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BELL'S PHOTOPHONE.

During a recent visit to Paris, Professor Graham Bell favored *La Nature* with an extended account of the investigations and discoveries which led to and resulted from his lateremarkable invention, the photophone. He also supplied our scientific contemporary with certain details not previously made public, together with drawings of his apparatus and experiments, the engravings of which we here reproduce, with *Nature's* translation of the text.

Our readers are already aware that the object of the photophone is the transmission of sounds both musical and vocal to a distance by the agency of a beam of light of varying intensity; and that the first successful attempts made by Prof. Bell and his co-laborer, Mr. Sumner Tainter, were based upon the known property of the element selenium, the electric resistance of which varies with the degree of illumination to which it is exposed. Hence, given a transmitting instrument, such as a flexible mirror, by which the vibrations of a sound could throw into vibration a beam of light, a receiver, consisting of sensitive selenium, forming part of an electric circuit with a battery and a telephone, should suffice to trans late the varying intensities of light into corresponding varying intensities of electric current, and finally into vibrations of the telephone disk audible once more as *sound*. This fundamental conception dates from 1878, when in lecturing before the Royal Institution Prof. Bell announced the possibility of hearing a shadow fall upon a piece of selenium included in a telephone circuit. The photophone, however, outgrew the particular electrical combination that suggested it; for not the least of the remarkable points in this research is the discovery that audible vibrations are set up in thin disks of almost every kind of material by merely throwing upon them an intermittent light. With the photophone as with the telephone, there are instruments of different degrees of perfection. The original telephone of Philip Reis could only transmit musical tones, because it worked by rapid abrupt interruptions of the electric current; while the articulating telephone of Graham Bell was able to transmit speech, since by its essential construction it was able to send undulating currents to the distant receiving station.

We may in like manner classify the forms of photophone under two heads, as (1) articulating photophones, and (2) musical photophones.

Up to the present time, Prof. Bell informs us, the simple receiving disk of ebonite or hard rubber has only served for a musical photophone; the reproduction of the tones of the voice by its means has not yet been demonstrated in practice—at least to his satisfaction. For while it produces unmistakable musical tones by the direct action of an intermittent light, in the experiments made hitherto with articulate speech the instruments have by necessity been so near to one another that the voice of the speaker was audible through the air. Under these circumstances it is extremely difficult to say whether the sounds that are heard proceed from the diaphragm, or whether they merely come through the air to the ear, and if they come from the diaphragm, whether they are really the result of the varying light, and not mere sound vibrations taken up by the disk from the speaker's voice crossing the air. Prof. Bell hopes soon to settle this point, however, by appeal to experiment on a larger scale with the receiving and transmitting instruments at greater distances apart, and with glass windows in between to shut off all sounds.

