THE TELHARMONIUM-AN APPARATUS FOR THE ELECTRICAL GENERATION AND TRANSMISSION OF MUSIC,-[See page 210

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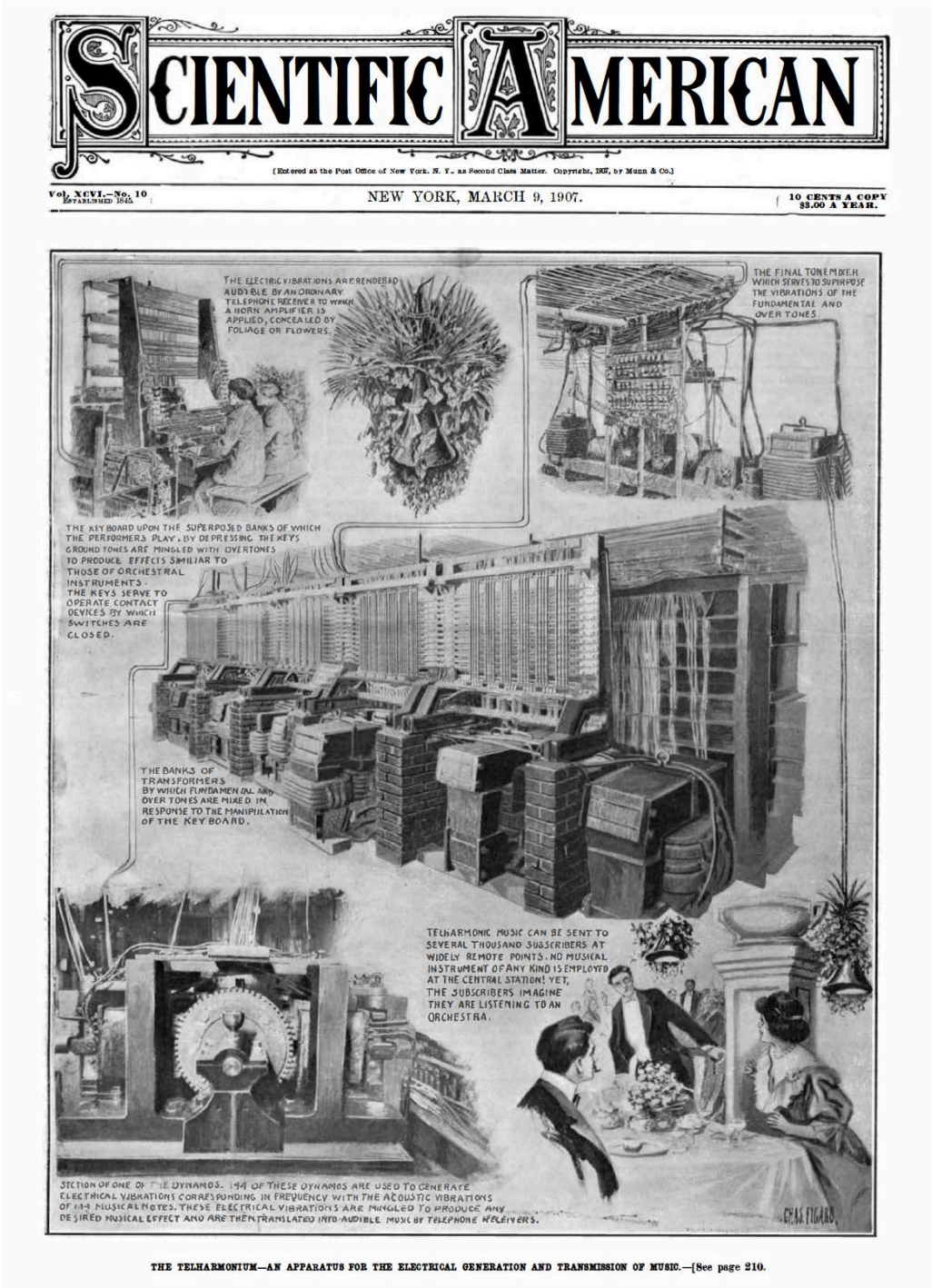
Electronic Music Inquiry Unit

