tiful will be the picture. The picture made on this instrument is as exact as the tuning fork in determining pitch. and the pitch of any note may be at once ascertained by reference to the chart. It was my wish to reproduce the intricate picture of d‴ in altissimo on the tonograph, at the demonstration of the invention at the Academy of Medicine, in April, but for a moment it seemed impossible to get the pitch, as there was no fork or piano at hand. I however stated that, possessing natural pitch, I could strike c″ an octave below, and verify it by the picture produced on the chart, and then by taking the note above give the pitch to the boy soprano, Master Witter Peabody, who had kindly consented to sing the high notes for me. I did this, at once making the beautiful figure c″, when taking the next note and singing the octave above, Master Peabody immediately duplicated the most intricate d‴ in altissimo on the chart in its minutest detail. The plates of the chromatic scale are reproduced from the photographs without any retouching or disturbance of the salt. Two of these plates will be seen to be duplicates, c‴ and d‴, which are inserted to show the differences of the figures as sung by widely differing voices. Thus the second plate of c‴ was sung by a very celebrated light soprano, while the heavier lines in the first plate of c‴ (1,024 vibrations of the vocal cords per second) was sung by an equally celebrated prima donna. whose voice is of a more dramatic quality. The differences in timbre of the two voices are shown in such a way that we can see the strength of the overtones and the preponderance of certain harmonics which go to make up the quality of the respective tones—a truly visible musical analysis. The plates of d‴ were sung by a very high soprano and by the boy soprano mentioned above. In the second plate we see the quality of the male voice in the heavier lines and a wider plan of segmentation.

Plate III shows b′ and c″ on the staff, sung by a male voice, a well known tenor. There occur two or three figures between b′ and c″, as also between many of the notes, showing that there are notes in the geometric scale not taken into consideration by our musical notation on the piano, but which undoubtedly we recognize on the violin and cello. This subdivision of intervals undoubtedly lends the peculiar charm to these instruments.

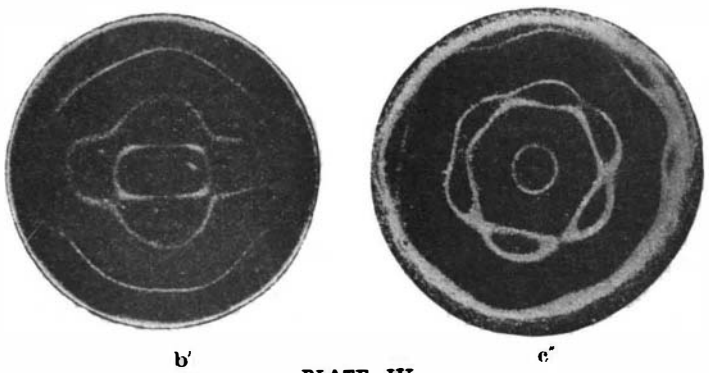
Plate IV shows the intermediates between c″ and d″. As we descend lower in the scale, the figures become simpler, Plate I showing a′, a′♯ and b′, as sung by a basso.

The above figures were sung by Madam Calvé, Jean de Reszke, Ben Davies, Plancon, Plunkett Greene, Ed. de Reszke, Miss Marie Donavin and Miss S. K. Peck. From a careful study of the results with such distinguished co-operation, I have arrived at the following conclusions:

A tone, to make a perfect geometric figure, must be sung well forward, with no forcing or tension, and with absence of shock or breathiness of tone. In other words, perfect production must be employed to make a harmonious figure, in the same way that it must be studied to make an agreeable impression upon our ear; and, from the same analogy, may we not reason that the little membrane of our ear drum may be divided up in the same exquisite arrangement of nodal lines by audible tones, and thus communicate to the brain, by means of the auditory nerve, the impression of agreeable quality in tone.

