 to 14,000 lb. If a bottle of ordinary glass bears an internal pressure of 570 lb. per square inch, if toughened it will bear 760 lb. Too much was, of course, made of this process at first, and it is now utterly neglected; probably owing to the somewhat unreliable nature of the process, and possibly in some cases to careless manufacture. The demand was not sufficient to lower the price below a fancy value.

In February, 1885, was read a paper before the Society of Arts, on a new, and so far very successful, method of toughening glass. This hard glass, instead of being common glass the substance of which is in a state of intense strain, is just the opposite—it is common glass, so uniformly cooled that internal strains have nearly or entirely disappeared. It is a familiar experiment that tea poured into the saucer cools more quickly than if left in the cup. In scientific language, other circumstances being similar, a substance cools more quickly, the larger the surface it exposes. Thus the edges of a sheet of glass cool more quickly than the middle portions, and a state of strain is caused. Mr. Siemens uses two methods for insuring that the temperature of the article is the same throughout during the whole time of cooling:

1. *Press Hardening.*—In this case the glass is cut and shaped in the ordinary way, and then heated in a special furnace by radiant heat for a minute to the softening point. It is then pressed for thirty seconds between cold metal plates, until it reaches the temperature of the air. The greatest care must be taken to insure uniform temperature and absence of draughts. This process can be partially applied to bottles and other articles which cannot be pressed, by heating them in suitable cases and allowing them to cool in the same cases, but it is only applicable to glass of good quality.

2. *Hard Casting.*—This can be used with any kind of glass, which is rendered about four times as strong as by ordinary annealing. Thus even such rough articles as floor plates, tramway sleepers, and grindstones may be cheaply made. The glass is melted in a regenerative tank furnace, and run out into moulds having about the same specific heat and conductivity as glass. This material is rather expensive. Various mixtures of powdered glass pots and porcelain, metal turnings and filings, heavy spar, and magnetic oxide of iron are found to be most suitable. The article and mould thus form, so far as heat is concerned, a nearly homogeneous body, which can be very rapidly cooled, without any fear of the glass cracking. Placing the article and mould in the open air has generally sufficient cooling power to produce the desired result. The cost of the common varieties of glass prepared by this process is only about 5s. 6d. per cwt., and it has been successfully used for such purposes as the windows of ironclads and water bottles for volunteers. It would probably be of great utility for drain, water, and gas pipes, roofing tiles, divisions between school rooms and the like. In an experiment shown by Mr. Siemens, a sheet of ordinary glass was broken by a cricket ball falling from a height of two feet; while a similar sheet of the same glass which had been toughened required the cricket ball to fall through five feet four inches to break it.

The lecture, which was interesting in itself, was made thoroughly plain and practical by means of a number of experiments, several with the blowpipe.

SLAG CEMENT.

AT a recent meeting of the Cleveland Institution of Engineers, held at Middlesbrough on March 7, 1887, a paper on "The Manufacture of Portland Cement from Cleveland Blast Furnace Slag" was read by Mr. J. E. Stead, F.C.S., F.I.C., Middlesbrough. The lecturer described the manufacture of Portland cement, and argued that English manufacturers were far behind those of Germany and Austria. As regarded the fineness to which the cement was ground, the manufacturers on the Continent ground the cement to such a degree that practically the greater part of it passed through a sieve with 32,000 holes per square inch; whereas of English manufactured cement not more than about 50 to 60 per cent. would pass through such a sieve.

The cost of extra grinding to produce the fine powder

such as was described was estimated at about 3s. to 3s. 6d. per ton; and this the manufacturer is not likely to incur unless engineers recognize the fact that fine ground cement is really much more valuable than is ordinarily supplied. In discussing the chemistry of cement making and hydraulicity of cement, Mr. Stead showed that practically Portland cement consisted of a slag in most intimate contact with about 12 per cent. of free lime, and what the slag cement manufacturer must aim at was to obtain as intimate an admixture of lime and slag to produce a similar compound.

Owing to the courtesy of Mr. Latsen, the managing director of the Improved Cement Company, he had personally taken some slag sand from Middlesbrough to their works in London, and had been allowed to see it converted into cement by the process patented by Mr. Bosse, of Germany. The dried slag sand was introduced into a small drum containing a considerable number of cast iron balls about one and a half to 1 in. diameter, and together with the slag sand about 25 per cent. by weight of slaked lime in powder was introduced. The door being closed the drum was slowly revolved, and the materials inside subjected to a most intimate mixing and grinding process, and with the result that in about two hours they were reduced to a powder sufficiently fine to pass through a sieve with 32,000 holes per square inch, and in that condition were withdrawn as finished cement. This material was carefully tested both neat and mixed with sand.

The cement might be classed as slow setting, and therefore the strongest. It was pointed out that the authorities both in Germany and England admitted that the value of a cement was best determined by the strength of a mixture of the cement and sand, and not by the strength of the cement alone. And so practically cement was never used alone in actual work, but always mixed with sand.

The fact that slag cement did not give such good results tested neat as Portland neat cement was, Mr. Stead urged, immaterial, as tested mixed with sand it was superior in strength. It was much lighter, having a specific gravity of 2·73, against 3·08 for Portland cement; but was an advantage, as it did more work in consequence. When set it had a fine, nearly white color, much finer than Portland. Aluminum cement neat contracted a little in setting, and it was necessary to use a mixture of slag to prevent this. It set readily under water, and behaved in every way like a good hydraulic cement.

Mr. C. Wood, of Middlesbrough, had practically carried on a process similar to the above for twelve years, with which slag, sand, gypsum, quicklime, and calcined oxides was mixed. But he had not been enabled to grind the slags to such impalpable powder, and failed therefore in producing a cement which would approach Portland cement. The mixture which Mr. Wood made was pressed into bricks, and had been used in large quantities during that period. The objection of slag manufacturers that slag would be liable to fall to powder and to disintegrate if made into cement, had been practically proved to have no weight by the fact that Mr. Wood's bricks had lasted in wet and damp situations for above eleven years without showing any sign whatever of disintegration. The bricks, instead of getting softer, had, without doubt, got harder and stronger with time and exposure. The importance of this new process to the district was manifest, as the slag cement for most purposes was equal to Portland cement, and could be sold probably at half the price. Samples of slag cement were tested in the room before the members, and gave satisfactory results.

IMPROVED PETROLEUM BURNER.

In the south of Russia, petroleum is now not only used for firing steam boilers, but also as a substitute for solid fuel in metallurgical and many other processes, the burners varying according to circumstances. The one we illustrate herewith was described in a recent number of *Dingler's Polytechnisches Journal*, and is intended for use with a smith's hearth. Fig. 1 shows a section through the burner proper, and Fig. 2 shows a section through the combustion chamber and the flue leading to the hearth. The crude oil, or the refuse of the refineries, is placed in a tank from 3 ft. to 6 ft. above the burner, and is conducted to the latter by a pipe, L, controlled by a stop valve, T. There is another stop cock, U, in the same pipe, which is ordinarily closed, so that the oil is forced to ascend

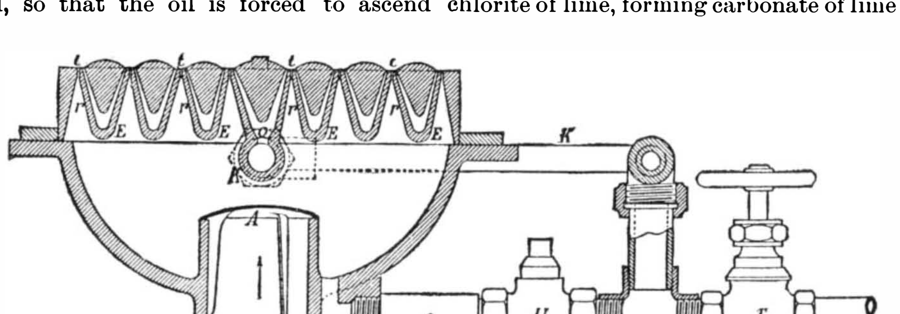


FIG. 1.

PETROLEUM BURNER.

through the T piece, and flow along the pipe, K, into the burner. The latter consists of a series of concentric annular chambers, E, communicating with the pipe, K, at the points of intersection by small holes, O. The oil fills these chambers, and issues at circular slots, *t t*. Air under pressure is supplied through the pipe, W, and passes through the intermediate spaces, *r r*, between the annular chambers, issuing through circular slots in close proximity to the slots above mentioned. In this way the air, in rushing out, diffuses the oil, and forms a highly inflammable mixture, which can be lighted by a torch. The stop cock, U, serves to run the oil out of the apparatus through the branch, V, if desired. The combustion chamber, S (Fig. 2), is placed over the burner, B, and is lined with fire brick. At the top there is an opening, *d*, through which the torch is introduced for lighting the fire. After that is done the opening, *d*, is closed, and the flame is forced on to the hearth through the opening, H. This apparatus is at present made in three sizes, and fitted with burners of 6 in., 8 in., and 10 in. diam. The 8 in. burner requires about 33 lb. of oil per hour. The arrange-

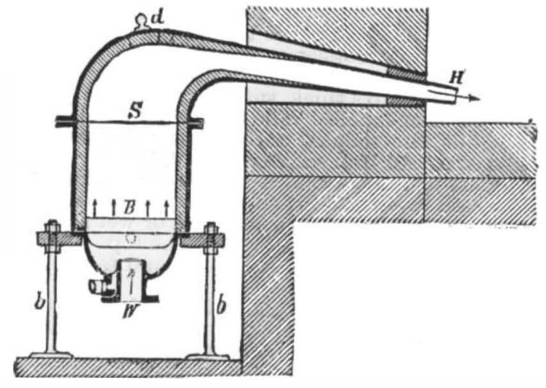


FIG. 2.

ment shown in Fig. 2 is extensively used in Baku and on the river Volga, and is known under the name of Westphal's burner for smithies.—*Industries.*

A REVIEW OF RECENT BLEACHING PROCESSES.

In the course of the last few years, says the *Centralblatt fur die Textil-Industrie*, a number of processes have been proposed for bleaching the textile fibers, and several have already been adopted in practice. It might be well, therefore, to collate these improved methods, and to make a few critical remarks on each. The process of bleaching the vegetable fibers has virtually remained at the same old spot it occupied when chloride of lime was introduced, excepting the modifications rendered necessary by the introduction of new apparatus and machinery. Taken as a whole, only occasional modifications of the old process have been adopted, as those proposed have, as a rule, been found to be practically useless, or too costly. In its essential features, the present method of bleaching vegetable fiber, especially cotton, consists in its treatment with alkalies, carbonate alkalies or lime, next in the operation of the chloride of lime and a mineral acid, finally the treatment with resin soap, if the fabric is intended for dyeing and printing. As far as regards the kind of mineral acid, sulphuric or hydrochloric acid is generally used for white goods, hydrochloric acid if the fabric is to be dyed. This acid is used so as not to load the fabric with insoluble or heavily soluble lime salts, which would occasion difficulties subsequently in the dye house. We first meet with a method of J. B. Thompson and J. P. Rickmann, which attracted the attention of practical men. According to the patent, the fabric to be bleached, if of vegetable fiber, must for the purpose of saponification and removing the fats and resins, be boiled several times, for three hours at each boiling, in a solution of cyanide of potassium and cyanide of sodium, then washed, and afterward left in contact, in a specially constructed apparatus, with chloride of lime solution. After the removal of the latter, gaseous carbonic acid is forced into the apparatus, whereby the actual bleaching is accomplished. The washed goods are finally drawn, first through a bath of aniline violet and oxalic acid, next through one of oxalic acid alone.

In this process the practical man will be astonished, first, at the expectation that he should work with agents so poisonous as cyanide of potassium and cyanide of sodium, which are, be it remarked, rather costly. Next, the use of carbonic acid, in place of mineral acid, is not new, as H. Schmid has correctly remarked, since the use of carbonic acid was proposed by P. F. Didot, in 1885. Schmid also criticises the use of oxalic acid and the fugitive aniline violet, which can never take the place of ultramarine.

This method is also further commented upon, and the fact is pointed out that in the description too little attention has been called to the continuous effect of the carbonic acid. This acid decomposes the hypochlorite of lime, forming carbonate of lime and chlorine, which has a decomposing effect upon water, by forming oxygen, which bleaches (oxidizes), and hydrochloric acid. This acid next decomposes again the originally formed carbonate of lime, chloride of calcium is formed, the carbonic acid is liberated, and can again operate upon the chloride of lime.

