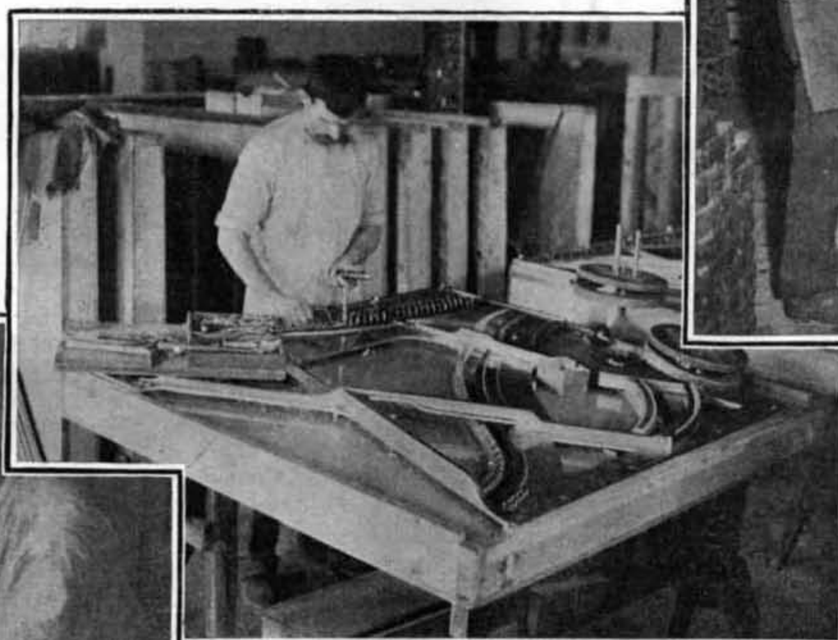
THE ART OF PIANO MAKING.—I.

In an age in which the old handicrafts are being rapidly swept out of existence by the invasion of labor-saving machinery, it is gratifying to find, here and there, an art, such as that of piano-making, which demands for the creation of its finished products the sensitive and sympathetic touch of the human hand.

The SCIENTIFIC AMERICAN has chronicled, from time to time, some wonderful triumphs of the labor-saving machine—notably its almost complete mastery of the delicate art of watch-making, in which it has succeeded in rivaling the finest handmade products of European handicraft; but in the present article, which is devoted to the making of the high-grade piano, we find ourselves in a field where the skilled artisan still reigns supreme, and is likely to so remain to the end of time.

It is a significant fact, taken in this connection, that the absolutely first-class piano firms in the United States are of old standing, and embody in their products a wealth of experience and shop traditions which, in itself, is no doubt one great secret of the high quality of the output; and this is essentially true of the Knabe Company, of Baltimore, the construction of whose piano forms the subject of the present article. The original works were built as far back as the year 1837, and the secrets of manufacture, the thousand-and-one shop "wrinkles," have been handed down from father to son, in the ownership, the management, and at the bench through three generations.

Japanning Room Showing Entrance to Oven.



Stringing the Rast.