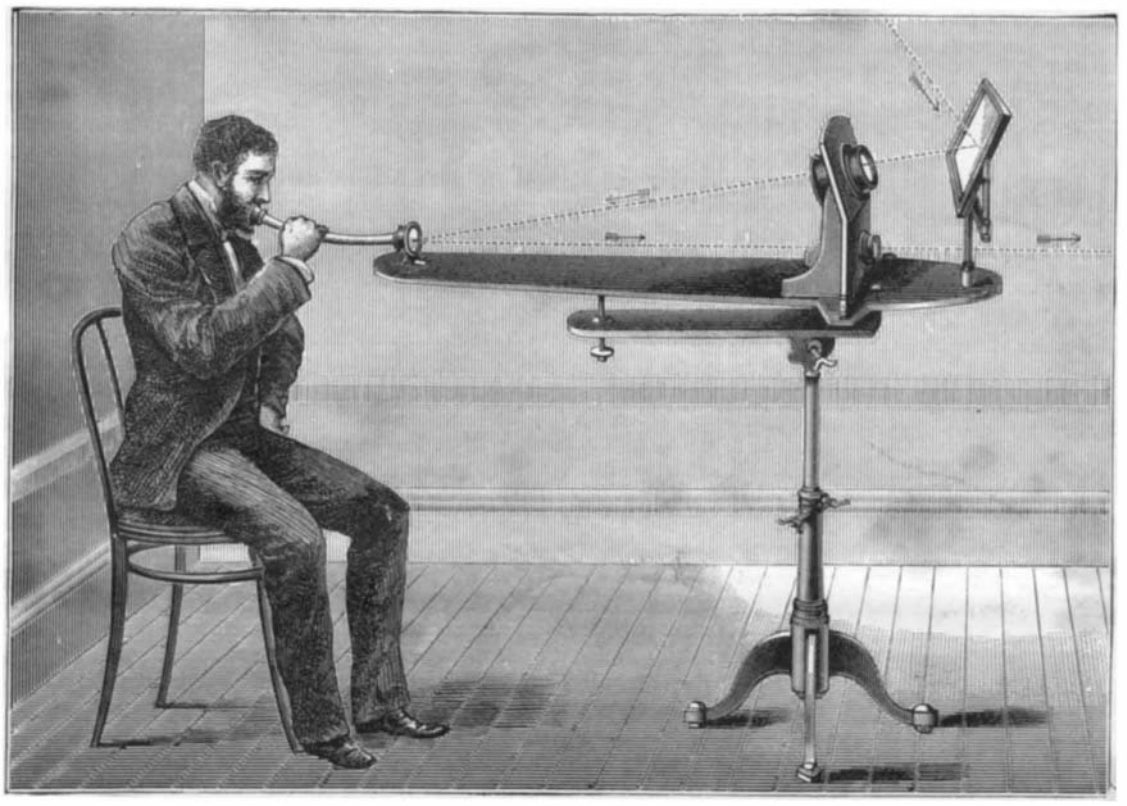


Fig. 5.—THE ARTICULATING PHOTOPHONE—THE TRANSMITTER.

In Fig. 1 we illustrate the simple musical photophone of Bell and Tainter. It might perhaps be described without injustice as an *optical siren*, producing sounds from intermittent beams of light, as the *siren* of Cagniard de Latour produces them from intermittent puffs of air. A beam of light from the sun or from a powerful artificial source, such as an electric lamp, falls upon a mirror, M, and is reflected through a large lens, L, which concentrates the rays to a focus. Just at the focus is interposed a disk pierced with holes—forty or so in number—arranged in a circle. This disk can be rotated so that the light is interrupted from one to five or six hundred times per second. The intermittent beam thus produced is received by a lens, T, or a pair of lenses upon a common support, whose function is to render the beam once more parallel, or to concentrate it upon the disk of ebonite placed immediately behind, but not quite touching them. From the disk a tube conveys the sounds to the ear. We may remind our readers here that this apparent direct conversion of light into sound takes place, as Prof. Bell found, in disks of all kinds of substances—hard rubber, zinc, antimony, selenium, ivory, parchment, wood—and that he has lately found that disks of carbon and of thin glass, which he formerly thought exceptions to this property, do also behave in the same way. We may perhaps remark without impropriety that it is extremely improbable that the apparent conversion of light into sound is by any means a direct process. It is well known that luminiferous rays, when absorbed at the surface of a medium, warm that surface slightly, and must therefore produce physical and molecular actions in its structure. If it can be shown that this warming effect and an intermediate cooling by conduction can go on with such excessive rapidity that beams of light falling on the surface at intervals less than the hundredth of a second apart produce a discontinuous molecular action of alternate expansion and contraction, then the mysterious property of matter revealed by these experiments is accounted for.

However this may be, the musical photophone, as represented in Fig. 1, produces very distinct sounds, of whose existence and dependence for their production on the light the listener may satisfy himself by cutting off the light at any moment with the little opaque disk fixed on the end of the little lever just in front of the holes in disk, R, and which can be worked by a Morse key like a telegraph instrument, thus producing at will alternate sounds and silences. With this musical photophone sounds have been carried by an interrupted beam of light for a distance exceeding a mile; there appears, indeed, no reason why a much greater range might not be attained.