What advantages are to be derived from the employment of cyanide of potassium and cyanide of sodium, is not very clear. Messrs. Thompson and Rickmann also appear to have recognized this, because in an additional patent they propose to treat the fabric with hydrate of aluminum and soda, or with kaolin and caustic soda. The alumina, boiled to a thin paste, is to be placed together with water and an alkali, or alkali carbonate, in a cylinder washing machine, through which the goods are drawn at a small pressure of the rollers. They are next boiled for five to six hours, thoroughly washed, and are then ready for the treatment with chloride of lime and carbonic acid.

According to a subsequent additional patent, these gentlemen made the astonishing discovery that the bleaching is also effected by exposing the goods to air with the ordinary or increased percentage of carbonic acid, after a repeated passage through chloride of lime solutions. Concerning this additional patent, it may be remarked that the gentlemen have newly discovered an old and well known fact, which can be learned from any of the older text books.

The Mather-Thompson bleaching process, recently mentioned in a number of textile journals, is in its essential features synonymous with the above, with the exception that in place of the treatment with cyanides or alkalies and alumina, the treatment is changed for a certainly more rational process. The goods are saturated in soda lye and then steamed with increased tension for five hours, being constantly sprinkled with lye. This treatment, however, is almost similar to the process of bleaching patented by Horace Kochlin. He also proposed to saturate the fabric with alkalies or caustic earth alkalies, and next to subject it to steam or hot air. Since, however, in the presence of an alkali, the hot air attacked the fiber too strongly, the inventor afterward used an addition of sulphite of sodium or disulphite of sodium. The quantity of this agent depends upon the quantity of air mixed with the steam.

If, in the ordinary process of bleaching with chloride of lime, the mineral acid is not thoroughly washed out after acidulating, the evil is easily invited that the fiber is in the subsequent drying attacked by the traces of the acid. In order to neutralize this evil, in fact, to dispense with the acid passage altogether, G. Lunge proposed to add small quantities of acetic or formic acid to the chloride of lime solutions.

These acids are to operate in the same manner as the carbonic acid in the Thompson-Rickmann process. The acetic acid liberates from the chloride of lime the hypochlorous acid, which, by surrendering its oxygen, furnishes hydrochloric acid. This hydrochloric acid, however, decomposes the acetate of lime, formed in the beginning, by forming chloride of calcium and acetic acid, the latter of which can operate again upon fresh quantities of chloride of lime. In this case also the effectiveness of the acetic acid may be called continuous.

The manner of employing the acetic acid may differ. As above specified, it is either added direct to the chloride of lime solution, or else the fabric is first passed through the chloride of lime bath, and next through water feebly acidulated with acetic acid, or, finally, by entering the fabric into acidulated water, into which a chloride of lime solution runs, the mixture being constantly stirred. Again, since the chloride of lime solution frequently contains larger quantities of caustic lime, a part of the acetic acid can be replaced by hydrochloric or sulphuric acid, in order not to use extra large quantities of acetic acid for neutralization. Concerning the proposition of employing formic acid, we are loath to ascribe to it the desired effectiveness. Formic acid, which is both an aldehyde and an acid, would doubtless be decomposed, first by the hypochlorous acid into carbonic acid and water, and only then the nascent carbonic acid would become effective, but through this oxidation process a part of its oxidizing strength would be lost to the bleach liquor—a loss well worthy of consideration.

C. F. Cross and J. P. Rickmann have obtained a patent for a process for bleaching vegetable fiber through the simultaneous effect of chlorine gas and alkali. The fabric, previously prepared in the ordinary manner, is saturated in an alkali lye of determined concentration, the excess of the lye is squeezed out, and the fabric, prepared in this manner, is, in a hermetically closed vessel, exposed to chlorine gas. After this process the formation and the instant effectiveness of the hypochlorites take place.

For the removal of the last adhering traces of the chlorine, that is to say, the hypochlorous acid, from the fabric, G. Lunge recommends the use of peroxide of hydrogen, as antichlorine. It possesses the property, when brought together with other oxidants, to let a part of its own oxygen enter into combination with that of the oxidant as ordinary (inactive) oxygen. By the use of this agent, he avers, the disagreeable after injuries resulting from the use of the hyposulphite of soda (antichlorine) do not occur.

According to W. Lindner, however, peroxide of hydrogen may also be used direct for the bleaching of cotton fabric that has become yellow by age, by immersing it in water to which from two to five per cent. of commercial peroxide of hydrogen and a little spirits of hartshorn have been added. We will subsequently enlarge upon the great importance which this agent will in the near future assume in the bleaching of fibers, especially animal fibers.

Bleaching has also been tried by means of electrolysis, although the majority of the processes are for the bleaching of paper stuff. In their essential features all these processes (of E. Hermite, A. Lidoff and W. Tichomiroff, R. Reichling, L. Naudin) are based upon the electrolytical decomposition of the metal chloride, in the solution in metals and chlorine, to the latter of which are due the bleaching effects. These propositions, however, appear not to have passed beyond the experimental stages.

As is well known, the bleaching of linen, and more especially of jute, offers far greater difficulties than that of cotton. For this reason, the grass bleaching of linen, with a preceding feeble chlorine treatment, is still the best, and it is very difficult to obtain equally good results with chlorine bleaching exclusively, under the supposition that the fiber itself is not attacked thereby. As to the other fiber, it is apparent from the investigations of Cross and Bevan on the condition of the jute, that this is not to be regarded as a cellulose, but as a bastose, a medium between aromatic substances and carbo-hydrates, and it therefore exhibits esssentially different peculiarites and another behavior than cotton.

By the operation of chlorine and subsequent treatment with sulphite of sodium, jute assumes a fuchsine red color, but with ammonia it is colored violet. Left for some time in a moist condition, jute decomposes and finally becomes reduced to a powder. Acids attack it easily—a fact worthy to be remembered. J.

Renouard made the following statements on the bleaching of jute fabric. It is first washed with weak alkaline fluid, 14 kilogrammes silicate of soda in 3.000 liters water [31 lb. in 792½ gal. water], at a temperature of 158° F. Next comes the bleaching in a solution of hypochlorite of sodium, containing 0·7 to 1 per cent. of effective chlorine. The jute finally enters a feebly acid bath, containing hydrochloric and a little sulphuric acid, when it is ready for dyeing. If it is to be printed, and thereby subjected to steaming, it is still necessary to draw the jute fabric through a bath of disulphite of sodium (corresponding to 1 or 2 per cent. of sulphuric anhydride), and finally to dry it upon the steam drum.

It must be remembered that jute easily undergoes an oxidation process by the steaming, whereby the fiber is destroyed, and this mishap is sought to be counteracted by the small percentage of disulphite. No chloride of lime must, under any circumstances, be used for jute, because it produces insoluble lime combinations, which are only removed with difficulty. In this bleaching process the jute loses from 7 to 8 per cent. of its weight, and is diminished 10 per cent. in its tensile strength. Jute can also be bleached quickly with permanganate of potash, although this process would be too costly.

C. A. Martin specifies another process for bleaching linen and jute fibers. The fibers are first to be boiled in a lye of soda and oil of turpentine, after which they are treated, boiling in another of soda and benzine, and then entered a bath of chlorine mixed with sulphate of alumina. A treatment in a feebly acid bath follows finally. With the exception of the first boiling, the other operations are to be repeated several times in the same series. The oil of turpentine is perhaps intended in this method to introduce the oxidizing process, and if possible to operate with a dissolving effect upon certain substances. What role, however, the benzine is expected to perform, cannot be learned from the description in the patent. The sulphate of alumina might perhaps be first converted into hypochlorite of alumina with the chloride of lime. The necessity of its addition, however, is not very clearly perceptible, as after the chloride bath follows an acid passage. Taken as a whole, this process is analogous to the old bleaching method, and is only a little improved by the addition of oil of turpentine and benzine.

Before we leave the bleaching of the vegetable fibers and turn to the animal, we will yet review the investigations of T. Haebler and E. Muller, who made the influence of the ordinary bleaching method with chloride of lime upon the fluid of the cotton and linen fibers an object of special research. Haebler examined the firmness of the cotton fabric in the several states of the bleaching process, and arrived at the startling conclusion that, by a rationally conducted process, the textile strength does not only not suffer, but it actually increases. Muller could but confirm this result by his investigations, and found the same result with linen thread (spun dry). He also found that the boiling of flax with lime does not act injuriously upon the fiber, but is better than boiling with soda.

The animal fibers were until recently bleached almost exclusively with sulphurous acid in a gaseous state, and certain kinds of silk were also bleached with nitro-hydrochloric acid (5 parts hydrochloric acid and 1 part nitric acid), or sulphuric acid saturated with nitrous vapors (azoto-sulphuric acid).

Although experiments were also instituted with the aqueous solution of the sulphurous acid, and the acid salts of this acid, still it was not generally adopted. The usual sulphuring is connected with certain disadvantages, which consist especially in that the last traces of sulphurous acid are removed from the fiber with difficulty. In order to annihilate these last traces, G. Runge has also recommended the use of peroxide of hydrogen. This agent oxidizes the sulphurous acid present into sulphuric acid, which can easily be washed out from the fiber. For this purpose highly dilute solutions are used, although an excess of the peroxide of hydrogen can only have a beneficent effect.

For bleaching wool with peroxide of hydrogen, C. H. Lobner says that the fiber must be washed thoroughly clean. By using as bleaching fluid a mixture of 1 part of commercial peroxide with 10 parts water, it is sufficient to immerse the wool for from thirty to forty minutes, keeping it in gentle motion. When, however, the dilution is as 1 to 15, the wool must remain in the bath for one hour. It is also advantageous to let the wool, after it has been taken from the bath, lie for some time before drying, preferably in free outside air, or to the direct influence of the sun, as it has been observed that this after effect is quite remarkable. Sharp drying in the hot chamber is followed by no good effect. According to the above authority, the necessary quantity of indigo carmine may at once be added to the dilute peroxide. When, however, a concentrated bath has been used, the bluing must be performed in a separate bath, as the peroxide quickly decolorizes this pigment also.

Lobner also proposes, in the case of strongly yellow wools, to add a little methyl-violet to the violet, so as to prevent a greenish tinge of the resulting bleached wool. This treatment with pigments has only one purpose for goods that are to remain white, and in consequence of this the use of methyl-violet, on account of being a very fugitive color, is just as little to be recommended for wool as in the case of H. Schmid's objections to it, whem detailing Thompson's bleaching process for cotton. According to Lobner, it is therefore possible to bleach wool successfully by using the so-called commercial acid peroxide of hydrogen.

Pelgrain prepares a peroxide of hydrogen in the factory of Durand & Huguenin, in Basle, which develops twelve volumes of oxygen, and which not only can be kept for a long time without decomposing, but can also be heated. In order to bleach wool with it, the wool is immersed in the bleach liquor, diluted with twenty times its volume of water and from 5 to 10 per cent. of a silicate of soda solution of 20° B., in which it is left for from twelve to twenty-four hours. According to H. Kochlin, better results are obtained by using more concentrated bleach liquors. For instance, 1 liter [8·454 gills] of the specified peroxide of hydrogen, 2 liters [4·226 pints] water, and 200 grammes [7 oz.] silicate of soda (waterglass) of 20° B. The pieces are drawn through the bath, left rolled up for twenty-four hours, washed and dried, or else they are passed through a bath of 1 liter peroxide of hydrogen, 1 liter water, and 50 grammes [1¾ oz.] waterglass of 20° B., and steamed for two minutes in the Mather-Platt apparatus. The advantages of the employment of peroxide of hydrogen are said to consist in the fact that the whiteness of the wool is handsomer than that produced with sulphurous acid, and that the fiber suffers far less. Special attention must be called to the later process, because wool can, contrary to Mr. Lobner's method, be bleached in an alkaline bath with peroxide of hydrogen.

It is also averred that peroxide of hydrogen is suitable for bleaching tussah or wild silk. According to Lindner, the silk is to be saturated with the so-called acid peroxide, then lightly squeezed out, tentered, and subjected to ammoniacal vapors in a closed vessel. The bleaching effect of the agent then becomes perceptible at once. According to Pelgrain-Kochlin, the process is to be performed in the following manner:

The silk is first passed through boiling water three times, and next immersed for twenty-four hours in a bath of 250 grammes [9 oz.] crystallized soda per liter. After having been squeezed out, a second bath with crystallized soda follows, in which the silk is left for three hours. It is next thoroughly washed, and entered in a bath of peroxide of hydrogen, of twelve volumes oxygen, which has been diluted with a sextuple quantity of water, and to which 1½ per cent. ammonia has been added. After having remained for three or four hours in this bleach liquor, another 5 per cent. of ammonia is added. The decolorization of the silk requires about twelve hours, although the process can be accelerated by warming. The silk is then washed, drawn through a bath of hydrochloric acid, finally washed again and dried. If Chappe silk is to be bleached with peroxide, the former must first be drawn through a boiling soap bath.