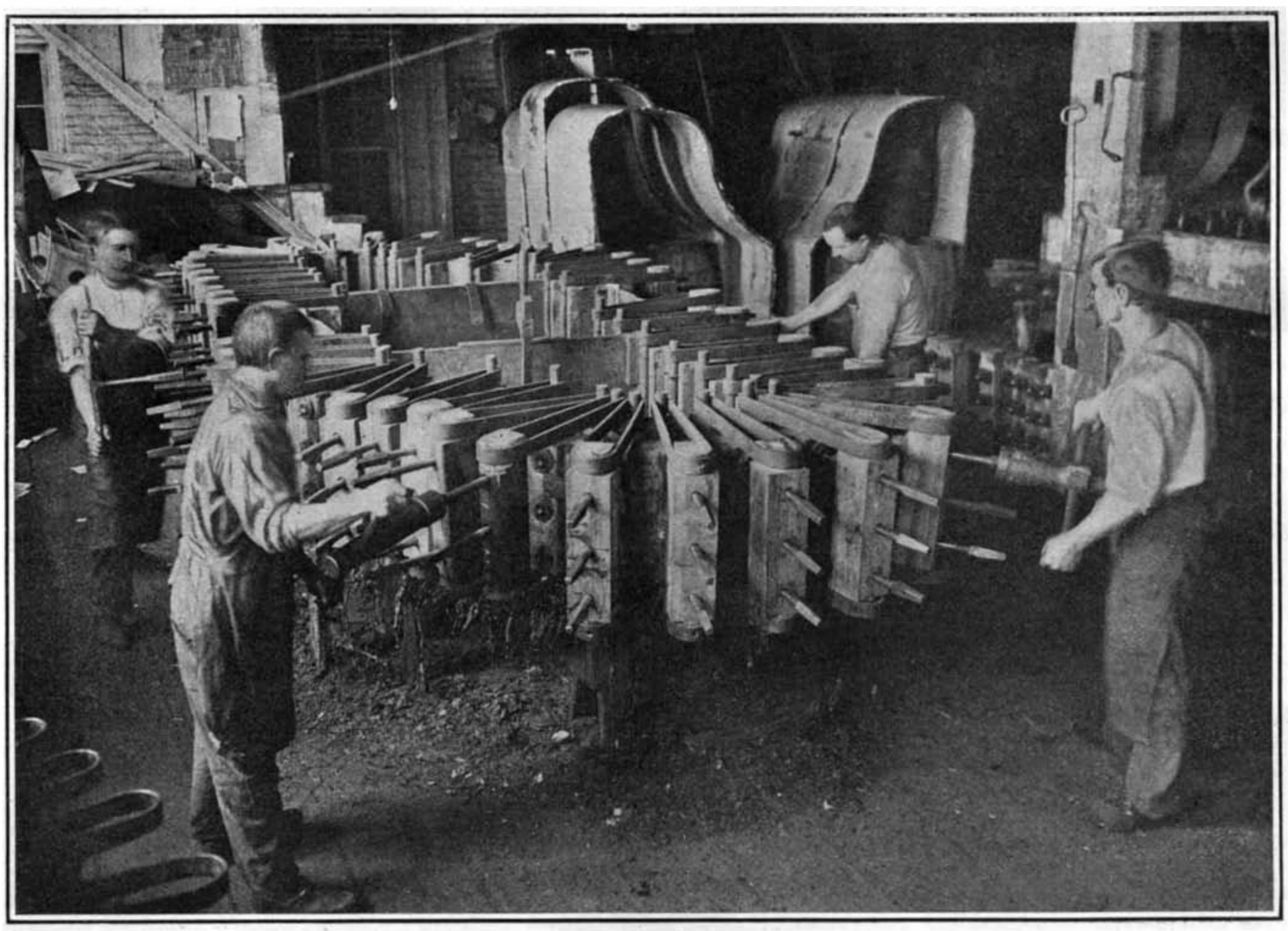
Drilling Holes for Tuning Pins in the Plate of a Grand Piano.

SELECTION OF THE WOOD.—There is, perhaps, no other object of manufacture in which the production of the desired effects is so little dependent upon one single element of the instrument, and so completely dependent upon the combined effect of all the elements, as in the high-grade piano. Thus, in the instrument under consideration, the primary object aimed at is to secure the characteristic singing tone for which it is famous. To this end the various kinds of wood—spruce, pine, maple, oak, mahogany, etc.—are carefully selected with a view to their resonant or singing quality. Each piece of lumber in the rough is struck to determine if it has the proper ring; its texture must be of a certain quality; its grain true and straight. Great attention is paid to the seasoning of the lumber, which upon its delivery at the works is stacked in the stockyard, where it is weather-seasoned for from two to six years before it is available for use in the shops.

THE WOOD MILL.—The seasoned lumber is first taken to the wood mill, where it is sawed into widths practically all of which are less than 6 inches, and many of them from 2 to 4 inches in width. From these small widths are built up the various larger members that enter into the piano, such as the legs, the heavy posts of the frame, the delicate sounding board, and the various sections of the case. The object of this process of building up, which is done entirely with glued joints, no metal whatever being used, is twofold. First, to so arrange the grain in the contiguous pieces of wood that the atmospheric changes shall have no warping effect upon the piano; secondly, to secure that harmonious arrangement of the grain of the wood which it has been found conduces so greatly to the tonal effects in the piano. It may be a surprise to many of our readers to learn that the resonant character of the wood in the case and even the legs of a piano can have its share in the final tone result; but this is a fact.