In 1895 Thaddeus Cahill submitted his first patent for the Telharmonium "The Art of and Apparatus for Generating and Distributing Music Electrically". The Telharmonium, considered to be the first significant electronic musical instrument, was a method of electro-magnetically synthesizing and distributing music over the new telephone networks in America. This article explains how the telharmonium works and the set up of a new working plant stationed in New York.



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THE ELECTRIC VIBRATIONS ARE RENDERED AUDIBLE BY AN ORDINARY TELEPHONE RECEIVER TO WHICH A HORN AMPLIFIER IS APPLIED, CONCEALED BY FOLIAGE OR FLOWERS.

THE FINAL TONE MIXER WHICH SERVES TO SUPERPOSE THE VIBRATIONS OF THE FUNDAMENTAL AND OVER TONES.

THE KEYBOARD UPON THE SUPERPOSED BANKS OF WHICH THE PERFORMERS PLAY. BY DEPRESSING THE KEYS GROUND TONES ARE MINGLED WITH OVERTONES TO PRODUCE EFFECTS SIMILIAR TO THOSE OF ORCHESTRAL INSTRUMENTS. THE KEYS SERVE TO OPERATE CONTACT DEVICES BY WHICH SWITCHES ARE CLOSED.

THE BANKS OF TRANSFORMERS BY WHICH FUNDAMENTAL AND OVER TONES ARE MIXED IN RESPONSE TO THE MANIPULATION OF THE KEYBOARD.

TELHARMONIC MUSIC CAN BE SENT TO SEVERAL THOUSAND SUBSCRIBERS AT WIDELY REMOTE POINTS. NO MUSICAL INSTRUMENT OF ANY KIND IS EMPLOYED AT THE CENTRAL STATION! YET, THE SUBSCRIBERS IMAGINE THEY ARE LISTENING TO AN ORCHESTRA.

SECTION OF ONE OF THE DYNAMOS. 144 OF THESE DYNAMOS ARE USED TO GENERATE ELECTRICAL VIBRATIONS CORRESPONDING IN FREQUENCY WITH THE ACOUSTIC VIBRATIONS OF 144 MUSICAL NOTES. THESE ELECTRICAL VIBRATIONS ARE MINGLED TO PRODUCE ANY DESIRED MUSICAL EFFECT AND ARE THEN TRANSLATED INTO AUDIBLE MUSIC BY TELEPHONE RECEIVERS.

CHAS. FIGARD.

THE TELHARMONIUM—AN APPARATUS FOR THE ELECTRICAL GENERATION AND TRANSMISSION OF MUSIC.—[See page 210.

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lent no assistance whatever. Steam tonnage and vessels of the schooner type are largely accountable for the retirement of the square-rigger, whether it be American or foreign-built. The advantages of steam need no enumeration here. Schooners have many points of superiority over the square-rigger. They make quick passages, are good carriers, and can take on large deck-loads. They require but half as many men as a ship-rigged craft, as their sails can all be handled from the deck, and mostly with steam power.

Upon the Pacific coast the schooner is no longer merely a coaster, but has invaded the field formerly held by the square-rigger. We find them taking cargoes to China, Japan, Australia, South Africa, and even to Atlantic ports. As they can run so economically, they can make a profit on charters that would mean a dead loss to a ship.

As the schooner can do the work of a square-rigger, and do it at less expense, it stands to reason that those wishing to increase their sail property will build fore-and-afters instead of barks or ships. In like manner, later on, if conditions justify, they will build steamers in place of schooners.