In conclusion, we wish to add that, according to the investigations of G. Lunge and L. Landolt, the chlorozone, for the production of which Count Dienheim-Brochocki obtained a patent in England, in 1878, essentially consists of a solution of free hypochlorous acid and a little chlorine in a cooking salt solution, and that every other solution of the free hypochlorous acid has the same effect. As far as regards the changeability of bleaching solutions, these authors have established that all such fluids should unconditionally be protected against light, and that a protection against air, at least for chloride of lime and chloride of magnesium, is not indispensable. It must also be stated that, according to the experiments of these gentlemen, the solutions of the hypochlorites of alumina and zinc, in the presence of only trifling quantities of carbonic acid, have an extremely rapid bleaching effect.—*Industrial Record.*

CONSTRUCTION AND OPERATION OF DYNAMO ELECTRIC MOTOR SYSTEMS.*

By STEPHEN D. FIELD, of New York.

THE subject to which I wish to call your attention is the construction and operation of dynamo electric motor systems.

By this I mean that organization of apparatus wherein a stationary steam engine is used to produce dynamo electric currents, and by conversion in dynamo electric motors reproduce the power of the steam engine at distant places.

Almost all the modern dynamos are based upon the inventions of Pacinotti and Alteneck, and between the relative merits of the two inventors I believe there is no choice; that is, with the same amount of wire and iron, equal results either as a generator or motor will be obtained for the same expenditure of power.

Much, however, depends upon the disposition of the wire and iron; an apparent advantage of one system over the other may easily be shown should the two elements not be placed to their greatest working advantage.

A marked analogy is seen between the behavior of a magnetic and an electrical circuit, and pole pieces of dynamos are made of greater section than the magnet cores, with a view of diminishing the air resistance between the armature and the field magnets. I believe that lamination of the pole pieces of a dynamo is of benefit in exposing a larger surface from which the lines of force may flow, and diminished heating results from this fact, and not from the suppression of Foucault currents, as has been by many assumed. It is difficult to see how Foucault currents could be generated in a piece of iron which is sensibly constant at all points to the flow of a steady current.

In the earliest form of electric motors direct magnetic attraction and repulsion was employed. Experiments with this form of motor show that the greatest effect is obtained when the armature is polarized to an exact equality with the fixed magnet. A somewhat similar relation of parts can be found in the modern motors. It would seem that the greatest amount of work will be obtained with a given current when the armature and field have equal magnetic strength. I imagine that a great loss occurs when the field magnet does not have a properly polarized armature to act upon.

A good dynamo electric generator is one having the least possible amount of wire on its armature to produce a given current. The best motor is one that has a sufficient amount of wire on its armature to bring it to a magnetic strength exactly equal to the polarization afforded by the field magnet.

Many assume that a slow running motor is a very inefficient contrivance. Such should not be the case. A perfect motor is one which will give the same return for a given amount of expended energy, whether run at ten or one hundred revolutions per minute; that is, for every 746 watts that it receives it will raise 33,000 lb. one foot high in one minute, no matter what its number of revolutions.

To approximate this result, it is obvious that the magnetic pull must increase as the speed diminishes and more iron must be used than has been as yet. Want of iron in the armature is particularly noticeable in motors of the Pacinotti type. In some cases, particularly railway motors, too much iron can hardly be employed.

In an arrangement of apparatus for use on high potential arc light circuits, I would arrange a shunt motor, the wire on the shunt having much greater section than that on the armature. I would place these motors in series on the circuit, and by means of a ball or torsion governor cut in more or less of the shunt, as the power called for may require; always preserving such a relation of resistances that magnetic equality between field and armature is assured. By this arrangement only the necessary amount of current to do the work will be taken from the exterior circuit. When the motor is running idle almost the whole current will pass through a very few turns of the shunt, going on to some other point on the circuit where its energy may be needed.

I am aware that objections have been made to this system of distribution on account of the reactionary effect which seems to occur between different motors on the circuit. This defect, however, is so easily remedied that it ceases to be a factor in the problem.

A great deal of late has been said and written about constant speed motors, self-regulating motors, motors with differential winding, etc., etc. It seems to me that nearly all these schemes amount to using current for the purpose of breaking itself—an arrangement which has about the same mechanical economy as would be obtained in admitting steam simultaneously on both sides of the piston of a steam engine whenever it had a tendency to run too fast.

In the adaptation of motors to railway propulsion we seem to be in the same state that engineers found themselves about the time of the introduction of the locomotive. It really looks as if we never should hear the end of various schemes involving the use of friction clutches, gears, pulleys, chains, belts, and screws. As with the locomotive, so with the electric motor—there is but one way to practically convey the power, and that is by direct coupling. The necessity for great periphery speed of armature ceases when plenty of iron is used, and in some cases multipolar motors employed.

The brush lead of dynamos and motors is a point upon which there is a wide difference of opinion. Some manufacturers have, I believe, gone so far as to twist the connecting wires back upon the commutator, giving an apparent line of commutation at right angles to the pole pieces, under the supposition that such a position would give an appearance of great efficiency to the machine. When we reflect that the lead is due to the magnetic distortion caused by the opposition of the polarity induced by the current flowing in the armature to the polarity given by the field magnet, it would seem that a dynamo without brush lead would be a monstrosity.

In a good motor, when in a state of rest, the brushes should have a backward lead of 45°. As the motor gathers speed this lead will become less and less, varying with the speed. If the motor be propelled mechanically, as in the descent of a loaded elevator, the lead will be found to have shifted to a forward position, as in a generator; hence, in variable speed large railway motors, automatic brush regulation would seem to be a necessity.

Motors propelled by secondary batteries have yet to prove their position; for railway propulsion they afford a beautiful experiment, but their excessive weight, together with cost of introduction and operation, renders their employment in this service extremely problematical.

You gentlemen, who represent the electric lighting interests of the country, should make use of your facilities. I doubt if there's a company doing an arc light business that cannot make twice as much in the distribution of power.

Use any of your continuous current dynamos as motors, only put in more iron and balance the magnetism in your armatures and field. Don't waste your time on mechanical gymnastics, but use what you have and are sure of, and the time is not far distant when small steam engines will be unheard of, and large ones only known in localities where cheap fuel abounds.

* Paper read before a special meeting of the Electric Club of New York, February 17, 1887.

THE ELECTRO-OSTEOTOME.

THE invention of a fundamentally new instrument of precision has often been found to result in opening up an entirely new field of knowledge, or of increasing greatly the range of knowledge within the branch of science to which it applies. We, therefore, watch with special interest the introduction of any new surgical instrument or appliance which will tend to reduce human suffering or lead to improved methods in operative surgery.

We, therefore, acknowledge a debt of gratitude to Dr. Milton Josiah Roberts, of New York city, for having invented a new surgical instrument, which he calls the *electro-osteotome*, with which he can make cross, oblique and linear sections of bone with exceeding ease and astonishing rapidity, while a mathematical precision can be maintained as to the accuracy of the cut both in regard to direction and extent. Take, for instance, such a deformity as knock-knees, due to a curvature of the bones; to remedy which, in the usual way, requires a long, tedious operation with a mallet and chisel, with which a wedge shaped piece of bone is cut away. It is perhaps the most brutal and unscientific method which could be adopted, and sounds like the operative butchery which existed in the last century. Yet that is now the practice with surgeons of the present day who perform such operations. Dr. Roberts reforms all this at a stroke. His electric osteotome is an instrument holding a circular saw at its extremity, which revolves with lightning speed by an electric motor. This, when held against a bone, makes a clean cut through it in a few seconds; in fact, its action is almost instantaneous. By holding the electric osteotome in a slanting position, wedge shaped pieces can be cut out with equal promptitude. There is no danger of the saw cutting the soft parts, as they are protected by a retractor, an instrument which is passed down and under the bone. When such a wedge shaped piece of bone of proper angle is removed, the remaining bones of the leg can be straightened, and the deformity is remedied forever.

There are a great many diseases of the bones requiring this kind of section cutting. In some instances they have to be cut through in several places. We understand that Dr. Roberts made over twenty-four sections on a single individual at one sitting with his osteotome. Sometimes the bones become diseased, soft and rotten. This is called caries of the bone. In such cases the diseased parts have to be cut away. The ordinary surgeon would require about three-quarters of an hour's work with his mallet and chisel to perform this operation. Dr. Roberts with his electric osteotome would remove the bone in a few seconds, not only insuring dispatch and precision, but with less

shock to the patient, and consequently removing one of the chief risks of life.

We have, perhaps, indicated sufficiently the value of Dr. Roberts' invention, and those who are unfortunately requiring relief from bone troubles requiring operative measures will be indeed foolish not to make use of it. Such operations at the best require the close attention of a specialist and the most perfect surgical appliances which science can place in his hands.—*Health.*

ELECTRIC WELDING.

By Prof. ELIHU THOMSON.

THE energy of the electrical current at any time at our disposal may be utilized to produce motion in its various forms, such as mass motion, as in electric motors, driving machinery, or propelling a train; wave motion, as in telephonic sounds; light or luminous wave motion, as in electric lamps; chemical decompositions, as in electro plating; and heat motion, which latter nearly always attends the conversions just alluded to as a waste or loss, more or less unavoidable.

While I do not share in the anticipations of some over-sanguine people, that the energy of electricity will be used when directly converted into heat for warming our buildings, still we have ample evidence of the fact that for special purposes heat so produced can not only be applied practically, but economically. Electric heating is perfectly applicable to cases in which the supply of needed heat is small and requires to be kept up for a prolonged period under perfect control, or in which a sudden, quick heating of moderate amount is to be used. Again, if the temperature required to effect a given operation is above that producible by combustion, electricity may be employed; for the temperature producible by its means is only limited by the vaporization and expansion of the materials heated. We find an instance in the Cowles electric furnace, used for the reduction of those metallic oxides which even in the presence of carbon will not at ordinary furnace temperatures part with their oxygen, but which in the electric furnaces are subjected to temperatures very near that of the vaporization of carbon, or that of the fusion of the oxides and consequent intermingling of their particles intimately with those of carbon.

It is my purpose in the present paper to give an account of a new way of utilizing the heating effects of heavy electrical currents, for uniting or causing union between pieces of metal, whether of the same or of different kinds. I have called the process "electric welding."

Hitherto the metals which have been welded with facility by the ordinary methods of furnace heating and subsequent hammering have been wrought or soft iron, steel, platinum, pure gold, and a few others. So far as I know, cast iron, brass, gun metal and bronze, German silver, zinc, tin, lead, aluminum, and other metals and alloys more or less commonly used, have not hitherto been welded, and even in the case of copper, which softens readily by heat, the welding together of two pieces, though not impracticable, has been so difficult as to have been seldom tried with success. Much less, indeed, has it been generally practicable to weld pieces of unlike metals together; and even with iron, very small pieces can scarcely be welded in the ordinary way on account of the rapidity with which the heat is dissipated, thus reducing the temperature below the welding heat.

All this, however, is changed when we come to the practice of electric welding. Some of the metals which it was before impossible to weld become those most easily dealt with. Such are cast iron, brass, bronze, zinc, tin, etc. Copper, formerly welded with so great difficulty and uncertainty, becomes remarkable for the facility with which joints are made when the proper temperature is reached. Iron, steel, platinum, and like metals, formerly known as weldable, are united electrically with great ease and certainty. Thus far pieces of all the metals tried have welded to other pieces of the same metal. When, however, the pieces are of different metals or alloys, failure may result from too great differences, either in their temperatures of softening or in their specific electrical and heat conductivities.

The method of electric welding may be briefly stated to consist in forcibly pressing together the bars or other pieces to be joined or welded, and then passing an electric current of large volume through the pieces, a small portion of the bars on each side of the place of abutment serving as a path for the current. The resistance at the meeting point of the abutted bars gives rise to a welding heat at this point, and the pressure causes a thorough union, with generally an expansion at the union due to the approach of the pieces under pressure. The process is evidently a simple one.

Now let us inquire what are the results and the possible uses of electric welding. An enumeration of some of them may be of interest.

One of the most evident applications is in joining, end to end, wires of copper and iron for various purposes, such as in forming coils of magnets, and in telegraph, telephone, and electric light line construction, thus avoiding the existence of clumsy and resisting joints.