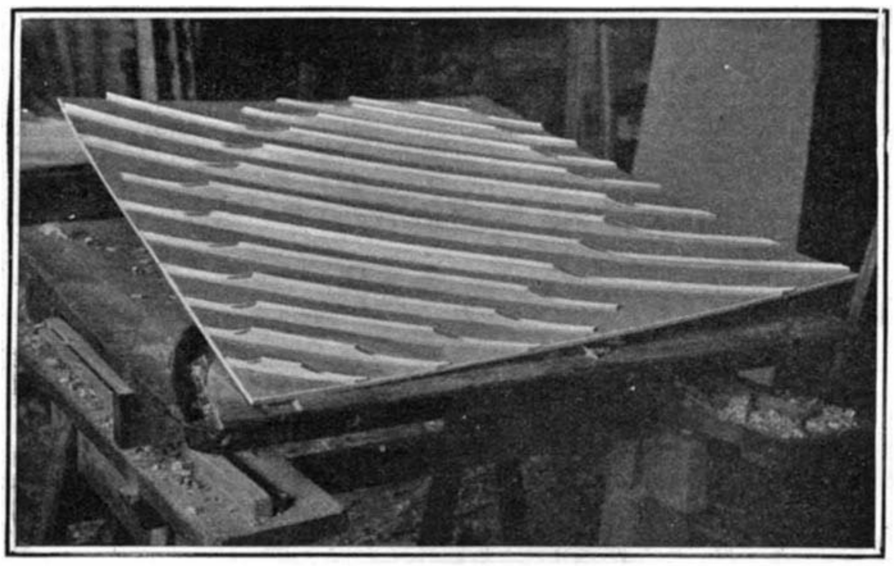
THE "RAST" OR FRAME.—The massive wooden frame which forms the back of the upright piano, and the base and sides of the grand, known technically as the "rast," is the foundation to which the whole system—sounding board, plate, pin-block, and strings, is attached. It assists the metal frame in taking the strain of the strings, which may aggregate from 25 to 40 tons, and by its intimate connection with the sounding board assists in securing the desired resonant qualities. In the Knabe piano each of the posts of the upright is built up of several carefully selected pieces of material. The whole frame is securely glued together, not a single bolt or screw being used. At its upper end it carries the pin-block or tuning block, a horizontal member built up of four layers of hard rock maple glued one upon the other, with the grain of the layers running in alternate transverse directions. After the rast has been glued together in the rough, it is placed upon the horizontal table of what is known as a "frazing" machine, a vertical rotary planer on which the rast is rapidly planed down to its finished dimensions. As will be seen from the accompanying illustration, the edges of the rast are moved past the cutters, the depth of cut being regulated by stops along which the work is guided by the operator.

The grand rast, as will be seen from our illustrations, is of an entirely different form and construction from the upright rast. Like the former, its strength is largely derived from a series of stout posts or columns, arranged in the same plane; but in this case, instead of standing parallel with one another, they radiate from a common center and butt against the curved, outside, vertical wall of the rast, against which they are securely fastened. The outer frame has the peculiar curve characteristic of the exterior shape of the grand pi-

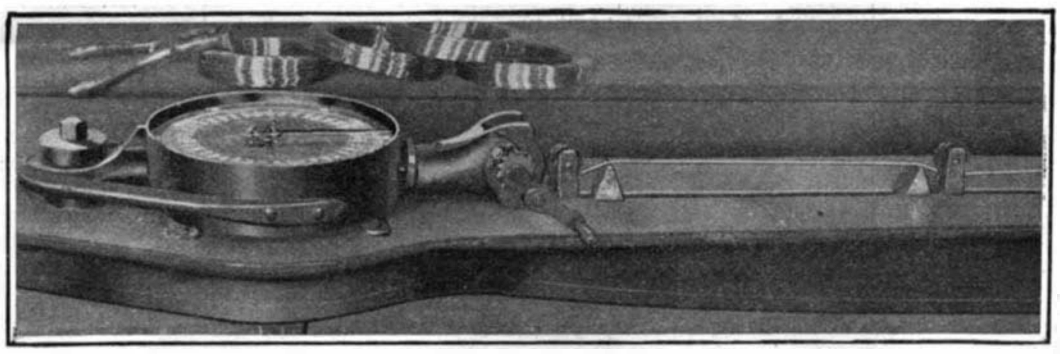


Glueing Together the Rast of a Grand Piano.