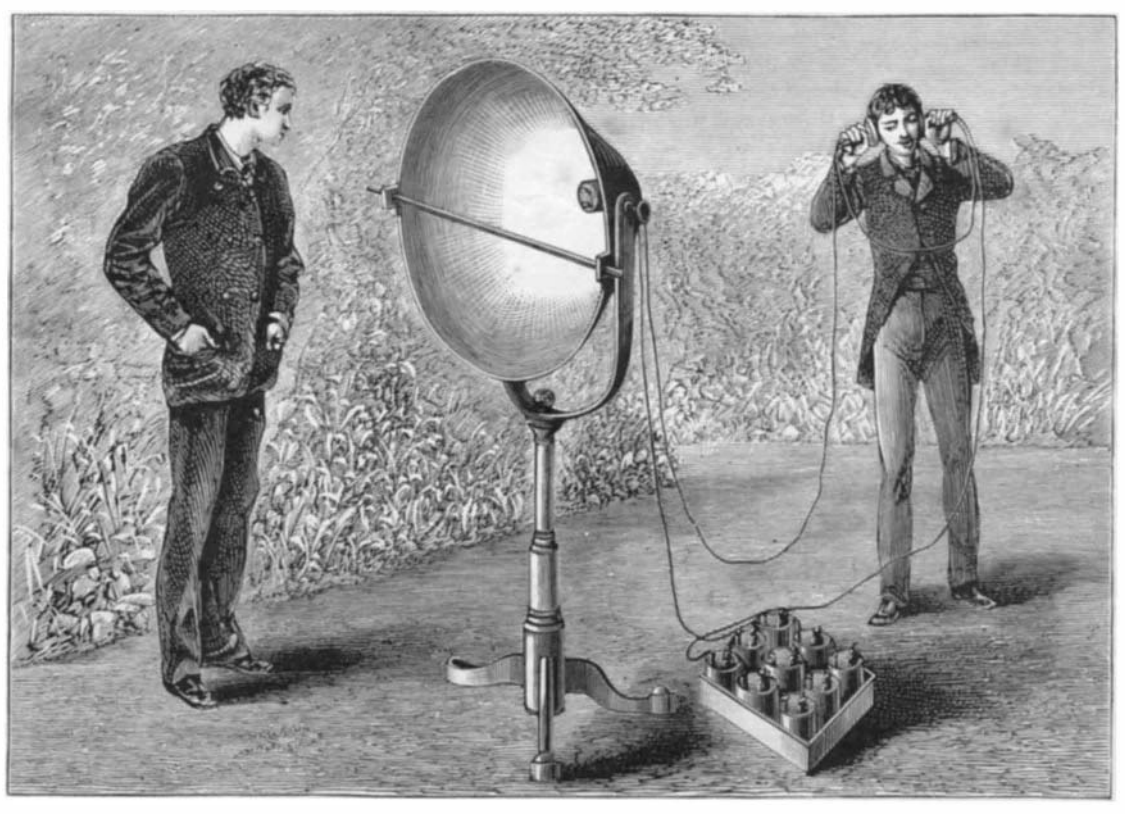


Fig. 6.—THE ARTICULATING PHOTOPHONE—THE SELENIUM RECEIVER.

The articulating photophone is that to which hitherto public attention has been most largely directed, and in which a selenium receiver plays a part. Fig. 2 gives in diagram form the essential parts of this arrangement. A mirror, M, reflects a beam of light as before through a lens, L, and (if desired for the purpose of experimentally cutting off the heat rays) through a cell, A, containing alum water, and casts it upon the transmitter, B. This transmitter, shown again in

[*Continued on page 4.*]

BELL'S PHOTOPHONE.

[*Continued from first page.*]

Fig. 5, consists of a little disk of thin glass, silvered on the front, of about the size of the disk of an ordinary telephone, and mounted in a frame, with a flexible India-rubber tube about sixteen inches long leading to a mouthpiece. A second lens, R, interposed in the beam of light after reflection at the little mirror, renders the rays approximately parallel. The general view of the transmitting apparatus given in Fig. 5 enables the relative sizes and positions of the various parts (minus the alum cell, which is omitted) to be seen. The screw adjustments of the support serve to direct the beam of light in the desired direction.

It may be well to explain once for all *how* the vibrations of the voice can affect the intensity of the reflected beam far away. The lenses are so adjusted that when the mirror, B, is flat (that is, when not vibrating) the beam projected from the apparatus to the distant station shall be nearly focused on the receiving instrument. Owing to the optical difficulties of the problem it is impossible that the focusing can be more than approximate. Now, matters being thus arranged, when the speaker's voice is thrown against the disk, B, it is set into vibration, becomes alternately bulged out and in, and made slightly convex or concave, the degree of its alteration in form varying with every vibration of the voice. Suppose at any instant—say by a sudden displacement such as takes place when the letter "T" is sounded—the disk becomes considerably convex; the beam of light will no longer be concentrated upon the receiving instrument, but will cover a much wider area. Of the whole beam, therefore, only a relatively small portion will fall upon the receiving instrument: and it is therefore possible to conceive that, if perfectly adjusted, the illumination should be proportional to the displacement of the disk, and vary, therefore, with every vibration with the utmost fidelity. The receiver of the articulating photophone is shown on the right hand side of the diagram (Fig. 2) sketched by Prof. Bell. A mirror of parabolic curve, C C, serves to concentrate the beam and to reflect it down upon the selenium cell, S, which is included in the circuit of a battery, P, along with a pair of telephones, T and T. Here again a general view like that given in Fig. 6 facilitates the comprehension of the principal parts of the apparatus. The sensitive selenium cell is seen in the hollow of the parabolic mirror, which is mounted so as to be turned in any desired direction. The battery standing upon the ground furnishes a current which flows through the selenium cell and through the telephones. When a ray of light falls on the selenium—be it for ever so short an instant—the selenium increases in conductivity, and instantly transmits a larger amount of electricity, and the observer with the telephones hears the ray, or the succession of them—hears, indeed, their every fluctuation in a series of sounds which, since each vibration corresponds to a vibration of the voice of the distant speaker, reproduce the speaker's tones.