In the factory of the Thomson-Houston Electric Company, wires have been so joined in the practical construction of dynamos, and the method will be extended in use there as soon as the necessary apparatus can be built.

I have specimen wires of copper and iron of varying sizes with electrically welded joints, some of which wires have been bent and twisted without rupturing the weld. There is no reason why very heavy bars may not be operated upon by using sufficiently large and powerful apparatus. The largest diameter of copper rod thus far welded measures nearly $\frac{1}{16}$ inch, and of steel nearly $\frac{7}{8}$ inch in diameter, and so far as can be determined by estimation alone, this required a current of over 20,000 amperes. This is probably a much larger current than has heretofore been produced in any single conductor or machine. The difference between the sizes of iron and copper welded by equal currents is due to the smaller resistance of the copper and the greater facility with which it conducts heat away from the junction during the operation. The specimens which I have comprise a variety of sizes and shapes of iron, steel, copper, and other bars, in some of which the expansion at the weld remains as formed, and in others it has been ground off or removed, to show the character of the metal at the weld.

Another obvious use of the new welding process is in the butt welding of metal tubes or pipes, examples of which are iron pipes of various diameters, brass and copper tubes joined end to end, and a lead pipe with two joints, which pipe has, as a test of complete union, been much bent after the formation of the joints. The joints on the iron pipes have in most cases been hammered during, or just after, the welding, and are very firm and strong. It is quite possible to make long lengths of cast iron or wrought iron pipe for street service, which may be laid with few calked, cemented, or screw joints, or even as a completely welded, unbroken pipe, bends being made at intervals to allow for expansion during change of temperature. For high pressures of steam, air, or gas, such a system would seem to be desirable. Long iron pipes are now very laboriously made from short lengths for bending into coils containing from 100 to 1,000 feet. The electric weld would render such an operation easy.

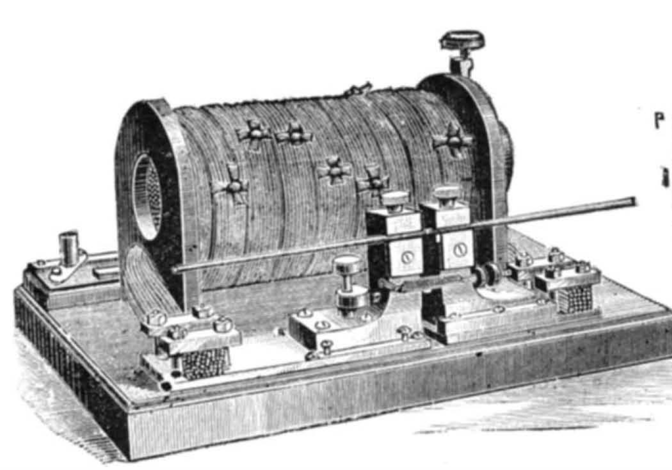


FIG. 1.

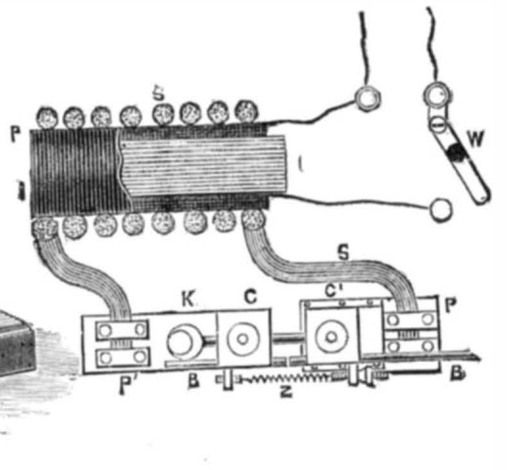


FIG. 2.—DIAGRAM SHOWING ARRANGEMENT OF COIL IN FIG. 1.

In making or repairing endless bands, such as band saws, wheel tires, barrel and tank hoops, the electric method promises to be of great utility, some specimens of such work having been produced. Analogous to this is the heating and welding of iron and steel links of various kinds.

Besides the application of electric welding to uniting together bars and pieces of various metals, of various sections and of various shapes, as briefly outlined above, there is a very wide field of usefulness to be found in the manufacture and repair of tools and parts of machinery. In the factory of the Thomson-Houston Electric Company, at Lynn, there are in use a number of tools having electric welds, and it is intended also to extend the welding to the construction of other tools to which it is applicable with a saving of cost.

As examples of such work, I may mention the lengthening of screw taps, drills, reamers, augers, to any amount required; mending chisels and punches when worn out or broken, by providing them with new edges welded to the old bodies; lengthening screw bolts by welding sections of bar between the screw and the head of the bolt, or shortening them by cutting out sections and reuniting the head and the body; welding new drills and reamers to the taper shanks of old and worn out drills and reamers; renewing the points of worn out centers for lathes; renewing the cutting ends of lathe turning tools when worn out or broken, instead of casting the steel aside as useless; uniting short pieces of shafting into longer lengths; reuniting the pieces of broken tools; and, in general, welding steel pieces to steel or wrought iron, or even to cast iron bodies of tools. One quality of steel may be used for the cutting edges and another for the body of the tool. There are, without doubt, many instances in which the construction of tools used in the various trades may be cheapened by joining together pieces to form such tools as would otherwise have been cut or forged from one piece of metal.

Electric welding is applicable to the very delicate work of the jeweler's art, and equally so to the joining of the parts of heavy machinery. I have united the

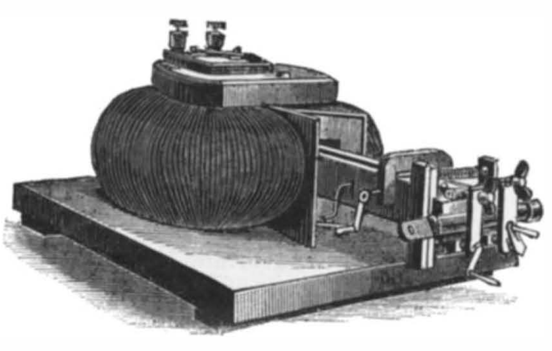


FIG. 3.

ends of wires less than $\frac{2}{100}$ of an inch in diameter, and the size of the larger pieces dealt with has only been limited by the power of the apparatus at command.

I have reason to think that the actual fuel consumed in effecting a weld by electricity, notwithstanding the loss in boiler, engine, and electrical apparatus used, is less than in the ordinary blacksmith's processes, and chiefly because of the very small time needed to effect the electric junction, as well as to the application of the heat to the metal locally at and near the weld, with the consequent small losses by radiation and conduction. Besides this, the time required is so short that quite a number of joints may be formed in the time ordinarily required to make one, and the pieces are not required to be skillfully manipulated during the process—a great advantage in the working of large pieces.

Having thus rapidly reviewed the possible applications, as they now present themselves, let us turn to the operation itself.

In the first place, electrical current energy is a product of its pressure or electromotive force by its amount of flow or volume. Hence, to represent a certain amount of energy, we can have a small volume of current with a high electromotive force or pressure, or a very large current with a very small electromotive force, just as we may have a small flow of water at a great head or pressure fed to a turbine, and yield, say, a horse power, while the same power may equally be yielded by a much larger flow of water under a small pressure or head, with a suitable wheel. Or electrically speaking, a flow of current of one ampere, with an E.M.F. of 746 volts, represents energy at the rate of one horse power, or 33,000 foot pounds per minute, and the same energy is represented by a flow of 746 amperes with one volt, or 1,492 amperes with half volt. In arc lighting, ordinarily, a current of 10 amperes and 2,500 volts E.M.F. is not infrequently used. In incandescent lighting in multiple arc, 250 amperes and 100 volts would represent an equal energy, and in electric welding 50,000 amperes and half a volt would be the equivalent; and this would probably weld a bar of steel 1½ inches in diameter, as nearly as I can now estimate the conditions. But there is quite a difference between running electric lights and welding. The lights demand the power continuously, while in welding the energy is demanded for a comparatively short time, varying from a few seconds to half a minute or more, according to the size of the piece. If my estimates are anywhere near correct, it would require to weld a bar of steel 1½ inches in diameter, an expenditure of about 35 horse power for less than a minute.

The apparatus used in generating and applying the currents for electric welding will vary according to the character of the work to be done. The chief essentials to be found in it are, outside of the source of current, (1) a means for getting the heavy currents into the pieces without too much waste, such means being solid conducting clamps bound upon each piece; (2) a means for forcing the pieces together during the passage of the current; and (3) a means for holding the pieces in

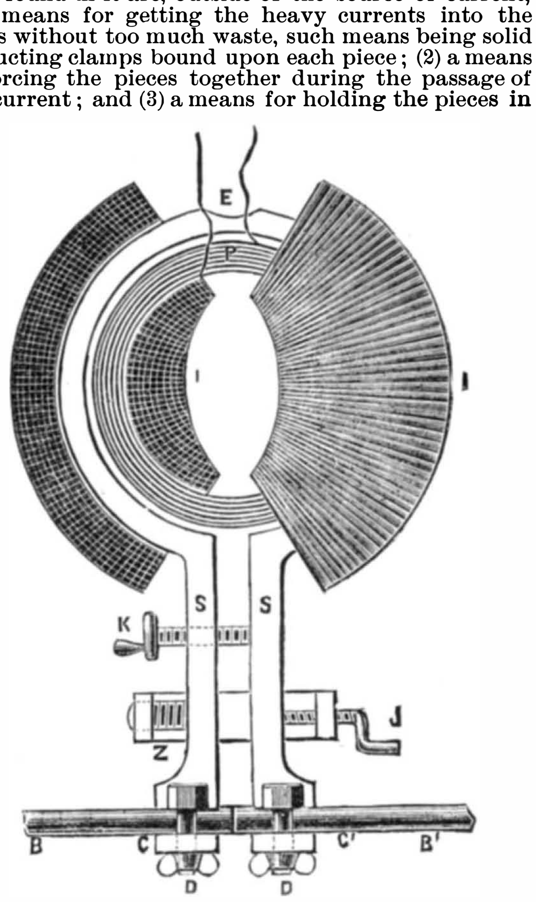


FIG. 4.—DIAGRAM SHOWING ARRANGEMENT OF COIL IN FIG. 3.

the position desired. The conditions are usually fulfilled by arranging the heavy copper clamps or chucks in line with each other, but at a distance apart which can be adjusted, and arranging a spring and screw for forcing the pieces together. The clamps are connected to the terminals of an electric current producer, such as a very coarse secondary coil of an induction apparatus, the primary of which is supplied with alternating currents from an alternating dynamo; or a cell of a secondary battery of very low resistance and low electromotive force may be substituted for the coil.

One form of the apparatus (shown in perspective and section in Figs. 1 and 2) may be described as follows: It consists of an induction coil composed of a core, I, I, of iron wire about 12 inches long and 2½ inches in diameter, around which has been wound a coil of primary wire, P, to be traversed by currents from an alternating current machine. The outside or secondary coil, S, is composed of 64 wires, No. 10 B. and S. gauge, bound together and passing only eight times around

the core. The ends of the secondary strand so formed are bolted down to copper plates, P, P′, upon which the clamps, C, C′, for holding the pieces to be welded are mounted. These clamps are formed of comparatively heavy blocks of metal. One of the blocks or clamps, C′, is arranged to slide upon its copper bed plate, and is guided so as to move in a straight line toward the other block, under the action of a spring, Z, which is adjustable. This permits the two pieces, B, B′, held in the clamps for joining, to remain in alignment during the welding, attended, as it is, by a slight movement of the free clamp toward the fixed clamp. A cam, K, is arranged to be turned so as to separate the clamp blocks by forcing back the movable block, C′, and to hold it so during the placing of the pieces in the clamps.

The clamps themselves are simple pieces of metal arranged to be screwed up or down to permit removal of, or to gripe, the pieces to be operated upon. The operation of placing the pieces in the clamps in this apparatus requires only a few seconds. This apparatus, as described, is especially adapted to joining small wires of copper, small steel pieces, band saws of small size, etc. The primary coil is put into circuit with an alternating current generator, and, together with the iron core, may be inserted or removed from the axis of the secondary coil to a greater or less extent, in order to adjust the current to the size of pieces operated upon. The current produced by induction in the secondary coil is of large volume and low electromotive force. The resistance of the secondary coil taken alone is approximately 0·00015 ohm.