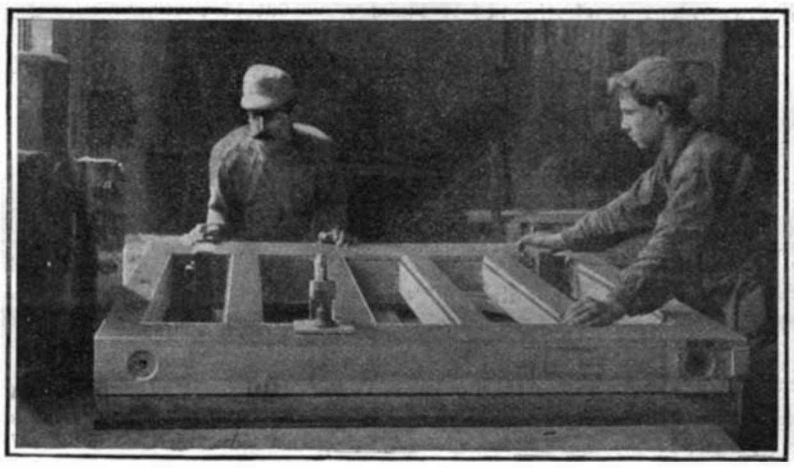
ano, and the very greatest care is taken in the selection of its material and its building up into the desired shape. Although it is from 4 to 4½ inches in thickness, it is not made from one solid piece, but is built up of from 16 to 28 thicknesses of 3/16-inch sawed soft pine, the pieces being selected for their texture, grain, and resonant qualities. The material is assembled, bent to the desired form, and thoroughly glued together, being held in place by a large number of hand clamps, in the way that is shown in our interesting photograph illustrating this process.



The Sounding Board, the Soul of the Piano.



Sonometer for Testing Piano Wire and Determining the Tension Necessary to Bring the Strings to Pitch.



Frazing Machine, on Which the "Rast" or Frame of Piano is Planed to Finished Dimensions.

THE SOUNDING BOARD.—Outside of the strings, and perhaps not even excepting them, the most critical element in securing the rich tone of this piano is the sounding board, which has been aptly termed the soul of the piano. The function of the sounding board is to increase the area of vibrating surface which is in contact with the air. The piano strings alone have too little surface to sufficiently condense and rarefy the air to affect the auditory nerve. In the simple string, the vibratory surface is simply the diameter multiplied by the length; but by having the sounding board connected with the strings through the bridge, the vibrations of the strings are communicated to it, and because of its large area the vibrating surface is increased many thousand fold. The building up of a sounding board is a continuous process of selection. Two pieces of apparently similar wood may have a wonderful difference of tone; for the sound is transmitted more freely in highly elastic wood. Sounding-board lumber should be very elastic with a view to its producing vibrations with a minimum expenditure of power. If it be not so, the vibrations are lost in the production of heat; the tone soon dies away, and loses that singing quality which is a distinguishing characteristic of the Knabe piano. The sounding board is made from carefully selected spruce pine, and the quartered wood is cut so that the "season rings" run at right angles to the grain of the wood.

As the result of the high elasticity of the season rings, the board presents a surface which responds to the most delicate impulses of the sound waves. It is built up of strips that run in a diagonal direction, and vary from 3 to 4 inches in width. Those strips which have a wide grain are placed opposite the base strings, those with the closer grain opposite the treble. The board, as glued together in the rough, is about one-half inch thick, and it is planed and sandpapered down to a finished thickness of from about a quarter in the bass to three-eighths of an inch in the treble end.