The firm of Arthur Sewall, of Bath, Me., have endeavored for years to keep a fleet of square-riggers on the high seas, but now, after building ships since 1823, have announced that they will build no more. To-day, their fleet flag, which has been a familiar sight in all the great ports of the world for the last three-quarters of a century, is rapidly disappearing, even as their great shipbuilding plant is rusting to decay.

About sixteen years ago the Sewalls projected a fleet of fine ships, to bear the names of southern rivers. The "Rappahannock" was the first constructed, followed by the "Susquehanna," "Shenandoah," and "Roanoke," ranging in size from 2,700 to 3,500 gross tons. Misfortune followed in their wakes, and of these fine ships, only the "Shenandoah" remains. They made but little money for their owners, but demonstrated conclusively that under present conditions to build more vessels of their kind would be folly.

The practice of dismantling old ships and turning them into towing barges has been in vogue for some time, but converting stanch square-riggers into schooners is a somewhat new idea. Nevertheless, it has been done in several instances upon the Pacific coast with perfect success, and bids fair to become a general custom. Recently the "Snow and Burgess," an old State of Maine bark, was transformed into a five-masted schooner and has been beating all her previous records, besides cutting down her running expenses and increasing her carrying capacity. The old ship "Invincible," built in Bath in 1873, has also been converted into a schooner, and is again in commission after having been laid up for an indefinite period.

Of the 298 square-riggers in commission June 30, 1905, a large majority are in the hands of western owners, and are operating upon the Pacific coast. The lumber trade of the Pacific Northwest offered some inducements to these vessels, and some years ago a general exodus took place from the congested Atlantic ports to the Pacific, where ready employment was found as lumber carriers.

But now the time has come when even this trade is being rapidly absorbed by steamers and schooners, and to-day a number of these fine old vessels are loading cargo for Atlantic ports, to be dismantled upon arrival at their destinations, not many miles from where they entered upon their careers years ago. Dismantling, or conversion into schooners—such seems the fate of the remainder of the square-rigger fleet.

It is doubtful if any plan could be devised whereby the decadence of these vessels could be stayed. Any scheme of subsidy that could be enacted would apply to other forms of carriers as well, and would not tend to lessen the handicap under which ships are laboring. Nor does it seem probable that circumstances will so adjust themselves as to bring about a revival of this class of shipping.

The square-rigger has fulfilled its mission in the world's transportation system, and like the canoe of the trader on inland waters, or the ox-team of the pioneer upon land, it seems destined to pass into history as one of the utilities that was good enough in its generation, but must now be superseded by those more in keeping with modern requirements.

An aerial screw propeller working on a novel system has been invented by Major Hoernes, an aeronaut, says the Cologne Gazette. In his new contrivance the inventor takes advantage of the fact that the screw to be used in air has a wholly different medium to encounter than the ship's propeller, working in water, since air is capable of compression. He has, therefore, made use of a screw which is driven in a series of impulses, and not at one continuous speed, as is usually the case. He effects this by means of a system of screws, which not only revolve round their own axes, but also rotate round a common axis, planet fashion. The screw is thus driven alternately fast and slow.

THE TELHARMONIUM—AN APPARATUS FOR THE ELECTRICAL GENERATION AND TRANSMISSION OF MUSIC.

Dr. Thaddeus Cahill's system of generating music at a central station in the form of electrical oscillations, and of transmitting these oscillations by means of wires to any desired point, where they are rendered audible by means of an ordinary telephone receiver or a speaking arc, is now embodied in a working plant situated in the heart of New York. Although this apparatus constitutes but a portion of a plant that may ultimately assume very remarkable dimensions, and although it has limitations imposed by its size, the results obtained are so promising, that many applications have been made by prospective subscribers for connection with the central station. When a larger number of generators and keyboards is installed, as they doubtless will be in due time, there is no reason why the telharmonium, as the invention is called, should not give the subscribers all the pleasures of a full symphony orchestra whenever they wish to enjoy them. At present very beautiful effects are secured on a less elaborate scale, but in every way comparable with those of a good quintet. And several additional keyboards now in building at Dr. Cahill's works at Holyoke, Mass., where the New York plant was built, are nearing completion, and will probably be in service at Broadway and Thirty-ninth Street in the course of another month or two.