The great difficulty to be overcome in the use of the selenium as a working substance arose from its very high resistance. To reduce this to the smallest possible quantity, and at the same time to use a sufficiently large surface whereon to receive the beam of light, was the problem to be solved before any practical result could be arrived at. After many preliminary trials with gratings and perforated disks of various kinds, Prof. Bell and Mr. Tainter finally settled upon the ingenious device to be described. A number of round brass disks, about two inches in diameter, and a number of mica disks of a diameter slightly less, were piled upon one another so as to form a cylinder about two and a half inches in length. They were clamped together from end to end, the clamping rods also serving to unite the disks of brass electrically in two sets, alternate disks being joined, the 1st, 3d, 5th, etc., being united together, and the 2d, 4th, 6th, etc., being united in another series. This done, the edges between the brass disks were next filled with selenium, which was rubbed in at a temperature sufficiently high to reach the melting point of selenium. After this the selenium was carefully annealed to bring it into the sensitive crystalline state. Then the cell is placed in a lathe and the superfluous selenium is turned off until the edges of the brass disks are bared. Fig. 3 shows, in section, the construction of such a shell. Prof. Bell has also used cells in which the selenium filled only the *alternate* spaces between disks, the intermediate spaces being occupied by mica disks of equal diameter with the brass disks. But this arrangement was in no way preferable, for in practice it was found that moisture was apt to penetrate at the surface of the bare mica, spoiling the effect.

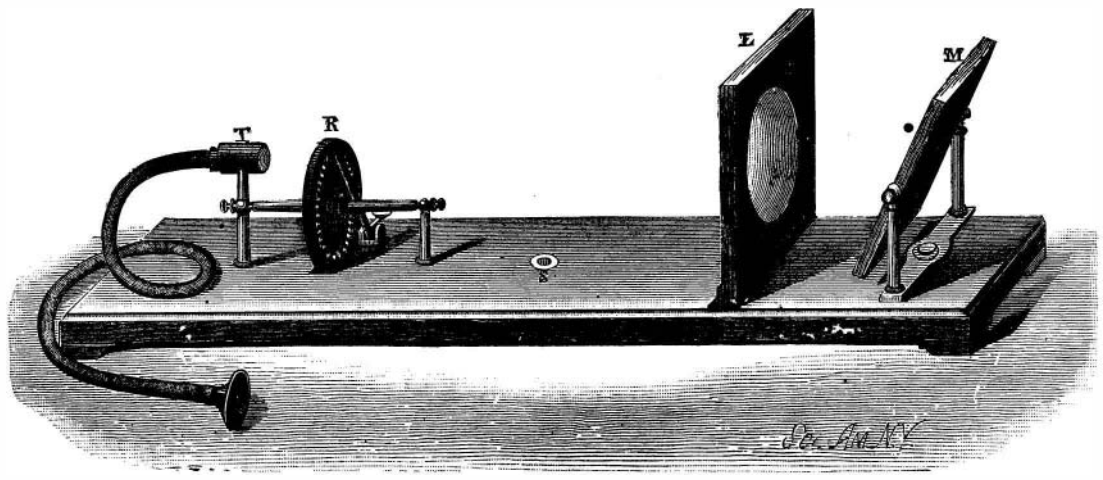


Fig. 1.—THE MUSICAL PHOTOPHONE.

Fig. 4 is a diagram which simply illustrates the action of the selenium receiver, and shows, first, the way of connecting the alternate disks; and, secondly, that the current from the battery, P, cannot go round the telephone circuit without passing somewhere through selenium from one brass disk to the next. The special advantages of the "cell" devised by Prof. Bell are, that in the first place the thickness of the selenium that the current must traverse is nowhere very great; that in the second, this photo-electrical action of light on selenium being almost entirely a *surface* action, the arrangement by which all the selenium used is a thin surface film could hardly be improved upon; and that, thirdly, the symmetry of the cylindrical cell specially adapts it for use in the parabolic mirror. These details will be of great interest, especially to those who desire to repeat for themselves the experimental transmission of sound by light. The greatest distance to which articulate speech has yet been transmitted by the selenium-cell-photophone is 213 meters, or 233 yards. When sunlight is not available recourse must be had to an artificial source of sufficient power. During the recent experiments made by Prof. Bell, in Paris, the weather has been adverse, and the electric light has been called into requisition in the *ateliers* of M. Bregnet. The distance in these experiments between the transmitting diaphragm, B, and the parabolic reflector, C C, of the receiver was fifteen meters, the entire length of the room in which the experiments were made. Since at this distance the spoken words were themselves perfectly audible across the air, the telephones connected with the selenium cell were placed in another apartment, where voices were heard without difficulty and without doubt as to the means of transmission. The transmitter shown in Fig. 7 consists of a fixed plate, P, provided with numerous slots and of a like movable plate attached to the diaphragm, *l l*, mounted in a frame provided with a mouthpiece, E. The vibration of the movable plate varies the intensity of the light passing through it. In Fig. 8 the transmitter is shown as used in combination with a collecting lens, L, in place of the parabolic reflector. In Fig. 9 a transmitter is shown which is based upon the effect of electricity on polarized light. A lens, L, throws the beam of a light, F, upon a Nicol polarizing prism, R, and the polarized beams traverse an analyzer, R'. A helix, B, is placed between the two prisms and in the circuit of an ordinary microphone, M. By speaking, the intensity of the current traversing the helix is varied, and this causes the plane of polarization of the rays to be turned more or less, and consequently more or less rays are extinguished by the analyzer, R'.