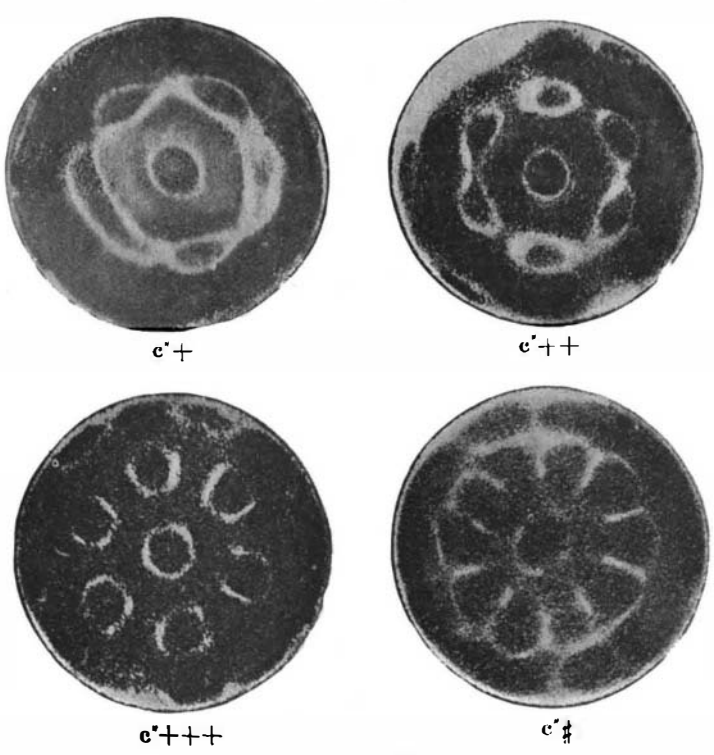
The pioneer in the study of shapes made by the voice in sand and pigments was Mrs. Watts Hughes, of London, and it was in attempting to imitate the shell and flower forms which she so beautifully described in the Century Magazine for May, 1891—pictures I have reproduced in my book on "Voice Building and Tone Placing," Appleton, 1896—that I conceived the idea of making a geometric musical scale, and the above mentioned figures have been the result of over a year's experiments with a vast amount of apparatus and many kinds of membrane. The simplest in the end has given the best results, and I describe my instrument in its easiest construction. The beautiful figures are of endless variety, and are as complicated as the sand forms on a Chladni plate or the scrolls made by the reflection of a ray of light from Wheatstone's luminous bead on a vibrating rod. My only claim to originality lies in the fact that I have utilized mixtures on a vibrating membrane to construct a geometric musical scale in figures, which are the same for equal tensions and diameters of membrane; and have further studied the relative specific gravities of the mixtures of salts and emery I employ to produce the best results for given thicknesses and tensions of the vibrating membrane—a subject I shall elaborate at another time.

The practical result I hope to attain is, to construct a tonograph which shall be so delicate that the pictures will record not only a mathematical expression for pitch, but for an analysis of tone quality as well.



b′ c‴

PLATE III.



c‴+ c‴++

c‴+++ c‴♯

PLATE IV—TONE PHOTOGRAPHY.

### Odd Causes of Electrical Fires.

The quarterly report of the Electrical Bureau of the National Board of Fire Underwriters makes mention of the following odd causes of fire:

A plush curtain in a theater, on being hoisted, came in contact with a 32 candle power incandescent lamp. The common size is 16 candle power. The heat from the lamp ignited the curtain, but the fire was discovered, with no loss, except the curtain.

A stage hand was ordered to turn out an incandescent lamp, and not knowing how to do it, instead of turning the switch, he wrapped a damp towel around the bulb. Some time afterward the towel was discovered smouldering.

A portable incandescent lamp was allowed to remain lighted lying on a mattress. The heat from the lamp ignited the cloth and the excelsior of the mattress, and the fire spread through the basement and store.

An electric pressing iron was allowed to stand with the current turned on. The heated iron after a time set fire to the table, and the flames communicated to the surrounding combustible material.

A wagon loaded with gasoline collided with an electric car. The wagon was demolished and the oil flooded the street. The accident attracted the attention of the motorman of another car, who ran his car up to the scene. Seeing the oil running under his car, he turned on the current to get away. A spark from the wheel immediately ignited the gasoline fumes, and instantly the street was ablaze. Four people were injured, one seriously, and one horse was burned to death.

Fire occurred in a basement, owing to dripping water falling on an electrical measuring instrument, thereby short-circuiting it.

Sparks from arc lamps in a department store ignited cloaks on a table underneath.