In another apparatus used by me (shown in perspective and section in Figs. 3 and 4) the construction is different, and much larger work can be accomplished with it. The primary coil, P, is simply a large open ring about 12 inches in diameter, 2½ inches wide, and ¾ inch or more thick, and is composed of many turns of insulated wire wound on a form. The secondary, S, S, is simply a single heavy bar of copper bent to make only one turn outside the primary coil, and the terminals of the single heavy convolution are bent outward to a parallel position and provided with powerful screw clamps, C, C′, at the ends for holding the pieces, B, B′, to be abutted. The secondary has the form, therefore, of a large copper jew's harp, with the clamps at the ends of the straight and parallel portions. The clamps are made movable toward and from each other by having the copper bar thinned and broadened at the middle of its curved portion at E, and farthest from the clamps, so as to give to the bar a certain degree of flexibility.

The clamps, C, C′, are arranged to be drawn together, when needed, by a powerful screw, J, and spring, Z, so that the desired pressure for forming the weld may be given; and another screw, K, is provided for forcing the ends bearing the clamps apart, when the pieces are to be inserted in the clamp preparatory to the passage of the current.

Both the primary coil and the secondary bar are wound over with a great mass of iron wire which passes through the open axis of the coils and over the outside of them, thus forming an endless iron core to both the primary and secondary conductors. These conductors are virtually inclosed in a tube or sheath of iron wire. The iron wire, I, I, is in reality wound upon a sheet iron casing or guide, which keeps the wire from bearing upon the secondary bar and interfering with the free movement of the parts of the secondary bar itself, as well as of the clamps. The calculated resistance of the secondary bar is about 0·00003 ohm, and under a very energetic primary current it should be capable of generating more than two volts of electromotive force, but it is generally used with much less than maximum excitation. The alternating currents passed through the primary coil produce, of course, rapid reversals of magnetic polarization in the iron sheath surrounding the copper conductors, and there results a transfer of energy by induction to the circuit of the secondary, such transfer being attended with a small percentage of loss. A current of a little over 20 amperes and 600 volts average in the primary may produce in the secondary nearly 1 volt and 12,000 amperes.

For furnishing the alternating currents needed I have designed and constructed a cheap self-exciting alternating current machine, one size of which machine, weighing only 500 lb., can absorb a maximum of over 25 horse power at 1,800 revolutions per minute, returning a fair percentage of the power as current for use in welding. The machine has only 10 pounds of wire on its armature and about 40 pounds of wire on the field magnets. The large output given by this small machine is rendered possible because the machine is called upon to furnish current at intervals only, as during the formation of a joint, and because at other times it runs without load.

Provision must be made by suitable switches to cut off the current from the pieces which are being welded when the weld is seen to be complete. This can be done, of course, by breaking the secondary circuit itself at the proper moment, but it is evident that for such heavy currents the switch would have to be very massive. Equally good results are, however, obtained by cutting off the primary current or by breaking the circuit of the dynamo, or by the shunting or cutting off of current from the field magnets. It is also desirable to provide a means for regulating the power of the currents so as not to suddenly overheat the pieces, especially where they are small or easily fusible. This can be done by inserting a variable resistance in the circuit of the primary, or by inserting into the same circuit a coil of wire with a movable iron wire core, the positions of which will govern the force of the primary currents. Another good plan is to vary the power of the field magnets of the alternating current machine in any of the various ways known for accomplishing such result.

To effect an electric weld, the pieces are rubbed bright near the ends to be joined, so as to insure a good electrical contact with the clamps by which the pieces are held, the pieces being firmly bound therein with their ends abutted in the space existing between the clamps, so as to leave a small portion of the bar projecting free of the clamps to the meeting point.

The ends abutted are, of course, kept clean to form good contact, and a little powdered borax is applied as a flux, usually after the pieces have been abutted; or, if the metal be of low melting point, as tin or lead, a little zinc chloride, resin, or tallow is applied.

When the pieces are of the same metal and of the same size or section, the junction is made by placing the ends of the pieces abutted midway between the clamps before applying the pressure to force them together and the current to weld them. But when they are of different metals or of different sections, the abutment or meeting point is placed nearer the clamp carrying the most resisting metal; or, the piece of smaller section, or the metal most readily fused, as the case may be, is so placed as to project least, for the purpose of favoring the accumulation of heat in the other piece.

In joining pieces of different diameters the end of the large piece is reduced to the size of the smaller before attempting to effect the weld. It is, of course, best to have the clamps formed to fit the pieces, especially when the pieces are of irregular outline, but for round or square bars, simple V grooves in the clamps suffice to hold the pieces in place and to give the requisite electrical contact with them. When the pieces are in place and pressed together by the means provided, the current is turned on, and at once the ends of the bars heat where abutted, a slight yielding or approach of the pieces takes place, and, more quickly than the operation could be described in words, the work is done. Sometimes the joint is pressed or hammered to still further perfect and consolidate the weld. This can often be done while the pieces are in place in the clamps, and while the heat is maintained by the current.

Whether the electric current has any peculiar action in assisting the welding I do not know, but I am inclined to think that, in some cases, it has some such influence, although much the larger effect is the simple result of heat and pressure. One circumstance, however, arising out of the electrical properties of the metals subjected to the action, may be noticed. This is the tendency exhibited toward a uniform heating of the section of the abutted bars, as a consequence of the fact that cold metal is a better conductor than hot metal, and that, therefore, any cooler line of particles in the section at once becomes the path for increased current and is brought up in temperature to equality with the other portions.

I would call attention to the fact that in the economical application of electric welding, cheap water power can be utilized to furnish the energy necessary, and that by conveying the currents over lines it can be utilized at distances from the site of the water power.

It only remains for me, before closing the present paper, to mention the fact that I am preparing to have specimens of metals which have been welded electrically subjected to tests of tensile strength, etc., to determine what proportionate strength exists at the welded portion of the bar. That the strength is great, the rough tests of specimens leave no doubt, but it is desirable to have the exact data. In illustration of this point, I would mention the case of a lag screw, which was shortened by cutting out a section and welding the square head and screw portion together again. The weld was far less perfect than usual, as was easily seen, little or no expansion at the weld having taken place. Nevertheless, in turning the resulting screw into a block of hard wood by a wrench applied to the head, it twisted off an inch or two below the weld, and the fracture shows that the metal was sound and strong at the point of breaking, while the weld was, of course, unaffected.

Among the curious things noticed in the use of the apparatus is the loud sound or snap due to the extra current in the secondary when the pieces in the clamps are not permitted to move together as the metal softens, and a rupture of the secondary circuit occurs between the pieces. This rupture, although occurring in a circuit whose length is a very few feet, is attended with a very loud snap, a bright flash, and forcible ejection of hot particles of metal, as if a fulminate cap had been fired between the pieces. I have seen this action throw white hot pieces of fused steel as large as peas a distance of six feet, and this fact suggests the advisability of keeping the eyesight out of line with the discharge.

As curious instances of work accomplished I may mention broken twist drills mended in the twisted portion, one specimen showing two joints made in the twisted portion of a twist drill. Another curiosity is a bar composed of steel, brass, and copper pieces joined end to end. Penknives which have lost their blades by breakage close to the handle have had new pieces of steel, which have been subsequently ground into blades, welded to the stumps of the old blades, such stumps projecting scarcely an eighth of an inch from the handle, and the welding has been done without removing the stump from the tortoise shell or other handle. Several other penknives have been thus resuscitated, and I am pleased to say that in the only instance thus far in which a subsequent breakage of the blade has occurred it gave way at a distance from the weld.

Iron wire rings have been made of many short pieces of wire, and afterward violently twisted and bent so as to produce short "kinks" without parting, although the short bends included the welded portions. Long pieces of copper wire have been made of a number of short pieces, and afterward twisted in like manner without yielding at the joints.

The accuracy of the work done depends upon the true alignment of the clamps for holding the pieces, or upon their true adjustment as to relative position, when the pieces are of irregular form. For irregular work, the clamps should be capable of being shifted into various relative positions—a condition not difficult to secure.

HEAT CONDUCTIVITY OF METALS.

TAKE a copper ball about three inches in diameter, and cover it with a piece of muslin or a fine cambric handkerchief. Upon the ball thus covered place a glowing coal taken from the fire with a pair of tongs, and then blow on the coal, in order to render it incandescent. The coal will continue to burn brightly without in any way burning or damaging the fabric upon which it lies. The reason of this is that the metal, being an excellent conductor of heat, and having, at the same time, great calorific capacity, absorbs all the heat developed by the combustion of the coal, and the fabric, taking up scarcely any of the heat, remains during the entire experiment at a temperature less than that at which it would harmed.

This experiment can be perfermed in a more remarkable manner. Take a cambric handkerchief, and cover a gas burner with it. It is indispensable that the tip of the latter shall be of metal. If the cock be turned on and the gas be lighted, the latter will burn above the handkerchief without harming it (Fig. 2). In order to succeed in this experiment, it is necessary that the handkerchief shall be applied closely to the metal, and that there shall be no wrinkles in it where it covers the tip of the burner. It is well to hold it in position by means of a fine copper wire, as shown in the figure. In these experiments, we would recommend our readers to use nothing but very fine cambric, and that which is not of service, so that they will not have to regret the ruination of a good handkerchief in case of want of success.

These experiments, when properly performed, succeed perfectly. We have tried them several times ourselves.—*La Nature.*

FIG. 1.

FIG. 2.

EXPERIMENTS ON THE HEAT CONDUCTIVITY OF METALS.

CLIMATE IN ITS RELATION TO HEALTH.*

By G. V. POORE, M.D.

LECTURE I.

IT seems necessary, to begin with, to offer some definition of the word "climate;" and yet, as we all know pretty well what we mean by climate, it is perhaps hardly advisable that I should fetter your ideas by any hard and fast definition, and I am sure that it is not advisable that I should fetter myself, for I intend to treat of climate in the freest manner possible, and I must by anticipation ask your indulgence for many divergences from the conventional ideas of "climate." The definition given by Dr. Hermann Weber, in the second volume of Von Ziemssen's "Handbuch der allgemeinen Therapie," is probably wide enough for all purposes, and although I do not promise to be bound even by it, I offer it as a sort of foundation upon which to build my remarks. Dr. Weber says: "By climate we mean the sum of those influences which act upon the life of organic beings through the air, soil, or water of a district."

The earth is surrounded by a gaseous envelope, having a depth, it is supposed, of some forty miles. Crawling at the bottom of this ocean of air is man, who may be likened to a crustacean crawling at the bottom of the sea. Some animals there are—birds, insects, and

* Three lectures before the Society of Arts, London. From the Journal of the Society.

the like—which are able to live in the higher, purer regions of the atmosphere. Man crawls along the bottom, and lives in the lowest strata, which are often rendered cloudy by the dust of various kinds, which is raised by himself and his teeming fellows. Life without the atmosphere is inconceivable. Not only does it minister to those chemical changes which are constantly going on in the body, and the cessation of which means death, but the pressure which the atmosphere exerts on our bodies (varying from twelve to fifteen pounds per square inch of surface, according to the elevation above sea level) is probably essential for the well-being of our bodies as at present constituted. Without the atmosphere, the evaporation of water and its recondensation in the form of dew, rain, and snow would probably cease; and, finally, without the atmosphere, which is spread like a transparent curtain between us and the sun, not only would the sun's rays be perfectly insupportable, but the transitions of temperature would have a suddeness and severity to which it would be impossible to accommodate ourselves.

The atmosphere is almost uniform in composition. In 100 volumes of air there are of—

Nitrogen	79·00 volumes.
Oxygen	20·96 "
Carbonic acid	00·04 "
	100·00

Of these gases the oxygen is the most important. It is the great supporter of life, the gas that carries on the combustion of the human body, that makes the flame of life burn brightly, that calls forth the energy of the animal machine, and enables us to maintain our body temperature in all weathers.

Since we breathe some sixteen times in a minute, and inspire about a pint of air every time we draw our breath, it is evident that the amount of air we require per diem is prodigiously great, and that the purity of the air we breathe is a matter of prime importance.

Whence come the gases which form the chief constituents of the atmosphere? Of the source of origin of the nitrogen we know nothing. Of its uses we know nothing. Its chemical action in the great function of respiration appears to be *nil*, and, although it constitutes nearly four-fifths of the total bulk of the air we breathe, its properties seem to be to a great extent negative. Even supposing that its main function be to diffuse and dilute the oxygen, we must be careful not to underrate such a function.