Perhaps the feature which most astonishes the technically uninformed man when Dr. Cahill's invention is first exhibited to him is the fact that music in the ordinary sense of the word, in other words, rhythmic vibrations of the air, is not produced at the central station. The vibrant notes of the flute, mingled with the clarinet or viol-like tones which are heard at the receiving end of the wire, spring from no musical instrument whatever. Nowhere is anything like a telephone transmitter used, although the electrical oscillations which are sent to the receiver and there

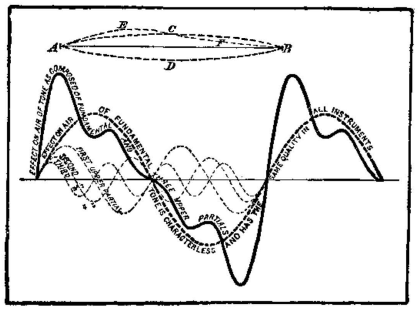

Diagram Showing Effect of the Upper Partials in Modifying the Fundamental Tone.

translated into audible vibrations are quite like those set up in an ordinary telephone circuit, except that they are enormously more powerful.

Briefly summed up, Dr. Cahill's wonderful invention consists in generating electrical oscillations corresponding in period with the acoustic vibrations of the various elemental tones desired, in synthesizing from these electrical vibrations the different notes and chords required, and in rendering the synthesized electrical vibrations audible by a translating device.

In the New York plant the electrical vibrations are produced by 144 alternating dynamos of the inductor type, having frequencies that vary from 40 to 4,000 cycles. These alternators are arranged in eight sections or panels, each inductor being mounted on an 11-inch steel shaft. One inductor dynamo is used for each note of the musical scale, each generator producing as many electrical vibrations per second as there are aerial vibrations in that note of the musical scale for which it stands. The fixed or stator part of each dynamo carries both the field and armature windings; the rotors are carried on shafts geared together, the number of teeth (pole pieces) on the gear wheels corresponding with the number of frequencies to be obtained. Because the rotors are geared together, the frequencies are fixed and tuning is unnecessary. The alternators are controlled each by a key in a keyboard upon which the musician plays. Each key serves to make and break the main circuit from seven alternators, not directly, but through the medium of plunger relay magnets wound with layers of enameled wire. Only feeble and harmless currents are needed to control the relay magnets, by which the task of making and breaking the currents from the main circuits is really performed. No appreciable time elapses between the depression of a key and the closing of a main alternating circuit, so that the keyboard is as responsive and sensitive as that of a piano. The elemental notes generated by the 144 dynamos cannot alone be used to produce the most pleasing musical effects. Why this should be so becomes apparent from a consideration of some simple principles in acoustics. If a wire be stretched between two points *A* and *B* (see the accompanying diagram) and plucked or struck, it will vibrate above and below the line *A*, *B* and give what is known as a fundamental tone. This fundamental tone is without distinctive musical character or timbre, and would sound the same in all instruments, so that one could not distinguish whether it came from a violin or a piano. In addition to its fundamental vibration between its points of attachment, the string undergoes a series of sub-vibrations above and below its own normal curve, which it will pass at certain points, nodes, dividing it into equal parts. Thus in the accompanying sketch, *A*, *C*, *B* and *A*, *D*, *B* represent the fundamental vibrations, and *A*, *E*, *C*, *F*, *B*, the first sub-vibration intersecting the fundamental vibration at the node *C*. Again, the string may vibrate in three parts, four parts, five parts, etc. The effect of the sub-vibrations is added to the effect of the fundamental vibration, and their total effect is heard in the distinctive quality or "tone color," as it is called, of the particular instrument played. The sub-vibrations are known as the upper partials or overtones, and generally speaking, they are harmonious with one another and with the fundamental tone. That very elusive and uncertain quality called timbre is dependent entirely upon these overtones. By properly controlling the blending of the overtones and the elemental tones, it ought to be possible to imitate the characteristic timbre of any musical instrument. This Dr. Cahill has in a large measure succeeded in accomplishing.