An elevator motor was burned out, having been left running when the employes left the store, the motor brushes being badly adjusted.

A carpenter dropped a nut on the coils of a rheostat, short-circuiting them with an iron frame resting against a gas pipe. An arc was formed between the frame and the pipe; the latter was melted and the escaping gas ignited.

Rats gnawed the insulation from a wire which lay on a gas pipe; an arc was established between the wire and the gas pipe, setting fire to the gas.

ACCORDING to recent experiments of Prof. Trowbridge, says the Electrical World, with a 20,000 volt storage battery, it appears that the lowest voltage which will produce satisfactory Roentgen rays is about 100,000. He also found that electrostatic polarization is largely instrumental in the generation of X rays.

### THE PRODUCTION OF GRAND OPERA.*

Grand opera, to be given adequately, requires a permanent home, and the Metropolitan Opera House, New York City, may be regarded as the home of grand opera in America, for here is given the longest season and here the great artistic triumphs are made. The Metropolitan Opera House has many interesting features; therefore we have selected it for the subject of the present article.

The building is built of yellow brick and occupies the entire block bounded by Broadway and Seventh Avenue, Thirty-ninth and Fortieth Streets. The auditorium is handsomely decorated and is capable of seating an enormous audience. We shall, however, confine our attention to that most interesting of places—the stage.

The stage of the Metropolitan Opera House is 101 feet wide and the depth is 84 feet. The height from the stage to the "gridiron" overhead, from which hang the scenes, is 90 feet. The first "fly gallery" is 36 feet above the stage, and the depth of the cellar is 28 feet. A reference to the plan will show that the stage is divided laterally into four sections, called "bridges," which run entirely across the stage. Each bridge is in turn divided into four parts, so that there are really sixteen working bridges. When it is desired to raise any part of the stage above the level, to represent broken ground or for any other purpose, a narrow trap door is lifted and a man at each end of the bridge raises it up to the desired height, as shown in our engraving. The bridges are counterweighted, so that it requires very little effort to raise them. It is possible to lift them to a height of 22 feet. The plan also shows the wing posts at the sides; these also slide up and down freely. They secure the "wings," or side scenes. No use is made of the cellar for raising the scenes, as it is found more satisfactory to operate the scene from above. The cellar is used for storage purposes and is divided into two mezzanine stories. When not in use the large drop scenes and the borders are rolled up and placed in racks. A section of the stage floor is arranged to lift up so as to permit of the long rolls of canvas being lowered into the racks. In the cellar is also machinery for working the various traps which will be noticed in the plan. These traps are very useful for suddenly elevating persons or properties to the level of the stage.

Going up several flights of stone stairs, the visitor arrives at the first "fly gallery." The "fly galleries" are narrow galleries which extend across each side of the stage. From the "fly galleries," which are most massive, the curtains, the "drop scenes" and the "borders" which form the sky are lowered. As the "drops" at the Metropolitan measure 45 × 70 feet, it will be seen it would be no small task to raise and lower them. From the "fly galleries" a very large number of these "drop scenes" are hung; more are hung up than are to be used for the opera. The canvas is hemmed so as to permit of a wooden pole or batten being thrust through it. This bar is secured to the ropes which raise the scenes or "drops" by means of clamps. At the very top of the building, underneath the roof, is what is called the "gridiron." It is an iron framework covering the entire top of the stage. It supports the pulleys over which the ropes run to raise the "drops," "borders" and "border lights." Each scene drop is supported by five ropes and most of the "borders" are also supported by an equal number. These ropes are attached at equal intervals along the length of the scene or border, and each rope passes over a pulley on the "gridiron" directly above the clamp which secures the wooden bar. The ropes are then assembled and pass down on the left of the stage to the first fly gallery. It will be noticed by reference to our engraving that all of the ropes are brought over to one side. This is called the working fly gallery. In raising or lowering a scene the five ropes are pulled at the same time and are secured to the "fly rail" by means of the belaying pins. The fly men climb up to the second and third fly galleries when heavy scenes are to be raised, and, catching hold of the ropes, descend to the first fly gallery on them. The curtain is raised and lowered by hand power by means of a winch, wire rope being used. An asbestos curtain is provided which may be instantly dropped to the level of the stage in case of fire.