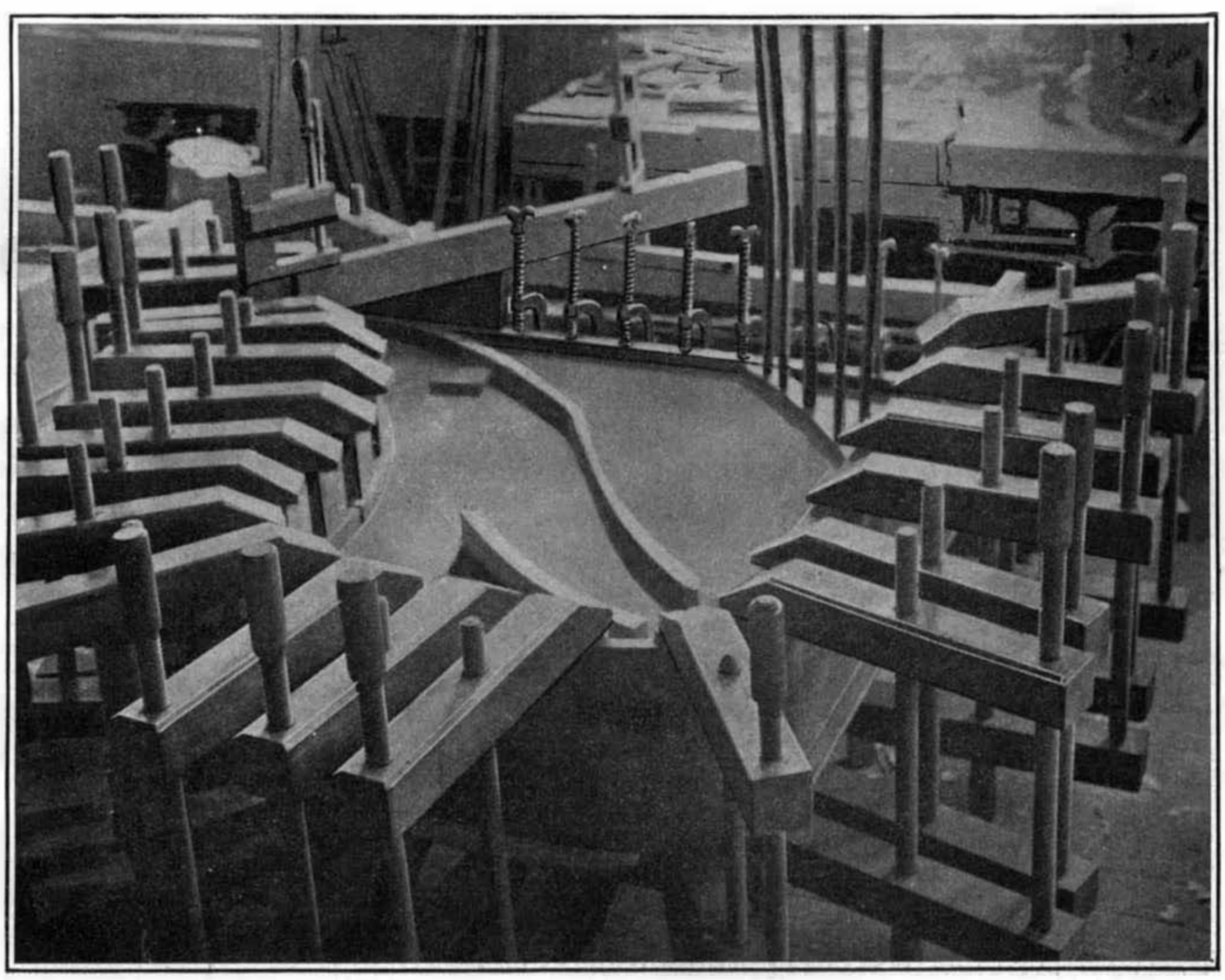
The selection of the wood, and the arranging of it according to its grain and other qualities in the built-up board, is considered at the Knabe works to be, perhaps, the most important art in all of the many departments. The specialist who does this work represents the third generation of a family that have been engaged for the past seventy-five years in doing nothing else. The sounding board is strengthened on its back by a series of parallel pine battens or ribs, glued firmly on, which also serve to give the correct curve to the board. To produce this curve, which is rather complicated in form, so that the bridge (a maple strip measuring 1 inch by 1⅛ inch, and running diagonally across the board from treble to bass end) shall lie everywhere along its highest point, is a most important feature in the production of the sounding board. After it has been carefully planed and sandpapered, during which process it is given no less than seven inspections, the sounding board is glued down upon the rast, and held in place by means of covering strips along its edges.

THE PLATE.—Above the sounding board, and extending over the whole width and height of the rast, including the pin-block, is securely fastened down by bolts and set screws what is known as the "plate," a strongly-ribbed, carefully-designed casting made of a special iron alloy, which has to perform the important function of carrying along its lower end the pins upon which the strings are strung and of bracing at its upper end the pin-block into which the tuning pins are driven. In addition to performing its principal function of presenting a reaction to the tremendous aggregate tension of the strings, amounting to the enormous pull of 25 to 40 tons, the plate serves to hold the whole fabric of the piano to true line and surface.

The company make all of the castings required for their pianos—the most important of them, of course, being the plates. The rough castings are smoothed down and chipped to bring them to the smooth surface which characterizes the plates, and are then taken to the plate department, where the hundreds of holes required for the pins, tuning pins, and fastening screws are drilled by templates—a work which requires the greatest accuracy. The work is done in special drilling machines, the plates being placed on tables, with a universal movement for speed and facility of handling. The finished plates are then bronzed and japanned, an illustration of the latter operation being included in the photographs.