"Tone mixing," as this building up of harmonious notes and chords is called, is effected in the telharmonium by superposing the simple or sinusoidal waves of the alternators. By means of bus-bars the oscillations of the ground tones are all brought together in one circuit, those of the first partials in another circuit, those of the second partials in a third circuit, etc. The actual blending is done by passing the various oscillations through a series of transformers. In order to understand how a chord is blended, we must begin at the keyboard. As soon as the performer depresses his keys, the bus-bars electrically superpose the ground tone currents through the primaries of closed-iron magnetic circuit transformers, the secondaries of which are joined in circuit with impedance rheostats governing the strength of the currents, which rheostats are controlled from the keyboard by means of stops. Similarly the bus-bars superpose the first, second, third, and other desired partials in separate circuits. The composite ground-tone and overtone oscillations thus produced in the secondaries of the transformers are next passed through the primaries of an open-iron magnetic circuit transformer, in the secondary circuit of which a current is produced composed of all the ground tone and overtone frequencies of the particular chord under consideration. This secondary current is in turn passed through the primary of an air-core transformer, and the resultant secondary current is converted by telephone receivers or speaking arcs into the musical chord desired.

In order to listen to this musical chord, the telephone receiver is not held to the ear. It would be bad for the ear if it were, when a loud note is sounded. The current of the receiver is literally thousands, and at times millions of times stronger, measured in watts, than those to which an ordinary telephone receiver responds. Whereas less than six ten-millionths of an ampere are sufficient to produce a response from an ordinary telephone receiver, a current of an ampere is sometimes used in the Cahill system for an instant when loud tones are produced.

The composition or quality of a note or chord is controlled by eight rheostats called stops. By skillful manipulation of the stop rheostats, it is possible to obtain very accurate imitations of the wood-winds and several other orchestral instruments. Imitation, however, is hardly the right word; for the notes are built up of exactly the same components as the tones which come from the real instruments. Furthermore, beautiful effects are obtained that cannot be produced on any existing instrument. These stop rheostats control merely the timbre or quality of the music produced. Fluctuations in volume are produced by "expression rheostats." Both stop and expression rheostats are constituted by impedance coils, differing however in mechanical construction. The stop rheostats are manipulated very much like the stops of an organ, and the expression rheostats like the swell. Unlike an organ swell, however, the expression rheostats are used not only for producing captivating crescendos and diminuendos of individual notes and chords, but also in reproducing the peculiar singing tremolo of the violin and 'cello.

The rather complex system of transformers described serves not merely to blend partials with ground tones, but also to purify the vibrations corresponding with the different sets of partials by purging them of their harsher components. The air core transformers, fur-

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Source: 120 Years of Electronic Music
The 'Telharmonium' or 'Dynamophone' Thaddeus Cahill, USA 1897

thermore, permit the selection of voltages according to the resistance which the final current will encounter.

Inasmuch as each keyboard controls ground-tone and overtone mixing devices, it is possible to produce notes of the same timbre or of different timbres. Excellent orchestral effects can, therefore, be obtained by causing the one keyboard to sound wind instruments, such as oboes, flutes, clarinets, or horns, and the other to sound the tones of the violin or other stringed instruments.

From this necessarily cursory consideration of the telharmonium, it is evident that the music is initiated as electrical vibrations, distributed in the form of electricity, and finally converted into aerial vibrations at a thousand different places separated hundreds of miles, it may be. No musical instruments in the sense in which we understand the word are used. Not a string, reed, or pipe is anywhere to be found. The vibrations produced by the performers' playing are wholly electrical, and not until they reach the telephone receiver can they be heard. The telephone receiver acts for us as a kind of electrical ear to hear oscillations to which our own ears are insensitive.