We present an engraving of a corner of the stage showing the great switchboard and the prompter's desk, though, of course, in grand opera the prompter takes up a position under a hood directly in front of the conductor, just beyond the footlights. Just before the conclusion of the act the conductor rings an electric bell in the fly galleries as a warning and later gives the signal to drop it. The curtain calls from the audience

* Abridged from "Magic, Stage Illusions and Scientific Diversions," a new work which will be published in the autumn. Copyrighted, 1897, by Munn & Co.

# SCIENTIFIC AMERICAN

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A WEEKLY JOURNAL OF PRACTICAL INFORMATION ART, SCIENCE MECHANICS, CHEMISTRY, AND MANUFACTURES.

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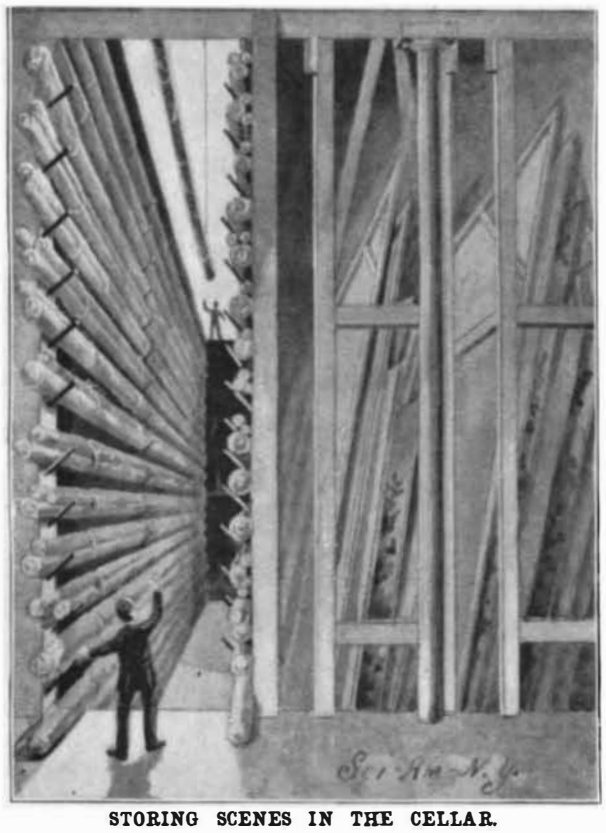
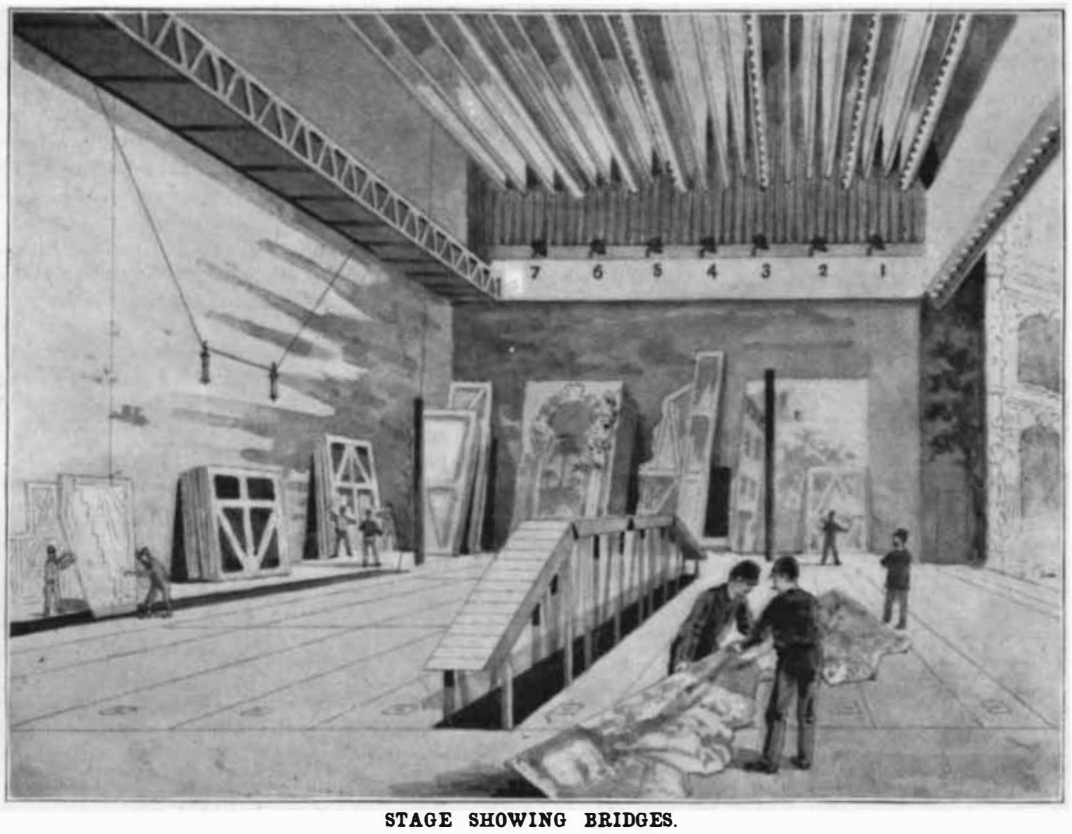