THE STRINGS.—Although, as we have shown, the final tone of a piano is secured as the result of careful design in every element of the instrument, the strings or wires are essentially the sound-producing mechanism, and no part of the piano calls for more thoughtful design and careful construction than this.

The wire used in the first-class piano is of a highly-specialized grade, the best of which is manufactured in Germany. It must have a very high



Glueing in the Grand Sounding Board.

THE ART OF PIANO MAKING.—I.

coefficient of elasticity, the elastic limit being close to the breaking point, and much greater than the tension put upon the strings during the operation of tuning. Secondly, it must be of uniform diameter and uniformly round in cross sections, otherwise the over-tones to which is due the tone quality will not be perfectly secured; thirdly, it must have permanence, that is to say, it must not stretch under continued stress.

The number of vibrations per unit of time, corresponding to the fundamental tone produced by a string, varies inversely as the length of the string, inversely as the square root of its weight, and directly as the square root of its tension. If a wire be stretched between two points *A* and *B* (see accompanying diagram), and plucked or struck, it will vibrate above and below the line *A B*, giving what is known as a fundamental tone. This fundamental tone is without character, 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 production of the proper sub-vibrations, and the determination of their power relative to the power of the fundamental vibration, constitutes one of the most abstruse problems in the art of piano making; for 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 instrument. The sub-vibrations are known as the upper partials or over-tones, and generally speaking, they are harmonious with one another and with the fundamental tone.

The over-tones which correspond to the division of the string into seven or nine aliquot parts, however, are inharmonic, and in order to destroy them the hammers are so placed that they will strike at one-eighth of the length of the string. The width of the striking surface of the hammer is sufficient to intercept and dampen out the seventh and ninth upper partials, leaving only those which are harmonic. In the accompanying diagram, the sinusoidal curve representing the condensation and rarefaction of the air produced by the fundamental tone is shown by a heavy dotted black line, and the effect produced by the first, second, and third upper partials by fine lines. The effect of the latter upon the fundamental is to produce the irregular heavy final curve, which is shown here by a heavy black line. It must be understood that three only of the upper partials or over-tones are shown, whereas they may run up to the thirty-fourth or thirty-sixth, all tending to give fine quality to the resultant tone.

In laying out the "scale," a certain standard tension (in the Knabe piano about 141 pounds) is adopted for all the strings, and it is invariable. The variable elements are the weight of the wire and its length. The scale starts in the treble with a short length of about 55 millimeters, and if the same weight of wire were used throughout, the lowest bass strings would have to be 32 feet in length, which is, of course, impossible. The piano builder chooses, therefore, the greatest length of bass string compatible with the size of the piano which he intends to build, and then to obtain the correct pitch, he winds on a sufficient weight of copper or other wire to reduce the pitch to the proper standard. The number of vibrations varies from 26 per second in the lowest bass string, to 4,136 in the highest treble string per second.

(*To be continued.*)

EARTHQUAKE OBSERVATIONS.

BY PROF. EDGAR L. LARKIN.

A cemetery filled with monuments, columns, and obelisks is a capital place to study the effects of an earthquake. Amplitudes and azimuths of disturbed monoliths and pillars reveal at once the action of the earth upheavals. I had no instruments with which to measure, so had to make estimates.

Laurel Hill Cemetery I found a field of distorted, shifted, turned, cracked, overthrown, and ruined columns, pillars, shafts, capitals in white marble, gray granite, and other materials. Angels' wings were broken, sculptures were round about, and heavy bases were twisted out of their original positions. At first I noted distortions on both sides of an avenue of tombs. Here are directions in which the tops of fallen columns and monuments were pointing along either side, in a distance of 150 feet: N. 1, S. 2, E. 9, W. 5, N.E. 4, N.W. 5, S.E. 5, S.W. 6. From this I thought that the chief distortion was toward the east. Then facings of those that were skewed around on their bases, but not overthrown, were noted, as follows: N. 1, S. 1, E. 2, W. 1, N.E. 4, N.W. 0, S.E. 2, S.W. 1. All these had been twisted around against intense friction at their bases. The one marked N. originally faced eastward, and the one shown as facing S. once faced westward. I examined many others, hoping to make order out of chaos, or find a general trend in direction, but could not. The conclusion reached was that the monuments were thrown over and twisted in every direction.