The main source of carbonic acid is the respiration of animals and other forms of combustion. The air we breathe returns from our lungs highly charged with carbonic acid and moisture—too impure to breathe a second time. Countless millions of animals, high and low in the scale, are engaged in fouling the atmosphere, and in pouring carbonic acid gas into it, and at the same time in using up the oxygen. If, then, every creeping thing that lives upon the globe is constantly using up oxygen and giving off carbonic acid, the question arises, How is the oxygen renewed, and how is the carbonic acid got rid of? The answer is that vegetable and animal life are complementary to each other, and that every green leaf of every waving forest tree, every blade of grass that clothes the sward, every green seaweed and river weed, is actively engaged in absorbing carbonic acid from the air or water, fixing the carbon, and returning the oxygen to the air for the benefit of animals. Thus carbonic acid is constantly being given off by one class of organisms (the animal), and greedily devoured by the other great class of organisms (the vegetable), while the oxygen given off by the vegetables is devoured by the animals.

If the renewal of the chief constituents of the air is thus provided for, it is still not at first obvious why it is that the air is almost uniform in composition. In some places, as in this great overgrown city, for example, animals are greatly in excess of vegetables, and we should expect to find that, in the air of London, there was great excess of carbonic acid. Excess there is, but not to the extent that we should have perhaps imagined.

The almost uniform composition of the air is accounted for:

1. By the equal distribution (taking the whole world over) of animal and vegetable life, the animals living to a great exte t on the excremental gas of vegetables, and *vice versa*.
2. By the law of diffusion of gases.
3. By the movement of the air produced by local and meteorologieal causes. Besides the incessant local movement produced by the movement of animate and inanimate objects, variations in temperature and consequent variations in pressure, there is the general movement of the wind to be considered, and this, be it remembered, has a general average rate of speed in this country of ten miles an hour.

Thus the mixing of the gases is very thorough and very constant; and when (also) it is borne in mind that at the average rate of speed of the wind as much air blows over the surface of a man's body as would, at a pinch, serve for the respiratory need of 1,000, and that the supply of air is thus in great excess, and that the fouling of the atmosphere by animals is, in proportion to the whole bulk of the atmosphere, but trifling, we begin to see how it is that, in the open, the composition of the air very nearly approaches uniformity.*

The uniformity is, however, very far from being absolute. Thus, if we take the average amount of oxygen as 20·96 volumes in every 100 volumes of air, or 2,096 in every 10,000, we find that in the thickly populated parts of the east end of London it may fall to 2,086 parts per 10,000, while on the high ground to the northwest of the city it may rise to 2,100 parts per 10,000, which is, in fact, as much or more than Angus Smith found on the hills in Scotland. Thus the extreme range of fluctuation in the amount of oxygen in the open air is about fourteen parts in 10,000, or 0·14 per cent.

* Professor de Chaumont, in his admirable lectures on "State Medicine," makes the following interesting and curious calculation: "Now I reckon that at the lowest estimate there cannot be less than 300,000,000,000 cubic feet of carbonic acid generated in London in a year from combustion and respiration, or a mean of 822,000,000 per day or 34,250,000 per hour, or more than 9 500 cubic feet every second. Now this is sufficient to double the normal amount of carbonic acid in 23,750,000 cubic feet of air every second, or in about 14 cubic miles every twenty-four hours, or more than 5,000 cubic miles per annum. This represents a mass of air of the area of the metropolis, but extending upward to ten times the height of the Himalayan mountains. How constant and powerful must the varying currents be that produce diffusion through so vast a mass!"

I am not prepared to say that fluctuations of this kind have any appreciable effect on health. When we speak of air containing 21 parts per cent. of oxygen, we mean volume, not weight, so that this expression gives us no idea of the absolute amount of oxygen inhaled. Equal weights of gas or air are capable of occupying very different volumes, according to the temperature and pressure to which they are subjected. The effect of temperature is thus stated in a foot note to Parkes' "Hygiene," p. 436: "A cubic foot of dry air at 30° Fahr. weighs 566·850 grains, and is thus constituted:

436·475 grains of nitrogen.	
130·375 " of oxygen.	

At a temperature of 80° Fahr. the foot of air weighs 516·38 grains, and is thus composed:

397·61 grains of nitrogen.	
118·77 " of oxygen.	
516·38	

Thus, at the higher temperature (80° Fahr.), each cubic foot of air contains 11·605 grains of oxygen less than at the lower temperature, and if we assume that the rate and depth of respiration is the same at the two temperatures, and if we further assume that 16·6 cubic feet of air are drawn into the lungs every hour, then the man in the tropical temperature, as compared with the man in the arctic temperature, will have, so to speak, an hourly deficit of oxygen amounting to 192·6 grains.

The fire burns bright, we are told, in frosty weather, the reasons being, first, that those who have the care of the fire, and are themselves nipped by the frost, take care that it shall burn brightly; and secondly, the cold air which supports the combustion is rich in oxygen.

One of the great objects of respiration is to support the animal heat, and it is only one of the many instances of the absolute adaptation of means to ends which we meet with everywhere in nature, that the man who is exposed to cold is supplied with increased amount of oxygen, to cause a brisk combustion in the human furnace; while he who is scorched by the sun, and has less need of internal fire, gets a diminished supply of oxygen.

Again, diminution of pressure lessens the amount of oxygen in each cubic foot of air. If we ascend a mountain 5,000 feet high, the barometer will fall from 30 inches to 25 inches, *i. e.*, the pressure will be diminished one-sixth, and a cubic foot of air, which contained 130·4 grains of oxygen in the valley, will contain only 108·6 grains at the higher level, or a diminution of 21·8 grains per cubic foot. If we assume the rate and depth of respiration to be unaltered (which we have no right to do) then the deficit of oxygen at the higher level per hour amounts to 21·8×16·6=361·88 grains. These figures show that man is able to bear very great fluctuations in the weight of oxygen in the air which he breathes. They show certainly more than this, viz., that fluctuations in the amount of oxygen are necessary for his well-being under variations of temperature and pressure. Why it is that less oxygen is required to support life at great altitude is not very clear, but when we look at the hardy mountaineer, the type of health and manly beauty, we must admit that the fact is undeniable.

Although we are, at present, unable to say that the mere fact of a small percentage variation of oxygen in the air breathed is, by itself, a very important matter, still we have to remember that it is never an isolated fact, and has always to be considered along with other facts. What we have to look to is the reason why a diminution has taken place.

Whether the small amount of carbonic acid (0·04 per cent. by volume) which is present in the air serves any useful purpose in the animal economy, it would be difficult to say. Carbonic acid is regarded as an impurity, an impurity poured into the air as the result of respiration and combustion.

In the open air the amount is not found to vary to any very great extent, as the following list will show:

CARBONIC ACID, PER CENT.

Over open sea (Thorpe)	0·032
At Manchester (A. Smith)	0·037
At Portsmouth (De Chaumont)	0·032
At Aldershot "	0·040
At Tower of London "	0·042
At Chelsea "	0·047
At Paddington "	0·056
At Munich (Pettenkofer)	0·050
Top of Mont Blanc (Frankland)	0·061
At Chamounix "	0·063
Arctic regions, Alert (Moss)	0·055

It is well known that carbonic acid in large quantities is a narcotic poison. An atmosphere containing from 5 to 10 per cent. (*i. e.*, 100 to 200 times the amount in ordinary air) is fatal. It is stated that in soda water factories, where the amount of carbonic acid often reaches 0·2 per cent., no ill effect is felt.

The variations in the carbonic acid in the air are not very great; and it is probable that variations such as those shown above of carbonic acid per cent. would be incapable of working much, either for good or ill, but it must be remembered that carbonic acid always keeps bad and dangerous company; and when the chemist tells us that in such or such a place carbonic acid which he can analyze is in excess, we may feel sure that it is accompanied by organic matter which he cannot analyze.

In confined spaces where human beings or animals are closely packed, carbonic acid is found in great excess. In the forecastle of a ship, the almost incredible amount of 3 per cent. of carbonic acid has been found by Rattray, and the average of 150 analyses made between decks gave 1·64 per cent. of carbonic acid. These figures are the highest which have been obtained in any place which is inhabited and inhabitable, and the explanation is to be found in the small cubic space per head, and the constant occupation of the space day and night. As much as 0·58 has been found in theaters; 0·70, 0·50, 0·30 has been found in crowded schools; 0·20 in bedrooms; and similar amounts in hospitals, prisons, and other crowded places.

When the carbonic acid in a room is due to respiration, it is accompanied by a larger amount of organic matter given off by the lungs and skin, and this organic matter is but too plainly perceptible to the nose in overcrowded apartments. It is said that when in a crowded room the carbonic acid reaches 0·07 per cent. the air smells no longer fresh, and that as the carbonic acid increases, the foulness of the air steadily increases, till it becomes almost unbearable.

It is this organic foulness which we have mainly to fear in overcrowded places. It was the organic foulness rather than the carbonic acid which killed the victims of the Black Hole of Calcutta, and which caused symptoms of blood poisoning in those who survived. The chief sources of carbonic acid are:

1. Respiration.
2. Combustion.
3. Putrefaction.

With regard to ozone, a great deal has been said, but in reality very little is known. It is an allotropic form of oxygen, possibly nascent oxygen freshly evolved from the green leaves of plants. It has great power of oxidation (it is said), and great power of destroying organic manner. It is usually absent in the air of towns, and present in the fresh air of the country. Its absence seems to show that the air has been, to a certain extent, used.

Taking the two chief constituents of the air—oxygen and carbonic acid—we have seen that, in the open air, their relative proportions differ so little that it is impossible to believe that the slight variations in the amounts found can ever be considered as elements of climate of any importance. The truth of this is made apparent, because we have seen that variations of temperature and pressure cause most important variations in the amount of oxygen inspired; and we have abundant proof that the highest degree of health is compatible with these variations.

Please take note that I am speaking of the open air. I leave the interior of dwellings out of consideration. Even in the best ventilated dwellings the quality of the air is far below that in the open country or the open street; while in badly ventilated or overcrowded dwellings, the air is actually poisonous—poisonous not merely because the carbonic acid has reached a high percentage, but rather because this carbonic acid, being due to respiration, is accompanied by odoriferous organic matter, of which we shall have more to say hereafter.

The air usually contains other chemical ingredients. Traces of common salt and ammonia are always to be found, and in the air of cities, carbonic oxide, hydrochloric, sulphuric, and sulphurous acids, in greater or less quantity. It is these latter gases which prove so deadly to all kinds of vegetation in London and other large cities. They result from the combustion of fuel and gas, and are present in such quantity that the rain which falls through the lower strata of the London atmosphere is generally strongly acid, and often proves destructive to tender plants which are heedlessly left exposed to a shower ignorantly thought to be freshening.

It is the acid in the air of London which proves so destructive to most metals, which blackens the silver, corrodes the metal fittings of our houses, gives a worm-eaten look to some of our statues, and is causing the crumbling of what is still called the New Palace at Westminster. What the effect of this acid condition of the air is upon human beings we have no exact knowledge, excepting that in cold, still weather, the mortality from lung disease in this overgrown town is apt to become almost appalling.

This condition of the air is, after all, you will say, only a local condition, and has no right to detain us in a discourse on climate which should include only conditions affecting countries or large districts. This is very true; but if the acid condition of the London air is a local condition, it is a local condition which affects a vast population, and is, therefore, of great importance.

Of the gaseous constituents of the atmosphere which we have mentioned, the oxygen, nitrogen, and carbonic acid alone are constant and universally present.

There is yet another gaseous element of the atmosphere which is absolutely universal, although the amount which is present varies immensely under different conditions. This is watery vapor.

Although this vapor is invisible, we are constantly being reminded of its presence. The moisture that condenses on the cool window panes of a crowded room, or that dims the surface of the tumbler of iced water which one may be lucky enough to get at some suffocative dinner, are among the every-day evidences that watery vapor is present in the air, and ready to condense.

Air is only capable of keeping a certain definite amount of watery vapor in an invisible condition. For equal barometric pressures the amount varies with the temperature. The higher the temperature, the greater is the amount of vapor which the air will hold invisible. At a freezing temperature each cubic foot of air will hold just over two grains of watery vapor, while at a temperature of 100° Fahr. the amount which the air will retain is close upon twenty grains, or ten times as much. These figures are not precisely accurate, but they are near enough for our purpose, and are easily remembered. When the air contains its maximum amount of watery vapor (an amount which increases with the temperature) it is said to be saturated, and if saturated air be cooled the moisture is deposited in the form of dew.

Rain, in like manner, is caused by the cooling of air saturated with moisture.