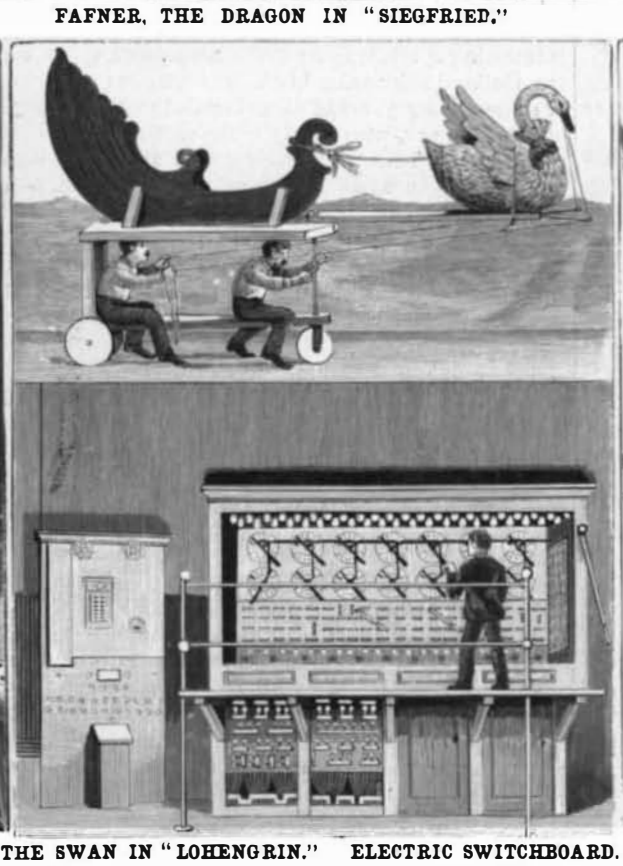
STORING SCENES IN THE CELLAR.




STAGE SHOWING BRIDGES.

FAFNER, THE DRAGON IN "SIEGFRIED."

WORKING FLY GALLERY.



THE SWAN IN "LOHENGRIN." ELECTRIC SWITCHBOARD.

PAINTING SCENERY FROM THE PAINT BRIDGE.

**BEHIND THE SCENES AT THE GRAND OPERA.**—[See page 346.]

are responded to by the stage manager, who orders the raising and lowers the curtain by bells.

The little corner of the stage next the switchboard which we show in our engravings very much resembles the conning tower of a ship. Here are speaking tubes and electric bells which communicate with all parts of the house, and it is from here that the signals are given to work the traps or to produce the thunder.

The electric lighting of the Opera House is very interesting, though it does not have its own generating plant, taking the current directly from the street. The switchboard shown in our engravings is believed to be the finest in the world. From the switchboard every light in the house is controlled, both in front of and behind the curtain. Of course, the necessity of having all the lights upon the stage arranged so that the colors may be changed greatly complicates the switchboard. It is possible for the operator to move all of the rheostats at once if desired, thus producing a gradual brightening or dimming of the lights.