When Mark Twain heard the telharmonium, he fancifully suggested that the military parade of the future would be a more beautifully rhythmic procession than our present pageants. The usual military bands heading the various regiments and playing marches, not in unison, although the same in time, will give place to musical arcs disposed along the line of march, all crashing out their strains in perfect time. The soldiers who will march in that future parade will all hear the blare of invisible electrical trumpets and horns at the same moment; they will all raise their left feet at exactly the same instant, just as if they were but one company.

So far as the capabilities of the telharmonium are concerned, it may be stated that the New York installation is able to supply ten thousand subscribers, or more, with music of moderate volume at widely remote places. The very remarkable and rapid development of the invention has been thus eloquently set forth by Prof. A. S. McAllister in an article published in the Electrical World:

"From Hero, who first proposed to utilize the motive power of steam, to Watt's first successful engine, was almost two thousand years. And between the proposal of Hero and the accomplishment of Watt many inventors in different countries made ineffective attempts to attain the goal desired. From Huyghens's proposal of an explosive motor to Otto's successful machine two centuries elapsed, with scores of patents in the different countries of Europe. So from Sir Humphry Davy's experimental arc to the Brush and Edison arc lighting machines, three-quarters of a century elapsed, during which scores of inventors in different countries endeavored to solve the problem in vain. Similar remarks apply to the progress of most great inventions, electrical and mechanical. But the process of producing music from dynamos has been carried from the first conception to the successful working machine by one man—Thaddeus Cahill—in a few years. And when one hears the plant at Thirty-ninth Street and Broadway, with its musical tones already equaling, if not surpassing, the instruments of the orchestra, one wonders what cannot be expected in a few years to come when the inventor will have had time to do his best, and when his work in all its details will be known to the world and open to improvement by others, and when musicians will have learned to use the new powers which electricity is placing at their command. Clearly the world has, through the wonderful powers of the electrical forces and the skillful use made of them by Dr. Cahill, a new music, a music which can be produced in many thousand places simultaneously, and which in its very infancy seems destined to surpass in sympathy and responsiveness—in artistic worth—the existing music of pipe and string, the evolution of many centuries."

Official Meteorological Summary, New York, N. Y., February, 1907.

Atmospheric pressure: Highest, 30.77; lowest, 29.62; mean, 30.10. Temperature: Highest, 44; date, 14th; lowest, 1; date, 12th; mean of warmest day, 38; date, 2d; coolest day, 8; date, 12th; mean of maximum for the month, 31.7; mean of minimum, 17.1; absolute mean, 24.4; normal, 30.6; deficiency compared with mean of 37 years, —6.2. Warmest mean temperature of February, 40, in 1890. Coldest mean, 23, in 1875 and 1885. Absolute maximum and minimum of this month for 37 years, 69 and —6. Average daily deficiency since January 1, —2.1. Precipitation, 2.52; greatest in 24 hours, 1.07; date, 4th and 5th; average of this month for 37 years, 3.74. Deficiency, —1.22; deficiency since January 1, —1.72. Greatest precipitation, 7.81, in 1893; least, 0.82, in 1895. Snowfall, 20.3. Wind: Prevailing direction, N. W.; total movement, 9.357 miles; average hourly velocity, 13.9 miles; maximum velocity, 48 miles per hour. Weather: Clear days, 9; partly cloudy, 11; cloudy, 8. Fog, 2d. The temperature of December was 1.3 below, January 1.7 above, and February 6.2 below normal; an average of 1.93 degrees below normal for the winter. The total precipitation for the winter had a deficiency of 1.59 inches.

Henri Moissan.