According as the moisture in the air falls short of saturation, so is its drying power, and its power of causing the evaporation of fluids. If complete saturation be spoken of as 100°, then the relative humidity of the air may be stated as a percentage of the maximum. Let us suppose that a cubic foot of air contains 50 per cent. of watery vapor. If the temperature of the air be 32° Fahr., then we shall know that each cubic foot (containing 50 per cent. of its maximum) holds about one grain of watery vapor, and is capable of drying up a second grain. If the temperature of the air, however, be 100° Fahr., we shall know that each cubic foot (containing 50 per cent. of its maximum) holds about ten grains, and that the drying power of each cubic foot is equal to another ten.

Now it is important to bear in mind that although the air in both these imagined instances has a humidity of 50 per cent., yet the drying power is ten times greater at the higher temperature.

Since the drying power, *i.e.*, the power of causing evaporation, is that which exercises most influence on our health and comfort, it follows that humidity must al-

ways be considered in conjunction with temperature. When the drying power of the air is great, the evaporation of fluid from our skins and lungs is great. When the drying power of the air is small, the evaporation of moisture from the skin and lungs is small also. It follows from this that a dry air is often of great use to persons suffering from what are known as chronic catarrhal conditions of the respiratory passages (throat, nose, windpipe, and bronchial tubes). The moist mucous surfaces of these parts are, as it were, dried up by the dry air which is drawn over them, and the sufferings of the invalid are greatly lessened.

As regards the effect of the drying power of the air upon the skin, it is quite impossible to consider it apart from the question of temperature, because the amount of perspiration to be evaporated depends mainly upon the temperature (exercise being left out of consideration), and hence it follows that the amount of perspiration to be evaporated may be ahead of the drying power of the air. Hence, it is not possible to consider the effect of drying power on the skin apart from the question of temperature, and we must therefore defer it until we come to talk of temperature.

The moisture in the air is due to the evaporating power of the sun. The heat of the sun is constantly raising water in the form of vapor; just as the water in a boiler is changed to vapor by the glowing fuel. In tropical regions the amount of water which is changed to invisible vapor is prodigious, but the evaporation in temperate climates is also very great, for it must be remembered that this evaporation goes on so long as the moisture in the air falls short of saturation.

The watery vapor in the air is of the greatest importance from a meteorological, and, therefore, indirectly from a climatic point of view. Mr. Scott, in his work on the "Elements of Meteorology," thinks that the distribution of moisture in the air is very local, and depends, to a great extent, on the proximity of free water surfaces to supply the moisture. It is, therefore, great in the air over tropical seas, slight in the air over extensive tropical deserts. The amount of moisture is generally more or less in direct relationship with the temperature. The dryness of the air during a Canadian winter is well known. The water, is, to great extent, locked up in solid form, and the evaporating power of the air is slight, and hence the dry, crisp atmosphere, of the pleasures of which we hear so much. The amount diminishes as we ascend in a degree rather more than proportionate to the fall of temperature. The air of high mountains is relatively dry, but the degree of moisture follows no regular law, and it has been observed by balloonists, as well as mountaineers, that in ascending to great heights, strata of air of varying degrees of moisture are passed through.

The watery vapor ever present in the air acts like a garment to the earth, an invisible robe protecting the surface of the earth, on the one hand from the scorching influence of direct solar radiations, and on the other hand peventing, to a great extent, the radiation from the earth itself, and the too rapid loss of heat when the sun goes down.

Like our own garments, the invisible watery garment of the earth moderates the heat and cold, and tends to produce equability of climate. In situations where the moisture in the air is slight, the extremes of temperature are excessive, as in flat, sandy deserts, and on mountains; the heat of the sun in these situations being in striking contrast to the bitter cold of the nights.

The watery vapor ever present in the air may become visible. Were I to bring a glass of ice cold water into this room, its surface would be dewed with moisture, because the air in contact with the glass being suddenly chilled, its capacity for moisture is lessened, and a part of it is deposited.

When the surface of the earth is suddenly chilled by radiation, dew is in like manner deposited from the strata of air in contact with it. When a clear night succeeds a hot summer day, the deposit of dew is always (in this climate) very large. Dew, it will be noticed, is always most abundant on grass and herbage, on the leaves and stems of trees, on wood and metal work, etc., while it is not present on gravel walks and in dusty roads. Dew is, in short, deposited on those bodies which lose their heat most readily by radiation.

The heaviest fall of dew which it has been my lot to witness was on a winter's morning in January, on board a yacht off Cagliari, in the island of Sardinia. I was roused about half-past seven by the pattering, as I thought, of heavy rain upon the deck, but on going on deck I found that the shower was exceedingly local, being produced by the deposit of dew upon the high spars and rigging of the yacht, and its subsequent descent upon the deck in a heavy shower. The power of the sun on the previous day had been very great, and had raised much vapor from the sea, and this moisture laden air, being cooled by contact with the cold spars and rigging, discharged its moisture in the manner related.

Humboldt has recorded how, in some of the forests of South America, the traveler, on entering a wood, finds, apparently, a heavy shower falling, while overhead the sky is perfectly clear. The formation of dew takes place on the tops of the trees, and so copiously, owing to the abundance of vapor in a tropical atmosphere, that a real shower of rain is the result.

Fogs and mists are due, it is now generally supposed, to the condensation of moisture on the infinitely fine particles which are always suspended in the air. If the air be absolutely free from dust, watery vapor forms no mist, but the presence of solid impurity determines a fog. For the formation of fog three things are necessary:

1. The cooling of moisture laden air.
2. Calm weather, so that the mist is not blown away as soon as formed.
3. Solid matter in the air.

When in winter the southeast wind blows, bringing moisture-laden air from the German Ocean and the Channel, up the estuary of the Thames, and when this moist air comes in contact with the cooler air of London, charged with solid impurity to an enormous extent, a London fog is the result. The fogs of Newfoundland are due to the chilling of moist air by coming in contact with a surface of water cooled by melting ice.

Most of the water evaporated from the surface of the salt and fresh waters of the globe returns to the surface in the form of rain.

Rain is produced by the chilling of air more or less charged with moisture. Near the equator the hot air charged with moisture rises into the cooler regions of the atmosphere, and descends again as rain, and in torrents of which we have no knowledge in these latitudes. Air which has traversed a large tract of sea, like that which comes to us from the south and west from off the surface of the Atlantic, is charged with moisture. As it strikes against the precipitous hills of our western coasts, it is chilled by the colder land, and, at the same time, is driven upward by the conformation of the hills, and the result is that the moisture is deposited in the form of rain. Hence it follows that the southwest corner of Ireland and the western coast of England and Scotland are the wettest parts of the British Isles, and in great contrast to the eastern coasts.

The wettest parts of the globe are those where winds blowing from tropical seas strike against the chilled tops of high mountains, and probably there is no place with greater rainfall than the district which lies at the eastern extremity of the Himalayan mountains, where the rainfall is said to amount to as much as 400 inches a year.

Winds ladened with moisture lose it at the first opportunity. Thus the southwest winds in this country cause heavy rainfalls on our western coasts, amounting to as much as 150 inches per annum in some parts of Cumberland. The winds, thus dried by a fall of rain, can cause but little rainfall elsewhere, so that in our eastern coasts the rainfall is not more than 20 inches.

The center of great continents are necessarily dry. The middle of Australia, Sahara, in the center of Africa, and parts of Central Asia, are among the driest regions of the world.

What are the effects of moisture and dryness?

It is a well-known fact that when water is evaporated and turned into invisible vapor, a certain amount of heat becomes latent, as it is termed, and cold results When, on the other hand, watery vapor is condensed and becomes liquid, the latent heat is given out, and hence rain has a great power of warming the air. Professor Haughton has calculated that, on the west coast of Ireland, the heat derived from the rainfall is equal to half that derived from the sun.

The presence of rain clouds has, of course, a great influence on the temperature of a district, as, by obstructing the sun's rays, they prevent the heating of the surface.

On the other hand, clouds equalize the temperature by preventing radiations of heat after sunset. Cloudless nights are cold nights, because of the comparatively unobstructed radiation. These are the nights when the gardener covers up his tender plants and looks to his greenhouse fires. Cloudy nights, on the other hand, are warm.

Rainfall has a very purifying influence on the air, by washing it of its solid and some gaseous impurities. Who has not watched a thunder shower after a spell of dry weather in London, in July or August? Previous to the shower the air is oppressive, and has a smoky ammoniacal smell, and the wooden pavements, kept moistened by the watering carts, smell like a stable. With the first drops of the shower, "blacks" as big as blue bottle flies are driven downward from the upper strata. These diminish as the shower continues, and soon the air smells fresh and wholesome.

As to the effect of moisture upon health, not very much is known.

Rainfall purifies the air, and if it be not sufficient to prevent exercise it apparently does no harm. When the air is hot and moist, so that evaporation, with its consequent cooling, cannot be effected on the skin, it is very oppressive. Moist air is most grateful to persons with dry chronic coughs.

There is one way in which moisture affects health, and which has been not much considered hitherto, and that is the effect which it has on the process of decay and putrefaction. Putrefaction, as is well known, is favored by warmth and moisture, and is checked by cold and dryness. Warmth and moisture for the most part favor the growth of the bacteria and other allied micro-organisms, some of which are definitely known to be directly connected with epidemic disease, while cold and dryness check them.

Parkes ("Practical Hygiene," page 37) remarks:

"The spread of certain diseases is supposed to be intimately connected with the humidity of the air. Malarious diseases, it is said, never attain their fullest epidemic spread, unless the humidity approaches saturation. Plague and small-pox are both checked by a very dry atmosphere. The cessation of bubo plague in Upper Egypt after St. John's day has been considered to be more owing to the dryness than to the heat of the air.

"In the dry Harmattan wind on the west coast of Africa, small-pox cannot be inoculated, and it is well known with what difficulty cow-pox is kept up in very dry seasons in India."

If infective disease be due to organisms, and if the growth of these organisms depends upon conditions similar to those that regulate the activity of putrefaction and fermentation—facts in which there is a daily increasing belief—then we must come to the conclusion that dryness and cold both check one class of diseases, and that the biting dry east winds in this country, and the much abused northwest wind which is known as the mistral in the south of France, are, although pitiless, and indeed often deadly to the sick and weakly, among our best friends from the point of view of health.

From the point of view of exercise and comfort, the absolute annual rainfall of a district is of less importance than the number of rainy days per annum. There is no necessary relationship between the annual rainfall and the number of rainy days; in fact, they often bear an inverse proportion to each other.

If we propose to visit a particular spot in search of out door exercise, pleasure, and health, this point of the number of rainy days to be expected is one of very great importance. Thus, at Valentia, on the west coast of Ireland, with a very mild, even temperature, some 235 wet days per annum may be expected. According to Hassall, who is quoted by Weber, there is, at Torquay, an average rainfall of 36 inches, with 200 rainy days; at Ventnor, 34 inches, with 174 rainy days; at Cannes, 35 inches, with only 70 rainy days; at Bournemouth, 28 inches, with 156 rainy days; and at San Remo, 28 inches, with only 48 rainy days.

Although I have no doubt these figures give a fairly correct notion of the relative raininess of the places mentioned, we must, nevertheless, be careful how we build our hopes upon average numbers. The average is sometimes calculated upon too small a number of years. Sometimes the years upon which the average is calculated are, so to say, picked, and the calculation, actuated by local bias, has begun with the year after and stopped short of a year when some extreme number has been reached. Even supposing that the averages are in every way just, we must still remember that there are extremes as well as means, and we may have the bad fortune to visit a spot with a dry reputation and get a daily drenching. Such was my luck at San Remo in the month of February, 1883.

(*To be continued.*)

SHADE AND ORNAMENTAL TREES.

THE matter of planting forest trees in a country so well wooded as New England must first be brought to the attention of individual planters as a matter of sentiment in planting and growing for shade and ornamental trees. By appealing to the taste and public spirit of individuals much desirable work may be done in this direction. After a community is educated up to the value and beauty of such plantings, and the ease with which trees are grown, it will be an easy step from that to forest plantations of greater or less size, for the purpose of raising wood and timber.

In this direction the Essex Agricultural Society is doing a good work through the offering of premiums for ornamental trees, and in its report for the year 1886 the committee on forestry awards a prize to Benjamin P. Ware, of Marblehead, for the best lot of ornamental trees grown by him. Upon Mr. Ware's place several hundred trees have been planted, on the farm, along both public and private roadsides, and also in groups and plantations. These consist of a variety of deciduous and evergreen trees. Some maples and ashes on the side of the approach to the house are in especially good condition, and give as grateful shade as any on the place. The trees between the house and the ocean are a good specimen of what can be accomplished by planting in groups where the exposure is considerable, and where the planting of the trees rather close together for mutual protection is the only way to secure mature trees.