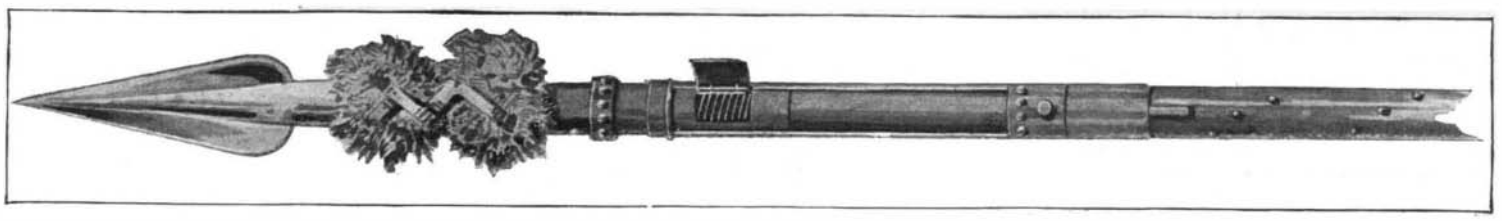
At the right will be noticed a number of small switches. These control the pilot lights which are fastened to the top of the switchboard. These pilot lights show the exact condition of every light both in the house and upon the stage, so that the electrician can see at a glance whether he has on the red, yellow, blue or white lights and the degree of brightness of any of them. The "drop scenes" and especially the "borders" are lighted by means of what are called "border lights," and which are shown in our engraving. The "border lights" run clear across the stage on a batten and they are suspended from the "gridiron" by means of wire ropes. There are 234 lights in each of the eight border lights. The lamps are arranged alternately in the four colors.

The cables for furnishing electricity to the border lights are attached at the level of the first "fly gallery." The "border lights" are maintained at a height just above the first fly gallery, and in case of any breakdown, gas is provided as a substitute. At the sides of the proscenium are what are called "side lights." Up in the first "fly gallery" are arc light projectors, which take the place of calcium lights. The wings are lighted by what are called "bunch lights"; they are supported by a standard. Gas and electricity may be obtained at any part of the stage. There is also an electric organ in the first "fly gallery," which may be played from any part of the stage.

The paint bridge is a wide platform at the level of the first "fly gallery," and it furnishes a means of communication between the two galleries. Canvas which is to be painted is run up and down the side of the paint bridge. The scenic artist thus has access to all parts of the canvas. On the paint bridge are long tables on which the materials of the scenic artist are kept.

Having now briefly described a few of the interesting features of the stage, we come to the "properties," which are so necessary to produce the many effects which contribute so largely to the scenic effect. Space forbids us to do more than refer to a few of them. In the SCIENTIFIC AMERICAN of December 22, 1888, various other properties and effects are described.

In "Lohengrin," two entirely distinct trucks are used to carry the car or boat and the swan. On the front page engraving will be seen the one used in the first act, in which the swan and the boat wind their way through weedy meadows. Two men sit in the three-wheeled truck and propel it with their feet by shuffling; the first man steers the truck, the swan turning with it, while the rear man works the neck and wings by cords. The truck carries the boat and swan in a graceful curve through set scenes representing the bank of the Scheldt, the set scenes gradating in height. In the last act, when Lohengrin takes his departure, it is no longer necessary to have the swan and car take a sinuous course; so a four-wheeled truck is used, propelled by pushing. The swan is secured to a parallel and is held in place by the cords held by the stage hand. When the swan is to disappear, the lines are loosed and the bird drops behind the set scenes which mask the truck and the bird is withdrawn into the truck. As the swan disappears, the brother of Elsa is raised by a trap, so that he occupies exactly the same place as the swan. A clockwork bird now descends on a wire, and, taking the place of the swan, appears to carry off the car containing Lohengrin.