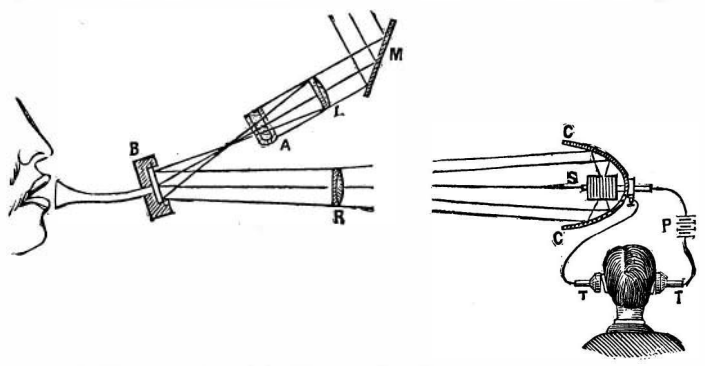


Fig. 2.—THEORETICAL DIAGRAM OF THE ARTICULATING PHOTOPHONE.

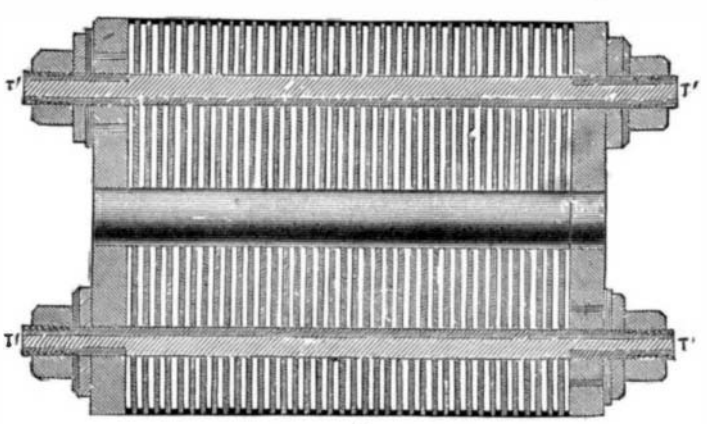


Fig. 3.—SECTION OF THE SELENIUM RECEIVER.

Of the earlier and less perfect forms of the photophone little need be said. One device, which in Prof. Bell's hands worked very successfully over a distance of eighty-six yards, consisted in letting the beam of light pass through a double grating of parallel slits lying close to one another, one of which was fixed, the other movable and attached to a vibrating diaphragm. When these were placed exactly one in front of the other the light could traverse the apparatus, but as the movable grating slid more or less in front of the fixed one, more or less of the light was cut off. Speaking to the diaphragm, therefore, caused vibrations which shut or opened, as it were, a door for the beam of light, and altered its intensity. The mirror transmitter of thin glass silvered was, however, found superior to all others; and it is hard to see how it could be improved upon, unless, possibly, by the use of a thin disk of silver, itself accurately surfaced and polished.

Whatever be the future before the photophone, it assuredly deserves to rank in estimation beside the now familiar names of the telephone and the phonograph.

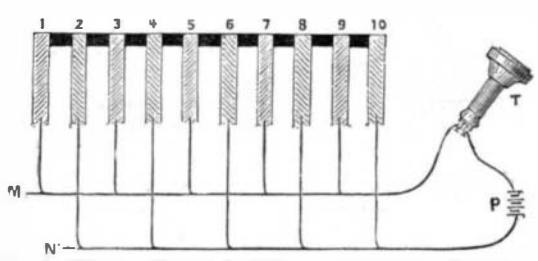


Fig. 4.—Diagram showing the action of the Selenium Receiver.

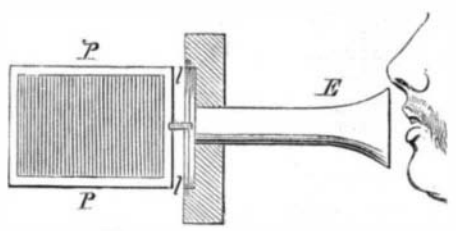


Fig. 7.—Slotted Transmitter.

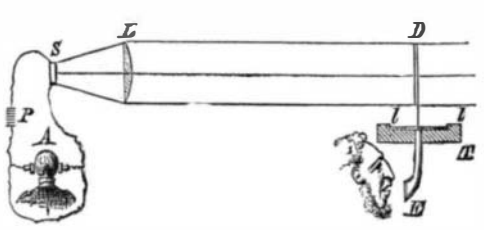


Fig. 8.—Condenser Receiver.

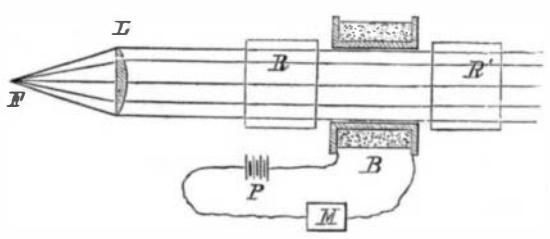


Fig. 9.—Polarized Light Transmitter.