With the death of Prof. Henri Moissan on February 24, the world lost one of the greatest of modern chemists, certainly one of the best known. Among the latest of the many honors which Prof. Moissan bore was the Nobel prize for contributions to science and chemistry, awarded last December for his famous experiments in the isolation of fluorine and his researches into its nature, and for his application of the electric furnace to scientific uses. Like the achievements of the Curies, much of Moissan's work was spectacular in the extreme, though never unworthily so. Among his best known experiments, and one which made his name familiar to practically all the civilized world, was the formation of artificial diamonds in the electric furnace in 1893. The great chemist was remarkable for the unselfish nature of his work. Had he patented his discoveries, he would doubtless have been enormously wealthy; but he gave all he learned to the sum of human knowledge freely and ungrudgingly. While his discoveries were almost uniformly without financial benefit to himself, he vastly assisted commerce and trade, and added to the wealth of the nations by teaching new applications of modern chemistry to the industries.

Henri Moissan was born at Paris on September 28, 1852. He obtained his education principally at the Museum of Natural History in Paris, and subsequently at the School of Pharmacy. For four years, until 1883, he taught at the Higher School of Pharmacy, and later, in 1886, he became professor of toxicology at this institution. In the following year he isolated and liquefied fluorine, and for this achievement, together with his investigations into the nature of the element, he won the Lacaze prize from the Academy of Sciences. In 1889 he took the chair of mineral chemistry in the School of Pharmacy, and there conducted his important and far-reaching experiments with the electric furnace. In 1892 he carried out a series of investigations which rendered the manufacture of acetylene practicable and commercially profitable. His was the discovery that calcium carbide results from the fusion of carbon and lime in the electric furnace, and that from the former acetylene gas can be liberated without difficulty. In the following year Prof. Moissan performed his sensational experiments in the manufacture of artificial diamonds. He melted iron in the electric furnace and saturated it with carbon, the furnace being at a temperature of over 4,000 deg. C., that is, more than 7,200 deg. F. At this high temperature the furnace was plunged into cold water, and the resulting ingot was subsequently attacked with hot aqua regia; this agent dissolved the iron and laid bare the diamonds. It will be remembered, however, that these diamonds were usually too minute in size for practical use, but they were genuine, being pure crystals of carbon.

The Current Supplement.

The opening article of the current Supplement, No. 1627, is the second installment on the manufacture of gas, begun in the last number. The present installment deals with the manufacture of water-gas. Mr. C. W. Parmelee's paper on the technology and uses of peat is continued. The treatise on corn-harvesting machinery is continued, by Mr. C. J. C. Zintheo in a second installment. Much curious information is contained in an interesting article entitled "Swindling Alchemists of Bygone Days." Minor articles of interest are those entitled "What Demands Are We to Make on a Serviceable Preserve Glass?" "Transplantation in Surgery," "Old and New Theories of Lightning Conductors," "The Channel Tunnel." The paper on the advantages and applications of the electric drive by Prof. F. B. Crocker and M. R. Arendt is concluded. Most important is a discussion of apparatus and methods of distilling alcohol.

Portable Rotary Converter Substations.

The Illinois traction system, which has under construction several connecting lines of 40 or more miles in length, has found that portable rotary converter substations are quite useful at the time of first opening new lines. This company has five such substations, each consisting of a substantially-built box car carrying one 300-kilowatt rotary converter, together with transformers and switching apparatus. According to the Electric Railway Review, when a new line is to be opened, one of these sub-stations is set off on a temporary side track and a short pole, with standard high-tension cross-arms and insulators, is erected close to the end of the car. In this way the three-phase transmission wires may be brought to the high-tension disconnecting switches in the car.

Correspondence.

The Vagaries of Railway Time Tables.

To the Editor of the Scientific American:

If the subject is of sufficient importance, kindly allow me space to draw the attention of your readers to what appears to me a misuse of the 24-hour system of time, as given in many railroad time bills.