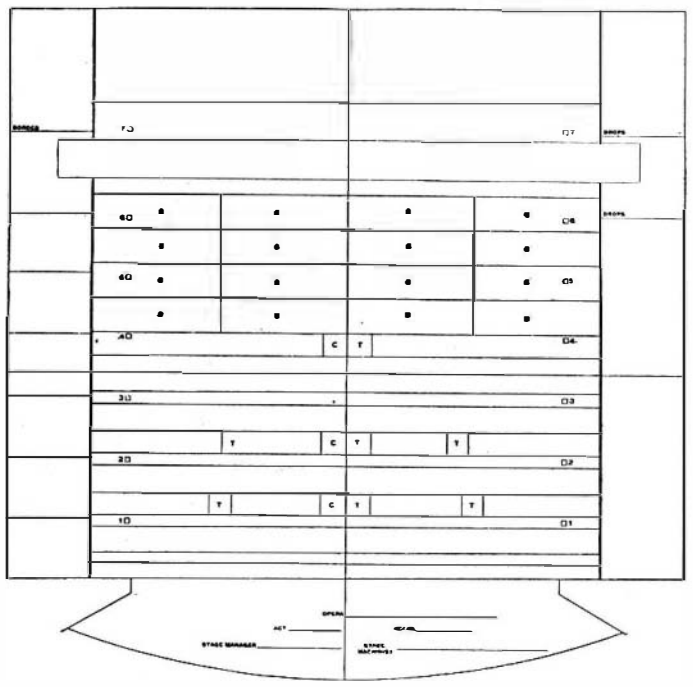


WOTAN'S SPEAR.

Siegfried's forge appears to be built of rocks, but really consists of an open framework covered with canvas. The top is masked in by painted work. Siegfried piles coal on the forge and blows the fire with a primitive leather bellows; he casts and forges the sword, the lighting of his face and the cave being very realistic. On the top of the forge are two incandescent lamps, and at the front three more of these lamps have red globes and are on two circuits. They are lighted and dimmed as required for the effect on the artist-smith's face. Gas is supplied by two pipes, one jet is kept going constantly, lighting the large rose burner which gives the effect of the flame when the gas is turned on to it. Steam furnishes the smoke and is turned on by a stage hand. A shelf underneath the forge permits of an exchange of swords. When the heated sword is thrown into the trough steam is admitted to it by a stage hand, producing a very natural effect.

Fafner the dragon, in "Siegfried," is one of the most interesting properties at the Metropolitan. It is the creation of Mr. Siedle, the property master, and is thirty feet long. The head is particularly terrible. It is made of papier maché and is painted in shades of green. The jaw, tongue and antennæ are all movable. The head is supported by the first man and is moved by the second man by means of a lever, the shoulders of the first man being the fulcrum. Each of the legs of the two men are incased in enormous boots which form the scaly, squat legs and hoofs of the monster. The body is of painted cloth and the tail consists of boards articulated with hinges. A hose runs through the tail and the body to the mouth, and carries the steam for the sulphurous breath of the monster; the steam is admitted by a stage hand in the wings. The eyes are provided with electric lights, the wires running through the tail. The dragon does not wholly withdraw from the cave, but stands in the mouth of it belching forth steam, the eyes gleaming fitfully.

The spear used by Wotan in "Siegfried" is made of two parts, the upper telescoping with the lower. In the lower part is a coiled spring which is compressed when the upper part is forced on the lower. The upper part is then secured by a catch. When Siegfried strikes the spear with his sword Wotan presses a button which releases the catch. The coiled spring now throws off the upper part of the spear, and in doing so strikes matches contained in the inside of the spear; the matches rub against sandpaper fastened to a small door which opens in the upper part of the spear. The matches set fire to a small quantity of guncotton, which lights flash paper concealed in the end of spear. This produces a remarkable effect, and is said to be superior to the electrical device formerly used. We are indebted for courtesies in the preparation of the present article to Mr. William Parry, stage manager of the Metropolitan Opera House, Mr. C. D. McGiehan, the stage machinist, Mr. Edward Siedle, the property master, and to Mr. Stewart, the electrician.