An avenue which divides Mr. Ware's farm from that of his brother is lined with a row of maples on either side, and a third row down the center forms a double roadway. The trees seem thrifty, and are doing well. The committee also examined a thrifty line of willow trees that had been planted as a windbreak to a fruit orchard. There was a large variety of trees throughout the estate, and the committee saw Norway, sugar, sycamore, white and cut leaved maples, white ash, horse chestnut, elms, willows, Scotch, Austrian, and white pines, with some larch trees; also some thorn acacia hedges.

At Mr. Ware's, shade and shelter in the heat of summer was the main object for which these trees were planted, and a continuous shadow had been secured after a number of years' waiting, which would be broken by taking away every other tree for the sake of preserving the natural form of each individual. Where trees are planted for ornamental purposes, every other one in the row should be removed when the trees approach near each other. This same principle should be followed when trees are planted in ornamental groups. For timber trees should be grown sufficiently near together to prevent the growth of limbs and encourage height and size in the trunk.

Mr. Ware, of Marblehead, makes a statement regarding the ornamental trees which he offered for premium substantially as follows: The row of rock maples growing along the avenue through the farm, forty-five in number and thirty feet apart, was taken from the woods of natural growth forty years ago, and when set out the trees were about two inches in diameter, and cut off at an equal height of ten feet from the ground. This gave them the appearance of bare poles, and caused them to put out branches from the top, thus adding to the beauty of the whole row by the uniformity of their branches. These trees, though healthy, have not made a very rapid growth, being now from twelve to eighteen inches in diameter. This first experience in setting shade trees proved so satisfactory that in later years Mr. Ware has planted from time to time some 300 ornamental trees of various kinds along the highways and railroad that pass through or by his farm, adding beauty to the landscape and comfort to man and beast that traveled that way.

The grove of twenty-five trees in front of the Clifton House, being near to the ocean, was difficult to make grow, as the exposure to the severe easterly storms and high winds is more than those trees will generally bear. This grove was started thirty-five years ago. by planting the trees quite near together, thereby affording protection to each other, and as they have grown the weak ones have been removed, following the natural law that the fittest survives. Several varieties were here planted to test those which would stand the exposure best. The American elm, Norway maple, sycamore maple, English linden, and balm of Gilead are now standing in the group, all in a healthy condition, varying in size from six to sixteen inches in diameter, and from fifteen to forty feet in height. There were originally some silver leaved poplars nearest the ocean, which grew quite well for a few years, but have since all died. They were never quite satisfactory, continually throwing up suckers and showing more or less dead branches.

In the summer season this grove affords a dense shade, which is highly appreciated by visitors. As an experiment, Mr. Ware trenched one half the land where this grove stands two feet deep, supposing that it would promote the growth of the trees, but no favorable result was secured.

Mr. Ware has another grove, composed of sixty-five evergreen trees, that serves as a screen for the barn and stable, and also for a delightful shade, with the pine odor which is so agreeable and beneficial to many persons. These pines were set quite near together to afford mutual protection, and are now three to eight inches in diameter and from six to twenty feet high, all in thrifty condition. They will be thinned out as future growth may require. Here also are the Norway, Scotch, and white pines, each of a different shade of green, each beautiful in itself and making a pleasant combination of color. Especially in the winter is this attractive in contrast with the barrenness of the sur-

rounding deciduous trees, and of the landscape generally.

A row of Norway maples along a private way is worthy of attention. This variety of maple naturally forms a compact mass of foliage, shaped like a spinning top inverted, admirable for a shade. It is very hardy, retains its foliage quite late in the season, and turns to a beautiful yellow color in many shades as the season advances. This row of trees, with their uniform shape and dense foliage, helps to make a walk to the railroad station a luxury rather than an annoyance.

Along Atlantic avenue and the approach to the railroad station, and on each side of the railroad, Mr. Ware has planted white ash, sycamore, maple, Norway maple, rock maple, and horse chestnut trees, thirty feet apart. These are all in a thrifty condition, varying from five to ten inches in diameter and from twelve to twenty-five feet in height. These varieties have proved hardy and well adapted to that location and to the object desired in planting. No variety will excel or, perhaps, equal the native elm for majestic grandeur and beautiful proportions.

Nearly all of the ornamental as well as fruit trees are subject to attacks of disease or insects, which mar the beauty, check the growth, and even cause death unless protected. Diligent watchfulness is the price of success here, as well as elsewhere on the farm. The elm is subject to the ravages of the canker worm in this section. Mr. Ware's linden trees were last year badly eaten by the same or a similar worm, and had he not sprayed them in Paris green in solution, they would have been stripped of all foliage. The white ash is subject to a blight in the early season, causing black spots on the leaves, though later growth seems to overcome it.

Mr. Ware thinks the Norway maple a very desirable tree, though it is liable to be affected unfavorably by atmospheric influences. One side of his had a brownish appearance, which came on suddenly from this cause. The Norway maple is in danger, more than other varieties, of splitting down where there are crotches of large limbs. When young, care should be taken in pruning to have a main central trunk, instead of cutting it off, and thereby causing several main limbs to branch out.

The horse chestnut is a beautiful tree in form, foliage, and especially in flower. It is a rapid grower after it is well established, but a heavy wind, while the foliage is tender in the early season, will seriously mar its beauty for the rest of the season. The balm of Gilead is a very hardy, rapid growing tree, and will probably bear exposure to the storms better than any other variety, and is valuable on that account. It also has valuable medicinal properties that with many persons are the cure-all of the family and neighbors. It has been found of great service on exposed places at Nahant in forming windbreaks for the protection of more tender trees. Parties were enabled to grow fruit quite successfully with this tree as a protection. The tree is, however, subject to a borer that will seriously injure, if not totally destroy it, unless protected.

The black poplar, introduced from Japan, is a rival to the balm of Gilead for hardiness to ocean exposure, rapid growth, and symmetrical proportion. It can be easily propagated by cuttings, and has been fully tested in this country for some fifteen years. Mr. Ware knows of no serious objections to it. It does not sucker, like the balm of Gilead, silver poplar, or the Lombardy poplar that was so famous seventy-five years ago. Take it all in all, Mr. Ware thinks the black poplar a valuable acquisition to our list of ornamental trees.

The sycamore maple proves hardy with Mr. Ware, and a rapid grower, with beautiful leaves. It grows very shapely, has pretty and abundant blossoms, and produces an abundance of clusters of winged seed that add to the beauty of the tree in the autumn. This variety is not subject to attacks of any disease or insects.

Mr. Ware also has in his collection of ornamental trees Wier's cut leaved maple, which, as its name indicates, has a beautiful double serrated leaf, attractive by its oddity. This tree is a rapid grower, with an abundance of long, slender branches, with a drooping habit quite desirable in a collection. Also the cut leaved, weeping birch, with its beautiful pyramidal form, very white bark on the trunk and large limbs, and dark colored on the smaller branches, which droop, and so fine, not larger than a knitting needle, that a gentle breeze will cause them to wave in a gentle undulating manner, making this one of the most beautiful and attractive trees. It is propagated by grafting on some strong growing birch of another variety.

FORCED LILY OF THE VALLEY.

AMONG hardy subjects forced in winter none are held in greater estimation than this charming little native plant, but when induced to come into bloom toward the end of the old year or the beginning of the new one success is not always achieved, for though most growers experienced in flower forcing are able to get valley lilies to bloom, still oftener than not the flowers forced so early are drawn and weak, and so far wanting in size and substance that they are much inferior to those that come later on, when less forcing is needed. One of the defects which the earliest forced lily of the valley often presents is the absence of leaves in sufficient numbers to set off the flowers to advantage. When required in a cut state only, this deficiency is often met by forcing some of the thin crowns that have no flowers in them, and which at once push up leaves when placed in heat. But when plants of this lily are wanted for ordinary purposes, the want of leaves obviously cannot be met in this way. The accompanying illustration, prepared from a photograph, represents a valley lily sent to *The Garden* office by Mr. Elphinstone, Shipley Hall, Derby, early in January, and which occupied only twenty-one days from the time when the crowns were put in heat to their arriving at the condition here shown. As will be seen, many of the spikes had nearly all their bells open. The individual flowers, too, were of unusual size and substance. In short, the plant taken altogether presented no more of the weak, drawn appearance that usually follows hard forcing than if it had been flowered in the open air, while the leaves were sufficient to give the requisite relief to the flowers. The way in which Mr. Elphinstone treats his valley lilies is to plunge the pots up to their rims in a brisk temperature, the thermometer sometimes showing as much as from 100° to 110°. Each plant is covered with an inverted pot, which is kept over it until some two inches of growth have been made, and after that the inverted pots are dispensed with. The crowns are deluged with water every day, given at a temperature equal to that of the bed in which the pots are placed, so that the soil is kept constantly saturated from the time the plants are put in until the flowers open. This thoroughly wet condition of the roots is considered to be essential to success, and I think there is little doubt that it is this saturation of the soil that enables the early forced crowns to produce leaves simultaneously with the flowers. Under this treatment the average

LILY OF THE VALLEY FORCED.

time taken to force lilies of the valley is as follows: December 25 days, January 21 days, February 20 days, and March 18 days.—*The Garden.*

ANALYSIS OF SHOT.

By H. HARDAWAY.

SEEING that the statements made as to the amount of arsenic in the lead employed for making shot are not very definite, and are apparently not based upon any recent analyses, it appeared of interest to ascertain whether or not there is so much variation in the composition of this alloy as now made. From the brands in our market the following were selected, all being clean, well shaped bird shot:

No. 1.—Wythe Lead and Zinc Mine Co., Virginia.
No. 2.—Merchants' Shot Tower, Baltimore.
No. 3—Leroy Shot and Lead Manufacturing Co., New York.
No. 4.—Tatham Bros., New York.

A complete analysis of each of these was made, employing for each over 100 grammes, from which the lead was separated as sulphate, but estimated by difference, affording the following results:

	No. 1.	No. 2.	No. 3.	No. 4.
Arsenic......	0·0824	0·0393	0·2725	0·1413
Iron.........	0·0986	0·0167	0·0099	0·0121
Copper.......	0·0072	trace	0·0081	0·0107
Silicon......	0·0041	0·0050	0·0002	0·0023
Carbon.......	0·0115	0·0269	0·0041	0·0055
Lead.........	99·7962	99·9121	99·7052	99·8281

We find in Muspratt's *Chemistry*, as to the amount of arsenic present: "The limits are from 3 to 8 or 10 parts in 1,000, the lesser quantity being employed as the lead is more ductile, and the larger when it is hard." In this selection of American shot it is seen that the amount is much smaller, and the range yet wider, being from 0·4 to 3·0 parts in 1,000. It does not appear from these results that there is any special connection between the amount of arsenic and copper and iron, yet it is to be noted that the amount of arsenic increases as that of silicon diminishes.

University of Virginia, Sept., 1886.

—*Amer. Chem. Jour.*

KNIGHTS OF TYRANNY.

THERE is one thing that the wicked capitalists unfortunately have not a monopoly of, and that is tyranny. In fact, any one who desired to discover in this country an example of despotic action unsurpassed outside of Russia or Persia, would perhaps find the search an easier one if he should look at the record of American employes rather than at that of American employers. For example: Last month a respectable woman, the only support of a widowed mother, found work in a Delaware cotton mill. The men in the mill objected to her presence because she did not belong to the Knights of Labor, and they commanded her dismissal. She thereupon applied for admission to membership in the order, and her application was promptly refused. Then, as the wicked capitalist who owned the mill declined to dismiss her, the down-trodden slaves who worked for him promptly struck and stopped the mill. Observe: This nefarious tyrant to whom the establishment belonged did not object to Knights of Labor, as such; nor did he pay wages so low as to warrant complaint. He did not forbid the woman to join the Knights. He only declared that he would give her a fair chance to earn her bread, whether she was a Knight or not. But the gallant Knights, whose mission it is to maintain the cause of the poor and the friendless and the oppressed against cruel and tyrannical employers, formally declared that the woman should not have a chance to earn her bread, and what they struck against was, in fact, an attempt to permit her to exercise her natural and inherent right to do that thing. It is a sorry business for "champions of the down-trodden" to be engaged in—an unheroic business to war upon a woman, and a woman, too, who was willing to comply with any conditions offered to her. If a cause, to have success, must be based on justice, what kind of success can this cause have?—*Textile Record.*

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