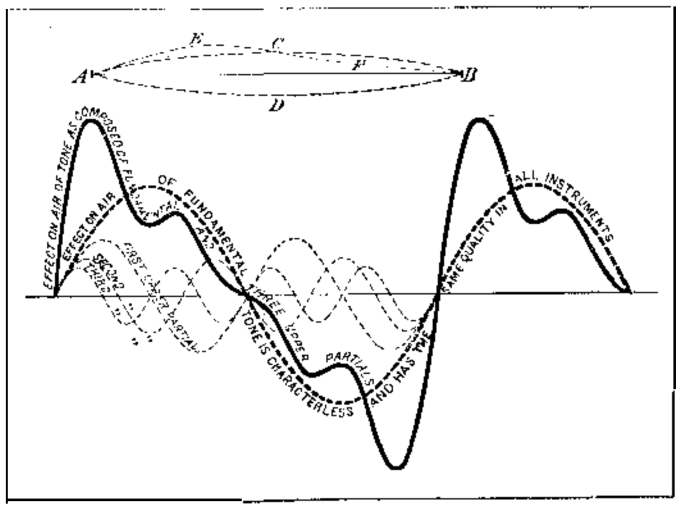


Diagram Showing Effect of the Upper Partials in Modifying the Fundamental Tone.

The Oddfellows' Cemetery was explored. This is more modern than Laurel Hill; the monuments are higher and heavier. They were fastened down by lead in some cases. The most complete confusion reigned. The displacements likewise were in every direction. An observer with instruments, upon making surveys during a month, might find a majority of fallen columns pointing one way, or facings, but it is doubtful. The earth's surface surely moved in every direction. As nearly every brick and stone building was destroyed, they could not be studied. The great Fairmount Hotel has rents in the corners, and several high up, along near the middle of the façades. The new $5,000,000 post office is torn near the corners. The towering steel and stone Spreckels Building stands as a skeleton, but looking down on a wilderness of ruins of all old-type buildings. For the new city will be erected around ribs of rigid steel. The accompanying diagrams show roughly the distortions in the cemeteries. The line N.S. is due north and south, in cuts Nos. 1 and 2. Twistings of obelisks that did not fall range from five to seventy degrees in all directions from their original foundations. My impressions gained in the cemetery were confirmed upon receipt by mail of the seismograph shown on page 419. It was sent me by F. M. Clarke, steward and executive officer of the California Veterans' Home, Yountville, Napa County. My thanks are hereby extended to him for the faithful record. It indeed shows that the ground moved in every possible direction. On leaving the cemetery I wrote an article for the papers, saying that it was a circular disturbance, and the graph reveals a circle near the center. Mr. Clarke says: "The first movement had a N. and S. direction, but was swiftly compounded with a circular, twisting movement, accompanied with severe upward thrusts. The first movement was decidedly wave-like; then a cessation, followed by the severe twist." Napa is 45 miles north of San Francisco, and San José, 50 south. Both were destroyed.

Mr. Edward Pickersgill, Alameda, Cal., sends me a series of photographs of great upheavals, distortions, and displacements of the ocean shore, four miles from Colma. Vast banks of sand slid into the sea, and a new high point of land was formed as shown on page 419. A place where gas escaped from soft mud is also shown. The soil is a foot or more high, and six wide.