Responsibility of Employers.

While a boy of 16 was at work upon a printing press in the press room of a New York paper the press was unexpectedly started. The boy sprang back from his dangerous position, and in so doing tipped over the bench he was standing on, causing him to fall against another press, which caught his arm and injured it so as to make it for ever useless. He sued the proprietor in the Superior Court and obtained a verdict for $3,000 damages. The defense was that the accident was caused either by the negligence of the plaintiff or of a fellow workman, for which the proprietor was not responsible. In charging the jury, Judge Speir said that if the plaintiff or a skilled fellow workman were negligent the plaintiff could not recover damages; but that if the agent of the defendant employed persons not skilled in their work and the accident occurred through the negligence of one of such persons, the defendant was responsible. An appeal was taken from the judgment on the grounds that Judge Speir erred in thus charging, and in permitting the plaintiff to exhibit his mutilated arm to the view of the jury, thus arousing their sympathy. The General Term has affirmed the judgment in a long opinion written by Judge Freedman and concurred in by Chief Justice Sedgwick.

Another Cliff Town Discovered.

The occurrence of ancient cliff towns, built upon or rather in almost inaccessible places along the precipitous sides of river canons in Colorado and New Mexico, was made known several years ago. Another very important discovery of this nature was made a short time since by Mr. James Stephenson, of the U. S. Geological Survey, in New Mexico. The city lies in a cañon thirty miles long, never before visited by white men, and is about forty miles from Santa Fe and ten miles from the Rio Grande. It consists of a succession of excavations in the solid rock throughout the length of the canon, making, perhaps, the largest cliff town yet discovered.

The houses are dug out of the rock side to a depth of from fifteen to twenty feet. Apparently they were excavated with stone implements. They are almost inaccessible from the plains. Mr. Stephenson, however, managed to clamber up the rocky precipice, and entered and examined a number of articles that he thought remains of their first possessors. A scientist who has traveled in that region and visited other caves and excavations of a similar kind says he is disposed to believe that they have been tenanted within modern times by Indians at war with other tribes, seeking safety and advantage over their enemies. He thinks the remains found there are the remains of the things these belligerents have used, eaten, or worn, and not the relics of the first owners of the rock houses.

The Utilizing of the Tides.

A Philadelphia engineer has invented, it is claimed, a machine by which the power of the tides can be utilized. Numerous plans have been proposed for the accomplishment of this most desirable end, but only under exceptional conditions have they been practical or economical. If the new device can harness the tide in an open channel, so as to convert any considerable portion of the vast power into working force, the inventor will rank among the great benefactors of humanity. Emerson says somewhere: Hitch your wagon to a star. A device for utilizing mechanically the free tides, as they sweep along our shores, would come next to that, since it would enable us, through converters and carriers of electricity, to hitch our wagons to the sun and moon.

CREMATION TEMPLE.

The engraving shows the Cremation Temple lately built in the beautiful cemetery of Milan by Mr. Albert Keller. This temple, built in the Greco-Doric style, is surrounded by columns and pilasters, and surmounted by a cupola, forming a chimney through which the products of combustion escape. The furnace is in the basement, and nearly in the middle of the building. The interior of the building is divided into four large halls, in the first of which the mourners assemble before the body is brought into the urn or cremation chamber; adjoining this hall there is a room in which the bodies in their coffins are awaiting cremation. The next apartment is a large storage room for coal and wood, and beyond this are the furnaces. In an adjoining hall the "Cremation Society of Milan" has its office, and transacts all its business. Here is a curious collection of antique and modern vases, documents relating to cremation, models of furnaces, etc.