It is not unusual to find something like the following:

"This time bill will take effect at 24:01 on Saturday, February 16." When does that minute arrive? This being written at 15 o'clock on Friday, the 15th, nine hours from now will be 24 o'clock on Friday, the 15th, and the day and date is ended.

Now the notice of change in time bill given above is probably intended to take effect at one minute after midnight to-night. Certainly the one minute belongs to date 16th, but not the hour 24; because 24 o'clock on Saturday, the 16th, does not arrive until to-morrow night, and we have the hour belonging to one date and minute belonging to another used together.

It seems to me that when 24 o'clock arrives, the date and day terminate. Any time desired to be noted up to 1 o'clock following should be expressed as 0:01, 0:05, etc., and the notice first mentioned would read: "This time bill will take effect at 0:01 on Saturday, February 16."

I have spoken to different railroad managers and superintendents on the subject, but so far have failed to find any to admit the error which I have endeavored to explain. H. W. D. Armstrong, M.C.S.C.E.

Saskatoon, Canada, February 15, 1907.

Tree Moss and Branches as Compasses.

To the Editor of the Scientific American:

Some time ago an article appeared in your paper—I do not now recall the writer's name—in which he denied the saying, or rather belief held by many, that the limb growth of trees and the growth of mosses at the base of tree trunks indicate, in a general way, the cardinal points of the compass; and cited in support of his statement, that extensive observations made by him in the forest districts of Kentucky, Tennessee, and I think he included Georgia, proved to his satisfaction that such was not the case.

I have been looking for some reply to this article, but as none has appeared, I venture a word or two.

That the growth of limbs and moss does indicate a general north and south line, is a fact not disputed by those who follow the trackless wilderness as hunters, trappers, explorers, or "cruisers," and is used by all true woodsmen as a successful guide in cases of emergency. This condition of growth does not apply to all sections of the country, hence we are not surprised that the writer of the article referred to failed to find this condition in the forests of Tennessee, Kentucky, or Georgia; but it does apply to the immense timbered district of the North, and here is where the saying originated. This condition of growth will not be found in cut-over or second-growth timber lands, but prevailed in the original pine, fir, and hemlock forests of Maine, Vermont, New York, Pennsylvania, Canada, and elsewhere in the forest districts east of the Mississippi and north of say latitude 42; and there still remain large tracts of timbered country, untouched by the lumberman's ax, where those who can read the signs of the woods have a sure guide to general direction in case of need. In northern Minnesota and Michigan this and other methods peculiar to woodcraft have been used over districts of high magnetic disturbance, where the compass is as likely to point west, east, or south as it is to point north.

It may be interesting to note some of the methods used by those accustomed to the woods to ascertain general direction in cases of emergency. First we have the growth of limbs and moss. This does not apply to every tree, but does in a general way, and to these generalities the woodsman's eye is trained, and he sees in the same general way, that the longest, largest, and greatest number of limbs grow on the southerly side of the trees; that the moss is more profuse on the northerly side and grows to a point, while on the southerly side, if it grows up on the trunk, it is not as high and is rounded at the point of highest growth. He will also find that the bark is thicker on the northerly side, and on pine and hemlock is rougher and more deeply corrugated. The woodsman always carries a watch, and when his compass fails and the signs of the woods are not plain, he points the hour hand of his watch toward the sun, and takes a line half-way between the sun and twelve on his watch as the south. If the sun is obscured, and he is unable to determine its position, he is still not without resource, for he places the point of his pocket-knife blade on his thumb and holds it in a vertical position, and if he does not perceive a shadow a slight rotatory movement of the knife will produce it, then with his watch he finds the north and south line as before, and goes on his way rejoicing. Henry S. Ely.

Duluth, Minn., January 18, 1907.

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YouTube Video that explains the technology behind the Telharmonium
https://youtu.be/AV34h-YCMbE (Mark Doty and the Bob Moog Foundation)