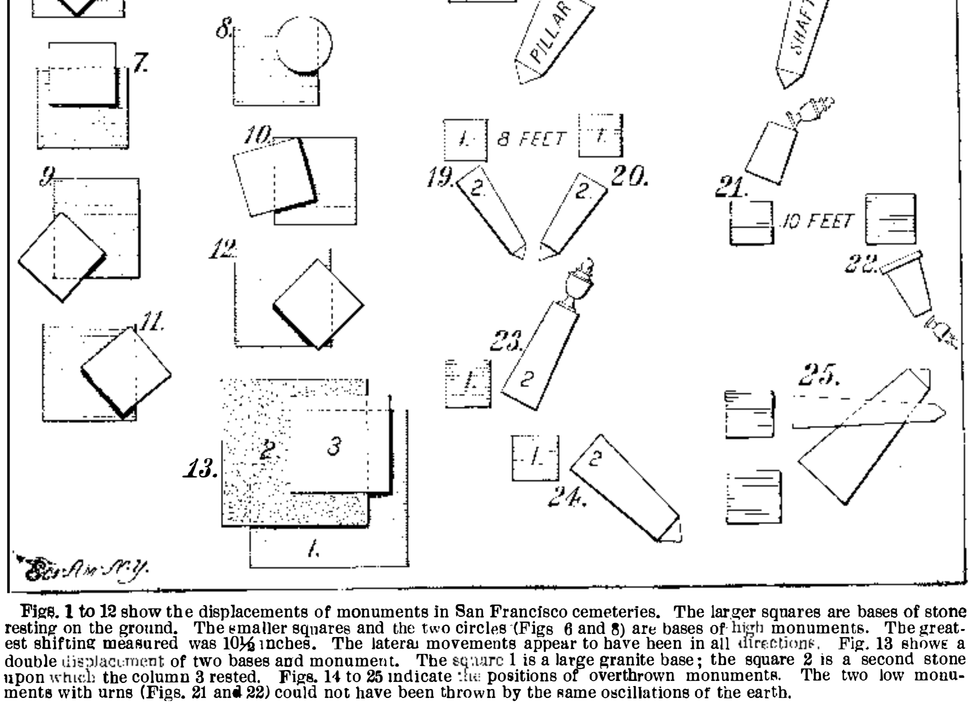
Without doubt, gas had to do with the great earthquake. Newspaper reports say that from April 18, 5:18:57 A.M., to April 26, 3:15 P.M., thirty-two shocks left their imprint on the seismograph at Berkeley, and that twenty-six occurred on the first day, the 18th. I felt the sharp shock that came on the 20th, 4:34:17 P.M., in a three-story frame building. It was my fourth earthquake. The priceless collection in the magnificent Lick Academy of Sciences vanished. All the replicas of historic, paleontological and geological finds were consumed; also early Spanish records of exploration. The great libraries and many private collections of literary treasures exist only in cherished memories.

Mt. Lowe Observatory, Cal.

EFFECTS OF THE EARTHQUAKE AND FIRE UPON THE CITY OF SAN FRANCISCO AND ITS BUILDINGS.

BY ARTHUR INKERSLEY.

About ten days after the San Francisco earthquake, which occurred at 5:13 on the morning of Wednesday, April 18, the city engineer sent out three parties for the purpose of ascertaining whether or not the whole city had sunk as a result of the shock. Many places were found where the ground had sunk considerably; especially on Valencia Street between 19th and 20th Streets, at the easterly end of Market Street near the ferry depot, on Howard Street between 17th and 18th Streets, on Van Ness Avenue from Vallejo to Green Streets, and on Folsom Street near 17th Street. The sinking is almost wholly on made ground in the lower parts of the city. At the southeast corner of the United States post office on Mission and Seventh Streets, there is a depression and a corresponding raising up of about four or five feet. That part of the post office was built over an old swamp. The building retained its position, but the concrete sidewalk pulled away from it, leaving a gap of six to ten inches. The city engineer's conclusion is that the city as a whole did not sink. There was no distinct subsidence of any considerable portion of the peninsula.



Figs. 1 to 12 show the displacements of monuments in San Francisco cemeteries. The larger squares are bases of stone resting on the ground. The smaller squares and the two circles (Figs. 6 and 8) are bases of high monuments. The greatest shifting measured was 10½ inches. The lateral movements appear to have been in all directions. Fig. 13 shows a double displacement of two bases and monument. The square 1 is a large granite base; the square 2 is a second stone upon which the column 3 rested. Figs. 14 to 25 indicate the positions of overthrown monuments. The two low monuments with urns (Figs. 21 and 22) could not have been thrown by the same oscillations of the earth.

CEMETERY MONUMENTS OVERTHROWN BY THE EARTHQUAKE.

The disturbance of the earth's crust on Wednesday morning, April 18, in San Francisco and its vicinity was really inconsiderable. The vibration was sufficiently great and sustained to shake down chimneys, bad masonry, and old frame buildings on rotten or insecure foundations. According to Prof. O. A. Leuschner, of the astronomical observatory of the University of California at Berkeley, Alameda County, the damage caused would have been vastly more serious had the vibrations not been distributed over so many seconds. If the shocks had been instantaneous, very much greater ruin would have resulted. The standard clock of the students' observatory stopped at 5:12:38 A.M. Pacific time, some less severe temblors being recorded at 5:12:03. The earthquake came chiefly in two shocks, the first series of vibrations