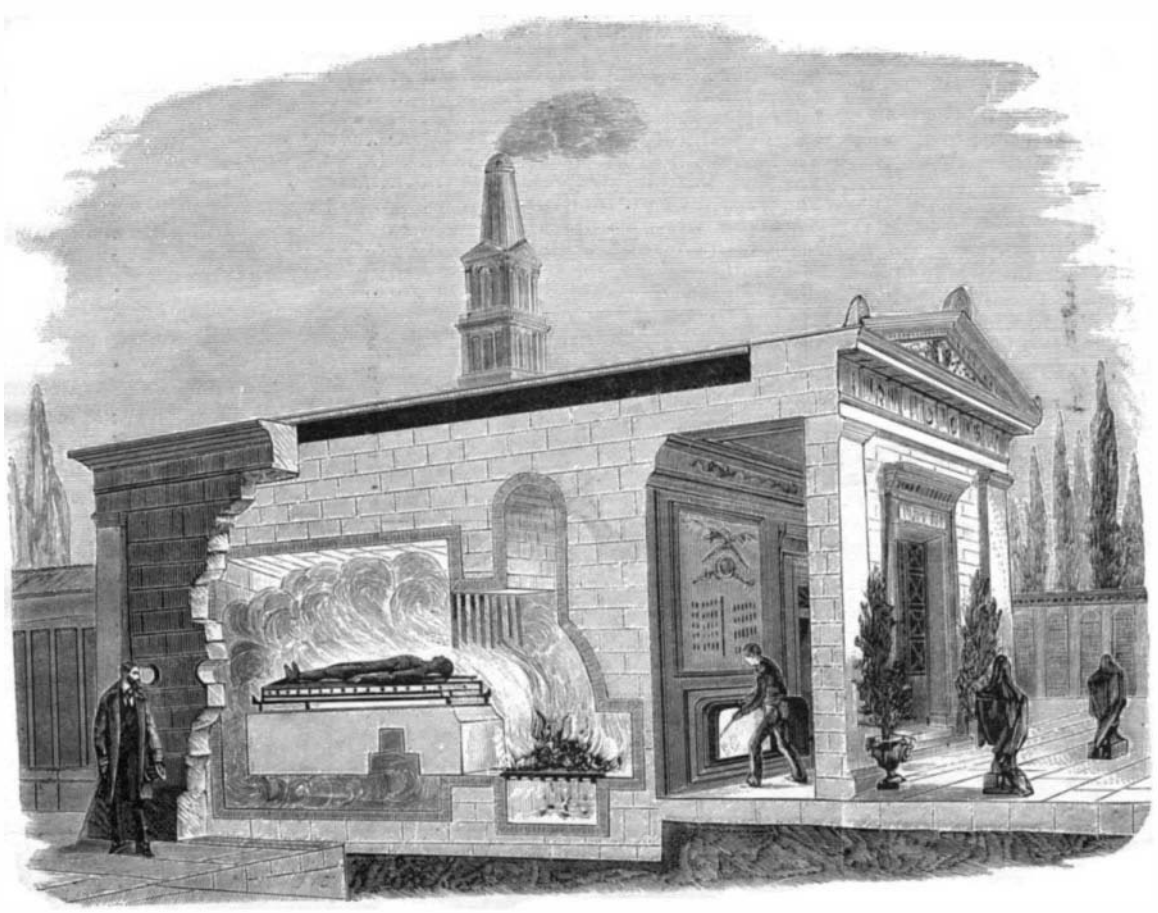
The cremating furnace is arranged transversely in the temple to permit of watching the entire operation through a small window in the side wall of the temple, as shown in the engraving.

The body is placed upon a grate, under which a basin is placed to receive the liquids and ashes that may drop down.

Two furnaces are now before the public, known as the Gorini and Venini furnaces, after the inventors.

The engraving shows Gorini's furnace, in which the flames and products of combustion pass over the body, thence down a flue and under the base upon which the body rests, thence up the chimney. The body, thus completely enveloped in the flames, is converted to ashes in from one and a half to two hours. Wood or coal may be used, and the expense is about one dollar.

Mr. Venini's apparatus is more complicated than that of Mr. Gorini, but it transforms the tissues of the body into gases in a more perfect manner than any other furnace.



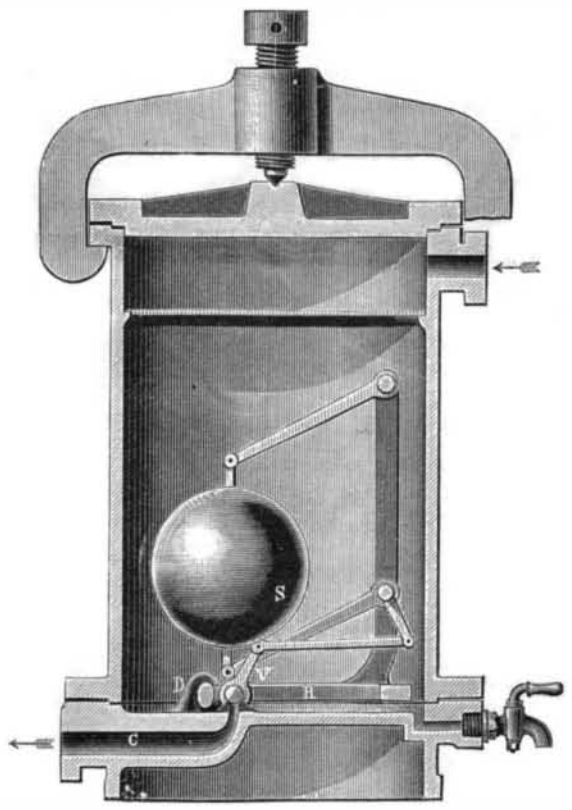
THE MILAN CREMATION TEMPLE.

THE ELECTRIC LIGHTING.—The Commissioner of Public Works, New York city, has granted Mr. Edison a permit to introduce his system of electric lighting in the lower part of this city.

AUTOMATIC GOVERNOR FOR WASTE WATER PIPES.

The governor shown in the annexed cut, taken from the *Deutsche Gewerbe Zeitung*, controls the flow of the waste water from a surface condenser.