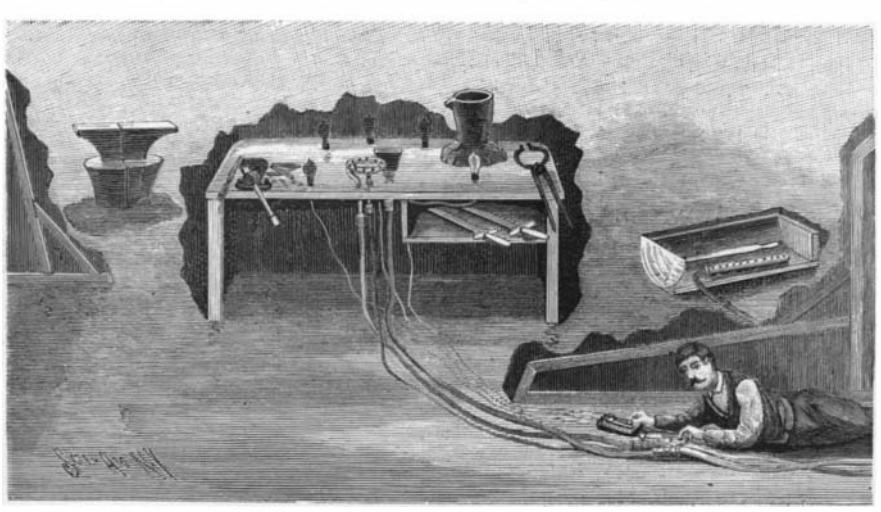


PLAN OF STAGE OF METROPOLITAN OPERA HOUSE.

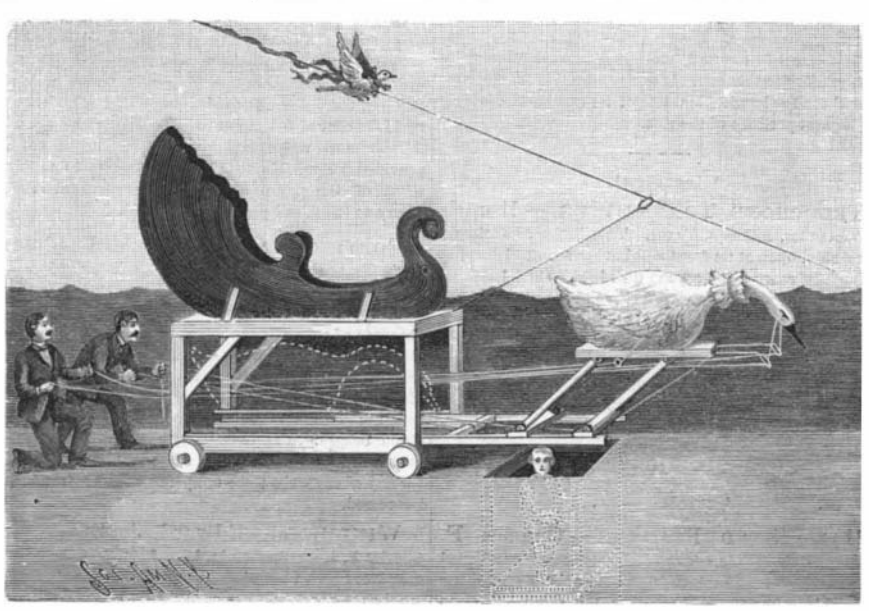
### A Fast Run on the Burlington Road.

The Chicago, Burlington and Quincy Railway surpassed all its previous efforts in two directions on May 9, breaking the best previous running time over its tracks. A short time ago we chronicled the run from Denver to Chicago of a special train carrying a New York broker who was anxious to reach the bedside of his dying son. The special train which he chartered ran at the rate of a mile a minute. On May 9, the same car covered the distance from Mendota to Chicago, 79 miles, in 76 minutes, making an allowance of six minutes for two stops and slow running at La Grange, where track elevation is in progress and the track is supported by a temporary structure. Between Sandwich and Plano, a distance of 43 miles, the running time was three minutes. The 46 miles from Mendota to Aurora were covered in 43 minutes. The 69 miles from Mendota to La Grange took up 65 minutes of the total running time. To Western Avenue, a distance of 79 miles, the train ran at the rate of just one mile a minute.

THE American Bell Telephone Company make, it is stated, an average of 2,630,071 connections per day.



SIEGFRIED'S FORGE.



THE DISAPPEARING SWAN IN "LOHENGRIN."