The valve, V, which closes the inner end of the outlet, C, is mounted in a frame, R, which has its fulcrum at D, and presses the valve upon the end of the outlet with considerable pressure, insuring a close joint, which is not affected by the accumulation of sediment. The valve is operated by a



GOVERNOR FOR WASTE WATER PIPES.

series of levers which are actuated by a float, S, which rises and falls with the water, and opens and closes the valve, V, accordingly. The apparatus is said to work equally well at low or high pressure.

Uncertainty of Blood Stains in Evidence.

The circumstantial evidence of minute blood stains in criminal cases has been made much of in several recent trials. The value of such evidence has been seriously questioned by Dr. Charles O. Curtman, of St. Louis, who shows that, even when the suspected blood has been shown to be unmistakably human, the accused may plead that the blood stains were caused by predatory insects. In his experimental investigations Dr. Curtman allowed mosquitoes to take their fill of human blood, then, after keeping them in close confinement for periods of varying length, he killed them and examined the blood.

In all cases, up to forty-eight hours after a meal, a large proportion of human blood corpuscles were unchanged and readily recognizable. The size and color of the corpuscles of mosquito blood are very different from human. As the result of more than a hundred careful measurements, he gives the following sizes: Human blood (after imbibition by the mosquito) averages, in dilute glycerine, 1-3200 inch; in 80 per cent alcohol, 1-4000 inch. Mosquito blood averages, in dilute glycerine, 1-14000 inch; in 80 per cent alcohol, 1-18000 inch. In the case of bedbugs it was found that these insects digest blood much more rapidly than mosquitoes do. After twelve hours no trace of human blood was discovered.

An Ice Cave in Montana.

Two explorers named Lambert and Caruthers discovered, last summer, a large cave on the Dry Fork of Arrow Creek, in the Belt Mountains, in which was half an acre of solid ice of unknown depth. At the time of the discovery, about August 1, the ice was covered with ten inches of water, which prevented a thorough exploration of the cave. The Fort Benton *Press* says that the ice gives every indication of being in great body, and it is believed, from its appearance, and the fact that in the hottest season only a few inches of it was melted, that it is perpetual. The cave is described as being a great resort for game, as all kinds were killed close to its entrance.

Pampas Grass.

The cultivation of pampas grass, now so much used for decorative purposes, has become quite a profitable industry in Southern California. Three-quarters of an acre planted in pampas grass yielded, at 2½ cents per head, $500. Another grower sold all he could raise at 7½ cents per head. Last year 10,000 heads or plumes of this grass were sold from that region.

ENGINEERING INVENTIONS.

A circulating device for steam generators has been patented by Mr. Dan Abell, of Carson City, Nev. This invention consists in combining with the feed water and circulation pipes of a steam generator a steam pump for keeping up a continuous and rapid circulation of the water within the space of the generator.

An improvement in that class of devices called "self-couplers" and "uncouplers," has been patented by Mr. Louis C. Slonecker, of Stauffer's Station, Pa. It consists of two spring-actuated spear-headed coupling pins or hooks, pivoted parallel with each other on either side of a vertically adjustable drawhead, and extending forward in front of the drawhead to couple with a like device.

An improved car truck has been patented by Mr. Edward P. Cowles, of Wequiock, Wis. The object of this invention is to provide running gear for a car or other vehicle designed especially to run on round rails, and to avoid the use of flanged wheels and the friction and abrasion caused by them. The invention consists of a car frame of novel design, provided with flat faced vertical wheels to run on the top of the track, and with inclined flat-faced guide wheels that run under the inside edges of the flat wheels squarely against the side of the track.

An improved propeller has been patented by Mr. Rio Gardner, of Westerly, R. I. The invention consists of a hub having short arms, and of blades united thereto by mortise and tenon joints and suitable bolts and screws.

Mr. John Forbes, of Harrisburg, Pa., has patented a core box having a lid fitted for use as a sweep in striking the core and apertured to give access to the box; also, in the combination, with the core box, of flanged tubes for strengthening the legs of the core and giving vent.

Mr. William J. Watson, of Marion, S. C., has patented an improved stump puller, so constructed that it can be readily applied to the stumps and will be powerful in operation. The invention consists in providing a stump puller with a lever strengthened by a truss rod and stud, and having a clevis at its forward end for the attachment of the draught, and a chain at its rear to be attached to a stump, a swiveled standard for connecting wheels, and an axle with the lever to carry it, and a right angled lever for adjusting the carriage and fastening it in place.

Mr. George W. Veil, of Bucyrus, Ohio, has patented a machine for opening and grading tile ditches, so constructed as to leave the bottom of the ditch straight and smooth.

An improved locomotive spark extinguisher has been patented by Messrs. G. A. Gunther, of Bath, and W. Kowalski, of Brooklyn, N. Y. The object of this invention is to deaden or extinguish sparks passing out through the smoke stack of a locomotive. The construction of this device is peculiar and cannot be readily described without engravings.